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Presa Universitară Clujeană

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Părinților mei.

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Introduction

In spite of a rather intensive research, the conundrum of the deductive reasoning is far from being solved in the cognitive psychology. However, finding an answer to it is not only a parochial matter, concerning only some curious psychologists particularly interested in such a research subject, but also a matter bearing on some pragmatic issues, regarding the rational behavior of the people in their daily activities.

As Johnson-Laird and Byrne (1991) have noticed, deduction is involved in many current tasks: planning, evaluation, determining the consequences of assumptions, interpreting and formulating instructions, rules and general principles, pursuing arguments and negotiations, weighing evidence and assessing data, solving problems, etc.. Therefore, their performance is dependent on the deductive ability of an individual. But such ability seems to be more like a humble and almost invisible servant, few of us and rarely being aware of its presence and activity. It is one of the reasons why its experimental study is rather difficult, which accounts also for the manifest tendency to undervalue its importance (reflected in its present negligible place as a distinct subject matter in the current formal education in Romania). But, Venet and Markovits (2001) have noticed that the ability to reason correctly deductively "in situations where the reasoner has little or no knowledge" (p. 76) is critical for the scientific activity, because it allows predictions about the "unobservable mechanisms that can be used to understand phenomena about which there is little knowledge" (p. 76).

Two general questions have been in the focus of the empirical studies so far, puzzling the researchers. The first one is why the performance of the normal subjects confronted (especially) with formal deduction tasks is so poor and sometimes seemingly irrational, why their motivation is so low in solving them, when deduction is still one of the most important and constant component of their everyday thinking. Such discrepancy has raised doubts regarding people's rationality or their deductive competence (Johnson-Laird & Byrne, 1991). The second question concerns the appropriate methods to be used in order to improve such a defective deductive competence. The present work brings new theoretical perspectives and empirical data intended to be new pieces for solving the puzzles of those questions.

Types of deductive reasoning and its definition

Deductive reasoning is usually put in contrast with other types of reasoning (mainly inductive, analogical or probabilistic reasoning), as being the only kind of thinking through which new certain information is obtained based on some known information in such a manner that its necessary truthfulness is not a matter of empirical (external) verification, but only one of "internal verification", correctly observing some so called logical principles guiding the mind functioning. The type, the existence, the origin, and the use of the deductive processes are the debated issues among logicians and psychologists alike[1].

Several types of deductive reasoning have been distinguished. The most general and important ones are *the propositional deductive reasoning*, with its main sort being: the conditional (or hypothetico-deductive)

[1] Only their focus is different. Logicians are interested mainly in giving a formal (abstract and general) description of the correct thinking, the one that secures the obtaining of necessary valid information (delivering norms of thinking), and in envisioning and constructing possible logical formal systems (based on some new axioms). Psychologists, on the other part, are more preoccupied with the actual use of the assumed logical principles, and with the reasoning performance (for example, the causes of the reasoning errors made by people in comparison with the results expected by logicians).

reasoning, *categorical reasoning* (mostly identified with the so called syllogistic reasoning), and the *relational reasoning.*

The *propositional deductive reasoning* in general involves, also, other types of so called logical connectives (or relations) than the conditional implication (for example: negation, OR, or AND), by which propositions are combined in order to produce new propositions[2]. Through a deductive propositional reasoning, the truth value of a proposition is found based on knowing the meaning of the logical connectives (or the so called truth conditions, i.e. when the obtained combined proposition is true depending on the truth of the component propositions) and the truth value of the remaining propositions taken into consideration.

Defined in a more abstract way, conditional reasoning is a kind of propositional reasoning based on the implication relation between a proposition **p** (the antecedent or the condition) and a proposition **q** (the consequent), i.e. $\mathbf{p} \rightarrow \mathbf{q}$.

In its classical form, the most important form of categorical reasoning is the syllogism[3], based on four types of judgments with a single quantifier ("all" or "some"), stating relations between classes of things or beings and their properties: the *universal affirmative judgment* ("All **M**s are **P**s."), generally symbolized in logics with **A**, the *universal negative judgment* ("All **A**s are **not** **B**s."), generally symbolized in logics with **E**, the *particular affirmative judgment* ("Some **M**s are **P**s."), generally symbolized in logics with **I**, and the *particular negative judgment* ("Some **M**s are **not** **P**s."), generally symbolized in logics with **O**. In a syllogism, the three so called syllogistic terms are related using the above mentioned judgments: two *"extreme" terms*, and a *middle term*. One of the two premises states a relationship between one extreme term and the

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[2] A concrete example of a *conditional deductive reasoning* is the following argument, composed of two premises and a conclusion:
Premise 1: "If litmus paper turns red, then the tested aqueous solution has an acidic pH"
Premise 2: "The litmus paper turns red"
Conclusion: "Therefore, the tested aqueous solution has an acidic pH."

[3] An example of syllogism is:
Premise 1: "All fishes are oviparous (produce and lay eggs)"
Premise 2: "All whales are not oviparous"
Conclusion: "All whales are not fishes".

middle one. The other one states a relationship between the remaining extreme term and the middle one. In conclusion, the relationship between the two extreme terms is derived (determined) based on their relationships with the middle term stated in the two premises. For the example given in the footnote, the extreme terms are "fishes" and "whales", and the middle term is "oviparous".

In general, a categorical deduction is characterized by the presence of the quantifiers or, in other words, of the quantified relations.

Representative for the deductive *relational reasoning* is the so called "three-term series" problem[4]. In general, in a relational reasoning, some relations[5] between some given entities are stated in the premises, and, based on them, a conclusion is derived, stating the truth of an unknown relation between two of the entities taken into consideration. The type of the relational reasoning depends on the type of the envisioned relations (for example, spatial: "on the right", "on the left", "under", etc., temporal: "before", "after", etc., social: "to be a subordinate", "to be a father", etc.). Sometimes, when a relational reasoning involves more than one type of relation, in order to derive a conclusion it is needed to know the relationship between the stated relations, i.e. second order relations[6], in order to derive a conclusion.

The *general definition* given by me for the deductive reasoning is as it follows:

A deductive reasoning is a thinking (conscious or unconscious) process by which the truth value of a propositional (relational) variable[7] is established (determined, derived) based on the known

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[4] A concrete example of such a problem would be to find out if Jane is taller than Mary, knowing that Jane is taller than Sue, and Sue is taller than Mary.

[5] Such relations could be of several types: for example, spatial: "on the right", "on the left", "under", etc., temporal: "before", "after", etc., social: "to be a subordinate", "to be a father", etc.

[6] For example, in a reasoning problem in which it is stated that "object X is *at the left* of the object Y", and "object Z is *above* the object Y", in order to derive that "object X is *at the left* of object Z", it is needed to know the second order relation between the relation "at the left", and "above".

[7] A propositional variable is a variable referring explicitly or implicitly (in the case of the formal propositional reasoning) to a kind of relation.

truth value of other propositional (relational) variables and the knowledge regarding their systematic relationships.

Existing theoretical approaches and models of the deductive reasoning processes

Numerous theoretical accounts were given by psychologists in their quest to understand the deductive thinking, which could be systematized in various ways, using multiple criteria. I am proposing the following classification scheme.

I. The symbolic computationalist approach and its models

Until recently, almost all of the earlier mentioned accounts were rooted in a symbolic computionalist paradigm, i.e. in a view in which cognition is understood using the computer paradigm. In other words, it is assumed that mental representations are static (analogous, having a resemblance with their referent, or arbitrary) symbols (instantiated by physical tokens) and that thinking implies an operation with these symbols based on some rules for changing their status or position (represented also based on symbols), applied by some mysterious mental agent. In fact, the computer metaphor seems to be rooted in some more primitive metaphors (Faiciuc, 2008a): the language metaphor (where we have linguistic arbitrary symbols manipulated by syntactic rules) and the metaphor of the usual description of our actions with the objects at a macroscopic level (where we have what seems to be static objects with clearly defined borders placed in some space endowed with characteristic properties and distinct forces by which the objects are put in motion), in the terms of the classical mechanics.

Since the thinking processes are expressed through language and not having a direct access to them, it may have been naturally to seek for their structures in the linguistic patterns. Once discovered in the linguistic medium, they were projected back into the thinking space, ascribing intuitively a language-like description for the reasoning processes (Faiciuc, 2008a). On the other part, when mental representations are conceived to be like some mental objects with clearly defined positions in a mental space, put in motion by hypothetical mental forces that could me manipulated by an agent, thinking is viewed more like a constructive undertaking in order to represent objects and situations, and to simulate processes from another medium.

The two metaphors mentioned above are, together, the assumed sources for what could be considered to be the main types of symbolic computationalist theories for the deductive reasoning at an algorithmic level. As, from a symbolic computationalist perspective, deductive processes must have a separate information interpretation phase (when the external information provided in premises is decoded into a symbolic representational format amenable for the subsequent specific processing), and what could be called a separate information use phase (when the decoded information is used in order to derive or generate a conclusion), the symbolic computationalist theories of the deductive reasoning are accordingly grouped in two principal categories: *information use*, and *information interpretation* theories, depending on the importance given to a phase or the other in explaining deductive performance. In the first category, two subcategories were distinguished: *rule theories*, and *analogical theories*.

1. Information use theories

A. Rules theories

Rule theories are of several sorts.

a. Syntactic models

The syntactic models posit that, essentially, a conclusion is derived in a deductive reasoning by applying some general syntactic rules (linguistic or of a mental logic) on the symbolic structures obtained after a decoding process, without any regard in what respects their meaning, being context-insensitive (for example, Braine & Rumain, 1983, as cited in Bucciarelli & Johnson-Laird, 1999; O'Brien, Braine, & Yang, 1994;

Rips, 1994, as cited in Bonatti, 2002;). Such rules are presumed to be either learned, or innate. The difficulty of various forms of deductive reasoning and the time needed to solve them is explained by the length of the deductive chain (the number of rules that are successively applied in order to derive a conclusion) and the accessibility of the applied rules. The errors made by people are presumably caused by a defective interpretation of the given information or by limited mental resources in applying the existing rules.

Though still intuitively attractive (through the appeal to the linguistic metaphor), the existing models of this type are considered to be not very successful for empirical and theoretical reasons. Their fit with the experimental data is rather poor or ad hoc adjusted, by assuming rules without an empiric base or logical meaning, merely describing than explaining the obtained results. They have, also, difficulties in justifying the prevalence of some erroneous answers in deduction tasks. On a theoretic level, they are vulnerable in explaining the ultimate origin of the rules and the way they are applied, since an extra-agent must be supposed (with the consequence of running into an infinite regression, when trying to explain how such an agent operates).

b. Pragmatic schemas models

This kind of models are based not on general abstract formal rules (as in the preceding case), but on rules with an intermediary level of specificity, named to be "context-sensitive" (Cheng & Holyoak, 1985), since they are applied in characteristic thinking contexts, having a pragmatic significance (being useful in fulfilling general classes of goals). As they are phylogenetically evolved (Cosmides, 1989), or are learned in order to be maximally useful in limited contexts (being sometimes more like heuristic rules than valid inference rules), the results of their application may be different than the ones expected by applying correspondent formal rules for those contexts.

Until now, to my knowledge, such models are formulated only in order to explain the experimental data regarding conditional reasoning tasks (especially the Wason selection task), indicating that the performance for them is improved by changing their wording from an arbitrary content to a content suggesting characteristic and frequent social relations situations (and their corresponding goals) such as the permission or obligation relations, for example, or situations in which the goal is to establish a cause or to prove something (Cheng & Holyoak, 1985).

Principally, the pragmatic schemas models stipulate that the difficulty of the conditional deductive tasks is dependent on two factors. The first one is "the ease of mapping concrete situations into pragmatic schemas" (Cheng, Holyoak, Nisbett, & Oliver, 1986, p. 296). The other one is the correspondence between the conclusions generated applying the rules of the existing pragmatic schemas and those expected by applying formal logical rules. Whether the content of a task is arbitrary or not (providing a concrete material eliciting an existing pragmatic schema), that correspondence could have, depending on the type of pragmatic schema in discussion, a facilitator or detrimental effect for the performance of a certain conditional deductive task. The erroneous responses occurred for conditionals are interpreted to be the effect of applying pragmatic schemas that are in disagreement with the formal logic.

The present main disadvantage of the pragmatic schema models is their narrow scope, the fact that they are not extended for other types of deductive tasks. A secondary vulnerable point is that the properties of a pragmatic reasoning schema as a knowledge structure are currently still vague and insufficiently analyzed (practically being at the border between the rules and mental models).

c. Heuristic rules models

This class of theoretical accounts for deduction is the most heterogeneous one. But the core assumption of all of them is the idea that people use rules of thumb in order to solve deductive tasks. They simplify the thinking effort needed for them, reducing the costs for reaching a conclusion, or provide the basis for a more or less educated guesses of the correct answer (securing an acceptable performance in most of the relevant situations). The most significant sorts of theoretical models of this kind are: the so called theory of the atmosphere effect (Wetherick & Gilhooly, 1990, as cited in Roberts, Newstead, & Griggs, 2001; Woodworth & Sells, 1935, as cited in de Vega, 1994;), the matching bias (Evans, 1998), the model of the fast and frugal rules in a bounded rationality (Gigerenzer & Goldstein, 1996). and the probabilistic theory of reasoning (Chater & Oaksford, 1999; Oaksford & Chater, 2009). The last one is the most elaborate, offering a rather systematic explanation, within the framework of a Bayesian rationality, at least for the syllogistic reasoning, in the terms of a heuristic based on probabilistic rules. Most of the time, the origin of such heuristics is not specified, but in some cases it is presumed that they are learned directly or elaborated based on the previous experience with similar tasks (by simple association or through some other more advanced processes). Implicitly, the heuristic theories do not imply, traditionally, the existence of a deductive competence. More recently, new versions of probabilistic reasoning theories were formulated by Pfeifer (2013) and by Lassiter and Goodman (2015). Pfeifer (2013) proposed a mental probability logic (MPL), "as a competence theory of human inference", which "interprets indicative conditionals as conditional events" and in which the consequence relation between the premises and the conclusion remains deductive, and not uncertain, as in the previous probabilistic approaches of reasoning. Mental probability logic is named by its author to be a coherence based probability logic because it "investigates the coherent transmission of the uncertainty of the premises to the conclusion", when "probabilities are attached to the premises and the relation between the premises and the conclusion remains deductive". In this theory, the "probabilities are subjective and conceived as *degrees of belief*". Lassiter and Goodman (2015), inspired by the "recent work in formal semantics of natural language", proposed a probabilistic model of reasoning with modal expressions such as "necessary" and "plausible": Probability Threshold Model (PTM). Their aim was to show that there is no psychological distinction between the heuristic and analytic reasoning processes (a distinction supported in the dual processes theories) and that the non-linear response patterns in the reasoning tasks can be explained only through the "semantics of modal words such as "necessary" and "plausible", "which can be modeled using a single underlying scale of argument strength—conditional probability" (p. 2),

B. Analogical theories

Analogical theories of the deductive reasoning are of several types, too.

a. *Mental models theories*

The mental models theories of the deductive reasoning are based on the idea that the information given in the premises serves to construct rather abstract symbolic models, that is mental representations which have a structure analogical with the one of the situations referred in premises[8]. The reasoning process is based on extracting conclusions from mental models that integrate the given information (based also on general knowledge or more specific knowledge evoked from the long-term memory). Once the models are integrated, the conclusion is implicitly obtained, and the reasoner has "only" to "read" it, i.e. to select the required partial description of the models needed in order to render that conclusion explicit and to secure herself/himself that it is a necessary one (i.e., that all the possible or relevant models compatible with the given information were taken into consideration). Therefore, this kind of theories (Erikson, 1974, as cited in Miclea, 1994; Guyote & Sternberg, 1981, as cited in De Vega, 1994; Johnson-Laird & Byrne; 1991; Stenning & Oberlander, 1995) is essentially semantic in nature, since it is based on constructing of a synthetic extensional (referential) meaning in which the sought conclusion is implicitly contained.

Several representational formats have been proposed in order to describe the analogical structures assumed to be involved in deductions: Euler circles (Erikson, 1974, as cited in Miclea, 1994), Venn diagrams (Stenning & Oberlander, 1995), equivalent strings of symbols (Guyote & Sternberg, 1981, as cited in De Vega, 1994; Newell, 1981, as cited in Johnson-Laird & Byrne, 1991), and mental models in the version of Johnson-Laird and Byrne (1991), instantiated by symbolic tokens with

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[8] In mental models theories, rules are not altogether excluded, but they are no longer directly involved in deriving a conclusion, but only indirectly, being a part in the procedures used in order to build or integrate mental models, or in order to render explicit a conclusion.

propositional annotations. Schaeken, Van Der Henst, and Schroyens (2006) have proposed the idea of "isomeric" mental models in order to represent indeterminacies and uncertainties, capturing all possibilities within a single, integrated representation via the addition of concrete, non-spatial elements (i.e., propositional or verbal "tags") that can denote uncertainty. A similar notion was proposed by Vandierendonck, Dierckx, and De Vooght (2004), named "annotated" mental models, the annotations being verbal footnotes that qualify the meaning of the information represented within spatially-based models. These new types of models combine more saliently the abstract spatial tokens with verbal symbolic information. Mental models of a special kind are involved also in the erotetic theory of reasoning, proposed by Koralus and Mascarenhas (2013), based on two specific semantics: semantics of exact verification or truth maker (van Fraassen, 1969 and Fine, 2012, as cited in Koralus and Mascarenhas, 2013) and the inquisitive semantics (Groenendijk, 2008 and Mascarenhas, 2009, as cited in Koralus and Mascarenhas, 2013).

The analogical theories differ not only in what respects the representational format of the implied analogical structures, but also in what respects the processes by which a conclusion is deductively derived.

The mental models theory, the most influential one (the others being unable to account for the experimental data in a similar measure), distinguishes itself through the idea that all the models compatible with the premises are not exhaustively constructed from the very beginning. Its main tenet is that a tentative conclusion is initially derived based on some initial model and that other models are constructed only as counterexamples, in order to verify that that conclusion is necessary valid. As a consequence, the difficulty of a deductive reasoning task is considered to be dependent mainly on the number of mental models needed to derive a necessary valid conclusion (as a consequence of the assumption that people have limited resources to maintain activated and operate with several alternative models). Secondarily, it depends also on the ease with each the initial model or the counterexample models could be constructed (given the general knowledge of a reasoner, her/his previous experience with the type of task at hand and the information provided in the premises). The pattern of the erroneous answers is explained by supposing that they represent mainly conclusions derived based on the initial models, as a failure in completing the verification of their validity.

Although the mental models theory has reached a high level of generality (being applied progressively to several kinds of deductive reasoning) and was adjusted in order to fit with a significant proportion of the existing experimental data, it is not without flaws and vulnerable points[9]. It is, at the very least, still an incomplete theoretical account of the deductive processes.

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[9] Only some of the drawbacks (considered to be the most important ones) of the mental models theory are mentioned here:

- In its present form it does not specify clearly how or why an initial model is chosen by a reasoner (with the consequent risk that its choice is made by an experimenter in order to fit the theory with the data). The so called principle of truth, in accordance with which, initially, only the situations in which "mental models represent what is true, but by default not what is false" (Politzer, 2007, p. 12) seems arbitrary, without a supplementary justification. There is an obvious dynamics of the transition from an implicit to an explicit status of the information involved in the building of the mental models that is poorly taken care of. Moreover, there are some findings that the idea of the existence of implicit information might be wrong. For example in conditional tasks involving an evaluation procedure in which "the implicit models are made explicit for the reasoner", "the not-A cases are evaluated as false about half the time", i.e. some errors still persist (Delval & Riviere, 1975, as cited in Politzer, 2007, p. 18; Paris, 1973).
- There are deductions for which the needed number of mental models in order to obtain a valid conclusion could not be precisely determined, because the information provided in premises cannot be determined from a referential point of view (Buciarelli & Johnson-Laird, 1999).
- The procedure through which a so called parsimonious conclusion is extracted from an integrated mental model is not psychologically specified in a sufficient manner.
- The processes through which the generation of counterexample models is initiated are not clearly determined. The process is merely a heuristic one (Miclea, 1994). It is only acknowledged that general knowledge and some specific experience with the content of a task are important and that some individual differences (for example, cognitive flexibility, or the working memory span) play, also, a role in that respect (Buciarelli and Johnson-Laird, 1999).
- A series of empirical data suggest that people, usually, do not search for counter-examples at all (Newstead, Handley, & Buck, 1999).

b. *Case-based reasoning models*

This type of theoretical models suggests that, in fact, deductive reasoning is rather a matter of analogical reasoning, no abstract knowledge structures or rules being necessary in order to derive a conclusion (for example Vosniadou & Ortony, 1989, as cited in Sun, 1996). An analogy between a situation described in the premises is made with some previous experience encountered before, and that experience serves to generate the needed conclusion, by completing the missing part in the current information. These models are predominant in the Artificial Intelligence domain (for example Touretzky & Hinton, 1985, as cited in Sun, 1996).

As it could be noticed, the theories of the deductive reasoning presented so far could be compared and classified taking in view other criteria. An important one is the relative accent placed in their explicative undertaking on the *syntactic vs. the semantic processes*. As it is obvious, for some rule theories (linguistic and mental logic models), the syntactic processes are primordial. That is why they are also called syntactic models. Still, for other rule theories (especially pragmatic schema theories), the balance inclines toward the semantic processes. Analogical theories are also of a semantic type.

- There are studies that indicate that there are no significant differences in the correctness for the two models syllogisms in comparison with the three models syllogisms (Llopis Marin, 1992).
- In spite of some efforts to account for the role played by the semantic and pragmatic knowledge, or by the reasoning context, in deductive tasks, the mental models theory is still, in its current form, deficient in that respect, having a difficult time to conciliate its generality with the needed flexibility.
- It has a difficulty in proving experimentally that mental models in the proposed representational format are generally used by reasoners.
- As in the case of the rules of a mental logic, for the mental models, also, it is needed an external agent to build and manipulate them, with the same issue regarding its way of functioning, and the same risk of an infinite regression.
- It is based on an ignored primitive and fundamental analytic ability of a combinatorial thinking (needed in order to generate exhaustively all the possible alternative mental models), the building block of the logical thinking, which remains unexplained. As Braine (1990, in Overtone & Dick, 2007) noticed, the mental models theory lacks "a general account of the deductive process itself" (p. 245).

No matter if the theories are primarily syntactic or semantic in nature, some of them (linguistic models, mental logic models, pragmatic schema models, and mental models theory) admit essentially *the existence of a deductive competence, as distinct of the deductive performance*, but differ in the *type of the assumed deductive competence* (for example, the existence of logic rules and the ability to apply them vs. the ability to build and interpret abstract mental models).

2. Information interpretation theories

Until now, there have been mentioned only explicative theories that consider that the deductive reasoning performance is not accountable solely by differences, or peculiarities in the meaning ascribed to the premises (as a distinct one in comparison with the classical logical meaning) during an assumed interpretation phase. But, still, there is a category of theories that claim that such is the case. One of them is the so called "conversion theory", conceived specifically for the syllogistic reasoning (Chapman & Chapman, 1959 or Revlin & Leirer, 1978, as cited in de Vega, 1994). It explains the difficulty of the syllogisms and the errors made by an illicit tendency of some of the reasoners to mistakenly interpret the conversion of the **A** and **I** judgments as valid, based on the peculiar meaning attributed by them to those judgments. But apart of this "misinterpretation", their logical competence (whatever its nature) is considered to be in principle flawless. A similar explanation is given in the case of the conditional reasoning, when it is supposed that there is a tendency that a conditional statement to be interpreted as a biconditional (Wagner-Egger, 2007). Geurts (2003) and Roberts, Newstead, and Griggs (2001) put the accent on the interpretation of the quantifiers in the case of syllogistic reasoning.

The idea has been further extended to other types of reasoning and judgments invoking the Gricean conversational principles, especially the one regarding the relevance in the relevance theory (Sperber & Wilson, 1990) in order to account for the occurrence of the presumed particular interpretations of some of the judgments included as premises. But this kind of theories, linked predominantly with the pragmatics of logic, is not entirely supported by the empirical data, and may be more useful in completing the explanations provided by other types of theories.

II. Integrative theories

A second kind of theories considered here are the ones having integrative aims, either only at a descriptive level or at an explicative level, too. They were conceived in order to account for the results obtained in a series of empirical exploratory studies (Bacon, Handley, & Newstead, 2003; Buciarelli & Johnson-Laird, 1999; Ford, 1995; Sloman, 1996; Stanovich &West, 2000) that had indicated (as it was suggested by the protocols derived from their introspection) that reasoners confronted with deductive tasks do not use a single strategy of thinking. There was a lot of inter-, and even intraindividual variability in that respect, and a lot of content and context-dependent variability. The various strategies indicated by data are compatible with several of the previously mentioned theoretical models. Therefore, no one is powerful enough to account for all the phenomena observed in the deductive reasoning research.

1. Unifying theories

a. Stenning and Yules's (1997) theory claims that rule theories and mental models theories could be subsumed into an integrative higher order principle, based on an algorithm that uses Euler circles. In their opinion, both rule theories and mental models theory are isomorphic with such an algorithm.

b. Polk and Newell (1995) concentrate themselves on the role of the linguistic processes. The given linguistic information is coded and recoded (especially by direct inferences) until the information necessary for a conclusion is obtained. But these linguistic processes are both semantic and syntactic processes, and that is why this theory is considered to be an integrative one. Information is coded into an initial model that is extended and changed progressively, as new information is received.

c. Overton and Dick (2007) classify the existing theories of the deductive reasoning as being competence or procedural theories. In the first class, only the mental logic theory is included. The second one comprises the remaining theories. They support the view that the two classes of theories are not actually incompatible, as it is usually believed, but they should be interrelated components of a general theory of the logical reasoning. Their theory is very close to a dynamic approach of the deductive reasoning, since they believe that the logical competence of the inferential schemas or deductive rules is originated in "embodied actions of the infant, child, and adolescent" (p. 236), as persons interact with the social and physical world. In their view, the logical competence is a "dynamic organization of mental logic" (p. 237), and logical rules are considered to operate as a "model of the dynamic system of psychological processes entailed by logical reasoning" (p. 235). In the framework of their theory, the development of the logical thinking moves toward the "integration of inferential schemes into a systematic network" (Müller, Overton, & Reene, 2001, p. 27).

d. For the special case of the conditional reasoning, Geiger and Oberauer (2010) elaborated a probabilistic revision of the mental model theory. In contrast with the traditional mental model theory, they assume that conditionals do not have "truth conditions by which we can determine whether a given conditional is true or false from what is the case in the world". So, in their new model, the conditional premise (if *p*, then *q*) "is not represented by a set of models", but "by a production rule", which adds a representation of the consequent *q* to every model of the antecedent *p* in the working memory, and which represents the core meaning of a conditional. This production can be used in two procedures: one in which mental models for the conjunction *pq* are constructed by adding a model of *q* to the model of *p* held in working memory, and one in which the degree of belief in a conditional is evaluated in the light of evidence. In the second procedure, the subjective probability of the conditional is estimated as the ratio of $P(pq)$ to $P(p)$, and not to $P(\neg q)$. as in other probabilistic theories for the conditional reasoning. Geiger and Oberauer (2010, p. 303) note that "models are constructed to represent the possibilities that are compatible with the minor premise", whereas the "conditional premise serves to constrain the set of models" built based on the minor premise. As a consequence, in this revised mental model theory, model construction may start not only with a *pq* model of the conditional premise, as in the traditional mental model theory, but also with other models, with the same probability, like the model ($\neg p$ $\neg q$). A particularity of this new version of the mental model theory is that "numerical annotations" can be added to the models, representing frequencies or probabilities of those models, a case in which the role of the conditional premise is not to eliminate the initial models built based on the minor premise, but rather to reduce their probability. This path will be chosen by a reasoner depending on the particular requirements of a reasoning task. Moreover, there can be two inference routes: the one described above, when the reasoners build "mental models of situations compatible with the minor premise", using "the production that incorporates the conditional to constrain these models", and a direct route, "when the minor premise matches the conditions of the production", "the conditional's consequent can be generated as a conclusion directly". As underlined by Geiger and Oberauer (2010), these two routes do not reflect "two separate systems of information processing, but simply two ways of using the same system".

e. Oaksford and Chater (2010, as cited in Barrouillet, 2011) also tried to unify their probabilistic theory for the conditional reasoning with the mental models theory, by suggesting that "mental models could constitute the algorithmic level of their computational probabilistic account of conditional reasoning" (p. 162), a theoretical proposal implemented in a constraint satisfaction network. In this case, annotated mental models from working memory can be used to encode and store the outcomes of the retrieval processes from the long term memory, particularly when more than one possibility is evoked by the information from a conditional premise. Although Barrouillet (2011) finds some merits and analogies with his previous work for the unifying model proposed by Oaksford and Chater (2010), he notes that it does not stand to the developmental test, i.e. it is in contradiction with the data obtained in what respects children's conditional reasoning.

f. Koralus and Mascarenhas (2013) proposed an erotetic theory of reasoning in which they try to integrate ideas from the mental models theory, mental logic, the probabilistic (Bayesian) approaches of reasoning, with an important accent placed by them on the role played by the way in which the premises are interpreted in the deductive reasoning (considering new types of semantics from the philosophy of language and linguistics) and on the dynamics of the interpretation process. Their theory is "based on the idea that the relationship between questions and answers is central to both our successes and failures of reasoning", introducing the erotetic principle, in accordance with which "the process of interpreting premises largely reduces to the search for answers to questions posed by other premises, regardless of whether those premises superficially look like questions" (p. 313). As, as stated by Koralus and Mascarenhas (2013), "having an unanswered question in attention is an uncomfortable state of affairs" (p. 319), people are motivated to find a sufficiently adequate answer, pressured also by conversational and social constraints. The erotetic theory is dynamic by stating that the new premises are interpreted in the context of previous premises, that the "premises are interpreted in the order that they were given" (p. 322), and "that in principle that order can make a difference", because there is an "update procedure" through which the initial model, built based on a first premise, is modified through the information accumulated from successive declarative premises or from premises interpreted as an answer given to the previous premises. In accordance with an inquisitive semantics, a premise is interpreted as a question when "there is more than one alternative" (p. 329) state of affairs represented in its mental model, and as a categorical statement when "there is only one combination" of states of affairs described in its mental model (Koralus & Mascarenhas, 2013). Mental models are built based on the exact verification semantics, in which "the meaning of a statement is modeled as the set of those things that would exactly make it true" (p. 325). The building of the mental models is associated with rules in their transformation (see Koralus & Mascarenhas, 2013). The erotetic theory of reasoning was applied initially by Koralus and Mascarenhas (2013) only to the propositional reasoning, but steps were made in Mascarenhas and Koralus (2017) for its extension to the quantified reasoning. It is supported by some empirical results that, as claimed by Mascarenhas and Koralus (2017), are not accountable by using other reasoning theories.

2. Dual process theories

As a reaction to the state of affairs in the reasoning research, in which several theories are in competition, based on data, some authors (mostly Evans, 1984, as cited in Evans, 2006a, Sloman, 1996, Stanovitch, 1999) have elaborated integrative theoretical frameworks for reasoning, generically named *dual processes theories*. These theoretical frameworks assert that deductive reasoning is based on two major kinds of processes: analytic and heuristic/associative ones[10].

Although dual processes theories were formulated initially in such broad terms, efforts have been made to bring them at an intermediate level of abstraction in order to be useful in analyzing particular deductive tasks. For example, Evans (2006a) has revised his prior heuristic – analytic theory of reasoning (Evans 1984, as cited in Evans, 2006a) that was centered on the idea of two successive stages in deriving a conclusion[11]. In its new version, named explicit-implicit theory, three

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[10] Analytic processes are consciously controlled, effortful, slow, sequential, general, and systematic. They have been assumed to be rather compatible with the theoretical accounts that are focused on the idea of logic rule, or mental model. The cerebral system supporting them is supposed to be evolutionarily recent, being "constrained by working memory capacity and correlated with measures of the general intelligence" (Evans, 2003, p. 454). Heuristic/associative processes are considered to be subconscious, effortless (automatic), parallel, domain-specific (context-dependent), and heterogeneous, unsystematic. They could be viewed to be more in line with the heuristic models, case-based reasoning models, or even pragmatic schemas models. The cerebral system supporting them is supposed to be evolutionary old, comprising "a set of autonomous subsystems that include both innate input modules and domain-specific knowledge acquired by a domain-general learning mechanism" (Evans, 2003, p. 454). The findings from neuropsychological research (Goel, 2003; Goel, 2004, Goel & Dolan, 2001) seem to partially support such a differential involvement of several cerebral regions in the deductive reasoning depending on the type of the required deductive task.

[11] In the first one, heuristic processes were assumed to generate selective representations for the given information (including or not the logically relevant information), and, in the second one, analytical processes were supposed to derive conclusions based on them (that could be biased if the logical information was not included in the heuristic stage).

principles are asserted. The singularity principle states that "people consider a single hypothetical possibility, or mental model, at one time" (Evans, 2006a)". In accordance with the relevance principle, this considered model is "the most relevant (generally the most plausible or probable) in the current context". Finally, the satisfying principle says that "models are evaluated with reference to the current goals and accepted if satisfactory" (Evans, 2006a). Together, the three principles convey the idea that the deductive reasoning implies the consideration of only one possibility (an hypothesis, or an epistemic model, "representing states of belief and knowledge") at a time, supplied by the heuristic system, which is maintained "until we find a good reason to give it up" (Evans, 2006a). It is the task of the analytic system to critically evaluate, to modify, or replace that model. Therefore, in this new version, the analytic system serves not only to derive conclusions, but also to assess the information received from the heuristic system.

In what respects the relationship between the two reasoning systems, Evans (2006a) acknowledges that they are "interdependent", since the heuristic processes supply information "continuously" to the analytic system, and "these systems interact in a complex way and often appear to be competing to control behavior" (Evans, 2006a, p. 378). In his view, in spite of the fact that the two reasoning systems seem to compete in generating an answer, the real competition is not between them, but between a default mental model from the analytic system, cued by the heuristic system, and processes of the same analytic system whose task is to "intervene in order to revise or replace such default models and to inhibit default heuristic responding" (Evans, 2006a). As a consequence, the strict order given in the first version of Evans's theory does not hold anymore. The reason is that there are situations when the analytic system does not generate a conclusion, the answer being given only based on the default model cued by the heuristic system (in case the analytic system is not able to inhibit it). Empirical data have suggested that the intervention of the above mentioned processes of the analytic system is dependent on several factors: cognitive ability (or working memory capacity), the instruction requiring abstract/logical reasoning, and the available time to generate a conclusion (Evans, 2006a).

The new version of the heuristic-analytic theory stresses, also, that the heuristic system is not the only one responsible for the occurrence of the reasoning biases in the deductive reasoning. The analytic system, too, seems to be "prone to biases of its own, especially due to the operation of the satisfying principle", that is to the "the tendency of the analytic system to hold on to representations that are merely good enough, leading to such characteristic features as the endorsement of fallacious inferences in deductive reasoning and apparent confirmation biases in hypothesis testing" (Evans, 2006a, p.383).

The *difficulty of a deductive reasoning* task and the *erroneous answers*, in accordance with the most representative theory of a dual processes sort, are due mainly to the competition between a default epistemic model (built considering the previous experience, and the contextual clues supplied by a heuristic system) and some analytic processes (whose function is to control the validity and the pragmatic relevance of such default models).

There are empirical data that are in contradiction with the dual processes theory (Morsanyi & Handley, 2008), indicating that the heuristic answers for four types of syllogisms increases with age and with the cognitive capacity. In my view, one of the major flaws of the explicit-implicit theory is the fact that the three above mentioned principles on which it was built are not substantiated enough, theoretically or empirically. Additionally, it seems to reach a point in which the distinction between heuristic and analytic processes becomes blurred. In fact, Evans himself acknowledges that. In the light of the accumulated evidence, Evans questions the assumed properties of the two stated reasoning systems, and claims even that "it is far from evident at present that a coherent theory based on two systems is possible" (Evans, 2006b, p. 206)[12]. He has a reversed perspective in

[12] For example, he provides reasons for not considering the so called "analytic system" to be necessarily "an abstract or logical system", suggesting that "solving logical reasoning problems is just one kind of strategic thinking that can be undertaken successfully" through such a system "by those of sufficient cognitive ability who are appropriately instructed" (Evans, 2006b, p. 204). In fact, Evans (2006b) disputes the idea that there is a reasoning system that has logic competence, and some of the tenets

comparison with those researchers sustaining theoretical models based on a logical competence. For him, "deductive effort, when made, attempts to modify pragmatic processes, and not the other way around" (Evans, 2006a, p. 392)[13].

From a neuropsychological point of view, the imagistic studies relevant for the dual processes theory provide unclear and complex results, too. For example, Goel (2009) reports that he is not aware "of a single report of neurological patients with a selective reasoning deficit" (p. 207) and that the imagistic data do not support the traditional version of the dual processes theory, but rather the idea that "human reasoning is underwritten by a fractionated system that is dynamically configured in response to specific task and environmental cues" (p. 207). As shown by Goel (2009), these data also indicate dissociations in what respects rather new distinctions, which overlap only partially with the distinctions that have underpinned the traditional dual processes theory. Such new distinctions are reasoning deductively with familiar vs. unfamiliar content, or with complete vs. incomplete information. Goel (2009) notes also that dimensions as innate vs. acquired, automatic vs. deliberate, mandatory vs. nonmandatory, slow vs. fast can be misleading when used to characterize systems of reasoning, some of them referring to superficial behavioral categories. Therefore, the above-cited author states that "the dual processing approaches, whatever their particular features, only account for one of several sets of dissociations that we are finding in the neuropsychological data on reasoning" (p. 13) and that it would be more appropriate "to start talking about multiple

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of the mental models theory (for example, the notion of mental model, and the assumption that people are able to operate with more that one model). In his view, deductive reasoning "may be seen as no more than an analytic-level strategy that bright people can be persuaded to adopt by the use of special instructions" (Evans, 2006a, p. 392).

[13] A reason for which he supports such a perspective is that, in his opinion, "the brain has been optimized by evolution for distributed processing" and it is "relatively inefficient when applied to sequential and logical forms of thinking" (Evans, 2006a, p. 392). Therefore, he pleads not to "see the psychology of reasoning as somehow apart from other research in cognitive psychology" (Evans, 2006a, p. 392), as he feels that other cognitive psychologists involved in the deductive reasoning research do.

reasoning systems rather than simply dual reasoning systems" (p. 14), which are thought to interact dynamically. As a consequence, Goel (2009) sketches his own version for a dual processing theory of deductive reasoning, based on the idea of bounded rationality and the model for the human problem solving proposed by Newell & Simon (1972, as cited in Goel, 2009). Deductive reasoning, seen to be a problem solving process, has a "problem space, a computational modeling space shaped by the constraints imposed by the structures of a time and memory bound serial information processing system and the task environment" (p. 12). In its case also, content free universal methods such as Means Ends Analysis, Breath First Search, Depth First Search, etc. can be used for searching this problem space. Because such content free universal methods, i.e. "formal, context independent processes", require "enormous computational resources" and "the cognitive agent is a time and memory bound serial processor", an answer based on these methods would not be given often in the needed time, so, new methods should be in place in order to circumvent formal search procedures, adding constraints that should decrease the burden of a systematic search. Such new methods can be based on task-specific knowledge, representing the heuristic part of the reasoning process. Goel (2009) defines heuristics as "situation specific, learned and consciously applied procedures" (p. 13). If such shortcuts are present, "they are given priority", and if they "are not available we fall back upon more general/universal (but computationally intensive) strategies" (Goel, 2009, p. 13). So, Goel (2009) states that neuropsychological data are more consistent with a view of the deductive reasoning as based on "two different strategies for processing information", rather than with one in which "two distinct systems/modules with different evolutionary history" are involved in the deductive reasoning. In this way, he also disavows a more extreme position (massive modularity) in what respects the dual processes theory, i.e. that "there is no formal system, just a collection of numerous modules evolved to solve specific evolutionary problems (Duchaine, Cosmides & Tooby, 2001)" (Goel, 2009, p. 9). Goel (2009) explains the neuropsychological data analyzed by him “in terms of an interplay between Gazzaniga's "left hemisphere interpreter" (Gazzaniga, 2000) and right PFC systems for conflict detection and uncertainty maintenance” (p. 14). In his view, “the function of this interpreter is to make sense of the environment by completing patterns by filling in the gaps in the available information” (p. 14), this interpreter not being “specific to particular types of patterns” (i.e., it does not matter “whether the pattern is logical, causal, social, statistical, etc.”). In accordance with Goel (2009), as this interpreter rejects any uncertainty, it “will complete any pattern, often prematurely, to the detriment of the organism” (p. 14). In case there are conflicts in a pattern, they are detected by a “conflict detection system”, and “representations of indeterminate/ambiguous situations” are actively maintained by an “uncertainty maintenance system”, in order to “bring them to the attention of the interpreter”.

In my opinion, Evans (2006a) is heading, too, toward a theoretical position in which there is no clear separation between an information interpretation phase and a conclusion derivation phase. Instead, it might be that derivation is obtained through interpretation. Ultimately, after presenting evidence also that the analytic system does not involve invariably conscious control, as it has been supposed to, and that there may be more than one heuristic system, he raises the following issue:

> If the conscious, analytic system is at best only partially in control and in competition with not one but several implicit systems, how come everything works so well? Understanding how generally adaptive behavior can result from such an apparently chaotic cognitive architecture is one of the great challenges for cognitive science. (Evans, 2006b, p. 206)

That quotation reflects the impasse reached by the deductive reasoning research. Even though efforts have been made in order to surpass this state of affairs in the reasoning research, in my opinion, no major breakthroughs are currently in discussion. In general, lately, the revision of the most significant existing reasoning theories and models has been the main research direction, by relaxing some of their strong tenets and adding supplementary clarifications and elements in order to explain away some new or contradictory data.

For example, in what respects the dual processes theories, Evans and Stanovitch (2013) tried to answer synthetically to the most important objections that were made in what respects their theoretical proposals, refining, in the same time, the definition given by them for the two kinds of reasoning processes that are presumed by this category of theories, named by them as Type 1 processes (synthetically characterrized to be the intuitive ones) and Type 2 processes (synthetically characterized to be the reflective ones). In a more detailed characterization, Type 1 processes are considered by Evans and Stanovitch (2013) to be "intuitive, fast, autonomous, and high capacity", and Type 2 processes as "reflective, slow, and resource demanding". They assume that Type 1 processes "provide default outputs that may be acted upon as explicit representations manipulated in working memory via Type 2 processing (reflective)" (Pennycook, Fugelsang, & Koehler, 2015, p. 35). Type 1 processes do not require "controlled attention", they "make minimal demands on working memory resources", and their execution is "mandatory when their triggering stimuli are encountered", not depending "on input from high-level control systems" (Evans & Stanovitch, 2013, p. 236). Evans and Stanovitch (2013, p. 236) show that Type 1 processes are heterogeneous in what respects their neurophysiology and etiology, including "both innately specified processing modules or procedures and experiential associations that have been learned to the point of automaticity", specific "modular subprocesses" and general "implicit learning and conditioning". In the cited study, it is underscored that Type 2 processes are distinguished by their nature in comparison with the Type 1 processes, involving "cognitive decoupling and hypothetical thinking", being "highly correlated with fluid intelligence", and having a "strong loading on the working memory resources", implying sequential processing. Type 2 processes enable "uniquely human facilities, such as hypothetical thinking, mental simulation, and consequential decision making" (Evans and Stanovitch, 2013, p. 235). Evans and Stanovitch (2013) specify that apart from the characteristic features mentioned above, other features, which in the past were associated to the two kinds of processes, "are simply correlates that occur under well-defined conditions and are neither necessary nor defining features" (p. 226). As a consequence, the above-mentioned authors emphasize the idea that "it is no longer the case that Type 2 thinking is regarded as abstract and context-free in contemporary theories" (p. 228), that both kinds of processes are content laden, not only Type 1 processes, as it was thought in the past, only that "prior knowledge affects Type 1 and 2 processing in qualitatively different ways" (p. 229), involving different mechanisms for content effects to occur. So, in their view, even though "Type 2 reasoning is often necessary for the kind of abstract and elaborated forms of reasoning needed to solve typical laboratory tasks, such a conclusion does not make decontextualization a defining characteristic of Type 2 processing" (p. 229). In the cited study, Evans and Stanovitch (2013, p. 229) also contest the widespread idea that "Type 1 processes (intuitive, heuristic) are responsible for all bad thinking and that Type 2 processes (reflective, analytic) necessarily lead to correct responses", considering that it is a false perception, given that, even though "various forms of dual-process theory have blamed Type 1 processing for cognitive biases in reasoning and judgment research and for prejudice and stereotyping in social psychology", that it is not true for all dual-processes theories. They state explicitly that "Type 1 processing can lead to right answers and Type 2 processing to biases in some circumstances" (p. 229). Moreover, they assert that brain processes cannot be characterized as rational or irrational per se, but only that they are either efficient or inefficient. In their view, only the decisions or beliefs in which reasoning processes are involved can be characterized as rational or irrational. Taking into discussion the quality of the result obtained through Type 1 processes, Evans and Stanovitch (2013) show that it depends on the kind of task environment in which those reasoning processes take place. A benign environment, in the definition of the two authors, "contains useful cues that, via practice, have been well practiced by Type 1 mechanisms" and does not "contain other individuals who will adjust their behavior to exploit those relying only on Type 1 processing" (p. 229). In such an environment, Type 1 processes are less error prone. A hostile environment, instead, is characterized as having no "overpracticed cues that are usable" for the Type 1 processes or "other agents discern the simple cues that are triggering Type 1 processing—and the other agents start to arrange the cues for their own advantage" (p. 229). It is in such an environment in which Type 1 processes lead to biases and reasoning errors. In what respects the possibility that the two kinds o processes to be reduced to only one kind, the two cited authors bring several arguments against such a possibility. First of them involves the introduction of a distinction between types and modes of processing, which are often confused. In their opinion, only modes can vary continuously, not the types, and modes are "actually different cognitive styles applied in Type 2 processing", seen "as the explicit processing of rules through working memory" (p. 229). In Evans and Stanovitch's (2013) view, unlike Type 1 processes, Type 2 processes "could be engaged in a slow and careful but also a quick and casual manner or any point in between" (p. 229), with more or less effort, depending on several personality characteristics as the Need for Cognition or Active Open Minded Thinking, or on cultural influences, as the holistic and analytic cultural styles or superstitious thinking, styles that can be confounded with the two types of processing proposed by the dual-processes theorists. Another argument against the hypothesis of a single kind of processing takes into account the idea that "Type 2 processing is the only type of processing that is characterized by flexible goals and flexible cognitive control" (Evans & Stanovitch, 2013, p. 229). So, the continuous variation indicated by all the thinking disposition measures is possible only for the Type 2 processes, and not for the Type 1 processes, so that those measures are considered by the two authors to be, in fact, modes of processing measures. The issue of the modes of processing led the two authors to the idea of replacing the dual processes theory with a tri-process theory of reasoning, as it was initially proposed by Stanovitch (2009), by splitting the Type 2 processes in two types of subprocesses and interpreting the three types of processes as associated with three levels of hierarchical control when solving a reasoning task. Type 1 processes are seen by them to have as a source a set of autonomous systems (TASS) and to be associated with a level of control oriented toward "short-leashed goals". Type 2 processes are separated, in their view, into algorithmic processes and reflective processes. The algorithmic processes can override, through an inhibitory mechanism, the autonomous Type 1 processes, but this inhibition is initiated through the reflective processes, i.e. by a higher level of control than the level of control associated with the algorithmic processes. That higher level of control is associated by them with "goal states and epistemic dispositions" that "regulate behavior at a high level of generality", as a self-regulation based on epistemic values. In accordance with the two cited authors, cognitive ability measures assess the ability of the algorithmic processes "to sustain decoupled representations" "for purposes of inhibition or simulation", whereas thinking dispositions measures assess "higher level regulatory states of the reflective mind", reflected into several tendencies: "to collect information before making up one's mind", "to seek various points of view before coming to a conclusion", "to think extensively about a problem before responding", "to calibrate the degree of strength of one's opinion to the degree of evidence available", "to think about future consequences before taking action", "to explicitly weigh pluses and minuses of situations before making a decision" (p. 230). So, in Evans and Stanovitch's (2013) opinion, there is a continuous probability that "a response primed by Type 1 processing will be expressed" dependent on the "continuous variation in both cognitive ability and thinking dispositions", but "the continuous variation in this probability in no way invalidates the discrete distinction between Type 1 and Type 2 processing" (p. 230).

In what respects the argument against the dual process theory, which is based on the empirical data, that both intuitive and deliberative judgments can be rule based, Evans and Stanovitch (2013) note that those data cannot logically invalidate the tenet that the intuitive and deliberative processes are qualitatively different, originating in "distinct cognitive mechanisms ". They show that they have never believed that rule-based processing characterizes exclusively Type 2 processes, as long as, in their view, too, "rules can be concrete as well as abstract and any automatic cognitive system that can be modeled computationally can in some sense be described as following rules", so that any reasoning "can be described using rules and modeled by computer programs" (p. 231). In other words, the associative Type 1 processing can be also rule-based, being "modeled by neural networks that are implemented using rules" (p. 231). But Evans and Stanovitch (2013) specify that, in their view, the rules for the Type 1 processes are still different from the rules from the Type 2 processes. Finally, the two cited authors admit that dual process theories were initially based on "conflict data" that, in fact, "provide evidence only for dual sources of variance", but, they cite other, more recent, empirical data that add support to the hypothesis of two qualitatively distinct types of reasoning processes. Such empirical new data indicate that Type 2 "aspects of performance" "are selectively correlated with intelligence measures, whereas features attributed to Type 1 processing are largely independent of such measures" (Evans and Stanovitch, 2013, p. 236), being more dependent on the particular past experience of a reasoner, as it can be inferred from the data presented by the two cited authors.

Two kinds of dual processes models have been proposed regarding the relationship between Type 1 and Type 2 reasoning processes: default-interventionist models and parallel competitive processes models, respectively. Evans and Stanovitch (2013) advocate the default-interventionist type, believing that "fast Type 1 processing generates intuitive default responses on which subsequent reflective Type 2 processing may or may not intervene" (p. 227). So, in their view, "most behavior will accord with defaults, and intervention will occur only when difficulty, novelty, and motivation combine to command the resources of working memory" (p. 237), seeing no way in which to combine parallel-competitive assumptions, in accordance with which "Type 1 and 2 processing proceed in parallel", with their definitions of Type 1 and 2 processing. They believe that, because they think that, in a parallel competition, the fast Type 1 processes will always gain the competition, and because Type 2 processes, in their definition, require the extremely limited resources of the working memory, it is not possible that Type 2 processes to be used in all the reasoning tasks, but only for the important ones.

More recently, De Neys (2014), based on a series of empirical results in what respects a phenomenon called by him "conflict detection" and explained by the same author through the proposed notion of logical intuition, has suggested a different version of the dual process theory. The empirical results obtained by the cited author indicate that biased reasoners question their heuristic answer in the case of the reasoning tasks for which there occurs a conflict between a heuristic answer and a logical one, as it is the task of solving syllogisms in which a belief bias occurs. In other words, they detect the conflict between their answers and the logical answers. In order to explain these results, logical intuitions were postulated by the above-cited author. In other words, he claims that besides the heuristic answers, "the classic reasoning tasks also automatically evoke an intuitive logical response" (p. 7). When there is a conflict between the two types of intuitive answers (the heuristic and the logical ones), an arousal will occur. By noticing this arousal, people will question their heuristic answers, without being able to explicitly identify the source of the conflict that generated that arousal. So, in the De Neys's (2014) version of the dual process theory, the parallel activation would be for two different types of intuitive responses generated by the associative system: "a heuristic intuitive response based on mere semantic and stereotypical associations, and a logical intuitive response based on the activation of traditional logical and probabilistic principles" (p. 8). The need to engage the analytic system would be signaled by the detection of a conflict between the two types of responses generated by the associative system. But, as it was noted by De Neys (2014), the mere detection of that need does not guarantee the actual engagement of the analytic system. The conflict detection is conceived by De Neys (2014) to be a different type of switch between the associative system and the analytic one than the ones envisioned by other authors: the fluency with which an initial answer is generated and the associated feeling of rightness (FOR), as an affective response with a metacognitive basis, as it was proposed by Thompson

(2009), or a monitoring process of a third system, which is automatic and unconscious, as it was suggested by Evans (2009, as cited by De Neys, 2014). Finally, Bago and De Neys (2017) present experimental evidences that "fast and automatic Type 1 processing can cue a correct logical response from the start of the reasoning process" (p. 90). They interpret their results by positing that a Type 1 process could be "conceived as a more superficial, recognition memory-like process that activates a stored logical principle and allows us to recognize that a competing heuristic intuition is questionable, without us being able to explicitly label or justify the principle" (p. 106) and that the "relative strength of different types of intuitions determines reasoning performance". In my opinion, the idea of logical intuitions competing with heuristic intuitions opens the door for other kinds of intuitions that may be in competition with them, acquired also based on experience, and it represents another step towards the blurring of the border between the analytic and intuitive reasoning.

Another recent version of the dual processes theory of reasoning, which tries to synthesize the previous ones, is the one proposed by Pennycook et al. (2015), a version stating a three-stage model for the engagement of the analytic reasoning processes. For the first reasoning stage, they assume the occurrence of autonomous Type 1 processes, which generate so-called ''intuitive'' responses, following a similar line with the one of the De Neys's (2014) proposal of the logical intuitions. Also, like De Neys (2014), Pennycook et al. (2015) predict that some stimuli are able to cue "multiple, potentially competing Type 1 outputs" in this first stage. Taking over an idea from Thompson (2009), Pennycook et al. (2015) believe also that, in this first stage, some of the initial responses "come to mind more quickly and fluently than others". So, in the initial stage, "alternative sources of information can cue an alternative Type 1 output in parallel", eliciting "competing initial responses" (p. 11). Through the processes from the second stage of the model, the conflict between Type 1 outputs is monitored, potentially leading to a conflict detection. In the third stage, if no conflict is detected (because there is no conflict, or because of a failure in its detection), the initial response generated in the first stage will be accepted after a superficial analytic Type 2 analysis. If a conflict is detected, then the engagement in the Type 2 analytic processing increases, taking two forms: rationalization (when the initial Type 1 output is analytically verified after its generation, "bolstering or verifying an intuitive response"), or decoupling (when the initial Type 1 output is falsified, expending additional effort to inhibit, override, or falsify an intuitive response in lieu of an alternative or "an alternative response (AR) is generated that represents a novel amalgamation of initial responses"). In other words, for Pennycook et al. (2015), there are two bottom-up sources of analytic thought: conflict detection, placed in the second stage, and decoupling, placed in the third stage. As top-down sources for the analytic thought, Pennycook et al. (2015) enlist, based on several cited works, instructional manipulation, the mere willingness to engage deliberative reasoning, individual differences in the ability to think analytically (i.e., cognitive ability or intelligence), the personality disposition to be "actively open-minded are more willing to question and perhaps rethink an initial response", the cognitive style (reflective or intuitive). In other words, the cited authors state that "how much someone values or enjoys analytic thinking may contribute to the probability that they engage Type 2 process, independent of any Type 1 output monitoring process and therefore regardless of the content of the stimulus" (p. 15). As a consequence, in the model proposed by Pennycook et al. (2015), reasoning failures could have the following two sources: the failure to detect a bias (and, implicitly, to think analytically), placed at an early stage of the reasoning process, or the failure to use the analytic thought to override the intuitive response after a successfully conflict detection, placed at a late stage of the reasoning process.

The last presented version of a dual process theory is the one elaborated by Ricco and Overton (2011), which essentially proposes an additional distinction within the so called system 2 (the analytic system in the traditional dual processes theory), based on a competence-procedural differentiation in what respects the logical thinking, pleads for dynamic relationships between the system 1 (the heuristic system in traditional terms) and system 2, but also between the algorithmic and reflective part of the system 2, and suggests the existence of some inference schemes. The two cited authors believe that the traditional characterization for the system 2 as analytic is misleading, because implies “reductionism, atomism, simple (additive) complexity, and linearity to the neglect of complementary explanatory principles including holism, synthesis, organizational complexity, coaction, and non-linearity” (p. 120). So, they prefer to name system 2 as a ‘competence system’. This competence system, in their view, has an algorithmic component (a kind of mental logic, as they specify), “consisting of operations, processes, rules and other cognitive structures underlying norm-based processing of reasoning and decision-making problems” (p. 120), and a reflective or intentional component, “consisting of practical and epistemic forms of self-regulation”, in which metalogical knowledge is the important part. Ricco and Overton (2011) support this distinction with theoretical and empirical arguments. An important argument, based on several studies cited by the two authors, is the “significant evidence that epistemic beliefs or levels of understanding and thinking dispositions predict reasoning performance over and above individual differences at either the algorithmic or the heuristic (system 1) levels” (p. 121). Another argument is the existing empirical evidence that “measures of algorithmic processing (e.g., intelligence tests, working memory assessments) are better predictors of reasoning performance when instructions pull for optimal performance (norms are prescribed for the participant)”, and that “measures of reflective processing (e.g., actively open-minded thinking, need for cognition) are better predictors of typical reasoning performance than of optimal reasoning performance” (p. 121). Ricco and Overton (2011, p. 122) suggest that the reflective system may involve “thinking dispositions which can determine whether or not to invoke metacognitive competencies as well as whether or not to engage the algorithmic system”, as it is “the disposition to engage in intellectual activity”, which may favor a “reflective capacity to distinguish between fluency and subtler, more accurate cues to whether or not a proposed answer is correct and they may appreciate the limitations of fluency as a basis for feelings of 'rightness' or of 'knowing'". In what respects the relationship between the two components proposed for the system 2, the cited authors state that it is "fundamentally dynamic and reciprocally co-active and co-constructed across their ontogenesis" (p. 123). The same dynamic accent is placed by Ricco and Overton (2011) when they explain their view on the distinction between competence, represented by the system 2, in their view, and procedural aspects, represented by the system 1, of the logical thinking. They see the competence system, system 2, as "a complex dynamic organization" that "is, in and of itself, content free and is not to be considered as the ''mental representations'' the adult mind uses when reasoning (Russell, 1987)" (p. 123), referring to "operations of mind that are relatively enduring, universal, and applicable to a broad range of phenomena" (p. 123). By contrast, the procedural aspect refers to "individuated, real-time action processes", by which the "enduring operations are expressed or manifest in particular individuals and contexts" (p. 123). Ricco and Overton (2011) suggest that "because the organizational properties of mind are not reducible to any particular set of real-time processes or representations, they can only be modeled by relatively abstract, dynamic, rule systems" (p. 123), in other words, competence is not reducible to procedures. Besides the lack of the competence-procedural distinction in the traditional dual processes theories for reasoning, the above-mentioned authors signal also that "dual processing accounts often lack an explicit recognition that the proposed systems of mind are highly complex and relationally integrated outcomes of a complex self-organizing and self-regulating adaptive developmental process (i.e., a relational developmental system)" (p. 124), stressing once again a dynamic perspective over the development of the two systems by stating that " the ontogenesis of mind is embodied, nonlinear, and epigenetic" (p. 124). Discussing the development issue, Ricco and Overton (2011) introduce the notion of "inference scheme", without an explicit definition for it. So, in their view, deductive competence can be attributed to an individual based on "a certain level of integration (and differentiation) among inference schemes" (p. 124), and this progressive coordination between the inference schemes, which yields "richer entailments among schemes or combinations of schemes", through a reflective process similar with a the dynamic recursion, leads to an emergent (a notion also pertaining to the dynamic systems theory) metalogical knowledge or understanding. This metalogical knowledge involves the explicitation of the properties of the deductive inference, "with a resulting capacity to invoke these properties as norms or constraints on reasoning".

Dual processes theories with their recent versions are only implycitly more or less committed to the symbolic computationalist paradigm, but many of their tenets are compatible with an alternative dynamic paradigm, too, sometimes even including more or less explicit dynamic interpretations. That is why they are considered to be integrative also in that respect, being rather paradigm-neutral, or a possible bridge between the existing paradigms. By recognizing that the distributed processing is fundamental for reasoning, a step is made by them in the direction of an approach of the deductive thinking from a dynamic perspective, presented in the following section. The integrative valence of the dual processes theories was put in evidence by Osman (2004, and Osman and Stavy, 2006), who pleads for an alternative framework, unifying under a single system the different forms of reasoning identified by dual-process theorists. In order to do that, she uses the idea that the reasoning processes depend on the quality (strength, distinctiveness, stability) of the representations on which they operate and on the degree of control that individuals have over those representations.

3. Synthetic theories

Recently, a third category of integrative theories emerged, named here synthetic theories, which try to bring new unificated versions of one or more traditional theories of the deductive reasoning into a framework similar with the one of the dual process theories.

A first example that illustrates this category of reasoning theories is the one proposed by Verschueren and Schaeken (2010) for the particular case of the conditional reasoning, based also on a previous work of

Verschueren, Schaeken, and d'Ydewalle (2005) for the causal conditional reasoning. They bring, as they say, the mental models theory and the probabilistic account of reasoning, and, in some measure, results from the pragmatic schemas theory, together into the dual-process perspective, supporting their theoretical endeavor with empirical data. The cited authors start by positing that there are three levels at which a dual-process polarity (i.e., the heuristic/analytic bipolarity) can be distinguished or located. The highest level (Level 3) is the one regarding the first decision: whether to incorporate or not background information (i.e., contextualization vs. decontextualization). If the decision is in the favor of integrating background information (contextualization), there occurs a second decision level (level 2): whether to take knowledge into account "by relying on probabilistic information or by searching for counterexamples" (probabilities vs. counterexamples), i.e. to choose between a probabilistic path of reasoning (an heuristic process) or a mental model path of reasoning (an analytic process). Finally, if the path of counterexamples is chosen, there comes the third decision level, the deepest one (Level 1): whether to access the counterexamples through strategic cue-based retrieval (an analytic process) or through automatic spreading activation (a heuristic process). In what respects the Level 3 (contextualization vs. decontextualization), the cited authors distinguish two cases in which the relevant information might not be taken into account when reasoning conditionally. The first case is when the reasoners have a low competence, not having "the cognitive resources that are needed to retrieve and integrate background knowledge". The second one is when reasoners have a high competence, being highly skilled in the formal reasoning, who discards the background knowledge as irrelevant (they "block the impact of available background knowledge when this information conflicts with normative standards"), using only formal reasoning principles instead. Adopting a tentative position, Verschueren and Schaeken (2010) tend to believe that, for the first case, the reasoning is predominantly heuristic, and, in the second case, analytic. For the second level of decision (Level 2), when reasoners choose the heuristic path, the probabilistic one, "the reasoning process places little demand on working memory, yields fast results and proceeds implicitly" (p. 360). When the reasoners choose the analytic path, i.e. of finding counterexamples using the mental models, "the reasoning process is slower, more explicit, and requires more processing resources" (p. 360). At this level, "the interaction between the generic heuristic and analytic processes centers on the override principle: A default, heuristic conclusion gets overwritten when an analytical conclusion can be produced" (p. 361) relatively fast. The two cited authors note that this principle "does not necessarily imply that the likelihood information is totally blocked or cancelled". It implies only that "the conclusion based on likelihood information is rather revised or amended with counterexample information", leading to a "more informative conclusion". Verschueren and Schaeken's (2010) conclusion is that, in what respects the second level of decision, "both theories on conditional reasoning – the probabilistic and the mental models account – are valid accounts and that they are best considered from a dual-process perspective", as "both theories describe a different yet complementary aspect of common-sense reasoning" (p. 367). Regarding the deepest level of decision, Level 1, Verschueren and Schaeken's (2010) note that the choice of a counterexample retrieval using strategic cues through an analytic process or using automatic spreading activation, a rather heuristic process, depends on the type of the to be retrieved counterexample. They distinguish between three types of counter-examples. Prototypical counterexamples "are semantically closely related to the content of the premises" and they are retrieved through "semantic association". The second type of counterexamples "refers to exceptions to the normal situation or to deferred conversational implicatures" and they are retrieved through a strategic, analytic, retrieval process, "guided by active cue generation". The third type is "of a low quality", including "answers referring to some magical interference, plain luck, a non-literal reading or invalid responses". Verschueren and Schaeken (2010) provide also an "alternative explanation for the effects of pragmatic content on the inference acceptance rates" in the case of the conditional reasoning. They bring theoretical and empirical arguments that those effects may occur because of the relative importance of the analytic and heuristic processes in one or several of the three distinguished levels on which those processes can be located for the particular case of a type of pragmatic conditional reasoning (due to different working memory demands, the strength of the relationship with a social context, the required type of counterexamples).

Barrouillet (2011) approaches dual-process theories from a developmental perspective, taking into account not only the results obtained for adults in what respects the conditional reasoning performance, but also for children and adolescents of various ages. He analyzes, first, a series of previous dual processes theories, finding their parts of agreement or contradiction with the empirical results obtained regarding the ontogenetic development of the conditional reasoning. Then, he proposes a model that integrates the main tenets of his revised mental model theory (Markovits & Barrouillet, 2002) within the revised heuristic/analytic model of Evans (2006a) with aspects from the pragmatic schemas theory. In his version for a dual process theory of reasoning, based on developmental data, he assumes that, initially, through some heuristic processes, "a default model representing the relation between the antecedent and the consequent" is delivered when several types of conditional sentences (i.e., indicative or causal conditions) are understood. This means, as he states, that that model is not delivered "necessarily for all conditionals". He also posits that other "heuristic processes could deliver pragmatic implicatures susceptible to enrich" (p. 170) this initial output for some particular conditionals like promises and threats, as they "strongly cue invited inferences that are inherent to their meaning" (p. 170), so that, in their case, there is a two-model initial representation. This initial model can be enriched by analytic processes, through the representation of other possibilities, which requires a process of decoupling and storage of those possibilities in working memory. Depending on the task context or some individual differences, the building of the additional models through analytic processes "can be triggered by the minor premise in inference production or evaluation, by the perception of state of affairs in truth table tasks, or even by the internal drive resulting from metacognitive processes" (p. 170), and it is constrained by two main factors: "the availability of relevant knowledge in working memory" and the capacity of the working memory (which influences the "capacity to activate knowledge from long-term memory and the number of representations that can be held in working memory"). As "the number of models that can be constructed increases with age", there occur "successive levels of interpretation and reasoning", accounting "for the developmental increase in efficiency of analytic processes" (for example, it explains why the "fleshing out process in adolescents is limited to the construction of only one additional model instead of two as in adults"). Barrouillet (2011) underlines that his theory "departs from the standard mental model theory", as, in his view, mental models have another epistemic status, linked with the way they are constructed. Epistemically, the initial, default, models constructed by the primitive heuristic processes for a conditional sentence are considered to be by Barrouillet (2011) "as the core meaning of the sentence, what makes it true". The models added by the analytic processes, instead, in his view, although they are compatible with the conditional sentence, they "should not be considered as making it true". Based on the developmental data, he states that mainly analytic processes develop through childhood, adolescence and adulthood, whereas heuristic processes remain relatively unchanged, as they are conceived by him to be "processes of retrieval from long-term memory", by assuming that "unconscious and automatic processes governing spreading activation and retrieval from long-term memory do not greatly evolve with age from childhood to adulthood". However, he notes that the output of the heuristic processes can evolve with age, because it "depends both on mechanisms of retrieval and on the richness and structure of the accessed knowledge bases" and knowledge bases develop with experience. The development of the metacognitive processes plays also a role in the evolution of the output of the heuristic processes, as underlined by Barrouillet (2011), because this output may be enriched by the refined "metacognitive experiences that accompany memory retrieval such as feeling of retrieval fluency and FOR" (p. 171). Therefore, he thinks that it is "possible that, with age, individuals would have access to increasingly rich default models" (p. 172). Nevertheless, Barrouillet (2011) affirms that the enrichment of the heuristic processes through metacognitive processes does not lead up to the level of the representations for conditional probabilities or of the probability of conditionals, which were previously linked with heuristic processes. This affirmation is supported by him with developmental data that show that the ability to have these types of representations is "a late developmental achievement", its occurrence being influenced by "individual differences in fluid intelligence" and, in accordance with his supposition, by the emergence of the reflective mind. So, he maintains his view that "even in adults, the default model for indicative and causal conditionals is restricted to a representation of a directional relation between the antecedent and the consequent" and that "the main development observed in conditional reasoning relies on an increase in the number of mental models that can be constructed and manipulated in working memory" (p. 172). However, he concedes that the improvement with age in the "capacity to construct complex representations in working memory" "cannot account for all the developmental phenomena" in what respects conditional reasoning. He states that, for the analytic processes from the conditional reasoning, the development of the metacognitive processes is important, too, allowing "older adolescents and adults not only to construct appropriate representations to reason from conditional statements, but also to think about the system that these representations constitute" (p. 172). It is a level corresponding to the explicit metalogical stage as defined by Moshman (1990, as cited in Barroulliet, 2011), in which "meta-abilities needed to think about truth and falsity" emerge, leading "to higher levels of rationality only reached in adulthood".

Barrouillet (2011) notes that his vision on the development of the conditional reasoning can be traced back to the Piagetian theory, finding some common points between them. Firstly, Barrouillet's (2011) idea of the initial default model is linked with the Piagetian idea that "an intuition is always a process of substitution by which a rational concept is first assimilated to an undifferentiated perception or action" (p. 172). Another similarity noted by Barrouillet (2011) is the one between the idea occurring in some dual process theories, inclusively in his vision on them that "analytic thinking cannot operate without the heuristic system because heuristic processes provide the conscious content on which analytic processes apply" (p. 174) and the Piagetian view that rational thinking emerges from the coordination of intuitions, "which leads to their regulation and compensation into reversible operations", to "abstract and deductive abilities", i.e. to analytic reasoning. The involvement of the metacognitive processes in the development of the conditional reasoning and the idea of reflective mind, presented above in the Evans & Stanovitch's (2013) work, are put in relationship by Barrouillet (2011, p. 174) with the Piagetian notion of "reflective abstraction", "by which an operation becomes the object of some higher order operation", a process accounting the transition from concrete to formal thinking. So, synthetically speaking, Barrouillet (2011, p. 169) believes that "the development of conditional reasoning could be based on metacognitive development", not only on the "the increase in working memory capacity". From this perspective, for the relationship between the heuristic and analytic processes, it is relevant also another developmental theory, as Barrouillet (2011) notes, the theory of the metalogic development proposed by Moshman (1990, as cited in Barrouillet, 2011). This theory "distinguishes four successive stages in the development of metalogical understanding", describing "what is explicit in children's reasoning processes and what remains implicit" (Barrouillet, 2011, p. 168). These stages of the Moshman's theory of the metalogical development are, in the Barrouillet's (2011) description, as follows:

> At a first level, inference schemas remain implicit, young children being only explicitly aware of the content on which they reason. A second stage, typical of elementary school children, involves awareness that conclusions are based on premises and are reached by a process of reasoning, even if the underlying logic still remains implicit. It is only at the third stage that young adolescents are explicitly aware of the logical

> form of their inferences. Being able to understand the necessity of the relationship between premises and conclusions, they can appreciate the validity of argument forms, independent of the empirical truth or falsity of their content. It is only in a fourth stage only reached by some individuals at the end of adolescence that metalogic itself becomes explicit. Stage 4 individuals are able to think about a formal logical system and grasp its relationships with natural language. (Barrouillet, 2011, p.168)

Metalogical strategies are "planful, temporally extended and susceptible to introspection", being used to generate "multiple possibilities consistent with premises" or to actively seek "counterexamples to potential conclusions" (Barrouillet, 2011, p. 168), characteristics that lead Barrouillet (2011) to think that they should be linked with the analytic processes from the dual process theories.

Another example of the kind of endeavor discussed in this section is the one encountered in a series of studies of Johnson-Laird and Khemlani together with their collaborators (Johnson-Laird & Khemlani, 2013; Johnson-Laird, Khemlani, & Goodwin, 2015; Khemlani & Johnson-Laird, 2013; Khemlani & Johnson-Laird, 2016), who have proposed a new unified computational implementation of the mental model theory, named mReasoner. The new version of the mental model theory is based on three fundamental principles (Khemlani & Johnson-Laird, 2016). The first two of them clarify the meaning given by Khemlani and Johnson-Laird (2016, p. 2166) for the notion of mental models as an iconic simulation of possibilities: "mental models represent possibilities" ("a set of discrete possibilities that are observed or imagined"). Mental models are iconic "as far as possible" and have a structure "isomorphic to the structure of what it represents", but they "can also include abstract symbols, e.g., the symbol for negation" (Khemlani and Johnson-Laird, 2016, p. 2166). The third principle is of a dual process type, being introduced in order to account for the individual differences in the reasoning performance: reasoning "is based on two interacting sets of processes: intuitions yield an initial conclusion by building and scanning a single model; and deliberations search for counterexamples to intuitive conclusions and, where possible, formulate alternative ones" (Khemlani and Johnson-Laird, 2016, p. 2166). This theoretical model was implemented by Khemlani and Johnson-Laird (2016, p. 2166) in a stochastic computer program, mReasoner, which "generates an initial conclusion by building and scanning a mental model", taking into consideration "four separate factors" that can vary during a simulated reasoning process: "the size of a model, its contents, the propensity to consider alternative models, and the propensity to revise its heuristic conclusions". The cited authors state that "the former two parameters control intuitive processes and the latter two control deliberative processes". In fact, Khemlani and Johnson-Laird (2013, p. 4) envision "three systems of mental processes underlying inference", not two. The first system (named system 0) is "linguistic, and it may be autonomous", having as a role "the construction of an intensional representation of a premise's meaning – a process guided by a parser". The second system (named System 1) is "rapid and prone to systematic errors, because it makes no use of a working memory for intermediate results". It builds "an initial mental model from the intension", and the drawing of a conclusion is "based on heuristics and the model". The third system (named system 2) "has access to working memory, and so it can carry out recursive processes, such as the construction of alternative models", and, therefore, it allows, "on some occasions, the search for alternative models, such as a counterexample in which the conclusion is false". However, as Khemlani and Johnson-Laird (2013) note, "it too is fallible when the limited processing capacity of working memory becomes overburdened".

Zhai (2015) and Zhai, Szymanik, and Titov (2015) propose a computational model for the syllogistic reasoning based on a probabilistic natural logic, which aims to integrate Rips's Mental Logic approach with the Geurts's interpretation theory for reasoning, which is placed by Zhai et al. (2015) in a Natural Logic approach, and also "the probabilistic basis of reasoning and the atmosphere hypothesis". Unlike Rips, Zhai et al. (2015) hypothesize that, in the syllogistic reasoning, "the mental representations are given directly as natural language sentences, without an intermediate layer of an abstract formal language". In that way, the model substitutes "formal abstract inference rules with Natural Logic operating on the surface structure of Natural Language" (Zhai et al., 2015, p. 4). Like in the dual process theories, Zhai et al. (2015, p. 5) assume "that the procedure of reasoning consists of two types of mental events: the inferences made by the reasoners, which are deliberate and precise, and the guesses, which could be less reliable but fast". The two mental events are in correspondence with two parts of the proposed model, as shown by Zhai et al. (2015): the inference part, a probabilistic natural logic, where the inference rules are weighted with probabilities, and the guessing part, in which a reasoner arrives "to a possible conclusion in one step depending on a few heuristics" (p. 5). Zhai (2015, p. 14) envisions that two types of thinking system, represented by the two parts, may interact and cooperate in different ways: "it could be that subjects use system 1 to generate plausible conclusions and then use system 2 to deliberate on them", or "it could also be that system 2 is used in the beginning, however later, subjects may turn to system 1 due to the increasing complexity or the exhaustion of the cognitive resources", or "it might be that guessing, which uses no working memory and is fast, happens in parallel with the formal inference procedure which is deliberate and slower". He underlines that although the system 1, which is "faster and costs less resources and may be less precise", "accounts more for the errors", subjects could still make errors "when reasoning consciously and deliberately". In the description of the new model there is a part that has a dynamic "flavor" by defining a state of reasoning as a set of syllogistic sentences in the working memory, a "mental representation of reasoning", the reasoner keeping "a record of the sentences that he considers true at the moment" (Zhai, 2015, p. 20). A state of reasoning is changed, as it is noted by Zhai et al. (2015, p. 5), through reasoning operations, so that, "when performing reasoning, the reasoner generates a sequence of states in the working memory, where the initial state is the set of premises, and the final state contains the conclusion" or the answer "nothing follows". As Zhai (2015, p. 25) assumes, "different inference rules are of different cognitive complexities: the possibility to apply some of the rule can be quite straightforward while that of adopting some other may be harder", so that a reasoner "may prefer some rules over others". Zhai et al. (2015, p. 1) envision that the inference process is "a stochastic process where the reasoner arrives at a conclusion following a sequence of applications of inference steps (both logical rules and heuristic guesses)", in which "Natural Logic has replaced abstract rules, and the probabilistic parameters were derived from the data". Zhai (2015, p. 19) specifies that randomness may have two sources: from the "subject level, namely, each subject may adopt different possible inferential operations with different probabilities", and from the "population level", as "each subject makes relatively constant choices when reasoning", but "different subjects may vary significantly in their 'reasoning style'". In my opinion, the above description of the inference process as a succession of reasoning states in time can be interpreted from a dynamic systems point of view, as a trajectory in a state space, defined by all the possible reasoning states. In a more detailed description of the generative probabilistic model of reasoning, Zhai et al. (2015, p. 5) specify that, in a first step, "reasoners conduct formal inferences, adopting possible logical rules with different probabilities (related to the cognitive difficulty of the rule or some sort of reasoning preference)", i.e. there is a probability of transition from a reasoning state to another one by using the application of a specific reasoning rule. For this first reasoning step, Zhai (2015) was inspired by the difficulty weights assigned to each inference rules in the Geurt's (2003) proof system for the syllogistic reasoning. Zhai (2015, p. 25) specify that "easier (more preferred) rules get higher probability, while more difficult (less preferred) ones receives lower probability", so that each inference rule has "a tendency value, which is intended to be positively related to the probability that the rule is assigned". In this part of the model, illicit conversions are included by Zhai (2015) based on a pragmatic reason, because, in that way, the performance of his model was significantly improved. When an inference is too complex or the reasoner has doubts in what respects the obtained conclusion, in a second step, a guessing scenario may occur, in which "the probability that the reasoner guesses 'nothing follows' is negatively correlated with the informativeness level" (defined by the cited authors as "the amount of information that the premises carries", with the following descending order, empirically established: A > E > I > O): "the more informative the premise, the less faith the reasoner have for a 'nothing follows' conclusion" (Zhai et al., 2015, p. 6). The informativeness idea is taken by Zhai (2015) from Chater and Oaksford's (1999) probabilistic theory of reasoning, and the informativeness order for the reasoning judgments (A, E, I, O) obtained by Zhai (2015) coincides with the one obtained by Chater and Oaksford (1999). He also speculates that informativeness "becomes accumulated in daily reasoning", the life experience leading to a sophisticated unconscious assessment of the "amount of information to expect from each type of sentence" (p. 45). Zhai (2015, p. 42) show that the empirical data obtained in his research are "consistent with a mixture" of 'preference order', gained through experience, inherent 'complexity', and "the availability of rules" in explaining the probability with which the reasoning rules (conversion, monotonicity, all-some, and no-some not rules) are adopted when solving a syllogistic task. In the guessing scenario, "the reasoner chooses the remaining options with probabilities determined according to the atmosphere hypothesis" (Zhai et al., 2015, p. 6). In this way, Zhai et al. (2015) integrate in their theory the atmosphere theories for syllogistic reasoning: when at least one premise is negative, the conclusion should be negative, and, when at least one premise is a particular judgment, the conclusion should be also a particular judgment; "otherwise the conclusion are likely to be affirmative and universal". In fact, as Zhai (2015, p. 36) shows, when making a guess, a reasoner "is likely to arrive at the conclusion with the dominant type", where the dominant type in the premises is defined by the one that is greater from the order A < I < E < O. So, the informativeness order is exactly the reverse of the dominant type order, as Zhai (2015, p. 36) notes, explaining that it may be "that people prefer the conclusions indicated by atmosphere because they are less informative, hence, have a higher probability to hold". Zhai (2015, p. 35) specify that "the guessing procedure is a less deliberate process, intended to explain what happens when subjects partially give up on the inference and try to obtain a most likely conclusion within one inference step", as it is in the situation when a reasoner concludes that 'nothing follows', but he/she doubts the conclusion "since the premises might be highly informative", so that "a guessing event occurs with a certain probability". As a final note, Zhai (2015, pp. 48-49) stresses the idea that various reasoning theories "might be able to coexist harmoniously with each other", because "the mechanism of reasoning may be a mosaic of different paradigms, switching from one to another when the reasoning task changes", and "the way each subject reason may, to some degree, be shaped by the previous experiences, which depend on a random yet particular life trajectory". Zhai (2015) and his collaborators implemented and trained the model, by using machine learning techniques, and estimated its parameters on experimental data, a dataset of human syllogistic inferences, resulting that it "is accurate at predicting human conclusions on unseen syllogisms (including mistakes)", having "95% correct predictions", which outperforms "all other known theories of syllogistic reasoning".

The numerous traditional or more recent theoretical accounts, presented so far, that were given by psychologists in their quest to understand the deductive thinking could be systematized in various ways, using multiple criteria. I am proposing the following classification scheme, partially synthesized in Table 1.

III. The dynamic approach

Although the majority of the existing theoretical accounts of the deductive reasoning pertain explicitly or implicitly to the symbolic computationalist paradigm, being, at least, compatible with it, it has been argued, relatively recently, that it is possible to build models that might accommodate the deductive reasoning understanding into another paradigm: the dynamic one. This kind of approach originates in a different type of metaphors used in order to comprehend thinking than the ones used for the symbolic computationalist paradigm: the metaphors of the physics of complex dynamical systems (i.e. thermodynamics), or of the biological organism. It is supported by researchers who believe that the only way to link the cerebral processes with the cognitive processes is by adopting a common theoretical framework for both of them, a dynamical one. Since it is admitted that brain is a complex dynamic system (as it is admitted also for almost any artificial neural network), the cognitive system should be studied as a complex dynamic system, too, using similar conceptual and empirical tools[14]. In such an approach, the classical distinction between a computational level and an algorithmic, or implementation, level loses its relevance or importance. The same thing happens with the distinction between semantic and syntactic processes, between mental representations and rules for operating with them (see, for example, Kelso, 2003; Tsuda, 2001, or Faiciuc, 2008c, for a review in that respect). Kelso (2003) notices that a dynamic perspective leads to an understanding of the cognitive processes based mainly not on dichotomies, but on the complementarity of such concepts, since their coordination dynamics is dual in nature.

Seminal ideas of the new approach are found in the classical cognitive psychology in several forms (Faiciuc, 2008c). Moreover, "old" phenomena from cognitive psychology, important for the deductive reasoning research, can be "understood and reconstructed" within the framework of a dynamic approach (Kriz, 2001). The most obvious seminal idea takes the shape of the connectionist models and the theoretical concepts associated with them and with the notion of neural network. For example, the concept of a *distributed, parallel, processing* is naturally linked with a dynamic approach, since, if cognition is to be viewed as the result of an interaction in real time of the components constituting a cognitive dynamic system, it means that their changes occur simultaneously. Only that "parallel" means here not only simultaneous independent evolutions, but also simultaneous interacting evolutions.

[14] A more extensive presentation of the arguments supporting a dynamical view of the cognitive processes is to be found in Faiciuc (2008)

Table 1. *Traditional theories for deductive processes in cognitive psychology*

I. **THE SYMBOLIC COMPUTATIONALIST APPROACH AND ITS MODELS**		
1. Information use theories		**2. Information interpretation theories**
A. *Rules theories*	B. *Analogical theories*	
Syntactic models (Braine & Rumain, 1983, in Bucciarelli & Johnson-Laird, 1999; Rips, 1994, in Bonatti, 2002)	Mental models theory (Erikson, 1974, in Miclea, 1994; Guyote & Sternberg, 1981, in De Vega, 1994; Johnson-Laird & Byrne, 1991; Stenning & Oberlander, 1995, Schaeken, Van Der Henst, & Schroyens., 2006)	Conversion theory (Chapman & Chapman, 1959, and Revlin & Leirer, 1978, in de Vega, 1994;) or biconditional interpretation (Wagner-Egger, 2007)
Pragmatic schemas models (Cheng & Holyoak, 1985; Cosmides, 1989)	Case based reasoning models (Vosniadou & Ortony, 1989 and Touretzky & Hinton, 1985, in Sun, 1996)	Quantifier interpretation (Roberts, Newstead, & Griggs, 2001; Geurts, 2003)
Heuristic rules models: atmosphere effect (Woodworth & Sells, 1935, in de Vega, 1994; Wetherick & Gilhooly, 1990, in Roberts, Newstead, & Griggs, 2001), matching bias (Evans, 1998), probabilistic theory of reasoning (Chater & Oaksford, 1999), etc.		Gricean conversational principles, relevance theory (Sperber & Wilson, 1990)

II. **INTEGRATIVE THEORIES**		
A. *Unifying theories*	B. *Dual processes theories*	C. *Synthetic theories*
Isomorphism of the mental models theory and rules theory with an algorithm using Euler circles (Stenning & Yule, 1997)	Analytic vs. associative/heuristic processes (Evans, 1984; Sloman, 1996; Stanovitch, 1999), explicit-implicit theory (Evans, 2006), cognitive neuroscience theories (Goel & Dolan, 2001; Goel, 2003; Goel, Shuren, Sheesley, & Grafman, 2004), unifying framework of the dynamic graded continuum of the representations (Osman, 2004), recent versions of dual processes theory (De Neys, 2014; Evans & Stanovitch, 2013; Pennycook, Fugelsang, & Koehler, 2015; Ricco & Overton, 2011)	mReasoner (Johnson-Laird & Khemlani, 2013); the probabilistic logical model (Zhai, 2015), the developmental model (Barrouillet, 2011)
Integration of the syntactic and semantic information trough a process of successive recoding of the linguistic information (Polk & Newell, 1995)		
Competence (mental models theory) and procedural theories are interrelated components of a general theory of the logical meaning (Overton & Dick, 2007)		
Unification of probabilistic and mental models theories (Geiger & Oberauer, 2010; Oaksford & Chater, 2010)		
Erotetic theory of reasoning (Koralus & Mascarenhas, 2013)		

Another example is the concept of *activation of a feature or of a mental representation*. Presently, it is viewed to mean not merely the change of the place of a memorized information from the store in which it was placed to a separate work space, i.e. it is not a discrete property of a representation defined by the place occupied at a certain moment of time. Instead, activation is conceived to be rather an actualization process, characterized by a continuous, gradual and quantitative evolution in time of a property defining the functional status of a representation in what respects its capacity to influence the cognitive processing, i.e. its potency as an agent of change. In other words, the representation is not physically moved as an object from a warehouse to a workbench, undertaking only an exterior change. The assumption is that it passes from a potential, or virtual, passive state to an active, actual state in which it is able to change the activation status of other representations, in accordance with its activation power. **Therefore, the activation of a representation is more like an internal property, by virtue of which it influences or it is influenced by other representations. It might be said that, in this case, a feature or a representation acts like an agent, interacting in real time with other agents, forming, in this way, what it is called to be a complex dynamic system that needs no external agent or executive structure in order to explain all its state changes.** The semantic networks of the types proposed by Collins and Quillian (1967, as cited in Miclea, 1994), too, are, minimally, primitive dynamic networks in that respect, even though their dynamics completely ignores the internal dynamics of the concepts and of their links (offering only an approximate description of some cognitive processes on a higher spatio-temporal scale), and they have a defective interactive architecture. In such networks, representations are not able to change their representational content through interaction, but only their functional status. A real time dynamic interaction could be simulated effectively (not in principle) up to a point through some physical dynamic systems (the hardware of a computer) implementing symbolic processes, as a useful approximation in special cases. But they are not able to replace it altogether, especially when it comes to simulate complex dynamic nonlinear systems, comprising a lot of simultaneous nonlinear interactions between infinitesimal variables, because they rapidly reach the threshold beyond which a computational explosion occurs (see, for example, Weiskopf, 2004). That is why a dynamic model of the notion of representation activation is not reducible to a symbolic computationalist one.

Another seminal idea is the notion of dynamic memory proposed by Schank (1999)[1], which supports also a dynamic view in what respects the concept of cognitive schema, generalizing the notion of dynamic script proposed by him. In fact, as Eysenck and Keane (2000) have shown, a connexionist approach (and implicitly, by extension, a dynamic systems approach, if we take into account the note made earlier) offers a solution for the main problems that the generic cognitive schema theory has had encountered: underspecification, and an insufficient flexibility. In accordance with Eysenck and Keane (2000), a schema is a general or generic knowledge structure that can be applied to or instantiated by many specific situations. It was conceived mainly in order to explain the expectancies that occur when people are confronted with recurrent similar situations and their capacity to fill in some

[1k] Discussing the scenario notion, Schank (1999) sustained that it implies three important characteristics. The first one is that it is not possible that the content of a scenario to be completely specified, as it is constantly actualized. The second one, related with the first one, is that a scenario, as an organizing structure of the semantic memory is something that has a life of its own, inseparably linked with episodic memories. He conceived the structures of the episodic memories to be identical with the processing structures. Therefore, scripts are viewed as dynamic structures, active organizers of the memory. The third characteristic is that a script is like any dynamic memory, defined by him to be a "flexible, open system". He shows that a dynamic memory is not like a library, having a fix system of classification of the contained information. Such a structure would need an external intervention in order to be changed. Therefore, Schank (1999) argued that a dynamic memory has to have the property of changing itself, to be able to "self-organize" when new experiences demand changes. His conception of the scenario notion suggesting a dynamic stand is in line with his opinion regarding reasoning. In his view, a case-based theory of the reasoning is more appropriate since no system using rules is functional in modeling mind, because rules are inappropriate in characterizing mind processes. Schank (1999) seems to have dynamic intuitions, but he lacks the more sophisticated conceptual tools of the present dynamic system approach in order to elaborate them.

missing or missed parts in a perceived pattern. It is like a "prototypical, frame representation in memory" (Eysenck & Keane, 2000, p. 256) of objects or events. Initially, the structure of a schemata was supposed to consist of various relations (of different sorts) and variables/slots (containing concepts or other sub-schemata), and values for these variables (specific values that fill the slots). A specific filler of a slot is tested in order to see if it fits with the general type of that slot in what respects its meaning. The slots could be "open" (unfilled), or are "associated with default concepts that are assumed if a slot is unfilled" (Eysenck & Keane, 2000, p. 254). But empirical data (for example, Bower et al., 1979, as cited in Eysenck & Keane, 2000) suggested that such a structure is too rigid. That is why, Schank (1999) revised the schema theory, hoping to gain flexibility and dynamicity by stipulating that a schema has to have a hierarchical organization on three levels: at the top it is the general goal, at the intermediate level there are sets of actions, and at the base there are actions themselves. But some prominent theorists (for example, Rumelhart, Smolensky, McClelland, & Hinton, 1986a, as cited in Eysenck & Keane, 2000) "still consider that the intuitive flexibility of the schematic approach has not been realized in any of the present schemes" (Eysenck & Keane, 2000, p. 257). For example, Rumelhart and Ortony (1977, as cited in Eysenck & Keane, 2000) showed that what is missing is a specification of the "interdependencies among the possible slot fillers. That is, if one slot is filled with a particular value, that it should initiate changes in the default values of other slot in the schema" (Eysenck & Keane, 2000, p. 257). In the opinion of Eysenck and Keane (2000), this useful and important characteristic of schemata was never realized in the classic schema theories, built in a symbolic computationalist theoretical framework. However, a solution for this problem was proposed by Rumelhart et al. (1986, as cited in Eysenck & Keane, 2000) from a connectionist point of view, being able to encode schema type knowledge in a connectionist network (based on which many empirical finding were reproduced). The connectionist schema concept was summarized by Eysenck & Keane (2000) as it follows: "Schemata emerge at the moment they are needed from the **interaction** of large numbers of parallel processing elements all working in concert with one another. In this scheme, there is no explicitly represented schema, but only patterns of activation that produce the sorts of effects attributed to schemata in previous research. When inputs are received by a parallel network, certain coalitions of units in the network are activated and others are inhibited. In some cases, when coalitions of units tend to work together, the more conventional notion of schema is realized, but when the units are more loosely interconnected, the structures are more fluid and less schema-like" (p. 257). In that way, it is admitted (Eysenck & Keane, 2000) that not only the flexibility problem is solved, but also, the underspecification issue, given that Eysenck and Keane (2000) believe that its solution lies in showing how schema structures are acquired by combining different selected experiences. Learning in connectionist networks seems to them to be a promising modality to specify the way schemata acquire their contents in a remarkable manner, without the need to specify those contents. Beyond the fact that recurrent neural networks are dynamic systems, since in a connectionist version of the schemata slots are permitted to interact, being interdependent, the similarity with the idea of dynamic variables interacting in a dynamic system (i.e. variables whose evolution in time is reciprocally dependent on the evolution in time of other variables with which they are linked) is apparent.

A dynamic definition of a cognitive schema was proposed also by Gärdenfors (1994), within the framework of a more general theoretic enterprise, trying to integrate the symbolic computationalist approach with the dynamic one in what respects the understanding of thinking. By generalizing the notion of proposition, he defines it as corresponding to a vector in a state space of a dynamic system (in particular, a neural network). In comparison with the classical notion of schema, the present one has the following specific properties. A schema "can have variables even though they do not have any explicit representation of variables. Only the value of the variable is represented and not the variable as such" (Gärdenfors, 1994, p. 7). As Gärdenfors (1994) notices, schemas, in fact, replace "symbols by vectors representing various forms of patterns" (p. 7). As in the case of the classical notion of schema, a dynamic schema supports "*default assumptions* about the environment", being capable to fill in the missing information (Gärdenfors, 1994, p. 7).

The phenomenon of gestalt, as a precursor concept for the schema notion with more salient dynamic properties, is interpretable too from a dynamic point of view, especially within the framework of synergetics (Kriz, 2001), i.e. the science of the self-organization in complex systems. The astonishing parallel between the synergetics and gestalt psychology was noted by the founder of the self-organization science, H. Haken (1992, as cited in Kriz, 2001) and other psychologists (for example, Kruse, Stadler, Pavleković, & Gheorghiu, 1992, as cited in Kriz, 2001).

Priming is also a phenomenon that calls for a rather dynamic theoretical account (Becker, Behrman, Moskovitsch, & Joordens, 1997[2]), Ferber, 1996[3]), being intimately related with the notion of activation of a mental representation.

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[2] Becker et al.(1997) have proposed an attractor neuronal network for the simulation of the long-term semantic priming, which is attributed to an incremental learning, leading to the increased stability of an attractor corresponding to a presented pattern that plays the role of a prime.

[3] In accordance with Ferber's (1996) dynamic explanation for the priming effects, a prime stimulus moves the state of the dynamic cerebral representational system in its state space (i.e. the space of all the possible configurations of a neural network modeling that system) toward the region in which it is placed the attractor structure (the configuration or the set of configurations toward which a neural network tends to evolve in time, given a present state, based solely on its intrinsic dynamics), correspondent to the target stimulus. Therefore, when the target stimulus is presented, the system arrives in a shorter period of time in the state space region of its representation. Apart from the theoretical proposal made by Ferber (1996), it could be noticed that all the models that have been proposed to explain priming (for a synthesis see McNamara, 2005) share the idea that, one way or the other, the activation status of the involved features or mental representations must have a role in its occurrence. But, as it was argued above, the notion of representation activation is dynamically in nature. Furthermore, several of the proposed theoretical models (McClelland & Rumelhart, 1986, as cited in McNamara, 2005) were implemented in recurrent neural networks, whose behavior is known to be analyzable using the conceptual tools of the dynamic systems theory since they are actually dynamic systems.

A flavor of dynamicity could be traced in the concept of "bias", too. It seems to imply that there are some forces that lead to bias, that there is a dynamic competition involved. It is used as a convenient label to cover a diversity of phenomena, but usually the nature of the processes leading to it is ignored.

Another curious phenomenon from the cognitive psychology, less known among psychologist, having a dynamic nature, is what has been called the "representational momentum" (Freyd, 1987; Freyd & Finke, 1984). It is a phenomenon in which the last remembered state of affaires of an interrupted movement or of a sequence of events is not the actual one, but the one that should have been if that movement or sequence of events were to be continued. It is assumed that there is a mental schema of that type of movement or that series of events, and its completion is automatically triggered by the first presented positions or events. The phenomenon is presumed to be similar with the perceptual recognition of a spatial pattern based on incomplete information, only that, in the currently discussed case, a temporal pattern is completed.

A comparison between the symbolic computationalist paradigm and the dynamic approach made by Saulnier (2003) emphasizes their most important characteristic differences. They are synthesized in Table 2. Regarding the comparison between the symbolic computationalist approach and the dynamic one, three notes are to be admitted. In the first place, as Provonost (2006) notices, the source of the controversy generated by the two theoretical approaches originates mainly in the conceptual confusions in what respects the meaning of notions like "cognition", "computation", "mental representation". He points out a tendency for the supporters of both sides to distort the adversary position (by pushing it to ridiculous extreme stands, illicitly radicalizing it, for example) so that it could be easily defeated as a seemingly absurd theoretical stance. In the second place, in Gärdenfors's (1994) opinion, the two approaches could be viewed sometimes as two different perspectives, on different spatio-temporal scales, over the same information processing processes. It is suggested by him that a symbolic perspective ignores the successive transitions between input and output, and uses only the relation between what is represented by them. That relation is interpreted to be a "symbolic inference". Therefore, in his view, the symbolic inferences are emergent from dynamic "associations". In the third place, it is generally admitted that the symbolic processes could be implemented in a dynamic system as it is the brain. However, that does not mean that the two approaches are totally equivalent. In fact, there is a major difference of strategy between them. It is true that a symbolic process is always supported by a dynamic one, but, in a symbolic cognitive model, the dynamic properties of this supportive process are not harnessed. On the contrary, its purpose is to minimize their effects, considered to be pernicious for a cognitive process. Instead, in a dynamic model of cognition, the computational properties of a dynamic process are rendered profitable, being used in order to understand the information processing. This idea was emphasized by Yamamoto and Kinyioshi (2002). They show that there are several properties of the dynamic systems that could be exploited in order to understand the cognitive behavior at any level. For example, the fact that in the state space of the body dynamics there are both unstable and stable regions would allow that the control input to be decreased when the body system is near the stable regions. On the other part, the unstable regions will be used in order to shift the system between two stable regions. That is why the external input will be used only to move the system between the stable regions. Therefore, symbols would correspond to those points in the evolution of a system in which the control input is needed in order to obtain a desired change. So, there are changes produced without effort, based on an intrinsic dynamics, and changes realized through external control, by taking advantage of the unstable regions. Therefore, in a dynamical approach, the appropriate metaphor for a cognizer is not the builder metaphor (with symbols as bricks), but rather the navigator metaphor, who uses the dynamic forces of the water and wind to lead him to a desired path (although this is also not an altogether appropriate metaphor).

So far, there are no fully fledged dynamic theoretical models as such dedicated to the deductive reasoning. But several authors have made theoretical comments and proposals regarding the manner in which a dynamic approach could be useful, in general, in the reasoning study, making reference implicitly or, sometimes, more explicitly to the deductive reasoning case, too. They could be viewed to be sketches of some future more elaborate dynamical models accounting for the deductive processes, offering guiding principles in their development.

1. Theoretical underpinnings for a dynamic modeling of the deductive reasoning

In what follows, there are presented some personal considerations, or tentative theoretical views existing in the scientific literature aiming to explore the relevance of the conceptual tools of a dynamic approach in what respects the study of the deductive processes.

A. Preliminary notes

The first, and maybe the most important consequence of a dynamic approach to cognition in what respects the understanding of the deductive processes stems from a basic property of the dynamic system as a model for a psychological process. A **dynamic system** is a system composed of one ore more *dynamic variables* (variables changing in time) that reciprocally interact in real time (the change in time of the value of a variable is dependent on the change in time of the values of other variables) and the so called *control parameters*, values of some external variables, which control the interactions between the dynamic variables. They are included as constant values in the system of (differential or difference) equations describing the way the dynamic variables interact (in which the dynamic variables appear as unknown variables).

Table 2. ***A comparison between the symbolic computationalist paradigm and the dynamic approach in accordance with Saulnier (2003)***

Comparison criteria	The symbolic computationalist paradigm	The dynamic approach
The relationship between the cognitive system and its physical support, and environment	Clear separation between the cognitive system, its physical support, and environment, having a distinct, functional, causality in comparison with them	Continuity between the cognitive system, and its physical support, and environment, inclusively at a causal level, because they are dynamically coupled; environment is defined by a cognizant
The goal of the cognitive science	To understand the adaptation of the cognitive system in order to represent an external preexistent reality/environment	To understand the stability, and the internal coherence of the cognitive system
The relevance attributed to the neurophysical processes supporting cognition, which are ontologically dynamic in nature	They have no bearing in what respects the study of cognition as such, as they are placed on an assumed irrelevant implementational level	They are not to be ignored, since the properties of the cognitive processes are assumed to be dependent on their properties as dynamic processes
The organization in time of the cognitive processes	It is exclusively a discrete, sequential, serial order of them, with clearly separable stages	It is a continuous temporal coevolution of them
The importance attributed to the corporeal and the extracorporeal environment	It is not essential	It is essential, supporting a "situated", and "embodied" cognition view
The attitude toward the notion of mental representation	Its necessity is not questioned	Its necessity is questioned, and, if it is admitted, its significance is reinterpreted
The representational format	Symbolic (physical symbols systems)	If the notion of representation is admitted, the representational format is either changed to have dynamic characteristics in such a manner that it would allow stability and context dependency, or there is assumed a way through which symbolic representations are emergent from dynamic processes

Comparison criteria	The symbolic computationalist paradigm	The dynamic approach
The type of the allowed compositionality	Universal, "concatenative" (van Gelder, 1990) compositionality	Local, "functional" (van Gelder, 1990) compositionality, securing only a contextual systematicity, since it is not possible that the three constraints: systematicity, unlimited compositionality, and functional relevance for a cognizant organism to be fully satisfied
The attitude toward the state of a system, and its temporal changing	It is centered on the notion of discrete state. Temporal changing allows passing from such a state to another one.	States are considered to be the change medium, but the focus is on changing
The geometry and the structure of a state	Defined through a syntactical, and combinatorial structure	Conceived to be as a point, position, in a state space, geometrically interpretable
The temporal structure	It is assumed a successive transformation of a static structure into another one	It is assumed the simultaneous existence of several structures that are in interaction.
The serial or parallel nature of a state transition transformation	It is assumed that during a state transition only a (simple or composite) variable changes, and the remaining ones are kept unchanged	It is assumed that during a state transition all variables change simultaneously
Input and output definition	There is a clear distinction between input and output, cognitive processes being strictly delimited in that respect: at first, there are processes for the reception of clearly defined inputs, then there are processes for their internal processing, and, in the end, processes for the generation of an appropriate output	There is no clear distinction between inputs and outputs, since the cognitive process is conceived to be without clear limits, without an identifiable beginning or ending. In each moment, an adjusted change occurs.

In other words, *through a dynamic system, the variation in time of one variable is bound to the variation in time of other variables, their way of bonding being controlled by some set values of other variables*. It is this property of a dynamic system that, in my opinion, is fundamental for an understanding of the logic processes if those processes are to be modeled dynamically[1]. As it was stated before, in the general definition proposed for the deductive reasoning, deriving a conclusion means, practically, to determine an unknown value for a relational variable based on the values of some other variables. Since, in our mind, reasoning processes are not instantaneous, but take place in time, it might implicitly mean that the involved values are values that are changing in time.

Therefore, taking in view the above mentioned property of a dynamic model, it would be reasonable to assume that the values determined on a certain point in time through a deductive reasoning process for the variables included in a logical conclusion (for example, truth values or meanings) are the result of the evolution in time of a dynamic system in which they are included as variables together with other relevant variables (such as those whose values occur in the stated premises).

As a consequence, it could be said that the time at which an involved dynamic variable takes a certain value has a cognitive significance (Van Gelder, 1998), directly contributing to the result of the considered cognitive process, given the temporal constraints expressed by its inclusion in a dynamic system.

In comparison, in a process based on a symbolic system, time as such has no cognitive relevance, being considered only for pragmatic reasons linked with the so called implementation level, or with aspects of the human behavioral deductive performance. A symbolic system is a static one, because symbols and the semantic or syntactic rules through which they are manipulated do not change in time, and do not interact. Rules provide constraints regarding the allowable transitions (from the

[1] It offers a natural and elegant manner to explain the way a variable is settled into some particular value based on the values of other variables within a particular process, by assuming that all the involved variables are linked in a dynamic system.

entire set of possible transitions) from a symbol of the system to another one (inclusively from a rule to another). But these are not fully temporal constraints, for two reasons. The first one is that they operate as constraints only if an external mysterious agent puts them to use, in a physical system (which is, in fact, a dynamic system). The second one is that they do not determine a relative duration in time of a transition in comparison with the duration of other transitions, but only an allowed temporal order (a rudiment of temporality) in the context of a certain goal (therefore, the time length of a transition is considered to be only an implementation matter). A process linked to a symbolic system is initiated and driven from outside, by such a mysterious agent capable of choosing and applying only successively the relevant rules to an array of symbols, substituting and rearranging them serially, in order to obtain another array of symbols. So, the resulting temporal order implicitly existing in that process is not ascribable to that symbolic system, but to an agent who uses that system in order to attain a goal of her/his own, since a symbolic system has neither goals, nor agentic power. Without the possibility of ascribing states (as temporal properties having values variable in time) to the symbols (even only with binary or discrete values), through which they could gain the status of dynamic variables, symbolic systems are inert. In a symbolic process, what could be defined to be its state is the array of symbols that are allowed to be at a certain time in an operational state (defined by their activation status or their presence in a work space that are properties variable in time). But this state does not have cognitive significance, does not lead by itself to another state, if the symbols are not allowed to interact autonomously. Without an external agent and its goals, the process would remain indefinitely in that state. From a dynamic view, it is a state of neutral equilibrium, not of dynamic equilibrium.

Symbolic systems could be conceived, at most, as being simply languages for an idealized descriptions and formalization of the behavior of some dynamic systems (of whatever nature they might be) when it is projected on a geometrical space. It is known that it is possible to define the state of a dynamic system at a certain time as the set of values taken by its dynamic variables at that time. Therefore, the behavior of a dynamic system is describable in a state space having as coordinates its dynamic variables with their allowed variation intervals. The points of that space represent all the possible combinations of the values from the domain of variation of each dynamic variable with the values of the variation domains of the remaining dynamic variables of that system, i.e. all its possible states. But given the interaction between those dynamic variables, not all those states are actually attainable, and their status differ in what respects the time the systems remains in them without an exterior influence, or in what respects the necessary power of that influence in order to change that state. In other words, there is a dynamic property ascribed to each state, named stability, indicating its power to retain the system in it. Through the interactions among the dynamic variables of a dynamic system, the possible transitions between a state from its state space and the neighboring states are also restrained. Expressed differently, it means that those interactions determine all the possible trajectories of a system through its state space. If the states with a significant stability and the trajectories linking them are symbolized in some way, then the behavior of a dynamic system becomes describable using a symbolic system, in which the primitive symbols represent states in the state space, and the syntactic rules are, actually, transition rules from such states to other states.

B. Theoretical contributions from the scientific literature exploring the relevance of a dynamic approach for a deductive reasoning understanding

1) The dynamic system as a provider of change without representations with a mediative role

From the property discussed in the previous paragraph, Eliasmith (1996) derived another consequence important for the understanding of the logical processes. He notices that, by coupling the equations describing the interactions from a dynamic system, the change of one variable will lead to an immediate effect over the other variable components of that system. Therefore, there would be no need to exist discrete symbolic representations (with a constant content) in order to transmit the information regarding the change of a component toward another one during a reasoning process. So, it is possible that a deductive inference to be made only in one step, with an extreme speed, when the change of a variable through the information given in the premises leads to an almost simultaneously change in another one with which it is in a dynamic interaction.

2) The emergence of a deductive conclusion from coupled dynamic systems corresponding to more concrete meanings of the concepts, and the linguistic structures involved in premises

If the cognitive system is modeled to be a complex dynamic system (composed by coupled dynamic subsystems[2]), then the semantic processes should be also dynamic in nature, as Dimitrov (2000) has argued. In his view, meanings evolve in time and new ones emerge by dynamic semantic processes called bifurcations[3], changing the dynamic structure of a state space (that is the stability status of its various regions that could be merged in synthetic thinking, or become separated in an analytic thinking). Adopting such a perspective, since deductive reasoning implies semantic processes, it would mean that deriving a conclusion is dependent on the semantic evolution of the concepts and the relationships between them, stated in premises, during a deductive task.

3) Conclusion derivation as an iterative search for a stable coherent dynamic structure in a perceptual-cognitive loop, as the one proposed by goertzel (1994)

The basic idea relevant for the deductive reasoning from the perceptual-cognitive loops model of Goertzel (1994) is that to think means the coherentization of the received input given in the form of dynamic percepts or concepts (conceived to be associations, or associations of associations of dynamic neuronal groups that tend to survive based on their self-supportive connectivity). They enter into a per-

[2] Two *dynamic systems are coupled* when at least one dynamic variable of a system is a control parameter for the other dynamic system.

[3] *A bifurcation* is a dynamic process through which the behavior of a dynamic system is qualitatively changed by changing the value of at least one of its control parameters.

ceptual-cognitive loop, and through an iterative, dynamic process involving a kind of "natural selection", they are finally replaced by a dynamic structure having a higher degree of stability (or self-supportive/ self-reproducible capacity) than the initial ones. It integrates the information in an attractive pattern, as the system tends to autonomously generate it, by searching the highest level of coherence. In the same vein, in the particular case of a deductive reasoning, it could be said that, through the inference of a conclusion, it is obtained a higher level of coherence of the information from the stated premises.

4) Sabelli's distinction between a static logic and a dynamic one, and his dynamic interpretation of important types of reasoning

Sabelli (1995) suggests that a dynamic logic could be founded on three main assumptions: a) identity is defined through temporal evolution; b) there is no principle of non-contradiction (coexistence of the opposites is admitted instead); c) there is no law of excluded middle or of *tertium non datur* (multiple alternative possibilities could be generated). In his view, since the fundamental structures of the world are not permanent, a static logic is not reasonable. In that context, he suggests that the prevalence of a certain type of logic theory depends on particular circumstances, being, in fact, influenced by the dynamic of other psychological processes, such as the affective ones, and by the cognitive development dynamics.

The predominant choice of a static logic is explained, for example, by a desire of permanence, by considering the fact that the perceptual flux leads to recognizable stable identities for people, and objects. Also, the preference for mutual exclusive opposites (black or white thinking) is viewed to be as a sign of immature or pathological cognitive development, resulting either from a lack of experience or from an internal affective conflict.

Within a dynamic logic, Sabelli (1995) distinguishes three different main patterns of the rational thinking, which are put in correspondence with the three fundamental types of attractors[4] of a dynamic system.

[4] An attractor is a state or a set of states toward which a dynamic system tends to evolve in time (converge) in the absence of disturbing extrinsic influences, based on its intrinsic dynamics. A *fixed-point attractor* is an attractor with a single attractive state. A

Linear deduction, i.e. logical implication of the type "if-then", is modeled using a fixed-point attractor. Contradictory thinking of the type occurring in the logical paradoxes or in ruminations is modeled with cyclic attractors, revealing the dynamic hidden under what seems to be a static logic. The type of thinking needed in order to generate distinctions, syntheses, hypotheses, or in order to select options, since involves what Sabelli (1995) calls co-creation by considering two different perspectives, would require models with chaotic attractors.

5) The dynamic modeling of the logical paradoxes based on a fuzzy logic

Grim (1993, as cited in Vezerides & Kehagias, 2005), noticing the oscillatory behavior characterizing the answer for a logic paradox, supports the view that a dynamic explanation is intuitively appealing in order to account for such swings in thinking. One of his hypotheses is that each statement involved in a reasoning process has a fuzzy logical truth value (i.e. a graded truth value) ascribed to it, which evolves in time, interacting with the fuzzy logical values of other relevant logical statements. In that sense, several statements whose truth values are interacting constitute a logic dynamic system. A logical paradox, in his opinion, is characterized by a set of self-referential logical statements, speaking mutually of their truth. They generate an iterative behavior, characteristic for a dynamic system, having a high level of nonlinearity that originates in their self-referentiality. That is why, the trajectory in time of the answers found for logical paradoxes would tend to be either cyclic (oscillating regularly between two contradictory conclusions), or chaotic (when the pattern in the answer changing is less regular).

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cyclic attractor is a sequence of attractive states characterizing the convergence toward a cyclic behavior. A *chaotic attractor* is a set of attractive states having typically a fractal structure (a special geometrical structure with a fractional geometrical dimension, presenting self-similarity at all its scales). The trajectory of a dynamic system through such an attractive region is considered to be the result of two opposing tendencies: toward convergence into a set of states and toward divergence from them. Consequently, the chaotic behavior is characterized by a high level of nonlinearity, by sensitivity to the initial conditions (two trajectories leaving from two neighboring points become divergent in a very short period of time), and a limited predictability (in the absence of external disturbing influences, a dynamic system with a chaotic behavior tends to remain indefinitely in the same predictable region of states, but, in each moment, it is in another new, unpredictable, state of that region).

6) A dynamic interpretation for the notion of cognitive schema made by Gärdenfors (1994) as a basis for deductive inferences

As it was mentioned before, in a previous section, Gärdenfors (1994) supports a notion of *schema* defined *as a vector in a state space of a dynamic system*. Defined in that way, it means that it represents various sorts of learned patterns. He assumes that it is possible to define three elementary operations with such dynamic schemata, which are, in fact, operations with patterns. Those operations are: schemata conjunction, schemata disjunction, and finding a complement to a cognitive schema. All the schemata together with these three operations generate an algebraic structure (of a Boolean type when schemata have binary vectors), providing the required support for making inferences. *In Gärdenfors's (1994) perspective, to infer something means the stabilization of a dynamic system into a so called resonant state (the state representing the inferred conclusion) after receiving an input.* He proposes then a reinterpretation of the propositional logic, having in mind the idea that the ontology[5] on which logical statements are built has the power to determine the existing logic.

7) Natural deduction as a pattern recognition ability

Bechtel (1994), as a philosopher, based on his experience in teaching formal logic and on simulations made by him on feedforward networks, adopting a connectionist stance, proposed the theory that the skill of natural deduction is a learned skill "to recognize particular patterns in arguments", requiring a "considerable experience in constructing derivations". He notes that:

> A dynamical system that does not use syntactically encoded internal representations and syntactic rules to operate on them may nonetheless be able to conform in its construction of sequences of symbols to the principles of a highly syntactically structured system such as natural deduction. (Bechtel, 1994, p. 26).

[11] Gärdenfors's (1994) thinks that that ontology resides in informational states (having the status of fundamental entities), conceived to represent equilibrium states, resulting from stabilized dynamic processes. As a consequence, the resulting logic has to have a dynamic character, reflecting an information dynamics.

In a previous work from 1991, Bechtel, together with Abrahamsen, supports the idea that the "higher-level cognitive performance might consist in a sequence of pattern recognition activities, so that what looks to be steps of reasoning might consists ultimately in sequences of patterns that elicit one another". The two authors envision the chain of pattern recognition processes in the following way: "the stable state representing one pattern could itself act as an input to the system which would initiate further pattern recognition". In formulating this idea, that "cognition might simply consist in a sequence of pattern recognitions", Bechtel and Abrahamsen (1991) were inspired by Margolis (1987). Also, Margolis (1987) supports, as a general hypothesis for thinking (implicitly for the deductive reasoning, too), that it is reducible to pattern-recognition processes, although he does not frame his theory of cognition in explicit dynamical terms. In Margolis's (1987, as cited in Bechtel & Abrahamsen, 1991) theory, "the recognition of one pattern constitutes an internal cue which, together with the external cues available from outside the system, facilitates yet another recognition". In accordance with his theory, even in unfamiliar context, there occurs a pattern recognition process, as a pattern template that matches the best the situation will be generated, remaining that, in the future, a better one to be found. Such a situation may be the solving of a complex problem, which may start with the recognition of a partial pattern and, then, combined with other results, continues with the recognition of more complete patterns. In his view, reasoning is also a process of pattern recognition. In order to support his theoretical position, he invokes the empirical results that show that people have limited logical performances. He explains the logical errors made by people through the triggering of a wrong scenario, i.e. he sees them to be caused by a misrecognition issue: the cues from a reasoning problem may activate wrong patterns.

8) Natural deduction as categorization in the Vigo's (2007, as cited in Vigo & Allen, 2009) modal similarity theory

Although the Vigo and Allen (2009)'s proposal to view deductive inference as a categorization process does not have explicit dynamic statements, indirectly it can be linked with a dynamic interpretation of the deductive reasoning through the dynamic approaches of the categorization processes, especially for the perceptual patterns, which are cited in the present work (e.g., Haken, 1995), and through its suggestions of an embodiment of the deductive reasoning in subsymbolic processes for similarity assessment and discrimination of a similar kind with the perceptual ones, grounded not necessarily in language or symbols, but in "the cognitive meaning of the logical connectives themselves" (p. 5).

9) Connectionist dynamic models for reasoning processes

I. ***Smolensky's (1986) harmony theory of cognition***

Smolensky (1986), through his harmony theory, supported by a sketched connectionist model, gave a more detailed perspective of how pattern recognition might be involved in reasoning. He posits, from the start, that his mathematical harmony theory is "founded on familiar concepts of cognitive science: inference through activation of schemata". In this theory, the knowledge base consists in a set of knowledge atoms that "configure themselves dynamically in each context to form tailor-made scripts" (p. 202) or schemata. Schemata, as coherent knowledge structures placed at a macrolevel description, which have conceptual interpretations, support the inference processes. In his view, "at the time of inference, stored knowledge atoms are dynamically assembled into context-sensitive schemata". So, schemata are not stored physically in memory as such. Inference is seen by the cited author to be essentially a completion task, through which missing parts of a representation are completed. During an inference process, "assembly of schemata (activation of atoms) and inference (completing missing parts of the representation) are both achieved by finding maximally self-consistent states of the system that are also consistent with the input" (p. 207). The requirement of consistency for an inference process was the reason for which his theory was named harmony theory. As in a cognitive task, such as reasoning, "many schemata become active at once and interact heavily", the coherence constraint is the one that lead to a final result for the interaction between several activated schemata.

II. ***Neural networks with cyclic or chaotic attractors with a temporal coding of information, representing higher order relations, rules, or cognitive schemas as sets of transition rules***

(i) Neural networks with fixed-point attractors for case-based reasoning (for example, Tourtezky & Hinton, 1985, as cited in Sun, 1996).

These are the first connectionist models used for reasoning simulation, adopting a case based strategy, where concrete stored episodes or scripts are used in order to solve similar problems (even deductive tasks). Their evolution in time toward a fixed-point attractor reflects the principle of satisfying maximally the given constraints. But, as several authors have argued, such networks have a limited value and numerous shortcomings. For example, Sun (1996) has noticed that they are not able to use uncertain information, or gradual truth values. There is a single exception, which functions based on the minimization of an error function (Derthick, 1988, as cited in Sun, 1996), but that network has a slow stabilization, and it is not adequate to represent all logical relations between propositions, or all the inferential modes (Sun, 1996). Sun (1996) argues that such networks are principally unable to simulate the majority of the usual inferences. His reason for that is that this type of connectionist networks allows only association processes, not having means to represent rules or to bind the represented variables. But the majority of the usual inferences imply more complicated situations, surpassing the association level. The same opinion is sustained by Raffone and Leeuwen (2002). For them, the dynamic systems in which the information is stored exclusively at the level of some fixed-point attractors have an "inert dynamics", and a limited flexibility. The invoked reason is the fact that recalling the information through the convergence toward a fixed-point attractor is considered to be equivalent with a simple association stimulus-response. Moreover, in order that such networks to function, an equilibrium has to be kept between their excitatory and the inhibitory connections, which is an impossible task in the context of the cerebral system (Raffone & Leeuwen, 2002). Another shortcoming of the networks with fixed-point attractors pointed out by Raffone and Leeuwen (2002) is that they necessarily code the information exclusively as activation patterns. But, in their view, in order to extend the performance of the connexionist networks in what respects the reasoning simulation, it is required also a temporal code for information. The envisioned solution for such a code is the neuronal synchronization. As the synchronization relation has an implicit transitivity, Raffone and Leeuwen (2002) argue that it should be useful in order to represent higher order relations (for example, relations between activation patterns) and, consequently, for modeling higher order inferences.

(ii) Neural networks with cyclic or chaotic attractors with a temporal coding of information, representing higher order relations, rules, or cognitive schemas (as sets of transition rules)

a) *A dynamic connectionist general model of reasoning based on the notion of cognitive schema proposed by Oaksford and Malloch (1994)*

Oaksford and Malloch (1994) have initiated a more elaborate undertaking in what respects the possibility to simulate deductive processes using connectionist neural networks (having the status of dynamic systems). Their general thesis is that deductive reasoning occurs not in a deductive device serving general purposes, but from a natural dynamics resulting from the interaction between neuronal representations. The thinking flux is conceived to reside in transitions from a cyclic attractor (its states corresponding to the dynamic representation of a mental relation and the dynamic representations of its argument roles) to another one. Passing through a cyclic attractor several times would be analogous with rehearsing a cognitive relation. The solution of a cyclic attractor representing mental relations is considered by Oaksford and Malloch (1994) to be useful because it offers the possibility to represent in a differentiate manner both the direct and the inverse relationship between two arguments (in correspondence with the two possible directions of passing through the successive states of a cyclic attractor). Moreover, since in the Oaksford and Malloch's (1994) model, the arguments are bound with their roles in a relation by transient relationships (through temporal coincidence), to be an argument in a relation is considered to be only a transient property of an object, and not a constant trait, requiring a distinct and permanent representation as a node in a network. In that way, in Oaksford and Malloch's (1994) opinion, the interference between a direct and an inverse relationship occurring in the networks with localist representations (where a relation and its argument roles are represented as separated nodes in the network) is eliminated. Another argument suggested by Oaksford and Malloch (1994) in the favor of a distributed dynamic representation in the form of cyclic attractors in order to code the cognitive relations and their arguments is that that type of dynamic representation allows dynamic transitions between relations that do not share common arguments.

Since Oaksford and Malloch (1994) consider that a relation could be viewed to be as an elementary cognitive schema, that it would mean that, by learning or passing through transitions between cyclic attractors representing cognitive relations, a means to represent more complex cognitive schemata is available. *In Oaksford and Malloch's (1994) opinion, dynamic systems are able to provide the needed temporally articulated structures required by a cognitive schema representation. Therefore, they have pleaded for an interpretation of the cognitive schemata as dynamic structures of the neural networks that are dynamic systems*.

But, the two cited authors have suggested that in order to model thinking through dynamic cognitive schemata is needed not only to provide a manner in which they are distributively represented in a dynamic neural network, but also a manner through which thinking processes are hierarchically controlled and goal directed. In that respect, they admit the possibility to represent goal states as attractors in a dynamic network, as Rumelhart et al. (1986, as cited in Oaksford & Malloch, 1994) and others (Carver & Scheier[6], 2000) have suggested. Assuming that, goal orientation would be realized through a hypothetic

[6] Carver and Scheir (2000) show that "the idea of attractors and trajectories within phase space provides an interesting complement and supplement to the idea that behavior is guided by feedback processes regarding goals and antigoals." (p. 70)

global assessing function, indicating the distance between the present state and a goal state. When the system is not evolving toward the attractor representing the expected result, a covert verbal self-instruction would have the function the move the system in another initial condition in its state space, favoring the goal attainment. In this case, verbal self-regulation plays the role of a control parameter for a reasoning system.

Conceived as attractors[7] *of a complex dynamic system (and not as discrete symbolic representations), cognitive schemata are thought to be intrinsically unstable, vulnerable to noise effects*, as Oaksford and Malloch (1994) have shown. The cited authors suggest that *when the representation of a cognitive schema that integrates several rules is unstable, some of its elements (rules) will be lost (not active) or their activation is fluctuating in time, in the same way the sound of a radio station is progressively lost or has a fluctuant quality when the radio set is not able to settle on its appropriate frequency*. *The instability of the cognitive schemata may lead, also, to unwanted transitions between attractors, disturbing the progress toward the expected goal, to phenomena of distractibility or perseveration* (Oaksford and Malloch, 1994)[8].

b) *Complex dynamic networks as means for discriminating the temporal order of the stimuli and for learning rules: Kentridge's (1994) model*

Taking a similar stand to the one adopted by Oaksford and Malloch (1994), Kentridge (1994) supports the idea that rules cold be represented in a dynamical neural network. He starts with the idea that learning

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[24] See the note 21 from the page 21.

[25] Oaksford and Malloch (1994) have suggested three possible solutions in order to stabilize an active cognitive schema: 1) through an external feedback indicating that the context relevant for that schema is kept unchanged; 2) through an internal feedback indicating that the currently active schema contributes toward the attainment of a goal or the satisfaction of a motivational impulse; 3) through signals originating from a conscious control system, acting through attentional processes that mediate also the effects of the verbal self-instruction in what respects the stabilization of a cognitive schema. Assuming that the representation of a rule (schema) and the representation of its name are distinct, but dynamically coupled, it is to be expected that the covert verbal rehearsing of the name of a schema contributes to the stabilization of its representation. As Oaksford and Malloch (1994) have noticed, the three stabilizing factors are similar with the three factors identified by Norman and Shallice (1988, as cited in Oaksford and Malloch, 1994) to be important in a cognitive schema selection: 1) prominence of an external stimulus; 2) intrinsic motivation; 3) explicit instruction, or command.

rules requires the discrimination of the temporal order of a sequence of stimuli. In his view, complex dynamic networks are capable of such discrimination in the following way. When the sequence of stimuli is a learned one, the system will not be disturbed away of its trajectory toward an attractor. But when the sequence of stimuli is new, the system will be disturbed away of its trajectory, arriving in another attractor, In other words, a new sequence of stimuli behaves like a distractor, changing the dynamic behavior of the network.

c) *SHUTRI: A connectionist model for reflexive reasoning (Shastri & Ajjanagadde, 1993)*

Adopting the view based on the complex dynamic systems as models in what respects reasoning, Shastri and Ajjanagadde (1993) have stated that such a view precludes the possibility of a single general reasoning system with a universal purpose, capable of any kind of inference[9]. So, SHUTRI, the model built by them, does not aim to account for every type of reasoning, but only for what they called to be the *reflexive reasoning*. In comparison with a reflective, deliberative reasoning (which requires an effortful pondering of alternatives, sometimes with the aid of an external representation), the reflexive reasoning is characteristic for the everyday inferences[10]. Such inferences are effortless, spontaneous, and they have a remarkable efficiency, "as though these inferences were a reflexive response of their cognitive apparatus" (Shastri & Ajjanagadde, 1993). They are supported by a large body of background knowledge. Shastri and Ajjanagadde (1993) have assumed that the speed in reasoning is due to a "rapid representation and propagation of dynamic bindings"[11]. They

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[26] They show that the empirical findings support such a stance, because people are able to reason efficiently only for a limited number of types of inference. That is why they notice that a reasoning model needs only to explain the qualities and the limits of the human reasoning.

[27] It is the kind of reasoning that puzzles the most the researchers who want to build symbolic models in order to simulate it, because it seemed to be paradoxical. Although it involves a large set of connections to be made between the known data in order to reach a conclusion, they are made with a surprising speed.

[28] Shastri and Ajjanagadde's (1993) model was built on the following principles:

have shown that their dynamic model is capable to encode "rules involving n-ary predicates and variables and perform a class of inferences in a few hundred milliseconds". It is also supported with neurophysiological findings, suggesting, as the cited authors say, that "synchronous activity occurs in the brain and may play a representational role in neural information processing".

d) *Raffone and Leeuwen's (2002) connectionist model with gradual synchrony sustaining a functional logic*

Raffone and Leeuwen (2002) propose a more advanced connectionist model in what respects its dynamic complexity and means of temporal coding. They think that temporally encoding information through the synchrony of oscillators is an insufficient step for the reasoning modeling. As a consequence, they sustain, based on cited evidence, that it is possible to encode information through a gradual synchronization between the behaviors of neuronal systems with chaotic attractors[12].

By moving the information coding from the attractor level at the level of chaotic trajectories, the consequence pointed out by Raffone and Leeuwen (2002) is that states and processes become indistinguishable at a micro level. Therefore, they plead for the existence of a *functional logic*,

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- Reasoning means a transient, but systematic propagation of a rhythmic pattern of activity, and not the application of syntactic inference rules, or a mechanism in order to manipulate and write symbols;
- Every entity from the dynamic memory is characterized by a phase of its own in what respects that rhythmic pattern of activity;
- Dynamic bindings as realized by a synchronous firing of the appropriate nodes;
- Rules are "interconnection patterns that direct the propagation of rhythmic activity";
- Long-term relations are represented as subnetworks through which temporal patterns are matched.

[29] The degree of synchronization between the activity of some neuronal assembles would allow, in their opinion, to code similarity and proximity relations, as well as the intensity of the association between stimuli. An advantaged offered by the systems with a gradual synchrony coding is that they are capable of intermittent behaviors, accounting for those situations in which regular activity patterns alternate after irregular periods of time with irregular activity patterns (Raffone & Leeuwen, 2002). As Raffone and Leeuwen (2002) have stated, the intermittent behavior allows the occurrence of selective links, which are not possible with a simple temporal synchrony.

in which there is no clear separation between mental representations (conceived as states in those models in which information is stored at an attractor level) and their processing (conceived to be represented at the trajectory level). Raffone and Leeuwen (2002) think that they are only aspects of the computation realized by a dynamic system.

e) *Breakspear's (2004) connectionist model with generalized synchrony*

As in the case of the Raffone and Leeuwen's (2002) model, Breakspear (2004) assumes that the information coding is made through a variable synchronization between dynamic systems with nonlinear behaviors (inclusively with a chaotic behavior). But changes in their synchronization are not only quantitative, but also qualitative in what respects the behavior of the resultant complex dynamic system, obtained by coupling them. Taking the coupling intensity as a control parameter, through bifurcations elicited by changes in this control parameter, it is possible a sudden transition from a stable dynamics of the "composed" system (emergent through synchronization), having a low dimensionality, to a more complicated dynamics. This latter dynamics is characterized by Breakspear (2004) to be unstable, to have many dimensions, combining traits of the different attractors of the two coupled dynamic systems. The synchronization dynamics and its intensity are supposed to be controlled by two control parameters: the intensity of the physic coupling between the considered systems, and the external input, which is interpreted to be a kind of noise with distinct characteristics, coded at the level of synchronization.

f) *A model of thinking using metadynamics (Kataoka & Kaneko, 1999, 2000)*

Kaneko (1998), too, is one of the authors who support the view that a solution for a dynamic interpretation of the logical thinking is a system with nonlinear oscillators, because it has useful properties in that respect. In the first place, it allows that the grouping or the separation, differentiation, of its nonlinear oscillators. Their separation could result from the amplification of minor differences between them as a consequence of the instability of their chaotic trajectories. Instead, their tendency to maintain synchronization leads them to unions into new groups. In the second place, in a system with nonlinear oscillators, it is possible the occurrence of another useful behavior: chaotic itinerancy. Chaotic itinerancy means a dynamic behavior in which the transitions between attractors are facilitated because they have in their neighboring attractive regions a few directions of evolution that are extremely unstable, so that, at the smallest disturbance, the system moves into other neighboring attractors. In that way, it is impeded an indefinite lingering of the system solely in a region of its state space. Consequently, it is also possible to move a dynamic system from a stable state to another one without changing the value of some external control parameters. Chaotic itinerancy is considered to offer, in Tsuda (2001) opinion, a solution for a memory recall, other than by random access or by simulated annealing. The invoked reason is that it allows the occurrence of some rules for linking the dynamic trajectories so that memories become causally related. Thus, neighboring memories would be tied with a higher probability through an itinerant dynamic process. It is also believed that the emergence of logical rules from a dynamic behavior could be explained through chaotic itinerant processes (Kaneko, 1998), as preferential transitions between attractor regions having a representative function. Additionally, Kataoka and Kaneko (1999, 2000) assert that a dynamic approach of the logical thinking requires the extension of the classical definition of a dynamic system. Their proposal is *to include as components of a dynamic system not only dynamic variables, but also networks of dynamic relationships.* Therefore, they have envisioned a dynamics of a higher order than the dynamics of some variables: a *dynamics of the functions, having the status of a metadynamics.* Based on such methadynamics, Kataoka and Kaneko (1999, 2000) suggest a way through which symbols or rules could be generated in continuous dynamic systems. The process starts with an iterative, recursive, application of a function on its domain of variation. By the convergence of that function toward constant values, its domain of variation will be separated in several distinct subdomains of variation. In other words, a variable will be coded through the values resultant from the convergence of a function recursively applied, having as a domain of variation that variable. Such a process of "articulation" is thought to justify the generation of the symbols, by categorizing continuous objects. In the following step, an object begins to symbolize other objects by virtue of the existing dynamics of the networks of relations between those objects. The recursive application of a rule of changing the relations between continuous objects leads to a relation stabilization in a fixed-point attractor, occurring a relatively constant correspondence between inputs and outputs, as an emergent symbolic relation representation. In that way, symbols are conceived to be stable objects, and the connection between symbols as relatively stable relations. The iterative process is needed in order to generate the invariant structures represented by symbols. Symbolization starts with an "inarticulate" network, in which no distinction is being made between a rule (operator) and a variable (operand), since it, initially, involves an iterative application of a function to itself, i.e. a recursivity characteristic for any dynamic system.

As Kataoka and Kaneko (1999, 2000) have shown, iterative dynamics is conceived to function not only on the resultant symbols, but simultaneously on those symbols and on the objects assigned to those symbols. Therefore, they think that the rules emergent from such a dynamics are not entirely syntactic rules, because they are dependent also on the symbolized objects. So, *the semantic-syntactic distinction is irrelevant in their case.* Progressively, the metadynamics will be operant also at the rules level, leading to metarules, or hierarchies of rules. The iteration of rules (through language using) starts the separation between an operator and its operands. In the view of the cited authors, the final result is that, through all the above mentioned successive iterations, invariant, stable structures emerge from the initial inarticulate network of relations, having an unstable dynamics. These invariant structures will control the dynamics of the initial network of relations and the transmission of the emerged signs. *This separation between a variant and an invariant part of the initial network is not given from the beginning, as it is stipulated in the hybrid models (which have a dynamic and a separated symbolic part), but it is the result of a characteristic dynamics. Moreover, their* *connection is not limited to a simple information transfer from a dynamic part toward a symbolic part as it happens in the existing hybrid models. The two parts, having a dynamics of their own, are instead dynamically coupled, so that they could mutually influence each other in what respects their own dynamics.*

The model proposed by Kataoka and Kaneko (1999, 2000) has integrative valences, because even though it recognizes the importance of a distinction between an operator and its operands, or between representations and rules, the fundamental dynamic nature of the cognitive processes is not undermined and finds a way to avoid forced integrative solutions, as the one proposed in the hybrid models.

Kataoka and Kaneko (1999, 2000) believe that their model is to be preferred also in comparison with those symbolic models that use a fuzzy logic. One of the invoked reasons is the fact that they assume that their initial system is a system without a predefined logic. Another reason is that they support the view that fuzzy logic is incapable to account for the semantic structures of a dynamic type of the cognitive processes, and for the apparent fusion between the semantic and the syntactic parts of those processes.

g) *Tsuda's (2001) integrative dynamic model for deductive inferences*

In Tsuda's (2001) conception, it is a natural thing to describe a deductive inferential process as being a dynamic one, as long as it involves successive stages of logic transformations starting with the first given premise and ending with a conclusion. Therefore, he pleads for a dynamic model of the deduction. In his opinion, such a model should use the informational structure offered by the chaotic itinerant processes and by metadynamics suggested by Kataoka and Kaneko (1999, 2000) in order to account for the emergence of symbols and rules in a dynamic network. But, in addition of that, it also needs the assumption that, in a deductive process, there are involved dynamic variables with continuous truth values.

More specifically, in Tsuda's (2001) interpretation, truth and falsity are represented as orthogonal vectors, defining a continuous bidimensional space of the truth values (as in the Tukasiewicz's logic). The truth value of a statement (more precisely of the neuronal vector representing it) would be dependent on the size of the resultant projection on the two coordinates of that space: truth, and falsity. Within such a theoretical framework, he suggests, for example, that a contradictory assertion may be represented as a cyclic attractor, and a self-referential assertion as a chaotic attractor. He also claims that a hypothetical-deductive reasoning needs a chaotic dynamic in order to derive a conclusion correspondent to the application of the modus ponens rule, because of the separation required in order to derive a conclusion (modus ponens being a separation rule). This assertion needs to be understood in the context in which Tsuda (2001) believes that recalling an item from memory, and, implicitly, its differentiation, needs a dynamics characterized by divergent trajectories, as it is the case for a chaotic system having sensitivity to the initial conditions.

10) The inhibitory-control theory of the reasoning and its development, elaborated by Houdé and Borst (2015)

Houdé and Borst (2015) propose an extension of the Siegler's (1999) application of the non-linear dynamics for the development of the cognitive strategies to the deductive reasoning development. In Siegler's (1999) view, the Piagetian theory of the cognitive development in discrete stages is replaced with a theory in which the development is similar with the "overlapping waves within a non-linear dynamic system". As Houdé and Borst (2015) notice, in a nonlinear dynamic view of the cognitive development, "at any point in time and at any age, different strategies with different degrees of complexity and sophistication might be in conflict in the brain". The cited authors apply this idea to the reasoning development issue, envisioning that "the progressive ability of the prefrontal cortex to inhibit irrelevant or misleading strategies to activate the most logical one sustains the conceptual development of children and the shift from one Piagetian stage to the next". They show that, as the heuristics and the algorithms interact within a nonlinear dynamical system, their relative strengths will fluctuate at each age and in each situation. So, in Houdé and Borst's (2015) model, the reasoning development "occurs in bursts with sometimes errors occurring after success in both children and adults".

11) Reasoning as the result of an internally-driven dynamics of the brain activity (Papo, 2015)

Papo (2015) suggests that, during reasoning, the brain activity is not event-related, as "many neurophysiological processes interact in a wide range of spatial and temporal scales" and "neural activity is driven by internal dynamics". In other words, he states that, for the long time scales of many forms of reasoning, the complex properties of the spontaneous brain activity become prominent and cannot be ignored as in the case of the short-lived psychological processes, because reasoning "may not be purely relaxational" as the perceptual processes are. In his view, the reasoning involves "an out-of-equilibrium endogenously modulated spontaneous brain activity", with a phenomenology that is "considerably more complex than the equilibrium event-related short time-scale one of perception or the gradient-driven regression to equilibrium dynamics of learning". More specifically, Papo (2015) thinks that reasoning, like other cognitive processes (e.g., memory recall), "can be represented as a search process similar to that of animals foraging in an unknown environment", which can be dynamically modeled in terms of random walks. At a higher scale of observation, comparing the brain with a "very complex engine", characterized by its thermodynamics, which can be derived from the brain dynamics, the cited author suggests that, during a reasoning task, it would be possible "to quantify variations in thermodynamic variables such as free energy, entropy, or temperature" and also to quantify "possible transitions in some other property of neural activity, for particular values of these variables".

Synthetic conclusion

The review of the existing studies from the scientific literature dedicated to the application of a dynamic approach in the reasoning research shows that the dynamic modeling of the deductive reasoning is only in an incipient stage[13].

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[30] Those studies generally contain reasons sustaining the utility of a dynamic modeling of the deductive reasoning, suggestions or principles supposed to be useful in building dynamic networks capable to solve deductive tasks, or in the interpretation of some empirical findings (for example, the oscillatory behavior that occurs in trying to solve a

Synthesizing the above mentioned contributions, the following ideas seem to be fundamental for the present dynamic approach of the deductive reasoning:

- *Deriving a conclusion requires the stabilization of a cognitive dynamic system into a dynamic structure*[14] after receiving the input information given in the premises.
- A stable dynamic structure could be important for a deductive reasoning because of two reasons: it brings coherence to the given data and it *allows the needed reduction of the degrees of freedom when selecting the answer for a deductive task through the constraints generated by dynamic interactions*. In the same time, the stabilization in a dynamic structure with no guaranteed constancy in time (being vulnerable to noise or fluctuating due to an intrinsic dynamic in the case of the cyclic or chaotic attractors) offers *an elegant way to explain the temporal fluctuations and the context-dependency in an individual's performance when solving a deductive task* and the obvious needed flexibility in approaching it.
- In order to facilitate a dynamical modeling of the deduction, the *classical notions of symbols, concepts, relations, rule, or cognitive schemata*, which are invoked in the symbolic computationalist models of the deduction, *could be dynamically interpreted to be such emergent stable dynamic structures, having a meaning partially changed*[15]. In fact, they represent rather conceptual tools to describe the dynamic deductive processes at a higher spatio-temporal scale, without the need to assume an external agent charged with the task of manipulating the symbolic

logical paradox). Only a few of them present actually dynamic networks with a limited, but encouraging, deductive performance. What is still missing is a systematic theoretical approach at an intermediate level of analysis and a substantial link with the empirical findings and the existing theories from the cognitive psychology.

31 Such dynamic structures could be attractors of various types or configurations of attractors, together with the trajectories linking them, resultant from chaotic itinerant processes.

32 For example, a rule is thought to be a regular transition between stable states, whereas a cognitive schema is meant to be a stable state (i.e. a configuration in a multidimensional space) or a configuration of such stable states together with the trajectories linking them.

representations and with that of applying symbolic rules[16]. In such a theoretical framework, even the border between the semantic and syntactic processes is erased.

- *The truth values of the statements or the semantic meanings involved in a deduction might be interpreted to define continuous or discrete dynamic variables, which evolve in time through their mutual interactions until a conclusion is generated*. The dynamics of the truth variables could be coupled with the semantic dynamics defined by temporally evolving meanings (at various levels of abstraction) of the concepts involved in a deductive task, *accounting for the interaction between the so-called syntactic and a semantic levels in deriving a conclusion*.
- *Logic in a dynamic context is conceived to be of a different type than the classical static logic, having changed principles*.

In the first place, the *identity principle*, in its classical form, looses its meaning. *In a symbolic theoretical framework*, this principle reflects the demand that a symbolic representation has to be discrete and to preserve its semantic and referential meaning throughout a deductive process. Such a requirement stems, in fact, from the clear separation between a relation representation and the representation of its arguments, and, consequently, between a semantic and a syntactic level that imposes a serial application of rules in successive steps. Therefore, symbolically thinking, in a deductive reasoning process, is progressing through chains of relations (operational through rules) that must have common points of contact in order to be bound together. It is a linear, additive process. Even the building of an integrative symbolic mental model from precursory models is based on the same assumption that its symbolic constituents (symbolic tokens) have the same meaning in all the precursory models, as a necessary condition of their integration in a unified model. So, the bounding link between two relations must be a common argument that is to be found in both of them as a symbolic representation having the same meaning, separated from the meaning of the relations in which it was included.

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[33] A dynamic approach, in some radical versions (Chemero, 2001; Lawson & Luis, 2004, Portugali, 2002), admits even the possibility of a deductive reasoning without rules, or even without the classical notion of representation.

In a dynamic theoretical framework, instead, if the idea of representation is admitted, a so called dynamic representation does not have any clear identity in the classical sense, because it rather has continuous, fluid borders and a context-dependent actualization of its meaning constituents. At most, its identity could be defined in what respects the continuity of its dynamic coupling or interaction with a referent system, or of its states changing in time. It has, therefore, temporal borders (i.e., when the transition from a state to another one does not passes through intermediary states, or, in other words, it is not gradual, and sudden jumps occur in the evolution of a system through its state space). Moreover, a dynamic representation is able to change itself and other representations not solely by an external intervention (changing the value of some control parameters), but also by virtue of its intrinsic dynamics. In consequence, its semantic meaning incorporates an inseparable relational meaning. So, there is no need of a distinction between the representation of a relation and that of its arguments, between a semantic level and a syntactic one. Because it is assumed that thinking implies a progression not through concatenation, but through parallel, simultaneous interactions, in a nonlinear fashion, instead, the supposition of a common constant link is, in a dynamic context, rather irrelevant. Deriving a conclusion dynamically requires continuity in time, finding a trajectory toward a stable state leaving from an unstable one, and not continuity in the meaning of the involved symbols from an external representation of the given information. In fact, if ones introspects herself/himself, it is possible to discover that, for example, in a syllogistic reasoning, the meaning of the middle term is changing from the first premise to the second one (in accordance with its particular relations with each extreme term, or simply by acquiring the status of middle term at its repetition in the second premise). Similarly, if deduction means knowledge progress, it is reasonably to assume that the meanings of the two extreme terms are also changed in conclusion in comparison with their meaning in the given premises, incorporating the knowledge regarding the derived relation with the other extreme term. *The emergence phenomenon*, through which a totally new entity results on a higher level of organization by the interaction of dynamic entities placed on a lower level of organization emphasizes the fact that, in a dynamic system, new information could be obtained through sudden jumps, without an interrupted semantic chain of links between precursory concepts and the resultant concept. In other words, an emerged concept is not compositionally approachable.

In the second place, there is no need of *the principle of non-contradiction*, also, since representations may have a fluctuating meaning, and truth values for assertions are allowed to vary continuously. In a dynamic version, this principle would mean that a system could not be in two different states at the same time.

Finally, *the "tertium non datur" principle* is not tenable any more, from the same reasons, in general, as the previously mentioned one (for the non-contradiction principle). Its dynamic version would be that a dynamic system could be only in one of the two (or more) competing attractors.

Therefore, *the deduction is not explained any more in the terms of the constraints stemming from the classical logical principles, but in the terms of the constraints stemming from the definition of a dynamic system and its related concepts.* They are temporal constraints generated through the interaction between dynamic variables, and the competition for actualization of a state or dynamic structure to the detriment of another state or dynamic structure.

- A *temporal code for the information at the level of the transition between states, or of the dynamic coupling between systems* (leading to relationships of synchronization), by its intrinsic properties, could be beneficial for a dynamic modeling of the deductive reasoning.
- In explaining the deductive reasoning, *it would be preferable to assume the existence of at least two dynamically coupled systems that are operating on a micro and, respectively, macro spatio-temporal scale, which are able to control (by providing control parameters) the dynamic behavior of the other one*. Through this physical separation, it is possible that the circular influence existing between different levels of organization in what respects their dynamics to be altered and, consequently, controlled.

C. Advantages of a dynamic modeling of the deductive reasoning

Apart of the general advantages of a dynamic modeling of cognition presented extensively in Faiciuc (2008a, 2008c), there are some particular beneficial aspects, referring specifically to the deductive reasoning research. They are presented at large in Faiciuc (2008a, 2008c).

a) It could offer an account for some currently unexplained deductive reasoning phenomena (e.g., paradoxes);
b) It could provide some integrative principles necessary for a general theory of the logical thinking, linked also with dynamic theories formulated for other cognitive processes, and in accordance with the existing neuropsychological data regarding the dynamic nature of the cerebral processes;
c) It could integrate the existing theories and empirical results in a general account, by reinterpreting them. For example, it could use the conceptual tools of the nonlinear dynamic systems theory to explain a strategy change or the competition among several deductive strategies (as a multistable state);
d) It would bring the deductive reasoning research closer to the current type of modeling existing in artificial intelligence (which is based more and more on the embodied cognition paradigm, on a nonlinear dynamic systems approach), gaining, thus, pragmatic relevance;
e) It could contribute to a change in the experimental paradigm. For example, it would focus research more on the study of the dynamic processes occurring during the solving a deductive task.

Proposal of a schema-based dynamic model of the deductive reasoning

As it could be noticed in the previous section, a major drawback of the present dynamic approach of the deductive reasoning is that, in spite of some attractive and compelling theoretical arguments on its side, it lacks a substantial link with empirical findings regarding the human deductive reasoning performance and the existing symbolic theories. My supposition is that the reason for this state of affairs is that the existing studies are either too general and unsystematic (stating some principles of such an approach), or too particular (being focused on the issue of finding an adequate architecture for a dynamic network capable of a particular deductive performance). Unlike them, my theoretical proposal of a schema-based dynamic model of the deductive reasoning *is placed at a rather intermediate level of analysis*, assumed to be more useful for designing empirical studies, or for the interpretation of their results. Its conception is rooted in several underlying ideas.

In the first place, the proposed model was *centered on the notion of cognitive schema*, because I felt that it might represent a conceptual bridge between the symbolic models of the deductive reasoning and the theoretical suggestions of a dynamic approach of the deductive reasoning.

Arguments for the choice of the schema notion as being central for the proposed model of the deductive reasoning

1) *Rules are conceived by some authors to be a kind of elementary schemata* (Cheng & Holyoak, 1985; Oaksford & Malloch, 1994; Braine, 1990, as cited in O'Brien, Braine, & Yang, 1994), and they are the key notion in what was named to be rule theories of the deductive reasoning. Particularly, pragmatic schema theories (Cheng & Holyoak, 1985), involving pragmatic rules instead of formal, logical, ones, are powerful in explaining the hypothetical-deductive reasoning with a thematic content. Rules are schemata in the sense that they represent in an abstract manner the key elements of some elementary procedures of transformation in a more or less general domain of action. Whereas formal rules are particularly focused on specifying the allowed transformations for a given class of input situations, pragmatic rules are particularly focused on the required or probably useful transformations in order to attain a class of goals. Therefore, *rules are conceivable as schematic memorized representations of classes of constraints*. A similar interpretation for the deductive rules is given by Galotti, Baron, and Sabini (1986), who state that such rules are "abstract templates that operate on the form of premises to yield conclusions" (p.17), which "might be triggered by quantifiers, negation, and/or the figure of the problem" (p.17). It could be said that mental models theory, too, covertly resorts to the idea of schema, but as an ad hoc built abstract schematic analog representation of a current new situation (i.e. a mental model), besides the schemata of the rules/procedures involved in building mental models.

In the version of the *mental models* theory supported by Barrouillet and Grosset (2007), the notions of "relational schema" and ready-made models are considered to be essential for the conditional reasoning.

2) The *interpretative relevance theory* of Sperber and Wilson (1990) speaks of *assumption schemas* as incomplete logical forms important in the inferential processes.

3) The *dual process account of the reasoning could be linked with its precursory theory of two complementary processes in the action control* (Norman & Shallice, 1980, as cited in Cooper & Shallice, 2006). That theory stipulates that there are actions controlled by schemas, understood "as flexible, interactive control structures" (Goldman, 2001) that are based on associative, unconscious, effortless processes, and actions controlled by processes that consciously select such schemas, based on a deliberate, effortful processes because they are new and do not have a learned, ready made, schema for them. The parallel between the reasoning case and the action case is obvious.

Also, the unifying theory proposed by Overton and Dick (2007, Müller, Overton, & Reene, 2001) speaks of "inferential schemes" that are integrated through experience during the cognitive development into a "systematic network".

4) *Schema notion is invoked, too, in the dynamic approach of the deductive reasoning*. Particularly, it occurs in Smolensky's (1986) harmony theory and in the Oaksford and Malloch's (1994) theoretical contribution as a regular ordered set of rules (conceived to correspond, in this case, to the transitions between states, allowable by virtue of the trajectories of the dynamic system of a neuronal network) involved in a deductive reasoning. Also, Gärdenfors (1994) has based his model of deduction on a notion of cognitive schema dynamically defined as a vector in a state space.

5) The schema notion made career in the domains of perception (Haken, 1995) and action control (Norman & Shallice, 1980, as cited in Cooper & Shallice, 2006) research, domains in which the dynamic systems theory has reported the most successful and widely recognized application (Thelen, 2003).

In conclusion, schema notion is spread over the entire domain of the theoretical endeavor with the deductive reasoning, and yet, its primordial importance has not been recognized as such explicitly, remaining only a background intuition. Still, other notions as rules and mental models as representational formats continue to be in the forefront of the deductive research.

An integrative definition for the notion of dynamic cognitive schema

There is a particular difficult task to define what the notion of cognitive schema traditionally means, because it has been progressively extended in different areas of research and for different purposes. Presently, the notion seems to be almost confounded with the idea of a mental representation having a higher level of abstractedness than the considered stimuli. Still, it has to have some differentiating elements in order to justify its maintenance. Its distinguishing feature seems to be the fact that it is a type of abstract representation having two parts: a fixed one, and a variable one. That feature is conferring it special functions, especially processing ones (generating expectancies, organizing information based on ready made models).

I. The traditional cognitive schema notion in the cognitive psychology

The traditional idea of cognitive schema occurred out of the need to find a *format of representation between specific experiences and discrete, constant symbolic representations through which memories are organized and expectations are generated* (Bartlett, 1932, as cited in Schank, 1999; Schank, 1999) in a more flexible manner. It is linked with the hypothesis that the recollection of a memory or the perception of a situation or object are reconstructive processes. In these processes, there are involved not only the current stimulation or cues, but also an internal framework (resulted from meeting other similar experiences, by abstracting their invariant structure) that provides a partially ready made organization in order to guide the information recollection, or the interpretation of the received stimuli[1]. The metaphor of a slot[2] was used in order to express the variable part of a schema as a flexible memory structure. The schema construct was further extended when it was adopted in the action control, and planning research, as a *ready made available organization through which effectors are rapidly and efficiently organized and controlled*, allowing also local and contextual decisions. Here, the schema is *organized around a central element, the general goal of a class of actions*, schemas being differentiated by their goals (Norman & Shallice, 1980, as cited in Cooper & Shallice, 2006). It is this version of the schema notion that was taken into consideration in the pragmatic reasoning schemas theory (Cheng & Holyoak, 1985).

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[1] Therefore, the schema construct was meant to explain the way people generate expectancies in what respects the incoming stimuli and recollect false memories under the influences of such guiding representations. The variable part of a schema was provided (Schank, 1999) out of the need to explain the way the skeleton of a schema is fleshed out with the variable, specific elements of a situation in a particular context, or to account for the effects of the unmet expectancies generated by a schema. More generally, it was a way to render understandable the obvious existing flexibility in the way information is represented and processed, without falling into the apparent unacceptable solution that only specific and concrete experiences are stored in the memory. At the same time, it is a point of insertion, of confluence between such a solution, and the other unacceptable solution, that there are only general static symbolic representations that are too rigid to be useful for the adjustment to an environment and to contexts in constant change.

[2] As it was shown in a previous section, soon, it became evident (Rumelhart & Ortony, 1977, as cited in Eysenck & Keane, 2000) that the slot metaphor was insufficient in order to model the empirical findings. That is why Schank (1999) revised his conception over schemas, introducing the notion of a dynamic schema. He shows that if variables represented by slots are not allowed to interact with each other, then the schema notion has a limited explicative value, especially in what respects the kind of expectancies generated through a schema. But the notion of interaction is intrinsically dynamic, even though it could be awkwardly simulated by symbolic processes, in a forced, inefficient, and artificial manner. That is why the most successful models in implementing the schema notion have been the connectionist ones (Rumelhart, Smolensky, McClelland, & Hinton, 1986, as cited in Cooper & Shallice, 2006), i.e. associative networks having an elementary dynamicity, as it was the case for the *prototype notion*. In fact, the schema and prototype notions share the same underlying idea and were defined for similar purposes. Only that the schema notion is bound more with the research tradition regarding memory, the action control and planning, and prototype notion with the research regarding perception and categorization.

Norman and Shallice (1980, as cited in Cooper & Shallice, 2006) have suggested a model through which cognitive schemas, as passive representational structures, become functional in a cognitive process by making appeal to the idea of the *schema activation*, without having in mind a particular implementation[3]. Although such a model includes some dynamicity by defining the schema activation as a dynamic variable (with continuous values that vary in time), and by allowing interactions between schemas through phenomena of cooperation and competition, it has drawbacks in several respects.

Finally, Smolensky (1986) defines mathematically the notion of cognitive schema, based on a representational vector composed by a set of representational features. Schemas can represent concrete or abstract realities. Representational features are implemented into the connectionst model elaborated by Smolensky (1986) within the framework of his harmony theory as knowledge atoms, whereas schemata as subassemblies of such activated knowledge atoms "that tend to recur exactly or approximately". Schemata are not stored in memory as such, as they are dynamically assembled in a particular context. In Smolensky's (1986) view, a schema is composed by a set of variables, a set of default values and of value restrictions for those variables, and by dependency information. The default values are the values assigned for the variables of a schema "in the absence of any contraindicated information". The value restrictions define the values "that cannot be assigned to a variable". The dependency information indicates "how assigning a particular value to one variable affects the values that can be assigned to another variable". Smolensky (1986)

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[3] In what it is named an "activation trigger schema system" (Rumelhart & Norman, 1982), each schema is endowed with an activation value, reflecting the total amount of received excitation. The resting activation of a schema is assumed to be zero. This value is increased by excitation, and decreased by inhibition. The activation of a schema is influenced by the activation of other schemas (upwards especially by the "parent" or "source" schema in a hypothetical hierarchy of schemas, and downwards by rival schema, with which it is in competition), and by the satisfaction of the so called "trigger conditions" (referring to the appropriate environmental circumstances for a schema activation). Selection of a schema is made when its activation surpasses a specified threshold.

notes that the these components of a schema “can be expressed through probability theory”: default values are the most probable values encountered for a variable, value restrictions are the least likely values for a variable, and dependency between variables is expressed by their statistical correlations, as “joint probability distributions”. In the Smolensky’s (1986) opinion, “schemata provide a useful but significantly limited description of the cognitive processing”, as they are metalevel descriptions. In this respect, he compares the relationship between the microlevel and macrolevel descriptions in the cognitive domain with the one from the physics domain:

> Just as the statistical behavior of matter disappears into the deterministic laws of thermodynamics as systems become macroscopic in size, so the statistical behavior of individual features and atoms in harmony models becomes more and more closely approximated by the higher level description in terms of schemata as the number of constituents aggregated into the schemata increases. (Smolensky, 1986, p. 255).

With the partial exception of Smolensky’s (1986) schema theory, which represents a first step toward a more elaborate dynamical approach of the schema issue, the limits of the traditional schema notion in cognitive psychology are:

– It ignores the internal dynamism of a schema, the interactions between its elements.

– It does not specify if and how the activation thresholds are changed. It is reasonable to assume that those thresholds could be also dynamically defined, in dependence with the activation level of other activated schemas.

– There lacks a clear explanation in what respects: a) how default values are acquired and included in a schema; b) how and in what conditions they are substituted with the values provided by a current situation; c) if and how they could change their status, being included in the fixed part of a schema. In other words, the relationship between the variable part and the fix one has been ignored, remaining still rigid and unfunctional.

– It inherits the general limits of the symbolic paradigm, especially the ones regarding: a) the necessary existence of an external agent who has to make decisions regarding the way schemas are built, maintained, changed and operated (leading to the peril of an infinite regression); b) the implicit separation between an executive part, and a representational part of the cognitive system. This problem was, for example, signaled by Shallice (1994), who showed that, because schemas are provided with a continuum of activation values, then there is no way to draw a clear line between the processes having automatic characteristics from those consciously controlled. Therefore, in his opinion, there is a continuum, not a dichotomy in what respects the automatic-controlled dimension of the cognitive processes. Also, Allport, Styles, and Hsieh (1994), based on their findings in six experiments in which they tried to explain the task set inertia (a concept equivalent with the cognitive schema notion) have questioned the idea of a fundamental distinction between a controlled system and a separate executive, controller system, with a limited capacity, pleading for the need of another metaphor in order to explain their results. They oriented themselves toward the notion of a kind of priming as being explicative for what they called to be a "task carry-over effect".

Shortly said, the traditional notion of schema is, in general, a hybrid version, trying to accommodate both the demands of a symbolic paradigm, and the empirical findings[4]. But, since the notions of activation, interaction, or competition used in the schema theory are hardly compatible with symbolic processes, it is not coherent, remaining

[4] In the traditional cognitive psychology, the cognitive schema construct was elaborated progressively, its properties being added in order to explain dynamic aspects of the empirical findings in various domains of investigations. It is not particularly linked with the symbolic paradigm of cognition, but it is merely a way of accounting for some empirical findings by grouping them under a unifying label. Miclea (1994) emphasizes this idea by stating that the existence of the cognitive schema is a postulate, for which only indirect evidences exists: its effects on the information selection and interpretation.

a rigid representational format, and, therefore, it has a limited explicative power.

II. Dynamic cognitive schemas and their properties

A dynamic definition of the cognitive schema preserves its established properties and explicative value acquired in the traditional cognitive psychology research. But, at the same time, it is supplemented with other properties that could be valuable in interpreting the empiric findings from the past, as well as in obtaining new ones.

The existing theoretical contributions (Gärdenfors, 1994; Oaksford & Malloch, 1994) regarding the dynamic interpretation of the schema notion were presented in a previous section. The current section is dedicated to a systematic and integrative proposal in that respect.

a. *Dynamic schema as a dynamic representation*

In the first place, a dynamic schema has all the usual properties ascribed to a dynamic representation. The most important one is that *it corresponds to a state or a set of states from the state space of a dynamic system defined by their stability, and having a representational function*[5] *by its dynamic coupling with the external represented systems*. *Stability* of a representation is a functional property, derived from the intrinsic dynamics of the underlying dynamic system. A state (or a set of states) is said to be maximally stable if it has an *attractive power*[6], It is

[5] The stable state is said to represent in an abstract manner the external situations corresponding to all its neighboring unstable states within its attractive range, because the dynamic system clusters them in what seems to be like a category (as all those states are similar), by virtue of its intrinsic dynamics. In fact, the category is represented at the level of the entire attractive region of a stable state, usually having fluid borders, and the stable state itself is what was traditionally named to be the prototypical case or a well-formed gestalt.

[6] The attractive power of set of states means that a system tends to autonomously evolve toward them when it is placed in another state or that it tends to return to them spontaneously if it was displaced by external influences, when these influences cease. The evolution of a system toward the nearest stable state is like an answer given by that system to those external influences that placed it in an unstable state (which might be conceived to correspond to an unlearned, unknown stimulus or to a more particular stimulus).

reasonable to think that a cognitive schema, as an abstract representation, could be put in relation with the stable states or sets (configurations) of stable states of a dynamic system.

b. The dynamic interpretation of the properties of a cognitive schema and new properties

1. *The structure composed from a fixed part, and a variable part*

From one perspective, *the variable part of a schema* would correspond to the dynamic variables, or, in another interpretation, to the unstable states from the attractive region surrounding the stable states[7]. *The traditional fixed part* would correspond to the dynamical law governing the interaction between the dynamical variables (including the control parameters), and, in another interpretation, to the stable states themselves (to be noted, although, that, in a dynamic view, that part is not actually fixed, but only stable)[8].

2. *Stability of a dynamic schema*

This property lacks in a symbolic account of the schema notion.

More precisely, on the one part, stability of a schema means:

– that the *actualization of a schema is differentially resistant to noise effects*: different intensities of noise (disturbing, unspecific stimuli or changes in the control parameters) are needed in order to move away a dynamic system from a stable state correspondent to a cognitive schema to neighboring states (states from the state space having a partial resemblance to the sate of the cognitive schemata). When a system is moved from the state of a schema to a neighboring one, phenomenally it may appear as if that schema is partially actualized, with only a few of its elements.

[7] They correspond to the configurations of values ascribed to the variables of a schema (named slots), but, in this case, those variables are allowed to interact dynamically.

[8] The values defining those stable states will be the ones that correspond to the *default values* of a schema. In that way, it is given an explanation both for the origin of the default values of a schema, and for the power of the expectations generated through them to replace the actually received stimuli, which lacks in the traditional symbolic paradigm. In this perspective, the schema is represented through a dynamics, not at the level of a dynamics.

- the *power of a schema to attract back the system into its region*, reflected in the: a) *speed of this return*[9] and b) in *the size of the region from the state space within which such an attractive power is exerted* (i.e., the level of dissimilarity of a distant state from which the system still tends to evolve toward the states of that schema). In traditional terms, it would mean the number of indices (cues, features) needed in order to actualize a schema, if those indices are interpreted as the common part between an initial state and the final schema state.
- when it represents a stable set of states (cyclic or chaotic attractors), *a more or less regular pattern of fluctuations in time of its states, resulting phenomenally in the occurrence or the disappearance, at more or less regular time intervals, of some of its elements*.

3. *Generation of expectations*

The property of a traditionally defined schema to generate expectations and inferences (Miclea, 1994) is dynamically ascribed for a dynamic schema:

- to the existing interactions between the variables included in its underlying dynamic system. In other words, *a dynamic schema is a way to decrease the number of degrees of freedom through which the state of a system is defined, or through which its behavior could be controlled*. The fact that the value chosen for a first variable finally determines the unknown values for the remaining ones

[9] The stability of a state is less clearly reflected in the *time needed to reach that state*, because two factors are involved, with opposite effects in that respect. Those factors are the breadth and the depth of the region from the state space within which the respective stable state exerts an influence, i.e. it has an attractive power. Both are important in defining the speed with which a system will evolve toward the considered stable state, reflected in the slope of the trajectory followed by the system. Still, the time needed by a dynamic system to reach a stable state from an initial state may serve as an index of the distance or the similarity between the two states. Especially its evolution is important as an index for the changes occurred in the dynamics of the underlying system under the influence of some control parameters. If, through these changes, the stability of the stable state is increased (as in learning) even more, that time is shortened. If stability decreases (as in forgetting), that time is increased.

gives a way to *dynamically interpret the classical property of a schema to organize the interpretation of the incoming stimuli based on the ones already received*.

– to the idea of *emergent properties* in complex dynamic systems that have several levels of organization[10]. These properties are behaving in relation with the component systems as new control parameters, named *order parameters*. Through these order parameters, the behavior of the component systems could be controlled, "enslaved"[11]. In other words, the order parameters of a superordinate schema impose an organization onto subordinate schemas, and, from such constraints, expectations are generated.

4. *The hierarchical organization of the schemas*

At their turn, the order parameters of a system could be included as dynamic variables into another new dynamic system. Therefore, the system in which they emerged becomes, through them, dynamically coupled with the new one. This could go on in the same manner to new higher levels of organization.

5. *Schema priming*

A schema, also, could be dynamically thought to be primed or to prime other schemas, as it was traditionally suggested (especially in task switching experiments in which tasks or intentional sets are thought to activate schemas). The notion of priming is more naturally

[10] By being dynamically coupled, several dynamic systems form a new one, with superordinate stable states in a new multidimensional state space, having as coordinates all the coordinates of the component systems. The behavior of the resultant dynamic system has properties emergent from the properties of the dynamical behavior of the component systems, describing its state, but it is not possible to reduce them in any understandable way to those precursory properties. That is why they have an irreducible novelty in comparison with the existing, known properties. It is a property recognized in the traditional cognitive psychology (Miclea, 1994), but which is hard to be understood in a symbolic framework.

[11] The behavior of a dynamic system is "enslaved" in the sense that it is driven away to another states from their state space than the ones toward which they would have had evolved if they were not coupled with other dynamic systems.

accountable in a fully dynamic approach as signifying *the fact that a previous stimulation brings a dynamic system in the proximity of the attractive region of a stable state corresponding to a schema* (Ferber, 1996). So, the chances that that stable state to be reached by that system are increased, and the distance to be traveled in the state space toward it decreases (and, correspondingly, the evolution in time toward it decreases, too).

It is understandable then why, generally, *a primed schema is more readily actualized, in a shorter period of time, and with a higher rate of success*. On the other hand, if a system is destabilized from a stable state corresponding to a schema, the chances to arrive to another stable state (i.e. the actualization of another schema) are increased if the other stable state is close to it in the state space. *In that sense, the first schema could be considered to be a prime for the second one*.

6. *Schema activation vs. schema actualization*

To the notion of activation of a schema, the correspondent dynamic concept would be the notion of schema actualization. That change is justified by a change of perspective.

From a dynamical point of view, a schema, as a stable state, is always indirectly active, having the potential to influence the behavior of its underlying dynamic system by its attractive power. But it is not always *actualized, in the sense that the system is not always in a state from its attractive range of states*. In fact, *only the dynamical variables of a system are constantly active, and a stable state in its state space is actually a virtual structure*.

What traditionally *means to increase the activation of a schema* it would rather correspond to a change in its attractive power, or to a reduction of the distance between the current state of the underlying dynamic system and the stable state of that schema. The so called *activation threshold* of a schema would correspond to the borders of the attractive range of its stable state, thus receiving a natural accounting of its occurrence and possible change. Moreover, in the traditional accounts of the schema activation, the process is not clearly defined. It usually means that it has an additive nature, a schema being activated when the weighted sum of the activation values of its elements surpasses a given threshold (they are not allowed to be changed through an internal interaction between those elements). But the origin and the meaning (from an operational point of view) of that threshold have not been plainly stated. Some authors (for example, Shallice, 1994) believe that there is no such threshold, and the activation of a schema is continuous, not an all-or-none process.

In a traditional account, also, specifications in what respects the idea of partial activation are lacking. The activation being an additive process, it seems that no distinction could be made from an operational point of view between the case in which all the elements of a schema are equally poorly activated and the case in which some of its elements are intensely activated and others not at all activated. In a dynamical perspective, instead, it is predicted that no matter how increased is the activation level of an element, if it surpasses a certain threshold (given by the boundaries of the attractive domain of a schema), it would not lead to the actualization of the considered schema, even though the general threshold is met by summing all the activation values.

Also, for the assumed *interaction* or *competition* between the virtual, actualizable, schemas, there is no plausible mechanism through which they are symbolically rendered on a large scale[12]. From a dynamic point of view, when a schema is interpreted as a stable dynamic structure of a dynamic system, *the competition between schemas occurs when that dynamic system allows the simultaneous existence of several stable states in its state space*. Differently stated, it means that it is bi-[13] or *multistable*.

In a dynamic interpretation, a *partially actualized* schema would correspond to a state from the neighboring region of the stable state

[12] If the interaction between schemas is realized not by a direct contact, in real time, but indirectly, by a symbolic transmission of information regarding the activation state of a schema to another one, there is bound to occur, soon, a computational explosion. That is why the schema notion was more successfully implemented in connectionist dynamic networks, by distributed representations.

[13] A well known case of such bistability is the case of an ambiguous figure where two interpretations (or schemas of organization for the given sensorial stimuli) are mutually competing.

corresponding to that schema. It may be a transitory, unstable state, from which the system will evolve toward a more stable one.

7. *Schema selection and change, schema inertia, schema biases*

In what respects the *transition from an actualized schema to another one*, it could be made in two ways:

- by *a change in the values of the dynamic variables* of the underlying dynamic system trough its internal dynamics or an external intervention.
- by a *change in the values of one or more control parameters*.

In this last case, the *hysteresis phenomenon*[14] is possible to occur, explaining dynamically the known phenomenon of the *inertia of a schema*, manifested, for example, in the effects of a mental set. These effects are poorly accountable from a symbolical point of view[15].

The *selected schema* at a certain moment is the one that wins the competition with the others in a particular context (*defined* by the *initial state of the underlying system*, the *configuration of its control parameters,* and by the *recent actualization history* of that schema). Therefore, there is no imperious need for an external, executive instance in order to select an appropriate schema.

8. *The effects of learning on schema actualization*

A symbolic account of a cognitive schema also lacks a clear stipulation of the effects of an increased learning of a schema on its activation and operation (Burgess & Cooper, 1996). At most, it could be said that the activation threshold is somehow decreased by learning. But that would lead to an increased vulnerability to noise, which is not what is expected to happen by learning.

[14] Hysteresis occurs when, by changing control parameters, a stable state continues to be actualized because it has recently been actualized, even though for the new values of the control parameters other stable states should have been actualized if it were not for its recent actualization.

[15] As it was noticed before, the priming explanation is not in itself sufficient, and is not ultimately symbolically accountable.

Instead, in a dynamic account, by learning, in a first case, the *stability of a schema is increased*[16].

In a second case, learning means *to dynamically couple or to increase the intensity of the dynamic coupling between the variable elements* of a schema[17].

9. *Types of schemas with different levels of complexity*

When a schema is *more complex*, surpassing the concept level, especially when it is meant to represent a class of events or actions, from a dynamical point of view, it should mean that it includes besides states more or less regular transitions:

- between states (i.e. trajectories between states) within a limited stable region of states (as it is the case with a cyclic, or chaotic attractor region), or
- between one stable region to another one (as it is the case of the chaotic itinerancy); it is a way to dynamically account for the schema notion when it signifies a rule, or a set of rules, as it has been traditionally defined in some cases;
- between a dynamic structure characterizing a whole state space of the underlying dynamic system[18] to another one, through a change of one or more of its control parameters[19].

[16] The consequence is that *it becomes more easily actualized, and it is harder to be destabilized by a disturbing noise*. Dynamically interpreted, the more stable a schema is, and, implicitly, the more well-learned, the *fewer are the needed cues in order to be actualized* and *the less increased their intensity*. The argument is that a stable state of a well-learned schema has a broader attractive domain in the state space and an increased attractive power. Consequently, more dissimilar actualized states in comparison with the stable states of a schema will lead ultimately, trough the evolution in time of the underlying system, to the actualization of that schema.

[17] Therefore, as they are more tightly related, it would be sufficient to know or to set the state or the value acquired by only a few of them in order that the others to be obtained by virtue of the constraints internally generated by their mutual interaction. Stated in more traditional terms, the more learned a schema is, the fewer are the needed triggering cues for the actualization of that schema.

[18] It comprises all the attractor regions together with their borders and position, i.e. the structure of attractors for a given configuration of the values of the control parameters.

[19] Such transitions could be catastrophic ones: sudden, unexpected, and leading to a qualitative change in the behavior of the underlying system.

When a schema is put in relation with the dynamic structure of the whole state space of its underlying dynamic system, it could be said that it is a *schema of schemas* (the subordinate schemas being all the sets of stable states from that state space)[20]. At the same time, such a case shows that there are schemas that could be *actualized by changing only some values of their so called "constant" part (i.e. control parameters),* and that *their actualization would trigger the simultaneous actualization of a whole set of subordinate schemas*.

10. *The effects of the recent past on schema actualization*

The most important change of perspective introduced by a dynamic perspective is the importance ascribed to the temporal context or to the recent past history in the evolution of the underlying dynamic system in determining the actualized schema in a certain moment of time. Recent history determines the future evolution of a dynamic system in several ways:

- if a system has been recently in a region closer to a stable state than to another one, the chances that the system will be finally stabilized in the first one are increased;
- when a schema is represented by a cyclic set of states, the determination of the value of one of its variables at a certain moment in time (when the values of the other ones are known for that moment) will also depend on the recent direction of evolution of the system within the set of the stable states;
- the dynamic structure (or schema of schemas) in which a dynamic system will be stabilized when a control parameter is changed will depend on the recent values taken by that control parameter, i.e. on the direction and the continuity of the change of that control parameter.

Phenomenally, the effect of the recent past on a schema actualization leads to the expectation of ***the occurrence of order effects*** in what respects the previously actualized schemas or triggering cues for a schema.

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[20] It is another way in which schemas could be envisioned to be hierarchically organized.

c. *A synthetic definition of a dynamic schema*

Trying to give a synthetic and intuitive definition for the notion of dynamic schema, I will use the more familiar and concise term of pattern, since a pattern, as a configuration of values, is conceived to correspond to a point in a state space (Gärdenfors, 1994).

Taking into consideration the above mentioned note, the resultant definition is:

A dynamic cognitive schema is, simultaneously, a representational and processing structure that resides in a temporal pattern (configuration) of patterns, endowed with a degree of stability in time at a higher level of abstractedness (a higher spatio-temporal scale, in which the degrees of freedom are decreased) and through which expectations are generated by dynamic processes of pattern completion involving the stabilization of a dynamic representational system into that pattern. Stated differently, it means that a dynamic schema represents a set of states from a space of possibilities that is endowed with a temporal structure (i.e. temporal order) by virtue of an underlying dynamics defined on that space.

d. *Conclusion*

A dynamical point of view brings to the research focused on the cognitive schema notion a more natural and coherent way to conceive its necessary and defining flexibility, or dynamism. It succeeds that by providing underlying processes of a dynamic type that do not restrict a schema dynamicity by forcing it into an unfit symbolic framework. Apart of an external dynamism (at the level of the interaction between schemas), which could be symbolically simulated in an awkward, cumbersome, manner symbolically, a dynamic approach endows a cognitive schema with an internal, essential, intrinsic dynamism that is lacking in its symbolic interpretation.

By receiving a dynamic interpretation, the schema notion acquires also new, dynamic, properties. The most important such property is what is called the *stability* of a schema. *Through such a property it is accounted, in a unifying manner, its traditional bipartite structure, the way a schema is actualized, selected, changed, and the way it interacts with other schemas*. It also *accounts for dynamic phenomena for which there is no* *appropriate symbolic explanation: priming of a schema, the inertia of a schema*. A dynamical account has its main advantages in what respects the *explanation for the effects of learning, of noise, of the recent history, of the number of triggering cues, and of the context in what respects a schema actualization*.

The present dynamic account of a schema is not without its own problems or vulnerable issues, but it seems to be a step forward in comparison to a purely symbolic interpretation. It increases the coherence and the extension of the theoretical underpinning offered for a range of properties that have been traditionally ascribed to a schema notion more on empirical grounds (to describe or to explain some empirical findings) than on the symbolic paradigm grounds.

The idea that a cognitive schema involved in higher cognitive processes, although it has some characteristic properties as pattern of patterns, is still nothing more than a pattern has an important methodological consequence. It might provide a bridge through which it is reasonable to borrow successful research strategies (involving a dynamic theoretical underpinning) that were successful in studying the patterns at a perceptual and action control level in order to study cognitive processes at a higher level.

Dynamic reasoning schemas in deductive processes

I. General assumptions

Applied at the level of deductive reasoning, the general notion of dynamic schema needs some supplementary assumptions regarding its specific properties[21] and regarding the reasoning process in this particular context.

a) The first general assumption is that a dynamic deductive schema is primarily a *dynamic structure of a semantic space* endowed

[21] They are not necessarily represented explicitly as components of a deductive schema, probably being emergent properties with the status of distributed representations.

with a characteristic dynamics. Its *actualization is presumed to be dependent on semantic features* with *logical meaning*[22].

b) The second general assumption is that a deductive schema is *centered on a cognitive goal,* representing a class *of argumentative s linked with that cognitive goal*. When a deductive task is similar with the argumentative experiences in which that deductive schema emerged, actualization should be more likely to occur.

c) The third assumption is that during a deductive process *several kinds of dynamic schemas, at several levels of organization and with different cognitive goals, may be involved*, and that *the result of a deductive reasoning is dependent on the result of their cooperation or competition*.

II. Assumed types of dynamic deductive schemas

Using as a criterion the level of abstractness and generality of their cognitive goal, three main types of dynamic deductive schemas are assumed, as a rough approximation describing the multitude of dynamic deductive schemas that it is possible to exist.

1. Deductive dynamic schemas on the basic level (elementary spatio-temporal schemas)

The following properties are ascribed to them:

- ✓ They are assumed to be *the most frequently encountered in the usual everyday thinking,* having, consequently, *the highest basic stability*;
- ✓ Their *cognitive goal* is mainly *directly linked with concrete actions*: a) *orientation in space and time* (deriving the relationship between points in space or time); b) *finding out the physical relationships between concrete objects* or group of objects.
- ✓ They *are supposedly emergent early in the cognitive development*
- ✓ They are supposed to be the most stable deductive schemas.
- ✓ The most probably, they would be *correspondent predominantly to the traditional relational deductions*.

[22] They are emergent properties (subordinate schemas) of dynamic processes on lower levels of organization.

- ✓ The *dynamic neural networks* in which they are represented are placed on the *lowest level of organization*.

A *typical example of* such a schema would be one *of route finding*.

2. Deductive reasoning dynamic schemas on an intermediate level

The following properties are ascribed to them:

- ✓ They are centered on *more abstract pragmatic cognitive goals*, being only *indirectly linked with concrete actions* and more directly with *actions with abstract mental "objects"*: concepts and their relationships, or events and their relationships, or social relationships[23]. Their aim is to find out new relationships in such more abstract domains of action, involving representations on a higher spatio-temporal scale.
- ✓ They are *rather frequent*, since the situations in which their cognitive goals are encountered are supposedly rather frequent, although not the most frequent. Consequently, *their basic stability should be, also, at an intermediate level*.
- ✓ It is reasonable to assume that *they are placed on an intermediate level of organization of the cerebral semantic dynamic network*. At this level, *new semantic properties with logical relevance are presumed to be emergent, contributing to the generation of such deductive schemas*.
- ✓ *Developmentally*, it is reasonable to assume that they are *generated later than the deductive schemas of the basic type*.

Examples of such schemas would be the *pragmatic reasoning schemas* (Cheng & Holyoak, 1985), discussed in a previous section in what respects the hypothetical reasoning (permission or obligations schemas), or some pragmatic reasoning schemas for the syllogistic reasoning (proposed and discussed in more detail in a future section). There may be also pragmatic schemas for the relational reasoning such as finding kinship relationships.

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[23] Still, they remain at a pragmatic level, i.e. the level of classes of experiences with pragmatic purposes presumably encountered especially in social interaction situations.

3. Dynamic deductive reasoning schemas at the highest level

The following properties are ascribed to them:

- ✓ They are *centered on abstract, analytical, purely cognitive or meta-cognitive goals*, aiming *to exhaustively identify virtual possibilities* (of interpretation, or of evolution of a given situation, etc.). I named them *combinatorial schemas* because they require the identification of all the relevant potential variables involved in a presented situation together with their potential values and then the identification of the allowed relationships between these values given a set of constraints. Usually they may have as a cognitive goal finding out that a relationship is a necessary one, no matter the context and content of a deductive task.
- ✓ They are supposedly *rather infrequent in the current, day to day, life,* being encountered especially in the context of a formal education or scientific argumentation. Therefore it is to be expected that they have, statistically speaking, *the lowest stability*[24]. They might be needed especially for those new situations in which a substantial pragmatic experience[25] is lacking.
- ✓ Developmentally, they are *supposedly the latest*, requiring that the people to get used with the logical "objects".
- ✓ They are *assumed to be placed at the highest level of organization of the cerebral dynamic network* underlying them. At that level, representations for extremely general and abstract categories such as variable, constant, combination, necessity, possibility, exhaustiveness, etc. are presumed to emerge.

It may be the kind of schema envisioned in formal reasoning, the mental model theories or mental logic theories of the deductive reasoning.

[24] The reason is their relative rareness and level of complexity (their stability being dependent on the stability of the schemas existing on lower levels of organization from which they emerged).

[25] It is an experience that generates more specific schemas through which the degrees of freedom are decreased, and the space of all possible states is compressed to a smaller region.

III. Selection of a dynamic deductive schema through actualization

When a subject is confronted with a deductive task, it may contain cues that contribute to the actualization of the deductive schemas existing on all these three main levels or only on one or two of them. They could be compatible or incompatible in what respects the correct answer. Relationships of cooperation or competition may exist between them. But the answer will be based only on that deductive schema that wins the actualization competition.

The *actualization* of a dynamic deductive schema is presumably *dependent on the following factors*:

- Its *absolute (basic) stability* presumably derived from its level of learning, which in its turn should be dependent a) on the frequency of the encounters with experiences from the class having its cognitive goal, and b) on personal individual traits such as the general intellectual ability, attention functionality, the level of development of the executive functions, working memory capacity, motivational factors, cognitive styles, etc. that could influence the efficiency of the learning processes.
- The *current level of noise*, i.e. small external destabilizing nonspecific influences producing changes of the state of a system that are not ascribable to its internal dynamics (external perturbations, distractors, irrelevant stimuli). In its turn, it may depend on the temporary functionality of the attention, on the environment, and contextual factors. The current level of noise will contribute to determine the relative stability of a dynamic deductive schema.
- *The region from the state space where the underlying dynamic system was placed* when a deductive task is received, i.e. how far it is from the region corresponding to that dynamic deductive schema, especially in comparison with the distances to the regions of other competing deductive schemas. The closer the two regions are the higher are the chances that that deductive schema will be actualized.

- The *recent history in the evolution of the underlying dynamic system*, i.e. previously activated relevant dynamic deductive schemas.
- The *existence of other dynamic competing deductive schemas* and *their absolute stability*.
- The *level of similarity between the current deductive task and the type of experiences based on which that deductive schema was developed*. The more similar they are the higher are the chances of its actualization. The previously discussed level of similarity will be dependent on the salience (*prägnanz*) of the information needed to actualize a deductive schema in the current context of a deductive task.
- The *level of similarity between the current deductive task and the type of experiences based on which the competing deductive schemas were developed*. The more similar they are the lower are the chances for the actualization of the considered schema.
- The level of similarity between the competing dynamic deductive schemas (their distinctiveness)

Taking into consideration the above mentioned factors, the actualization competition should be won by a dynamic deductive schema more probably when *it is distinct, with a high level of stability relative to the stability of the competing schemas, relatively unaffected by noise in comparison with the competing schemas, and when the recent history favors its actualization*.

IV. Derivation of a conclusion as a pattern completion process

1. The application of the synergetic model of Haken (1995) to the deductive reasoning process

Derivation of a conclusion based on the winning dynamic deductive reasoning schema is suggested to be similar with the one envisioned by Haken (1995) in order to dynamically interpret pattern completion. His synergetic model was elaborated for perceptual processes, as well as for decisional ones, in which the available information is incomplete or conflictual. It could be extended for the deductive reasoning in the degree that this type of reasoning is based on dynamic processes involving complex dynamic systems. Essentially, his model exploits "an analogy between pattern formation by self-organization and pattern recognition, especially the completion of an incomplete set of data (due to the dynamical structure of an attractive process)" (Kriz, 2001, p. 517).

In Haken's (1995) model, the lacking information needed in order to take a decision is completed based on the similarity of a current situation with a previous one, which is analogous with the task of pattern recognition. Consequently, the same proposed model for the recognition of the ambiguous figures should be applicable. In the extended model, the given/known data play the role of patterns. A novelty of the extended model is the fact that it allows that the given data to be not only quantitative, but also qualitative: rules, laws, algorithms, diagrams, etc., since the patterns could be also arrangements of objects. These patterns are coded as vectors that are constant or time-dependent. The incomplete data of a decision correspond to an incomplete pattern. By introducing a measure for the similarity degree, a dynamic of the decisional process is initiated, having as control parameters the level of attention and contextual factors[26].

In a similar vein, it could be said that, in a deductive reasoning, premises offer incomplete information. The task of the reasoner is to complete that information based on a learned schema (pattern). But she/he will be confronted with a choice task if several schemas are compatible with the given incomplete pattern, in case this is an ambiguous one. That choice task could proceed in the same manner as

[26] As resultants of such dynamic process, there are possible unique decisions, or oscillatory behaviors between several decisional alternatives. The hysteresis phenomenon in this case would mean that a subject would continue the choose a previously chosen option, even though the circumstances are changed and other alternatives would have been chosen if it were not for the previously chosen option. The suggested dynamic process includes an attention saturation phenomenon, which means that attention, as a control parameter, becomes zero for a choice that leads to failure, allowing the choice of another alternative by reorienting the attention. All the options are considered in parallel, not serially.

in the Haken's (1995) model. In other words, ***the same dynamic phenomena occurring at a perceptual level should be apparent also at higher levels of the cognition***. ***Only that, in this latter case, the task is to recognize or complete (i.e. recall) patterns of patterns.***

2. Dynamic phenomena at the level of synergetic patterns

a) There is a *differential sensitivity to the disruptive effect of noise* (irrelevant information or attentional fluctuations) of those patterns having a higher level of stability (i.e. they are more resistant in comparison with those patterns with a decreased level of stability).

b) *The learning of a pattern (though frequent encounters with it) raises its stability* (by changing the relevant cognitive dynamics in dependence with the control parameters changed by learning).

c) *Stability of pattern has two components*. One is related with the level of similarity of the unstable patterns that still will lead (without external disturbances) to a stable pattern. The more dissimilar they are in comparison with the stable pattern, the higher its stability is. This component is reflected in the breadth of the attractive region of a stable pattern. The other component regards the level of energy (or the level of nonspecific input constituted by changes in the value of some external parameters) needed in order to move a system beyond the borders of the attractive region of a stable state, because a stable pattern is like a basin or valley in which the system falls automatically. This component is reflected in the intensity level, or the depth of the attractive basin corresponding to a stable pattern. It suggests, also, how abruptly, accelerated a system will fall into a stable pattern, and the level of tightness of the dynamical links for its neighboring states. It is assumed that when the same pattern is encountered repeatedly (or extremely similar ones), predominantly the depth component of its stability will be increased through learning. But when learning a pattern will proceed by encountering more dissimilar patterns, predominantly the breadth component will be increased. Sometimes, in this case, the stable pattern will be rather a prototype that has never been actually encountered.

d) The *unstable patterns within the domain of attraction of a stable one* (in which a system could be kept only by an external influence) have a lower level of constraint between their elements (in what respect the reduction in their variability or degrees of freedom) or *are less intensely coupled* than the latter one.

e) *Fewer triggering cues* (less information) are needed in order to actualize a stable pattern (in what respects the two components of its stability) in comparison with a less stable one.

f) A *ceiling effect in the recognition of a pattern* (in what respects its correctness or response time) occurs for fewer triggering cues in the case of the more stable patterns (explaining thus the phenomenon of a variable recognition threshold). In other words, adding information (supplementary triggering cues) to the one that has already been able to actualize a pattern would not lead to a significant improvement (or variation) in the recognition or pattern completion performance (since that information is already available, being generated through the stabilization into the required pattern).

g) There is a *dependency of the actualization (recognition) of a pattern on the patterns recently actualized* (the information recently presented or the task recently completed), i.e. there may occur order effects or a temporal context-dependency;

h) The *chances of a spontaneous return to a previously actualized pattern after its external destabilization are higher if that pattern is more stable*, which is a particular type of order effect, similar with the ones mentioned at the preceding point; also, the more stable a pattern is, the longer is the time interval when a spontaneous return to it is possible after a destabilization.

i) There is a *dependency of the actualization (recognition) of a pattern on the stability of other patterns whose actualization is also supported by the currently presented information, i.e. a context dependency phenomenon*. It is possible that a pattern to be actualized with fewer triggering cues (less information) than another more adequate one, for which more triggering cues are available in the current information, only because it is more stable than the latter one. Therefore, there is a competition between several patterns for which there are triggering cues in the current available information that will be won not by the pattern which is the most similar with the current situation, but by the pattern which is the most stable one in the current context. As a consequence, false recognitions (or false memories, or wrong derived expectations or conclusions based on a process of pattern completion) are possible. In the case of a false recognition, the winning pattern will constrain ("enslave") the interpretation of the ambiguous information or of the information supporting the competing patterns in order that the "required" fit to be obtained (because there are dynamic interactions between the levels of organization, so that the influences are simultaneously upwards and downwards). Stated more traditionally, it means that *biases effects* occur.

j) The *temporal order in which the information is received is important in what respects the actualization of a pattern*.

– In the first place, the received information is conceived to comprise stable subpatterns that are cooperating in order to generate a superordinate pattern. Their cooperation means that they offer the mutually supporting cues required for the actualization of a superordinate pattern. If the first presented patterns (information) trigger the actualization of a stable pattern that is not the intended or expected one (in comparison with the information provided later), its actualization will tend to constrain or to organize the information presented subsequently, biasing its interpretation in its direction. Consequently, the new provided subpatterns (or triggering cues) have to be more stable (salient) in order that the expected superordinate pattern to be actualized (replacing the pattern that was inadequately actualized) in comparison with the situation in which they are the first presented ones. In that way, a new type of order effect is possible and, also, of a biasing effect. In the case in which the information is not serially presented or received (as it is in the case of reading, foe example), but simultaneously, there would be no such *biasing in the competition between the possible superordinate patterns due to a head start for some of them*. In this case too, there may be a serial actualization of the subpatterns, but it depends on the order of their stability, or on the saliency of the triggering cues (i.e. salience effects).

– In the second place, the order in which the information given in the premises is presented is relevant in what respects the *similarity with the temporal organization of the required deductive schema in order to solve a deductive task*. For example, in a relational deduction, of a transitive reasoning type, it would be beneficial that the involved terms to be presented in the premises in the order of their size.

k) The fact that two similar patterns (with a low level of distinction) are placed in neighboring places in a state space will lead also to some *order effects in what respects the sequence of their actualization, especially in comparison with other, more distant (dissimilar) patterns*. The influence of a pattern over the actualization of another similar one is mixed in what respects the direction of the effect.

– On the one hand, *when one of them is somehow destabilized*, the chances that the other one to be actualized instead (in comparison with the other competing existing patterns) are increased due to their closeness, the transition between the two being the favored one.

– On the other hand*, if one of them is more stable, having a larger domain of attractive power in the state space*, the chances that, after its destabilization, the other similar one will be actualized are decreased, since a higher level of destabilization would be needed in order that the system to be placed in its attractive narrower domain. If a system is in a transitory state between the two attractive domains, lower levels of destabilization from its trajectory are needed in order to place the system into a trajectory leading to the most stable pattern between the two neighboring patterns. Consequently, the transition from a less stable pattern to a more stable one is favored in comparison with the reversed transition (between a more stable pattern toward a less stable one).

l) If a superordinate pattern organizing its subordinate patterns (from which it emerged) is less stable, then its *organizing influence will be intermittent, presenting more or less regulate fluctuations in time* (by being more vulnerable to noise). As a consequence, the less stable a pattern is, the more intra-individually variable will be the performance in a cognitive task requiring that pattern.

m) The stability of a pattern, on which depend the current actualization of that pattern and its maintenance, could be viewed of being of two types. An *absolute or general stability*, defined by the level of its learning (or, correlatively, by the frequency of the encounters with it in the long run), and *a relative, particular, stability*, defined by the patterns actualized in the recent past, the stability of the competing patterns simultaneously allowed by the current information (with its two components), and the distance to its neighboring stable patterns. That would mean that the effects of the stability of a pattern at a phenomenal level are context-dependent.

n) Taking into consideration the notes from the previous point, it would mean that, statistically speaking, *in order that a good average performance to be obtained by an individual it would be preferable that her/his representational patterns to have an intermediate average level of stability (i.e., a higher stability of a pattern does not mean necessarily a higher level of performance).* The general reason is that there should be a trade-off between flexibility and stability (rigidity) needed in order to complete a task at a higher level of performance, dependent on the criteria used to asses that performance. But, in general, it is logically assumed that the performance will be higher when there is equilibrium between flexibility and stability in the behavior of an underlying dynamic cognitive system.

More particularly speaking, at a dynamical level, there are two reasons for the requirement of an intermediate average level of stability for the patterns involved in cognitive processes:

a) The first one is that *the more stable a pattern is, the less able it will be to cooperate with other patterns in order to generate* (on a higher level of organization), through emergence, the superordinate pattern needed in order to complete a class of tasks. Instead, it will tend to compete with them, or to subordinate or recruit them, distorting, in that way, the interpretation or organization of the new incoming information. But it is not preferable to have a too low stability either, because that it would mean that the emergent superordinate pattern will be also rather unstable, resulting in a low performance.

b) The second one is that *a too stable wrong pattern, inadvertently actualized by some early triggering cues, will block or delay the actualization of the expected pattern needed in order that a task to be correctly completed*. On the other part, a too low stability of a pattern necessary for completing a task will probably lead it to lose the competition with other patterns actualized by the already received information.

Therefore, it is to be expected a nonlinear relationship between the average level of stability of the cognitive patterns and the average level of performance in the cognitive tasks. My hypothesis is that, given the characteristics of the cerebral dynamic system of an individual in a particular context and her/his educational environment, there could be defined such an average level of stability of her/his cognitive representations. It would be like an order parameter describing the general dynamic state of her/his cerebral dynamic system. It is assumed that the average level of stability of the existing cognitive patterns will define the average width of what, at a phenomenal level, would seem to be an information temporal window for integrating the incoming information. Another consequence, from a different perspective, is that the extreme stability of some acquired patterns (by overlearning them) will lead to costs and lower performance in those tasks requiring flexibility or necessarily involving patterns with a lower stability (insufficiently learnt).

3. Reasons for which the dynamic phenomena at the level of the synergetic patterns are hardly, awkwardly, or not at all accountable in a symbolic paradigm

a) It is notorious that the *symbolic models of the cognition have had difficulty in explaining the graded decrease of performance when noise is presented*, when they normally predict a total failure. That is one of the reasons for which the dynamic connectionist neuronal networks have gained credibility. The idea of stability is not a natural one (although it may be simulated in a cumbersome manner) for the symbolic models, and that is why they have failed to coherently account for the effects of the noise on the cognitive performance.

b) Searching for constancy instead of stability, the symbolic models have imposed *crisp models of information processing.* A pattern is either learnt or not, either in the working memory or not. Even if it is admitted that patterns could be partially learnt or partially actualized, they are not of much use for information processing, which will be seriously affected. Instead, in a dynamic view, the effects of an insufficient level of learning or a partial actualization are not necessarily detrimental, being dependent on a particular context.

c) Symbolic models would *not be able to explain systematically (not by ad hoc solutions) why two patterns, equally learned, could be differentially recalled or recognized based on the same number of triggering cues* due to a different temporal context.

d) Similarly, a purely symbolic interpretation is *not able to account for the ceiling effects (a threshold phenomenon)* in recognition, since it is to be expected that every new cue or feature will bring an improvement in performance based on the comparisons made with the symbolic patterns stored in memory (unless a threshold is not artificially imposed).

e) The *importance of the temporal context in the information processing and the order effects are, also, not adequately treated symbolically* (i.e. they are rather ignored), if at all. Generally, some of the order effects are explained in the traditional cognitive psychology by the phenomenon of priming. But, as it was argued in a previous section, the current tendency is to admit that it is intrinsically a dynamical phenomenon that could be more adequately approached from a dynamic perspective. Even so, the idea of priming, as it is traditionally understood, still, has limited explicative power. For example, it is known (Becker, Behrman, Moskovitsch, & Joordens, 1997) that it is hard to obtain a long-term semantic priming (that will last for several minutes, hours, let alone bigger time intervals). Other order effects are explained through learning, or through the idea of the order in which the information arrives in the working memory or the order in which it is issued from the working memory. But such explanations could not be involved in order to understand why a stable, learnt pattern could have a detrimental effect in the recognition of another one when the first is presented initially, but not the other way around, because they lack the notion of stability that introduces a differentiation between the two types of patterns.

f) Although for the symbolic models there is a difficult task, too, to explain coherently the context effects and biases, without ad hoc solutions, *the most difficult task for them is to explain especially the intermittency in the performance of an individual, its fluctuations in time.* Usually the problem is pushed at the level of attention. The puzzling mixture of regular and irregular performance in the empirical findings is more amenable and natural for a dynamic account.

g) By invoking the context, a symbolic account runs into the notorious "frame problem" and the consequent computational explosion when trying to understand a) the *selection of the relevant information dependent on context*, or b) *the selection of a single adequate pattern when several patterns are possible* in order to organize the given information.

V. The temporal course of a deductive reasoning process

1) As the given information is coming, *subordinate dynamical patterns (corresponding, for example, to the meanings of the words) are actualized*, guiding (organizing) the receiving of the new information and the search in memory, or trough the currently available one.

2) The actualized subordinate dynamical patterns lead to the *actualization of one superordinate dynamic deductive schema (pattern) that has won*[27] *the competition* with other superordinate dynamic schemas.

[27] When a subject is confronted with *a deductive task, it may contain cues that contribute to the actualization of deductive schemas placed on all the three assumed main levels* or only on one or two of them. They could be compatible or incompatible in what respects the correct answer. Relationships of cooperation or competition may exist between them. But the answer will be based only on that deductive schema that wins the actualization competition. The *actualization competition is supposedly won* by a dynamic deductive schema when it is *distinct, with a high level of stability relative to the stability of the competing schemas, relatively unaffected by noise in comparison with the competing schema, and the recent history favors its actualization.*

3) The recognition of a dynamic stable deductive schema that integrates and brings coherence to the relevant given and recalled information would allow *the occurrence of a conclusion based on a pattern completion process*. The missing part will be provided maybe by its salience in comparison with the already existing part.

4) If there are *no available deductive actualized schemas in the given context*, then a *"no answer" will be given*, or *an answer based on memorized information* (if there is some relevant factual knowledge available), or on a *guessing strategy* will be generated.

VI. Particular situations that favor the actualization of one of the three types of deductive schemas

1) It is assumed that in a deductive task, *an elementary deductive schema* will be used in two situations:

- the reasoner *does not have a) stable combinatorial schemas* (she/he has not acquired yet such schemas through learning), b) *nor a pragmatic stable appropriate deductive schema* for that particular deductive task, and c) *the given information is able to trigger the actualization of an existing elementary spatio-temporal schema*;
- when *a (already) triggered elementary deductive schema is more stable than the existing pragmatic deductive schemas or combinatorial schemas* a) *in general*, or b) *in the particular context* of a given deductive task.

2) If for a deductive task there are available a *stable pragmatic deductive schema* and a deductive combinatorial schema, mutually competing, then the derived conclusion will be based on the winning one, having the greatest stability in that particular context. The chances are supposed to be statistically the greatest for the pragmatic schemas.

3) It is reasonable to assume that a *combinatorial deductive schema*, if it is learned and stable, will be applied especially when a deductive task is: a) new or too complex in order that the pragmatic schemas to be useful; b) when the given instruction or the formulation of the deductive task encourages such an approach.

VII. Difficulty of a deductive task

a) The answers given in accordance with an elementary deductive schema or a pragmatic one may be not the ones given based on a combinatorial deductive schema. Therefore, *from the point of view of the errors assessed based on their coincidence with the logical expectations*, the most difficult deductive tasks should be the ones in which such mismatches occur.

b) *From the point of view of the effort needed to generate a conclusion and of the errors made because of the low stability of an underlying dynamic schema*, the most difficult deductive tasks are foreseeable to be the ones requiring unstable schemas (probably combinatorial deductive schemas, or a successive application of some pragmatic deductive schemas).

c) *From the point of view of the similarity between the current situation (described through the given information in a deductive task) with the class of the argumentative experiences correspondent to a dynamic deductive pragmatic reasoning schema* that allows the generation of the expected conclusion, the greater the dissimilarity between the two is, the more difficult the deductive task should be. Here it is included the case in which the temporal order of the given information (or the succession of the premises) is dissimilar in comparison with the temporal order existing in a stable dynamic deductive schema.

d) *From the point of view of the competition between dynamic deductive schemas*, a deductive task should be more difficult when several deductive schemas compete for actualization based on the given information and on the order in which it is presented. The most difficult deductive tasks would be those in which a wrong schema will tend to be more stable, winning the competition, leading to confusions or false, illusory schema recognitions[28].

[28] Here occurs a supplementary complication. If the answer generated based on the wrong schema coincides with the one generated based on an appropriate schema, then that kind of reasoning would appear to be falsely easy. The same problem occurs for other theoretical models of the deductive reasoning, too. For example, it is

Given that there are so many sources of difficulty for a deductive task and contextual criteria of its assessment, it is reasonable to assume that trying the find an absolute hierarchical order of the difficulty of a class of reasoning tasks (as it is in the case of the existing syllogisms) would be impossible and useless. Consequently, the evaluation of this dynamic theoretical model of a deductive reasoning based on the fit between its predicted order of difficulty for the studied deductive tasks and the one predicted based on the results in other empirical studies or the difficulty order stipulated by other theoretical models is considered irrelevant. At most, on a dynamic theoretic basis, it is possible only a relative hierarchy on levels of difficulty in the context of a particular type of deductive task.

VIII. The sources of error and the prevalent wrong answers in a deductive task from a dynamic point of view

In accordance with my dynamic theoretical proposal, errors are made because of a *failure to actualize an appropriate dynamic deductive schema*.

There are three cases: a) when *no deductive schema is actualized* at all (no answer is given); b) when *an inappropriate deductive schema is actualized*, and the answer in not the expected one; c) when an *inappropriate deductive schema* is actualized, *but the given answer happens to coincide with the expected one*.

The *prevalent wrong answers* would be the ones that are the consequence of the actualization of a wrong deductive schema, which, usually, is a deductive schema: a) *similar with the required one*, b) but *more stable* (probably because the class of experiences from which it emerged is more frequently encountered in the day to day cognitive activity).

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hard to distinguish for some syllogisms if they are easier because the predicted heuristic answer coincides with the logical one or because they require less effort in order that the logical answer to be obtained.

IX. Predicted dynamic phenomena in deductive reasoning

The dynamic phenomena foreseeable to occur in general in what respects the abstract patterns of patterns have a correspondent at the level of the deductive reasoning schemas. Some of them are important in what respects their potential to lead to testable predictions. In what follows, such predicted dynamic phenomena at the level of deductive schemas are enumerated.

1) *Dynamic deductive reasoning schemas should be differentially disrupted by noise* (information irrelevant for the actualization of an appropriate deductive schema, the presentation format, attention fluctuation, distractors), in accordance with their level of stability. Consequently, the performance of the deductive reasoning will be differentially affected by the same level of noise: some deductive tasks should continue to be completed successfully almost all of the time, but, for some of them, the performance will be fluctuant.

2) *The stability of a dynamic deductive schema should depend on the frequency with which the experiences that could lead to its emergence by learning can be encountered*. It is hypothesized that *the probability of encountering such experiences should be positively related with the importance of the cognitive function* in the everyday life of that kind of cognitive situations related to a dynamic deductive schema.

3) A *dynamic deductive schema has two components of its stability*. One is given by *the level of dissimilarity of a deductive task with the experiences (cognitive situations) underlying its emergence* that still lead to its actualization. It is a stableness reflected in the breadth of its attractive domain. The greater the dissimilarity, the more stable the schema is. The other one is given by *the level of distraction (noise) needed in order to disrupt the performance* in a deductive task that is solved based on that dynamic deductive schema. The higher the level of noise, the more stable is the deductive schema.

4) In tight relationship with the previous point, it is hypothesized that for those *schemas that are more stable* (in what respects the two components of their stability), *fewer triggering cues are needed in order*

that they can get actualized, leading to a successful completion of a deductive task. Consequently, *the higher the cognitive function of a type of reasoning is the more easily should be triggered its dynamic deductive schema.*

5) For *the most stable deductive schemas* (probably the ones having the highest cognitive function), a *ceiling effect* should occur, as in the pattern recognition. In other words, adding new conditions that are in general favorable to the actualization of a deductive schema (e.g., a characteristic presentation format of a deductive task, its thematic content, etc.), beyond a certain threshold, should not lead any more to a notable improvement in performance[29].

6) *Order effects* should occur, in the sense that the performance in a *deductive task will be affected (positively or negatively) by the completion of other preceding deductive tasks*, due to the cooperation or the competition between the deductive schemas actualized during their completion. There are possible the following two situations:

– if a deductive dynamic schema is actualized in a previous task, then the performance in a subsequent deductive task requiring the same schema should be improved in comparison with the situation in which there is no previous deductive task;
– if, in a previous deductive task, there is actualized another kind of deductive schema, which is in competition with the deductive schema needed to complete the current task, then it should probable to occur detrimental effects in what respects the performance in the current task (when the needed deductive schema is not so stable).

It is foreseeable that the order effects should be not so salient for those the deductive tasks that have a very important cognitive function (i.e., with very stable corresponding dynamic schemas).

7) The performance in a deductive task requiring a deductive schema that is not so stable should be higher if it is not preceded by deductive tasks requiring extremely stable deductive schemas (with

[29] The absence of the improvement in the performance by adding such conditions may also mean for some deductive tasks that there is no existing deductive schema for them.

the highest cognitive function). It is *another kind of order effect*, linked with the *differential probability of the transition from a stable pattern toward one that is not so stable in comparison with the reverse transition*.

8) If the information presented at first in a deductive task is able to actualize another deductive schema than the one required for the completion of the task (entering in competition with it), then it will be expected a deterioration in the performance of the current task. In other words, it is *another kind of order effect*, linked with the *order of the information given in the premises*.

9) *Order effects* should occur in what respects *the order of the information presented in premises* caused by the *level of similarity between this order and the temporal pattern of the required deductive schema* in order to solve a deductive task (for example, the order of the terms in a reasoning process based on transitivity).

10) For the deductive tasks requiring *deductive schemas that are not so stable* (having a lower importance of their cognitive function), it is expected that *their inter- and intraindividual level of performance variability to be higher in comparison with those deductive tasks requiring schemas that presumably have the highest cognitive function*.

11) A dynamic deductive schema has a) a *basic stability*, given by the importance of its cognitive function and the level of its learning, and b) a *relative stability* given by the recently actualized deductive schemas and/or the competing deductive schemas currently supported by the information given in the context of a particular task.

12) There should be a *nonlinear relation* between the *stability of a dynamic deductive schema* of a deductive task and *the performance of a deductive task requiring a similar deductive schema* that is not stable enough in comparison with the first one. The prediction is that an *intermediate level of stability* of the more stable of the two should lead to *the highest performance* in the deductive task requiring the less stable one. One reason could be the fact that if a schema is stable enough, there are higher chances to be entirely actualized, with all its distinctive features needed for its recognition in comparison with a less stable one. A less stable one would have higher chances to be only

partially actualized, with only a few of its distinctive features. Therefore, as in the perceptual recognition, a stable schema should allow an easier distinction between the situations in which its actualization is adequate and the situations in which it is not. In other words, the chances of confusion with the patterns of other schemas are lowered. Instead, when a schema is partially activated due to its low stability, the chances of confusion with a similar situation, requiring another, even less stable, schema, should be higher. But when a schema is extremely stable and the information to be organized and integrated is ambiguous, allowing multiple interpretations, then it should be expected that it will "enslave" it in accordance with its pattern of organization. In that way, the chances that a more adequate, but less stable schema to impose its structure onto the data are lowered.

13) There should be a nonlinear relation between the average level of performance in deductive tasks and the average level of stability of the abstract cognitive representations. The *highest deductive performance is expected for an intermediate average level of stability of the abstract cognitive representations*, no matter their content. The general reason is a presumed trade-off between the flexibility and the stability (rigidity) needed in order to complete a task at higher level of performance, dependent on the criteria used to asses the performance. But, on the average, it is reasonable to assume that the performance will be the highest when there is an equilibrium between flexibility and stability. More particularly speaking, from a dynamic point of view, there should be three reasons for the demand of an intermediate average level of stability for the patterns involved in cognitive processes:

- The excessive stability of some acquired patterns (by over-learning them) will lead to costs and to a lower performance in those tasks requiring flexibility or necessarily involving patterns with a lower stability (insufficiently learned ones).
- The more stable one pattern is, the less able should be to cooperate with other patterns in order to generate (on a higher level of organization), through emergence, the superordinate pattern needed in order to complete a class of tasks. Instead, it

will tend to compete with them, or to subordinate or recruit them, inadvertently interpreting or organizing the new incoming information in a wrong way. But it is not preferable to have a too low stability either, because that it would mean that the emergent superordinate pattern will be also rather unstable, resulting in a lower performance.

– A too stable wrong pattern, inadvertently actualized by some early triggering cues, would block or delay the actualization of the expected pattern needed in order that a task to be correctly completed. On the other part, a too low stability of a pattern, necessary for completing a task, would probably lead it to lose the competition with other patterns actualized by the already received information.

Therefore, it is to be expected a nonlinear relationship between the average level of stability of the cognitive patterns and the average level of performance in the deductive tasks. My hypothesis, presented also above, is that, given the characteristics of the cerebral dynamic system of an individual in a particular context and her/his educational environment, there could be defined such an average level of stability of her/his cognitive representations. It would be like *an order parameter (as it is temperature for gases) describing the general dynamic state of her/his cerebral dynamic system*. It is assumed that the average level of stability of the existing cognitive patterns will define the *average width of what, at a phenomenal level, would seem to be an information temporal window for the integration of the incoming information*.

14) There could be expected a feeling of familiarity at the encountering of a syllogism that has a greater cognitive importance and, therefore, it is more frequently practiced into the day to day life. In other words, a feeling of knowing may occur, based on the stability of the actualized schemas of that syllogism. Moreover, other metarepresentations of the deductive process could occur, reflecting the level of the competition between several dynamic deductive schemas.

X. The integrated dynamic model for the deductive reasoning and its general assumptions

The above general predictions of the proposed dynamic schema-based model for the deductive reasoning could be systematized and integrated in two schematic representations of that model. As it could be seen, these two schematic presentations include new elements or assumptions that have not been discussed at large so far.

1. General assumptions of the proposed schema-based dynamic model of deductive reasoning

As it can be seen in the Fig. 1, there are made some suppositions that are seen to be intuitively and logically plausible.

a) From the very start, it is assumed that the *deductive inferences could have specific cognitive functions, other than the general one of finding the truth value of a conclusion*, or to find the logical necessity of the truth value of a derived conclusion. Generally, with only a few exceptions (for example, Cheng & Holyoak, 1985), researchers believe that there is only one cognitive universal goal served by the deductive processes, ignoring the consequences of the fact that deductive reasoning is immersed in the daily cognitive activity of one kind or the other.

b) There is a tendency to think that people have a general logical competence and logical goals that are adapted by them to some particular circumstances and specific cognitive goals. The view supported in the proposed model is that it may be the other way around. *At the beginning, there are reasoning schemas built around specific, pragmatic, goals. Progressively, these goals become more general, more abstract, with a more salient cognitive nature.* Finally, under the influence of the formal education or the demands of a profession, people will adopt the goals stated to be important by the logicians.

c) The *cognitive goals* around which the deductive schemas are built *are defined and assessed in what respects their importance by the characteristic environment of an individual*. There are general and specific influences of such an environment. The common life style in an environment will give a general hierarchy of the cognitive goals of the deductions in what respects their importance for all the people from a community. The specific environment of an individual will adjust that general hierarchy. Still, another related general criterion might be stated in what respects the importance of a cognitive goal fulfilled by a deductive task: the level of informativeness of its conclusion. It is distinction made also by Chater and Oaksford (1999), who ordered the three kinds of judgments involved in a syllogism by the level of their informativeness. Even Johnson-Laird and Byrne (1991) use that criterion to explain in an *ad hoc* manner the chosen conclusion when several conclusions are supported by an integrated mental model.

d) It is logically plausible that *the general importance of a cognitive goal* of a deductive task *should be reflected in the frequency with which a person encounters experiences/situations that have such a cognitive goal.*

e) Intuitively, it is reasonable to assume that *higher chances to encounter a class of experiences should lead to a general higher level of learning of the assumed dynamic deductive schema associated with that class of experiences*.

f) The *higher the level of learning of a deductive schema, the higher should be the stability of that schema*. It is a common idea used in building dynamic connectionist networks the fact that, through learning, in such networks, the stability of their fixed-point attractors is increased (for example, Eiser, 1994; Elman, 1995). It is also a general current assumption in what respects the dynamic approach of the learning processes (see for details Faiciuc, 2008).

g) The *level of learning of a deductive schema is dependent also on some general individual traits that are widely known to influence any cognitive activity*. It is plausible to think that such general traits define some interactional styles with the informational environment. For example, such traits could be the autonomous thinking, as it will be investigated in the empiric part of this work, or other cognitive styles, as the level of cognitive complexity or the oligarchic type of thinking (Macsinga, 2001, 2007). Such traits may be also associated with some yet unspecified characteristics of the cerebral network as a dynamic system. A supposition of mine is that one such a characteristic might be a general intermediate level of stability for all the representational patterns on a certain level of organization (as a state or trait individual characteristic).

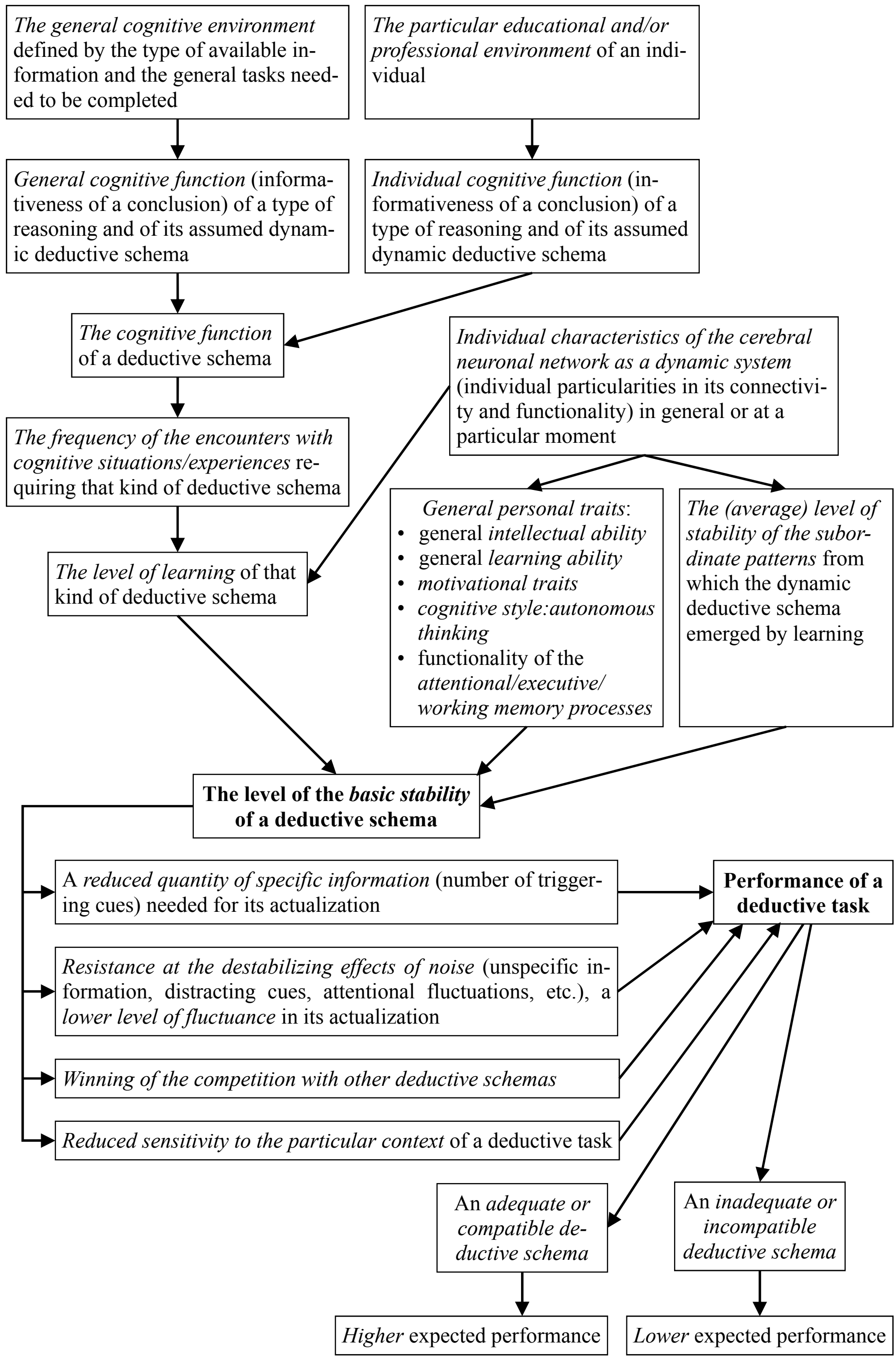

Fig. 1. ***The factors determining the basic stability of a dynamic deductive schema and the consequences of its basic stability relevant, in general, for the performance in a deductive task***

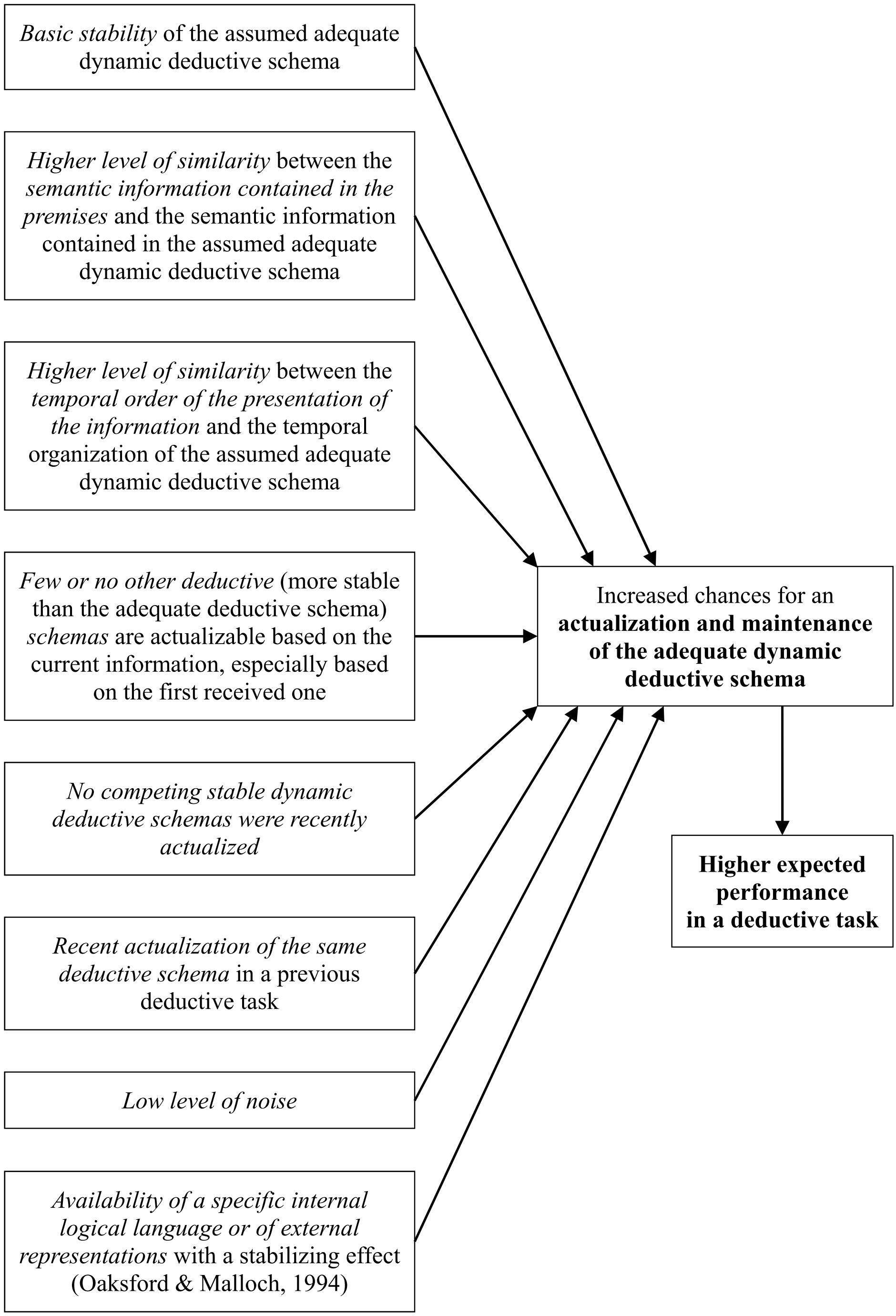

Fig 2. ***The factors that are beneficial from a dynamical point of view for the successful completion of a deductive schema***

So, the stability of a superordinate pattern (schema) should be dependent on the stability of the patterns from which it emerged, which are placed on a lower level of organization. My fundamental presupposition is that the deductive reasoning is a dynamic process sunk in the general dynamism of the entire psychological system and of its physical support, with which it is dynamically coupled. When the stability of the subordinate representational patterns is excessive, the emergence of a superordinate pattern corresponding to a dynamic deductive schema should be impeded or delayed. When the stability of the subordinate representational patterns is too low, it should be relatively easy that a superordinate pattern corresponding to a dynamic deductive schema to emerge. But its stability will be extremely low, too. So it will soon vanish, as merely a transient dynamic structure.

2. A general comparison between dynamic schema-based model and the existing theories of the deductive reasoning

In many of the existing theories there are aspects or empirical evidence gathered based on their specific hypotheses that suggest phenomena for which a dynamic approach could be beneficial for their understanding.

As it was shown before (Oaksford & Malloch, 1994), *rules* may be conceived as a kind of primitive schemas. This interpretation founds support, for example, in the fact that the mental logic model elaborated by Braine (1990, as cited in O'Brien, Braine, & Yang, 1994) actually uses the notion of direct, natural inference schema for basic logical rules. Cheng and Holyoak (1985) have captured that aspect when they named their theory explaining the conditional reasoning by *pragmatic rules* to be a pragmatic schema-based theory. The core idea from the dynamic schema-based model that the deductive reasoning is based on learning to represent at a higher level of organization a class of cognitive experiences or situations is more or less implicitly in their theory, too. Their schemas are like patterns that could be used in deriving conclusions based on the processes of generation of expectancies, a characteristic function of the schemas. They seem to be on different levels of generality. For example, they sustain the idea of a "covariation schema" which is applied "to any situations in which two situations or events are for some reason expected to co-occur" (Cheng & Holyoak, 1985, p. 398). The importance of the linguistic cues for the actualization of such schemas is emphasized by their suggestion that an abstract material, presenting arbitrary rules, without link to known experiences, "may fail to evoke even a covariation schema" (Cheng & Holyoak, 1985, p. 398). They explain the variance in performance through the evocation of different reasoning schemas, and through the coexistence of alternative knowledge structures relevant for deductive reasoning (logical rules, specific experience, and pragmatic schema). But their theory lacks a way to explain dynamically the relationships between such structures, because their pragmatic schemas lack dynamic attributes, like stability or the possibility to enter into competition with other schemas supported by the received data. Also, Cheng and Holyoak (1985) have not found a way to extend their theory to other kinds of deductive reasoning.

Mental models theory has a hidden dynamic aspect, rather unfairly ignored. In the first place, a dynamism of the transition from implicit to explicit information is implied in this theory. It is a transition similar with the one from a virtual status of an attractor structure in the state space corresponding to a schema to an actual state, or to a temporal structure of states when that schema is actualized. Until a schema is actualized, it could be considered to be implicit. The explicit information from the initial mental model could be compared with the explicit information from a schema, when its variable part is completed with default values. But in the conditions in which the level of noise is high and a lot of irrelevant information exists (as it is the case when the working memory is loaded with other information), it is possible that a schema to be only partially activated, with its most stable part. So, that partially actualized schema could correspond to an initial incomplete mental model. In the mental models theory, it is not very well specified what factors control the transition from implicit to explicit information. It could be suggested that the most stable part is determined by learning, through experience. It is a hypothesis not stated as such in the mental models theory. Though, it is possible that the experience of a person to be rather limited, and, therefore, not the entire schema to be learned. So, the initial model would be, in this case, not a partial actualization of an extended schema, but the entire schema. The fact that, in general, people do not generate alternative models by flashing out the initial models (Newstead, Handley, & Buck, 1999) could be invoked to support such a presumption. They do not flash out that information because there is none to be flashed out.

In the second place, the idea that a built model has some kind of instability is implied when it is asserted in the mental models theory that the limited cognitive resources affect the capacity to maintain active a built model. But it is a fugitive idea that it is not explored in its entire relevance for the deductive process. Limited cognitive resources may mean, dynamically, a high level of noise, or other schemas competing for actualization.

In the third place, the process of counterexample generation is left underspecified in the mental models theory, but it clearly indicates transitions between alternative competing states of affaires. Dynamically, that would mean transitions between attractor structures (schemas) in a system presenting multistability. It is more like in the dynamic processes involved in the perception of an ambiguous figure. A supposition may be that, in order to generate counterexamples, the several possible alternatives in interpreting the information should be included in a schema of schemas, i.e. a schema of a higher order. Alternative mental models that are compatible with the given information may be like the schemas from the schema-based model of the deductive processes, proposed in this work, which could be triggered by the incomplete information given in premises. Only that in the mental models theory such models are assumed to be built successively, i.e. they are not all present from the beginning of the deductive process. The initial model is supposed to be the simplest one, the one assumed to require the minimum cognitive effort. There is no direct empirical proof that this is the case, the argument being circular: they are the least effortful because they are generated in the first place. Also, such initial models are assumed to represent what might be usually more relevant from a pragmatic point of view: situations in which the referents of the syllogistic terms are present, not in which they are absent. But, as it is the case with our hypothesis regarding the cognitive importance of a particular type of deductive inference, here, too, there are no direct methods to prove that it is always more relevant to represent something true or present, than something false or absent. That is merely a postulate of the mental models theory molded on the obtained empirical data. In the dynamic model proposed in this work, the pragmatic relevance of a deductive inference is not so strict determined, being dependent on the particular life experiences of an individual or collectivity. Therefore, it might be possible that for a very astute scientists the representation of what is absent or false to become more relevant and therefore, through learning, less effortful. Moreover, in the proposed model, the possible alternative schemas compatible with the given information are not successively constructed or activated as the mental models are, but they are in competition from the beginning. However, such a competition is never won for good. The winner continues to be threatened by the competitors and may overturn it in favorable circumstances. Only that, in the absence of such favorable conditions for the competitors, alternative schemas are rarely actualized. In that way, it could be explained the results of the study indicating the fact that people rarely bother to build counterexample models and that they need special prompts and conditions to do that (Buciarelli & Johnson-Laird, 1999; Newstead, Thompson, & Handley, 2002).

Taking into consideration an idea from a previous paragraph, another supposition is made. *Formal rules and mental models theories* could refer to aspects linked with what in the proposed model is the level of combinatorial schemas, where schemas at a higher level of organization are built: schemas of schemas. In the cases where formal rules are applied in chains in order to reason deductively, it could be said that an existing elementary schema is applied recursively, serially, out of lack of more complex schemas. For example, an assumed transitivity schema may be applied recursively to link elements farther apart, when there is not a more complex integrating schema.

In a relatively recent *refinement and extension of the mental models* theory proposed by Barrouillet and Grosset (2007) for the conditional reasoning, the two authors resort to the schema notion more or less explicitly in order to account for the context and content effects suggested by the empirical findings. They state explicitly that "the initial model does not represent mere co-occurrence of p and q, but takes the form of a *relational schema* in which p is understood as a hypothetical state of affaires and q as its resulting outcome" (p. 3). Therefore they take into consideration the abstract cognitive significance and function of the antecedent and consequent, suggesting a possible cognitive goal for the conditional reasoning: to relate a hypothetical state with its possible consequence. On the other part, Barrouillet and Grosset (2007) admit implicitly the significance of the cognitive schema notion when they state that "Knowledge in LTM provide ready-made models in which different possible values of *p* are already linked to their resulting outcome." (p. 5). Those "*ready-made models*" could be assimilated to cognitive schemas. But unlike the pragmatic schemas proposed by Cheng and Holyoak (1985), they seem to be also of a more general and abstract type. Instead, for unfamiliar conditional relations, when no knowledge "could direct this construction and help reasoner to keep the constructed models active for processing" (p.5), the information from LTM provides only the values of the *p* and *q* variables that must be combined to form models" (p. 5). In other words, the classical process from the mental models theory of building alternative models by combining all the possibilities holds only for those cases where there is no schema (ready-made model) to constrain the variability of the two variables involved in a conditional reasoning by a relation between them.

The conclusion of Barrouillet and Grosset (2007) is that "Constructing and maintaining models should be easier from familiar rather than unfamiliar relations." (p. 5). Therefore, by acknowledging that "the standard theory lacks the precise machinery to account for content effects in a predictable way" (p.2), the two authors have oriented themselves intuitively toward to notion of cognitive schema, sometimes disguised under the term "ready-made models", built based on previous experiences. In their opinion, "although advanced reasoners may develop or learn strategies specific to logical reasoning, children and probably many adults use processes that are general and rely on existing cognitive architectures" (p.3). So, in my view, they implicitly admit that deductive processes could be of the same nature with the perceptual ones, but on a higher level of organization, as the proposed dynamic model implies.

Through their theory, Barrouillet and Grosset (2007) depart themselves from the idea of pragmatic modulation advanced by Johnson-Laird and Byrne (2002)[30], by making clearer the fact that knowledge and context exclude from the beginning the building of those models that are not relevant for a particular situation. Instead, in the Johnson-Laird and Byrne's (2002) work, the implied idea is that knowledge and content serve more to eliminate the already built models that are not relevant for a particular situation. In Johnson-Laird and Byrne's (2002) theoretical framework, otherwise, the logical necessity of a derived conclusion could not be ascertained.

On the other hand, Barrouillet and Grosset (2007) have envisioned also the possibility of a competition between older strategies of deductive reasoning and the new acquired ones. Their expectation is that "content and context effects should have a low impact in those participants who are already able to construct and manipulate 2-model representations." (p. 8). In the terms of the model proposed in this work, that would mean that higher level, more adequate and stable

[30] Johnson-Laird and Byrne (2002) have admitted that knowledge can have a role in deduction, by stating the principles of semantic and pragmatic modulation. In accordance with the semantic modulation principle, formulated for the conditional reasoning, the meanings of the antecedent and consequent term, and their coreferential link "can add information to models, prevent the construction of otherwise feasible models of the core meaning and aid the process of constructing fully explicit models" (p. 658). In accordance with the pragmatic modulation principle, context of the deductive task eliminates possible models. Therefore, knowledge determines the models that are retained in the final representation.

schemas for a conditional task compete with more pragmatic deductive schemas linked more with a concrete content. The more stable the schemas are, the more frequently they will win the competition and the less they will be influenced by a particular context.

The Barrouillet and Grosset's (2007) ideas in what respects the conditional reasoning can be encountered in a less elaborated version for the case of the categorical syllogism in the Santamaria, Garcia-Madruga, and Carretero's (1996) research. They, too, emphasized the importance of the content of a syllogism in the elaboration of mental models for its solving, taking into consideration particularly the conceptual relationships between the syllogistic terms. Such relationships can be interpreted, in their opinion, in five ways, representing five general categories ("typical concepts relationships representations" as they named them) with an abstract logical meaning: identity, disjunction, intersection, direct inclusion, and inverse inclusion. The cited authors hypothesized that the types of the extensional relationships between the concepts instantiating the terms of a syllogisms, defined by the knowledge of a solver in what respects those concepts, may guide the way the mental models are built, explaining in that way the other authors' results in what respects the belief bias in the syllogistic reasoning. The empirical data obtained by them supported that hypothesis. It may be noted that the Santamaria et al.'s (1996) idea of a logical abstract semantics of the relationships between the syllogistic terms is somewhat similar with the idea from the schema-based model proposed in this work in what respects the abstract logical meaning of the judgments of a syllogism. But, in their case, the logical semantics is an exclusively extensional one, whereas in the schema-based model is a mixed one: intensional and extensional. Moreover, in the schema-based model, a general logical meaning associated with a particular cognitive function is attributed to an entire syllogism, linked with its syllogistic figure.

Lately, the strongest tenets of the mental models theory have begun to be melted down, to the point of dissolution, by those trying to accommodate them to the empirical results showing the powerful effect of knowledge and context in the deductive reasoning. Although the empirical data refer almost exclusively to the conditional reasoning, they indicate a general issue. Such data have indicated the major role played by the kind of semantic information accessible from LTM in order to generate alternative models in the conditional reasoning so that the pattern of the answers gets radically changed. More precisely, empirical findings have shown that the number of alternative causes or of disabling conditions known by a subject (Cummins, 1995), as well as the strength of the known association between the given antecedent and consequent (Quinn & Markovits, 1998) determine the pattern of errors, reversing their direction. These results were interpreted in the mental models theory framework by Markovits and Barrouillet (2002) as meaning that the models built by the reasoners change depending on their existing knowledge in what respects the conditional association. Therefore, usually there is not involved a process of generating counterexamples through a content- and context-independent analysis of possibilities, based on an assumed logical competence. But then, that would mean that the hypothesis of the built mental models based on which the conclusion is derived becomes superfluous, as long as the derived conclusion depends actually on the recollected factual knowledge. However, De Neys (2003) have obtained results that indicate that a category of reasoners, having “the highest cognitive capacity”, are able to “block the impact of conflict background knowledge” (p. 178) in conditional reasoning. She interprets her findings as a competition between two kinds of processes: a standard “contextualization” tendency (to search for stored counterexamples) and a logical “decontextualization” tendency (“a basic ability to put knowledge aside when it conflicts with the logical standards”, which would involve an “elementary notion of logical validity). De Neys (2003) believes that the decontextualization tendency has manifested in her data as a tendency of high-span subjects to inhibit the spontaneous search for disablers in conditional reasoning. In a dynamic interpretation in accordance with the proposed model, her results would mean that the conflict between the two tendencies is a dynamic process of competition between pragmatic schemas and combinatorial schemas.

In what respects the *heuristic rules theories*, a dynamic schema-based approach could help in explaining the source of the heuristic rules and the way they could intervene in the deductive process. For example, Pollard (1982, in Evans, Newstead, & Byrne, 1993) has extended the availability heuristic in order to explain the reasoning processes: the salience of some of the presented information or of the information retrievable from LTM, its availability, will influence the reasoning tasks, inducing biases. Such a heuristic receives a natural dynamic interpretation if the deductive reasoning implies the recognition of a specific abstract pattern named dynamic deductive schema. Heuristic rules may be emerged primitive dynamic deductive schemas that continue to exist, competing with more evolved dynamic schemas. In case that the latter are less stable, depending on context, they may win the competition and, therefore, an instability in the deductive performance may occur.

The relevance interpretative theory of Sperber and Wilson (1990, 1995) comprises the seminal idea of schema. They think that a semantic representation resulting from the interpretation of the linguistic utterances is in fact an incomplete logical form or an "*incomplete assumption schema*". Such incomplete form participate then at the inferential process, guided by the relevance principle: obtaining a cognitive positive effect with the minimum effort. But as Gutt (2004) has noted, the idea of incomplete logical form is vague and contradictory. He shows that the incomplete logical form was meant initially to express the idea that a single state of affairs is chosen from the many state of affairs compatible with an utterance. But subsequently, as Gutt (2004) has emphasized, it was said by Sperber and Wilson (1995) that an utterance may have many logical forms, not only the intended one. In Gutt's view (2004), the output of an utterance interpretation may be "a number of rather abstract 'clues' that serves as input to and guide the inferential processes, but that themselves never amount to anything like a representation or assumption schema". My opinion is that such abstract clues may be inputs for actualizing dynamic deductive schemas that have not only a representational function, but also a processing one. Although the idea of relevance and of positive cognitive effect is similar with idea of informational gain and cognitive importance promoted in the proposed model, there are also some differences of opinion in that respect. In our model, the relevance is not decided by the reasoner, she/he does not have explicit representations of the relevance of different pieces of information and of the effort required to obtain different conclusions and then she/he makes a deliberate calculus of the optimal choice. Rather the relevance is an emergent phenomenon, decided by the stabilization of a subjacent dynamic cognitive system in a certain state, which is the most sustained by the given input, offering a temporary maximum coherence in its organization.

The theoretical model of reasoning proposed here also supports another idea of Sperber, who, together with Mercier (Mercier & Sperber, 2011), pleads for an argumentative function for reasoning, i.e. "to devise and evaluate arguments intended to persuade". They explain "the poor performance in standard reasoning tasks" through "the lack of argumentative context". My theoretical model would add that the argumentative context can explain also the emergence of some reasoning schemas.

From the beginning, *integrative theories* are closer to a dynamic approach than rules and analogical theories. In the first place, a dynamic approach of deductive reasoning support the Stenning and Yules's (1997) view that rules and analogical reasoning could be integrated by a unifying principle, that they are not as distinct as they seemed to be. In the second place, Polk and Newell's (1995) theory has principles in common with a dynamic model of the deductive reasoning: a) the annulment of the distinction between the semantic and syntactic processes; b) the importance given to the linguistic information in the deductive process. In what respects the last point, an observation made by Handley and Feeney (2007) is important. Their opinion is that "Mental models theory, in its current form, does not account for the multidimensionality of people's representations for reasoning", "it does not adequately specify how participants arrive at representations of conditional forms" (p. 36). From a dynamic point of view, since all the cognitive processes (whether they are on a lower level of organization or on a higher one) are dynamically coupled through mutual interactions, it is to be expected that the deductive performance could be dependent on lower-level cognitive processes as the linguistic, or the perceptual ones. Moreover, in a dynamic perspective over the deductive reasoning, the idea that there are two kinds of processes involved in the deductive reasoning, on different levels of organization, as the *dual-processes theories* assert is a natural consequence of its principles. But, unlike those theories, it is capable to offer, in my opinion, a more coherent view in what respects the relationship between the two kinds of processes, by assuming that they are dynamically coupled and permanently in competition (a view of a different kind than that from the parallel competitive processes models, which can withstand the objections raised by the supporters of the default-interventionist models against the competitive processes models). The winning one will depend on a particular context.

Evans's (2006a) theoretical position is placed on the brink of a dynamic approach of the deductive reasoning by sustaining that a) the brain is optimized for distributed processes; b) no clear distinction could be made between an information interpretation phase and a conclusion derivation phase, i.e. interpreting means derivation; c) the cognitive architecture involved in the deductive reasoning has a chaotic nature for which a new theoretical framework is needed in order to be understood. Also, Ricco and Overton's (2011) dual processes theory has many direct and explicit references to dynamic and non-linear aspects of the reasoning process, which were underlined in the presentation given above for their work. Pennycook, Fugelsang, & Koehler's (2015) theoretical proposal is in tune, too, with a dynamic schema approach for the deductive reasoning through its idea that stimuli from the premises are able to cue multiple, potentially competing outputs.

Another integrative theory that might be relevant for the dynamic approach of the reasoning proposed in this work is the Brainerd and

Reyna's (1990) fuzzy-trace theory, applied by them specifically to the transitive reasoning processes. Their idea is that solving a transitive inference is based not on the verbatim information, but rather on the identification of the gist of the given premises, that gist being a kind of abstract pattern, an "episodic interpretation of concepts (meanings, relations, patterns)" retrieved as a "result of encoding item's surface features". It might be said that their idea of gist is similar with the idea of dynamic deductive schema proposed in the present work.

As it was stated also above, Zhai's (2015) probabilistic logical model for the syllogistic reasoning supports a dynamic systems interpretation. In addition of that, it is a model that takes validity as "a crucial factor in the performance of the participants", an aspect that is also very important for the theoretical proposal of this work, as it can be seen below, predominantly in its empiric part. Zhai (2015) notes for the invalid syllogisms that "even if an error is made, the most probable wrongly endorsed syllogism is quite similar to a valid one, which differs only in the figure" (p. 12), a remark that can be linked with the idea from the schema-based model of reasoning proposed here that an inference schema for a valid syllogism may project itself onto the data of an invalid syllogism that is similar with the valid one. Like in the schema-based theory for the syllogistic reasoning, Zhai's (2015) model also stresses the importance of the previous experience with the day to day reasoning, in his case for the assessment of the informativeness of the reasoning judgments and in generating a preference order for the reasoning rules, not for building an inference schema.

Synthetically speaking, the dynamic schema-based model of the deduction is able to take over elements from previous various theories and integrate them into a new framework. This ability stems partially from the fact that a dynamic view transcends the distinction between the semantic and syntactic, analytic and heuristic aspects of the reasoning process, or the distinction between interpretation and inference.

3. Existing empirical data congruent with or suggesting the validity of the dynamic schema-based model

There are few studies in the scientific literature that could be invoked in order to support with empirical evidences the hypothesis of the three levels of dynamic deductive reasoning schemas differentiated based on the levels of their cognitive goals and of their interaction.

In what respects the first level, the one of the *elementary spatio-temporal schemas*, maybe the most relevant data that suggests its existence is the one obtained in the Piagetian research regarding the group of displacements (Piaget, 1970), and the developmentally early action schemas. An indirect suggestion for the involvement of such elementary spatio-temporal schemas in the conditional reasoning is provided also by Barrouillet (2011) who, based on developmental data, supports the idea that the "conjunctive interpretation" is the "most basic and simple interpretation" for a conditional sentence, "by which young children seem to represent the conditional by the mere co-occurrence of the antecedent and the consequent within an oriented relation from p to q" (p. 169). My assumption is that the origin of this conjunctive interpretation may be a spatial interpretation of the conditional relationship, i.e. a replacement of the conditional relationship with the only available schema to a child, an elementary spatio-temporal one, which can be automatically activated in the presence of the elements that are seen to be spatio-temporally contiguous, i.e. spatio-temporally related. It may be a phenomenon akin to the one involved by intuition in the Piagetian thinking, as described by Barrouillet (2011), i.e. "a process of substitution by which a rational concept is first assimilated to an undifferentiated perception or action" (p. 172). Moreover, Barrouillet (2011) cites empirical studies that support the idea that the conjunctive understanding of the conditional, i.e. its most simplistic interpretation, occurs, in the case of unfamiliar conditional relations, even in the young adolescents, who regress to such a primitive interpretation. A study by Von Hecker, Hahn, and Rollings (2016) offers hints in what regards a spatial interpretation of the abstract relationships, as the logical ones are. In a series of two experiments, they tested the hypothesis that the representations of the two concepts mentioned in the conclusion of a categorical syllogism "should be perceived to be at a lesser distance to one another in the case that this conclusion follows logically from the two premises (valid syllogism) as compared with a case when it does not follow (invalid syllogism)". Their results showed that the "two terms in conclusions from valid syllogisms (high coherence) were seen as spatially closer to each other than when 2 terms came from invalid syllogisms (low coherence)". The data of these studies can be bring support to the idea from the dynamic schema-based model of the deductive reasoning supported in this work that *elementary spatio-temporal schemas* are activated and remain in competition with the reasoning schemas emerged later in life and can win this competition in certain conditions (when the competing schemas are less stable).

For the *pragmatic reasoning dynamic schemas*, their existence is partially documented with reference to the hypothetical reasoning (Cheng & Holyoak, 1985), as it was shown in a previous section. For this kind of reasoning, it could be noted that, from a pragmatic point of view, testing whether a rule holds or not is not a frequent cognitive goal. Rather, what is important pragmatically is to follow the given rules. Similarly, it is usually more important pragmatically as a cognitive goal, and, correlatively, it is a situation encountered more frequently, to want to find out what results from a state of affairs (corresponding to the *modus ponens* rule) than to find out what are the consequences of the absence of a state of affairs. The previous statement holds, if not for other reason, only because in any moment there is an infinity of states of affairs that are absent (i.e. only one state of affairs is realized) and nobody could check the consequences of the absence of each one of them. So, unless there is a special need in relationship with a particular absence, one would not use what is called to be the *modus tollens* hypothetic reasoning. Therefore, it is to be expected that an inference schema for the *modus ponens* should be more stable and powerful than the schema for *modus tollens*. It is a prediction that may find support in the empirical results obtained by Reverberi, Pischedda, Burigo, and Cherubini (2012), which indicated a priming effect in the evaluation of a target "that matched the conclusion of a Modus Ponens inference", "even when participants reported that they were not aware of the second premise", but not when it matched the conclusion of "any other valid or invalid inference" that was tested, "including the Disjunctive Syllogism". These data are not accountable, as it was noted by Reverberi et al. (2012), by using the mental models theory, but, in my opinion, they can be explained by using the dynamic schema theory presented in this work, as the most powerful schema, the one for the *modus ponens* in this case, may be activated even by an incomplete information (when the second premise is not present or is not conscientiously activated). The role of a specific semantics in the conditional reasoning is supported also by Müller, Overton, and Reene (2001) who showed in a longitudinal study on 6th and 8th grade children that their performance is improved when "propositions were formulated with the antecedent phrase specifying an action and the consequent specifying a condition than they did when the antecedent specified a condition and the consequent an action" (p. 27). These results suggest that it is more important for people to infer the consequences of their actions, as a kind of experience more frequent and more relevant for their personal life, than to know what actions are implied by a condition. An alternative and possible complementary interpretation of those results would be that the association between an action and its consequence is less likely to be influenced by disabling conditions and has a more solid support in the concrete physical experience. In comparison, the relationship between a condition and an action is more likely to be arbitrary, as it is in the social rules, and, in its case, the same condition may support many actions. The results obtained by Chao and Cheng (2000) for preschool children support also the importance of the semantic content of a conditional reasoning task and the idea that the pragmatic rules for this type of reasoning emerge first, and only after that the formal rules occur (even the most basic one, the *modus ponens*), through the generalization of these pragmatic rules.

For the *categorical syllogistic reasoning*, there is no prior empirical evidence in what respects the existence of some pragmatic schemas.

For the *combinatorial schemas*, it would be reasonable to assume that the cross-cultural studies (Luria, from 1971, and Scribner, in 1977, as cited in Norenzayan, Choi, & Peng, 2007) suggesting the inability of people from primitive cultures to approach formal deductive tasks embedded in a Western traditional context could be useful. There are also useful, in the case of the conditional reasoning, the results obtained by Venet and Markovits (2001) when studying the level of understanding for the propositional uncertainty with abstract premises in a conditional reasoning task. The two authors cite a series of studies that suggest that "for children and even for many well-educated adults, reasoning with unfamiliar content will lead to a strong tendency to make logically inappropriate inferences on the two invalid forms[31]" (p. 75) of the conditional task. The reason is that "they clearly cannot successfully access alternative antecedents" (p. 76) if they use the same strategy as in the tasks with familiar content, when they recollect from LTM alternative antecedents. But there are people that are able to answer correctly even for tasks with unfamiliar content, in an abstract form. The purpose of the two authors was to find out information in what respects how such ability to understand propositional uncertainty with abstract premises is acquired. In dynamical terms, it would mean how dynamic combinatorial schemas develop. In order to do that, they have analyzed at several age levels the way the given answers are justified and the level of performance for a conditional task in two situations: with a familiar, concrete content, or with an unfamiliar, abstract content. The justifications were

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[31] There are four kinds of conditional arguments: two of them are valid, two of them are invalid. The valid forms are **Modus Ponens (MP):** "If *P*, then *Q*. *P* is true. Therefore, *Q* is true", and **Modus Tollens (MT):** "If *P*, then *Q*. *Q* is not true. Therefore, *P* is not true". The invalid forms are: "If *P*, then *Q*. *P* is not true. Therefore, nothing certain follows.", and "If *P*, then *Q*. *Q* is true. Therefore, nothing certain follows." There are two fallacies (incorrect answers) for the invalid forms. The **DA (Denying the Antecedent) fallacy** is to give the answer "*Q* is not true" for the first invalid form. The **AC (Affirming the Consequent) fallacy** is to give the answer "*P* is true" for the second invalid form.

categorized in three classes: specific (a concrete example of an antecedent alternative is given), general (indefinite possibilities of alternative antecedents are mentioned), and formal (reference to the necessity of a conditional relationship is made) ones. The results of their first study indicated that, although the secondary students had a poor performance for the abstract task, a very large proportion of them are still able to give adequate justifications (general or formal ones) for the abstract uncertainty when they do not have to make on-line inferences. The fact that the reasoners were not able to use their general justification in the on-line reasoning was interpreted by them as indicating that the needed information for making abstract inferences was restricted by the level of abstraction of the premises. The conclusion of the cited authors is that making abstract inferences must be, at least partially, a retrieval problem, similar with the one occurred for concrete inferences. In fact, they believe that their results suggest that there is a relationship between the kind of answers given for the concrete uncertainty and the ones given for the abstract uncertainty. There was, for a certain subject, a tendency toward stability in the pattern of the justifications given for the two kinds of tasks. Moreover, with an increased expertise, a shift from a specific justification of uncertainty to a formal one occurred.

In a second study, Venet and Markovits (2001) manipulated the context in which the (abstract or concrete) premises were embedded: a realistic, or a fantasy one. The task was administered again to high school students of two different grade levels (secondary 2 and secondary 5). They hypothesized that if successful abstract conditional reasoning implies the elimination of the interference from the empirical knowledge, the performance for the invalid forms should be better in the fantasy context than in the realistic one, because it provides pragmatic cues concerning the formal nature of the task. But if the abstract reasoning is the result of an "ongoing process that relies on previously developed concrete reasoning abilities" (p. 83), they expected that the performance for the two invalid forms should be better in the realistic context than in the fantasy one. The invoked reason was that the needed "abstract representations would be primed by the realistic context" (p.83). The results indicated that the performance was better for the realistic context than for the fantasy one even for the abstract premises and that the adolescents answered equally well to the MP form with abstract premises, no matter the context, but they had difficulties with the invalid forms. The Venet and Markovits's (2001) conclusion was that abstract reasoning is facilitated "by access to empirical knowledge, at least with adolescents and adults" (p. 87), giving them cues in what respects the activation of structures abstracted from the concrete inferences. The two cited authors consider that the obtained results support the view that children begin by using the concrete, retrieval-based strategy in making conditional inferences. But "with increasing mastery of this process, reasoners will begin to encode this concrete process into a more reduced (abstract) form that retains the basic structure of the concrete processes." (p. 82). When a reasoner does not have "a well-developed abstract representation of the nature of alternative antecedents", she/he "would tend to use specific counterexamples to justify concrete uncertainty and would be unable to justify abstract uncertainty." (p. 82). With an intermediate level of development of the abstract representation of the nature of alternative antecedents, the reasoners would be able to give general or formal justification, but not to use them in on-line inferences. Therefore, a successful performance in a conditional task would require a gradual abstraction of the "key elements that define propositional uncertainty" from more concrete situations.

Several possible *dynamic aspects of the interpretation* given by the two authors for the obtained results are to be noted. In the first place, the idea of an abstract representation in what respects the nature of the alternative antecedents, which structures the previous experience with concrete inferences, is assimilable to the cognitive schema notion. The fact that its influence on the conditional reasoning performance is dependent on the context and content of the task and on its level of development is consistent with the notion of level of stability of a cognitive schema that determines its actualization conditions. The variability in the performance for the invalid forms may indicate a dynamic competition between the newly developed dynamic combinatorial schemas and old dynamic pragmatic schemas. The independence of age, context, and content of the performance for the MP conditional task may indicate the highest level of stability for its corresponding deductive schema. In the same time, the authors' conclusion that the abstract representations are developed from inferential strategies used for reasoning with a concrete content is congruent with the idea that the combinatorial dynamic schemas are emergent from pragmatic dynamic schemas.

Relatively recent empirical results supporting the combinatorial-analytic strategy in solving syllogisms were obtained by Trippas, Verde, and Handley (2014). More exactly, their results indicate an influence of the deductive task format on the chosen strategy in order to solve syllogisms in which a belief bias is involved. When the syllogisms were presented side by side (one valid and one invalid) completely (with their two premises and their conclusion) and the participants had to choose which one was the valid one, no belief bias was obtained. When only the conclusions of the two syllogisms were presented and the participants had to select each one of them to view its premises in order to decide which of the two is the valid syllogism, i.e. the premises of the two syllogisms were no longer simultaneously visible, there occurred the belief bias effects similar to those obtained in the traditional task, when syllogisms are presented one by one, with no comparison. The cited authors interpreted their result making reference to an empirical research regarding knowledge acquisition, made by Pachur and Olsson (2012, as cited in Trippas et al., 2014), applying its results to the syllogistic reasoning. In the view of Trippas et al. (2014), when the syllogisms are presented one by one, in order to judge the validity of a given syllogism, people are inclined to choose a strategy based on prior experience, analogous to an exemplar strategy, that prior experience being assumed to be the source of the belief bias. When syllogisms are compared side by side, in accordance with

Trippas et al. (2014), people would be inclined, instead, to choose a strategy based on formal logical rules, being encouraged by that task format to reason from the premises to the conclusion. As it was shown by Morley, Evans, and Handley (2004, as cited in Trippas et al., 2014), this forward reasoning, from premises to the conclusion, tends to be immune to belief bias. Trippas et al. (2014) have shown that the tendency to adopt the above-mentioned strategy based on formal logic (i.e. an analytic-combinatorial strategy) depends on individual differences such as the level of cognitive ability, motivation to reason accurately or to reason analytically, i.e. an analytic cognitive style, a style that mediated the obtained effect for the unbelievable conclusions. That type of conclusions promoted an enhanced reasoning only for those participants with an analytic cognitive style, presumably because that style is associated with an increased "motivation or impulse control to ignore easier but less accurate strategies" (Trippas et al., 2014).

The data obtained by Galotti et al. (1986) in a series of experiments could be interpreted to support the dynamic interaction between the assumed pragmatic and combinatorial schemas for categorical syllogisms. They compared the way good and poor reasoners solve categorical syllogisms when giving possible conclusions, necessary conclusions or "gut" conclusions (i.e., the first conclusion that comes through their mind) in order to distinguish the theoretical model that best accounts the syllogistic reasoning from the two main alternatives: rule theories and mental models theories. Their results presented a mixed support for each of the two alternatives, indicating that neither of them is the best. The schema-based model of syllogism may account the data in a better way, by considering that the rule account is closer to a pragmatic schema account, and the mental models theory to a combinatorial schema account, each of the two types of schemas winning the competition between them in a particular situation (for a particular type of required answer or type of syllogism).

Both for the conditional and syllogistic reasoning, there comes another line of evidences in what respects the importance and the differential effect of various classes of deductive experiences and knowledge on the reasoning performance. There is a series of two studies (Artman, Cahan, & Avni-Babad, 2006; Cahan & Artman, 1997) showing that, at the children between 5th grade and 9th grade, the accumulation of everyday experience is dysfunctional in solving invalid conditional, or categorical syllogisms. Their results indicated a "negative, albeit very small effect of out-of-school experience" (p. 261), but a considerable positive effect of schooling. So, a support is brought for the counterintuitive hypothesis that the "accumulated daily experience with conditionals has a negative effect on the development of conditional reasoning, and that improved performance on invalid problems with age is entirely attributable to schooling" (Artman et al., 2006, p. 131) The results are interpreted (Artman et al., 2006) in the sense that schooling breaks daily life interpretational habits. For the case of the conditional reasoning, the correct answer depends on the dissociation from a biconditional interpretation. But as Artman et al. (2006) have shown, biconditional interpretation is typically used in the everyday conditional reasoning.

In two empirical studies, Morris and Sloutsky (1998) provide evidences for the effect of a prolonged formal instruction on the development of the abstract deductive reasoning. Their data showed that an instructional setting in a Russian elementary school for mathematics curriculum "that emphasizes the development of the metalevel of algebraic reasoning, particularly the ability to distinguish between logically necessary conclusions and empirical conclusions", in which "concepts of quantity, relation and mathematical structure are emphasized prior to computational or algebraic transformations", adopting a "top-down approach", in which the acquisition of mathematical concepts "starts with a definition followed by instantiations" leads in the long run (after three years) to a better performance in tasks in which understanding of the logical necessity is essential than an instructional setting in an English elementary school for mathematics curriculum, in which the emphasis was on the "development of the transformational components of the algebraic reasoning", i.e. "from computation to understanding of abstract algebraic principles", in "an inductive case-based manner", a difference and development that did not occur at the Russian and English pupils who were taught mathematics using the regular curriculum from the two countries. In Morris and Sloutsky's (1998) studies, there occurred a high positive correlation between the "understanding of logical necessity in algebraic reasoning and in the verbal deductive reasoning" (assessed with categorical syllogisms), suggesting the possibility of a transfer of the learning of logical necessity from the algebraic domain to the verbal domain. The cited data indicate that a specific argumentative experience, in this case a specific mathematics curriculum, can influence the developmental gain in what respects the deductive reasoning, possibly contributing to the emergence of what was named here combinatorial-analytic schemata.

The importance of a specific argumentative experience in the improvement of a particular type of deductive reasoning was suggested in a study by Morris and Nisbett (1993), in which they found that third-year philosophy students had better categorical reasoning (but not conditional reasoning) than the first-year philosophy students, whereas third-year psychology students exhibited better conditional reasoning (but not categorical reasoning) than the first-year psychology students. In the same line of evidence, Osana, Lacroix, Tucker, Idan, & Jabbour (2007) obtained at undergraduate students a positive association between of the accumulation of specific argumentative experience with formal reasoning through the exposure to popularized scientific texts, or the ability to comprehend high-inference-load texts, and the performance in solving syllogisms. Leighton (2006) examined the effectiveness of training, for a year, first year philosophy students in symbolic logic for improving their deductive reasoning. Her results indicated that students' strategies "changed with training (students increased their use of mental models and mental rules with categorical and conditional syllogisms, respectively), but their reasoning performance improved only moderately", especially for the difficult syllogisms. It is a result that suggests that formal training may improve especially the combinatorial-analytic schemas, but that, given the complexity of such schemas, their stabilization may require longer periods of training in order that the improvement to be more notable.

Unfortunately, the studies regarding the role of the particular argumentative experiences in the development of deductive schemas have not examined differentially the effects of those experiences on the performance for the valid syllogisms in comparison with the performance for the invalid ones.

An indirect, unspecific, evidence supporting *the idea of the interaction between dynamic schemas on several levels* is the series of empirical findings (Bacon, Handley, & Newstead, 2003; Buciarelli & Johnson-Laird, 1999; Ford, 1995; Sloman, 1996; Stanovich &West, 2000) suggesting a high level of heterogeneity/variability in the strategies used for solving the deductive tasks, both inter- and intra-individually. Such findings are compatible with the idea that different types of dynamic schemas win the actualization competition, dependent on a particular context.

The hypothesis that in the syllogistic reasoning are involved simultaneously dynamic representations on several levels of organization based on which a deductive schema is actualized by emergence is supported by recent empirical data obtained by Ball and Quayle (2009). In a series of two experiments, they manipulated the representational distinctiveness of the terms from categorical syllogisms for which the task was the evaluation of a given conclusion. In the first experiment, the syllogisms contained "either phonologically distinctive terms (e.g., harks, paps and fids) or phonologically nondistinctive terms (e.g., fuds, fods and feds)" (p. 759). The obtained results showed that the performance was better when the terms of the syllogisms were phonologically distinct in comparison with the condition in which they were not. In the second experiment, symbol-based syllogisms involved distinctive or nondistinctive visual content. The performance was again better for the syllogisms with distinctive content. The general conclusion derived by the two cited authors is that the "representational distinctiveness has a generic beneficial influence on deductive inference that is not restricted to one particular representational modality" (p. 762). The results were interpreted as showing that distinctiveness facilitates the maintenance of the information in the working memory, since similar items have fewer distinguishing features, and that the multi-modal representations are important for syllogisms. In the standard version of the mental models theory such results are not to be expected, since the tokens of the models are considered amodal, abstract. Moreover, in the case of the visual content, that theory foresees a negative effect of the visual distinctiveness due to the imagery impedance hypothesis (Knauff & Johnson-Laird, 2002). So, the obtained results run counter to this prediction of the mental models theory, questioning the "assumed primacy of abstract, spatially-organized representations in deduction as claimed by mental models theorists" (p 763). Ball and Quayle (2009) suggest that their empirical findings offer support to the idea that reasoning implies construction and manipulation of "multi-dimensional representations within a single, dynamic storage system that is capable of seamlessly integrating both phonological and visuo-spatial information" (p. 763).

Dynamically, the results obtained by Ball and Quayle (2009) could be interpreted as follows. A higher level of distinctiveness would mean a higher level of relative stability and, therefore, actualization maintenance. When two external representations have features in common, that would mean that their dynamic internal representations have very close or overlapping attractive domains. Therefore, their underlying system destabilized by the influence of noise, for example, from the region of one of the two representations could easily be stabilized in the nearby region of the other representation. The resulting general instability at the lower level of the dynamic representations (perceptual synergetic patterns) would impede the emergence of stable dynamic patterns at higher levels (synergetic patterns of patterns), important for solving a deductive task. It is to be expected that there should be a lower effect of the distinctiveness of the syllogistic terms for the more important syllogistic figures, with deductive schemas that are supposedly more stable.

In fact, Ball and Quayle's (2009) data could be connected with the results from the scientific literature indicating that the performance in a syllogistic task is poorer for a symbolic abstract format in comparison with the one for a concrete one (Wilkins, 1928, as cited in Dominowski & Bourne, 1994). It may be that here there is, again, a distinctiveness effect (and, correlatively, a stability effect), but one in a semantic space, not in a perceptual one.

The *importance of some linguistic cues* for the solving of syllogisms in a pragmatic or formal, logical, manner is suggested by the empirical results obtained by Schmidt and Thompson (2008). They have shown that such cues, embedded in the linguistic format of a syllogism, can lead to a pragmatic interpretation of the syllogistic quantifier "some" or they can disambiguate it in the favor of a logical meaning. Therefore, by changing the linguistic format from a rather ambiguous one, supporting both a pragmatic and a logical meaning for the quantifier "some", to another linguistic format, which offered disambiguating linguistic cues so that the meaning of that quantifier to be logically clarified, the syllogistic performance (from a logical point of view) was increased. Their result, the performance improvement, may be understood from the perspective of the proposed dynamic schema-based model of the syllogistic reasoning, in the sense that the meaning clarification may help the actualization and stabilization of an appropriate dynamic syllogistic schema. It also supports the idea that the reasoners are sensitive to the logical semantics of the information provided in the premises, to the logical status of the syllogistic terms and judgments, although, in the cited research, that semantics is not the one involved in the proposed model for the pragmatic syllogistic reasoning, but one that may be more relevant for the level of the assumed analytic-combinatorial syllogistic schemas. Moreover, that result draws attention to the difference between the semantics of the formal logic and the one encountered in the day to day reasoning.

The empirical data that have suggested *intuitive logical solutions* for the deductive tasks (see above, Bago & De Neys, 2017, De Neys, 2014, or Morsanyi & Handley, 2012; Trippas, Handley, Verde, & Morsanyi,

2016) and that have underlined phenomenal aspects of the deductive thinking linked with some metacognitive representations, such as the judgment of solvability or difficulty, the feeling of familiarity with the judgments of a syllogism, the feeling of knowing, of confidence, of rightness (Thompson, 2009), of cognitive fluency or disfluency (Alter, Oppenheimer, Epley, & Eyre, 2007; Thompson et al., 2013; Trippas, Handley & Verde, 2014), which can be related to a dynamical point of view, can support, indirectly (through the compatibility of these results with a dynamic approach of the reasoning), also, a dynamic schema-based model for the deductive reasoning. The existence of deductive schemas with a logical content may account for the occurrence of the intuitive logical solutions. An activated deductive schema could generate metacognitive feelings similar with the ones encountered at the recognition or recall of a perceptual pattern. As illusory cognitions may occur in the recognition or recall of an appropriate deductive schema in a particular context through the activation of a similar, more powerful, inappropriate schema, which gains the dynamic competition with the appropriate one, there are to be expected dissociations between the accuracy of the answers given for the deductive tasks and some metacognitive feelings (of confidence, feeling of rightness), based on the hypothesis that those feelings emerge in relationship with the actualization level of the involved deductive schemas and may reflect the status of their dynamic competition. Such dissociations have been found, for example, in the empirical research by Shynkaruk and Thompson (2006) and Prowse Turner and Thompson (2009). Finally, the competition between deductive schemas, or the difficult actualization of a rather unstable schema can lead to feelings of cognitive disfluency, which can be associated with the involvement of deductive schemas of a higher order (analytic-combinatorial ones or metacognitive ones) or some other metacognitive representations, as it is the feeling of rightness. Empirical evidences in that direction were obtained, for example, by Alter et al. (2007), Thompson, et al. (2013) and Trippas et al. (2014), their data suggesting that the cognitive disfluency may be a signal for an extra cognitive effort and for the selection of a strategy involving a more elaborate processing, and by Newstead, Thompson, and Handley (2002), whose results support the view that the analytic deductive processes could be activated by metacognitive processes, like the feeling of rightness. The same competition between deductive schemas may account also for the phenomenon of conflict detection between a heuristic intuitive solution and a logical intuitive solution, revealed by the empirical results obtained by Bago and De Neys (2017), De Neys (2014), Morsanyi and Handley (2012), assuming that the two kinds of intuitive solutions are supported by different deductive schemas that are activated by the cues of a reasoning task.

Finally, there are some empirical results in what respects particular dynamical effects in the language understanding, especially for ambiguous sentences, as a case of pattern recognition. These results may be relevant for the way the logical meaning of the premises is interpreted in the reasoning process based on the linguistic cues, i.e. the way an inference schema may be recognized, especially when the linguistic cues provide conflicting or incomplete information. Rączaszek, Tuller, Shapiro, Case, and Kelso (1999) used sentences with different surface structures (bracketing), supporting alternative interpretations. They created continuous variations through the "systematic manipulation of prosodic cues (relative foot duration), resulting in stimulus sentences that spanned the range between the two interpretations", so that prosody can be seen to be a control parameter from a dynamic point of view. Those continuous variations "were presented to subjects who were requested to indicate as quickly as possible which meaning they perceived". The obtained results (pattern of responses and response times) indicated a nonlinear dynamical phenomenon: hysteresis (in the present case, it means that when "the prosodic parameter is first systematically increased and then systematically decreased", "a given interpretation of a sentence tended to persist before switching", even though the value of the control parameter "favored the alternative interpretation", i.e. a subject "remains longer in the initially perceived interpretation", the switch to the alternative sentence interpretation occurring "at a larger parameter value when it increases than the switch back to the initial meaning when the parameter value decreases"), which occurred predominantly in the analyzed cases. In the remaining cases, there were observed another two dynamical phenomena: enhanced contrast (the meaning "switch on the way up occurs at the smaller parameter value than the switch on the way down"), and, for only a case, critical boundary (when "the switch between alternative sentence meanings occurs at exactly the same parameter value regardless of the direction of change of the parameter"). Rączaszek et al. (1999) predicted that "if the perception of ambiguous sentences depended only on the value of the durational parameter, then the critical boundary pattern should be the most common", but if "perception of sentence meaning can be conceptualized as a pattern-formation process", a systematic dependence on recent history should be observed (i.e. hysteresis and enhanced contrast). The data supported the latter variant. In other words, when the values of prosodic parameters were congruent with both interpretations, the individual's recent history decided which meaning would be perceived. Even in the random presentation condition, when there was no continuous variation of the control parameter, but a random change of its values, Rączaszek et al. (1999) "found that the probability of perceiving a given meaning was higher when the subject heard the same meaning immediately before and was lower when a different meaning was perceived before". So, the meaning interpretation (categorization) process is seen by the cited authors as a "transition in a multistable system", which starts with "only one state (category) available", and, by the manipulation of a control parameter (prosody in this case), the system is driven "into a bistable region, in which a new meaning becomes available", the chosen meaning being dependent on the previous context. Rączaszek et al. (1999) reasoned that if that is the case, i.e. if "recognizing a meaning is equivalent to settling into a stable pattern" and "if switching of the interpretation can be seen as a transition between two stable patterns", then "the stability of these patterns should differ depending on how far the system is from the transition". Because from a dynamical systems point of view, a transition to another preferred pattern should be preceded by a progressive loss in the stability of the previously preferred pattern (which means that it takes longer for the system to settle into that initially preferred pattern - i.e. to decide the meaning of a sentence in the present case -, a dynamic phenomenon called the "critical slowing down" before a dynamic transition), it should "take longer to decide which meaning is conveyed by a sentence as a transition to the alternative meaning is approached". By measuring and comparing the decision times for the values of the control parameter "where the percept was theoretically stable with those where the percept was close to switching to the alternative sentence meaning", Rączaszek et al. (1999) obtained data that supported this prediction: "near the transition points the response times were longer than in the regions far from the transition, and response times right before the transition were slightly longer than right after the switch". This result, too, was seen by the cited authors to be "consistent with the idea of a 'dynamics of meaning'", as "the longer response times near transitions are suggestive of loss of stability from which eventually a transition to an alternative meaning results". Rączaszek et al. (1999) note also that "characterizing states corresponding to alternative meanings in terms of stability has several important consequences", as the emergence of a new pattern can "enslave" the rest of the cues, "so as to form a coherent alternative organization, i.e., another stable state" or, in the other considered case, if the local cues are perceived as favoring an alternative interpretation, the global pattern of a previously perceived meaning can persist, being "able to change the effect of these cues on the ultimate interpretation". They show that there are individual differences in what respects the tendency of the subjects to "'stick' to the perceived interpretation", "to stay in one meaning", which can lead them to present consistently a predominant hysteresis phenomenon or, on the contrary, a predominant enhanced contrast phenomenon. Based on some previous empirical results, Rączaszek et al. (1999) link this individual variable, the "readiness to switch", with attention and learning and, also, with another individual variable: cognitive flexibility (as a cognitive style), which correlates positively with an empirical individual measure: “the rate of spontaneous ambiguous figure reversals (which is also a type of pattern switching)”. The cited authors interpret their results based on their claim “that the effects observed in perception of sentential meaning are common to perceptual phenomena in general and may stem from the underlying dynamics of a cognitive system”, that ”meaning perception” is “cognitive pattern formation”, for which dynamic concepts as stability and instability may be applied. It might be added that the same may be true when the logical meaning, an inference schema, is extracted from premises. In this case, too, the information encountered before a reasoning process starts may influence the interpretation of the information provided in the premises, so that recognition of an appropriate inference schema may be biased in a direction or another. Moreover, the needed time to recognize an inference schema might be dependent on its stability and on one’s readiness to change an inference schema with another one, which can be linked with her/his cognitive flexibility.

4. General assumptions of a dynamic schema-based model for conditional reasoning

Using the previously cited data, the following dynamic schema-based model for the conditional reasoning is possible.

The fact that there is a better performance for the valid forms in comparison with the one for the invalid forms (a validity effect) may be explained through their differential likelihood to be encountered in the usual life and through their associated cognitive importance.

Pragmatically speaking, for everyday actions, it may be a more frequently encountered situation and it is more important to know what follows or what to do when something is the case (*the MP situation*) than when it is not (especially when that would mean an infinity of other possible situations), that is *DA situation*. Therefore, it is less likely that a stable cognitive schema will be developed for the DA invalid form. On the other hand, the situation in which we want to find out why an expectation was not met (*MT situation*) may be more frequently encountered and cognitively more important than the one in which we would want to find out why something is the case (generally an infinity of causes may be invoked), that is *AC situation*. Therefore, for the AC invalid form is also less likely to be developed a stable dynamic deductive schema.

In accordance with a dynamic hypothesis, for an abstract ambiguous content, the answers for the invalid forms could be explained by an "illusory recognition" of the deductive schema to be used. In this case, it is more likely that the schemas for the valid forms will be able to constrain into their frame the interpretation of the given ambiguous data for the invalid forms that are structured similarly with them. So, the generated conclusion will be in accordance with their dynamic pattern.

The idea of deductive schemas for the conditional reasoning with more specific semantics molded on the typical conditional experiences in the everyday life is supported by the studies cited in the previous sections (Artman et al., 2006; Cheng & Holyoak, 1985, Cosmides, 1989, Müller et al., 2001; Venet & Markovits, 2001).

In what respects the *conditional reasoning in the Wason Selection Task*, it is to be noticed that the poor performance of the subjects might be explained by the fact that usually it is more important for people to know how to follow given rules in order to get the expected results than to investigate at a metalevel the validity of a rule. Therefore, they might tend to use the available procedures for the most frequent situation of following given rules out of lack of specific stable schemas for the rarely encountered situation involving the check of the validity of a rule.

5. Reasons for choosing the syllogistic reasoning case for a partially empirical validation of the proposed model

The empirical verification of this sketched model for the deduction in general it would be a lifetime endeavor. That is why I have chosen to find supportive empirical results only for some elements of the model, for some of its predictions, by focusing the research on only one type of reasoning: categorical syllogism.

The choice of the syllogism had several *theoretical and pragmatic reasons*:

- ✓ In comparison with the hypothetical reasoning, *there is no pragmatic schema theory formulated in its case*, and no empirical evidence in that respect, whatsoever.
- ✓ In *comparison with the relational reasoning, syllogistic reasoning has a higher level of complexity*, from many points of view. In a way, it is a kind of integrative, paradigmatic, kind of reasoning, because it involves partially the propositional (when the relationship between its judgments are considered) and the relational reasoning (when transitivity is used), too.
- ✓ It is a kind of reasoning that *requires necessarily a semantic approach* (Didilescu and Botezatu, 1976), being irreducible to a formal approach as it is the case with the propositional reasoning.
- ✓ I found *theoretical studies of Romanian logicians that have suggested distinctly the cognitive function of each of the four types of syllogisms* (the four syllogistic figures). So, syllogisms offer for the same deductive task an increased variability in what respects their cognitive function.
- ✓ Syllogistic reasoning *allows the elaboration of reasoning tests with many various items* to be solved.
- ✓ The *envisioned experimental manipulations were easier to be put in work with syllogisms*.

XI. A dynamic pragmatic deductive schema model for categorical syllogisms

1. General assumptions

a) This model is designed ***for the case of people untrained in formal logical reasoning, having a limited experience in that respect***.

b) The *fundamental assumption* of the model is that, in their case, syllogistic tasks are completed usually (most frequently) a) at *an intermediate level of abstractedness*, b) based on several dynamic pragmatic deductive schemas, c) built around characteristic cognitive goals d) that are associated to a class of cognitive (argumentative) experiences/situations.

c) All of the *assumptions of the general dynamic schema-based model of the deductive reasoning are valid, also, in this particular case*.

2. Specific assumptions regarding the cognitive function of the four syllogistic figures and the semantic logical content of the correspondent syllogistic schemas

The *general framework has to be completed with the specification of the cognitive goals and with suggestions regarding the semantic content of the assumed dynamic deductive reasoning schemas* for the case of the syllogisms. I have found in the work of three Romanian logicians regarding the natural logics the needed theoretical ground in order to complete such a specification, assuming that *the characteristic pragmatic dynamic syllogistic schemas correspond to the four syllogistic figures*.

A. Cognitive functions of the syllogistic figures

As it is known, syllogisms are grouped in four major categories taking into consideration the position of the three syllogistic terms in the premises. If the two extreme terms of a syllogism are symbolized by **S** (for the term playing the role of the subject in conclusion), respectively **P** (for the term playing the role of the predicate in conclusion), and the middle term by **M**, then the four types of syllogisms could be schematically represented as follows:

Fig. 1:
Premise 1: M-P
Premise 2: S-M
Conclusion: S-P

Fig.2:
Premise 1: P-M
Premise 2: S-M
Conclusion: S-P

Fig. 3:
Premise 1: M-P
Premise 2: M-S
Conclusion: S-P

Fig.4
Premise 1: P-M
Premise 2: M-S
Conclusion: S-P

Given that each premise or the conclusion could be of four types (A, E, I, O), as it was specified in a previous section, then a particular syllogism could be noted using the symbols of the judgments for its premises and conclusion and adding the number of its figure. For example, the syllogism named in the classical logic as Barbara, having as premises and as conclusion only universal affirmative judgments will be noted with AA1A.

In Didilescu and Botezatu's (1976) view, the study of the syllogistic reasoning is irreducible to class relations, as it is usually considered to be from formal reasons in logic, and from mimetic reasons in psychology. Instead, it necessarily involves both intensional relations (between classes and their properties), and extensional relations (between classes). They plead for a mixed syllogistic semantics, pointing out that the syllogism needs, in order to be properly understood in its entire real complexity, both a class interpretation and a predicative interpretation (in terms of attributes or properties). In their natural logic, the four syllogistic figures have the following cognitive functions. Through the syllogisms of figure 1, it is indicated if "the species is or is not in the possession of the property of the genre" (p. 450), considering if "the species is included or not in the genre" (p. 450). Through the syllogisms of figure 2, it is indicated if "the species is included or not in the genre" (p. 450), considering if "the species is or is not in the possession of the property of the genre" (p. 450). Syllogisms of figure 3 allow the indication if "the genre is or is not in the possession of the property of the species (p. 450), considering if "the genre includes or not the species" (p. 450). Finally, syllogisms of figure 4 indicate if "genre includes or not the species" (p. 450), considering if "the genre is or is not in the possession of the property of the species" (p. 450).

In a more essayistic work, Noica (1986) proposed a new classification of the judgments in six categories, based on their specific pragmatic function, and, consequently, he defined a specific cognitive function for each syllogistic figure. But, as he shows, only three of them are useful in a syllogistic reasoning. The judgment that relates an "individual" case (a class member) with a property is named a *"determinative"* judgment (symbolized by I-D). It has a descriptive function, "determining an individual reality" (p. 78). The judgment that relates an "individual" case with what is called a "general" (a higher class) is named *"integrative"* judgment (symbolized by I-G). It has a function of "direct integration of an individual reality under a law" (p. 79). The judgment that relates a "general" (a class) with a property ("determination") is named a *"delimitative"* judgment (symbolized by G-D). It allows "delimitations and nuances of a law or principle" (p. 79). A figure 1 syllogism associates a G-D judgment (as the major premise) with an I-G judgment (as the minor premise), resulting an I-D judgment as conclusion. Its suggested cognitive function is the transfer of an existent property (or of its absence) to an "individual" through the middle term that is a "general". A figure 2 syllogism associates a G-D judgment (as the major premise) with an I-D judgment (as the minor premise), resulting an I-G judgment as conclusion. Its cognitive function is defined based on the idea that "a common property does not authorize subordination", but "one that is not common authorizes to not subordinate" (p. 88). Finally, a figure 3 syllogism associates an I-G judgment (as the minor premise) with an I-D judgment (as the major premise), resulting a G-D judgment as conclusion. Noica (1986) calls this kind of syllogism a "syllogism of the accident", because it is distinguished through it an accidental aspect within a class, i.e. the fact that a property has a restricted validity in what respects a class, that that property does not have a necessary character.

In a shorter and integrative version, synthesizing both the suggestions made by Didilescu and Botezatu (1976) and by Noica (1986), the *cognitive goals* for the three most important syllogistic figures[32] might be the following:

[32] Although, as it could be seen, a fourth syllogistic figure is possible not only formally (by not ignoring the role of subject or predicate of the two extreme terms in the premises), but also in what respects its distinct cognitive function, too, it is usually not considered or recognized as a separate figure, given that, from a formal point of view, it is reducible to the figure 1 type of syllogisms. That is why it is ignored by logicians and psychologists alike. Since in my empirical research only the first three syllogistic figures are used, in what follows only those syllogistic figures are taken into consideration.

- **Figure 1**: To determine *if a group of cases of interest (i.e. a subclass) has or not in its entirety a certain property*.
- **Figure 2**: To determine *if two classes (subclasses)/categories are mutually exclusive in order to impede a falsely alleged or unwarranted subordination relation (inclusion) between them*.
- **Figure 3**: To *determine that a category is defined or not accidentally/circumstantially by a property or, in other words, that that property is not a necessary one (as it might have been presumably initially supposed to)*.

It should be noted that, in identifying the cognitive functions of the three syllogistic figures, the logical, the formal distinction between universal and particular judgments loses its importance. Although, logically, two judgments may seem identical (are of the same type: A, I, E, or O), they might have a distinct functional utility and informativeness (informational gain), based on the meaning of their terms.

B. The order of the cognitive importance of the syllogisms

1) *The order of the cognitive importance of the valid syllogistic figures*

The three cognitive functions could be *ordered in what respects their general importance* by supposing that it is positively linked with the *informativeness (informational gain) of the allowed conclusions in each syllogistic figure*.[33] *as it might have been presumably initially supposed to* From

[33] The *reasons for which it is plausible to assume that figure 1 and figure 2 syllogisms have a more important cognitive function than the figure 3 syllogisms are*:

- In the first place, the *figure 1 and figure 2 have both categorical, definite (Didilescu & Botezatu, 1976), conclusions* (no matter if they are universal or not), stating that something is the case with certainty, exhaustively, in what respects a group of cases of interest (no matter it is a class or only a subclass, when the conclusion is a particular judgment).

- Instead, the valid *conclusions of the figure 3 are only particular conclusions* (there is no universal conclusion in the figure 3 syllogisms), stating that a link or its absence between a category and a property is only partially, accidentally, circumstantially, valid. Therefore, the uncertainty is not completely reduced in what respects the considered group of cases of interest as in it is the case with the conclusions of the figure 1, and figure 2 syllogisms.

- *There is a difference between a particular conclusion of a figure 1 or figure 2 syllogism and a particular conclusion of a figure 3 syllogism*. In the first two cases, *the meaning of the term occupying the subject position in conclusion is one of an individual* (as a member of a category or subordinate category), the focus of attention being concentrated on this point of view, their decreasing order should be figure 1 > figure 2 > figure 3. It is to be noted that the difference between the figure 1 and figure 2 is not so salient[34], and, therefore, it might become insignificant for particular cases and contexts[35]. Figure 2 and figure 3 syllogisms supposedly have a more salient counterargumentative significance, pointing out the exceptions, the particular cases that have been previously ignored. They are, in the same time, placed at a more abstract

finding out its sense. *In the third case, the meaning of that term is of a general (a category)*, the focus of attention being on finding its sense not on the subclass of individuals that only mediates its circumstantial relation with a certain property. But, pragmatically speaking, it may be generally more important to find out that some link is valid no matter the case of interest, than to find out that it is only partially or circumstantially valid, for some not clearly specified cases.

[34] The *reasons for which there still may be a difference, even though a less salient one, between the figure 1 and 2 syllogisms in what respects their cognitive importance*, although both have certain conclusions, are:

- In the case of the *figure 2 syllogisms, there is virtually an infinity of categories that are in an exclusion relation with another category* (subcategory), because there is a virtual infinity of ways to gather individual cases into groups or categories.

- Instead, *the number of properties known by a person, especially those considered relevant in a particular context, is rather limited*.

- By *stating that a category (or subcategory) is not a subordinate of another one, no definite knowledge is gained in what respects its properties*. It is negated only the inheritance of all the relevant properties of the alleged superordinate category, not the fact that some of them could still be shared. Stated differently, a figure 2 conclusion determines only the fact that a certain position in a semantic hierarchy is not the adequate one for a category, but it does not determine its actual position. That is why there may be that the informational gain of a figure 2 conclusion by stating in particular an exclusion relation in what respects the meaning of a category is lower than the informational gain of a figure 1 conclusion when stating that a subcategory is completely defined or not by a certain property.

- There *may be also that the intensional relations are generally more important pragmatically than the extensional ones*, as a supplementary reason for ascribing a greater cognitive importance for the figure 1 syllogisms in comparison with the figure 2 syllogisms.

- It could be hypothesized that *figure 1 conclusions, by focusing on certain relations between individuals and properties are more concrete, more pragmatically relevant for the day to day activities*. Such a type of conclusions might have more frequent and direct consequences on the plan of the actions that a person has to follow given the gained knowledge in comparison with the conclusions of the figure 2 and figure 3 syllogisms.

[35] For example, such cases are when a reasoner wants to find out or to demonstrate to another person if a certain subordination relationship is warranted or not, or she/he wants to dispel a falsely alleged such relationship. But such cases are supposedly more rarely encountered than the cognitive situations in which figure 1 syllogisms are important.

level, because they are focused not on the description, definition at an individual level (as figure 1 syllogisms), but on the status of a relationship: if it is warranted or not (figure 2 syllogisms), or if it circumstantially or not (figure 3 syllogisms).

Synthetically speaking, it may be said that figure 3 syllogisms are less important cognitively because they determine the truth of a circumstantial relation, in comparison with the figure 1 and figure 2 syllogisms, in which the truth of an absolute, context-independent relation is determined. On the other hand, figure 1 syllogisms may be somewhat more important than the figure 2 syllogisms. This statement is grounded on the assumption that the intensional relationships between individuals and their properties are pragmatically important more frequently than the extensional relationships of subordination between classes. Moreover, through the conclusion of the figure 2 syllogisms, no definite such extensional relationship is established, but only that there is not a certain one.

2) *The cognitive importance of the valid syllogisms within a particular syllogistic figure*

Also within a syllogistic figure may be a hierarchy in what respects the cognitive importance of the conclusions from that figure, based on their informativeness (Chater and Oaksford, 1999). The four types of judgments would have the following partial order in that respect: A > E = I > O[36].

Consequently, in what regards the possibility to order all the valid syllogisms by their cognitive importance, there intervenes a complication, since there are two interacting factors to be considered and, therefore, overlaps are possible[37].

[36] Here, it is more difficult to establish a total order, especially because of the cases of the E and I judgments, which could be ordered contextually differently in what respects their pragmatic or cognitive importance. The criterion of the level of surprise produced by knowing that a judgment is true (Chater & Oaksford, 1999) is unclear, that level being context-dependent, too, in my opinion.

[37] It may be, for example, that a syllogism of figure 1 having an O or I conclusion to be cognitively less important than a syllogism of figure 2 having an E conclusion.

3) *The reduced cognitive importance of the invalid syllogisms*.

The invalid syllogisms *do not have probably a cognitive function* in most of the circumstances. The *reasons are* the following:

– It is *cognitively and pragmatically unimportant to state that nothing could be determined for certain based on the given information*. The *exception cases* might be when a person has *counterargumentative purposes* aiming a) to fight against a false conclusion or assumption, or b) to check if it is an unwarranted one. But such cases are presumably rarer and less important pragmatically than the ones involving valid syllogisms.

– The *relevant deductive processes are more abstract, being placed at a metalevel, linked with the logical status of a semantic relation*.

There may be *some typical situations, more frequently encountered, in which invalid syllogisms are more easily solved*. For example, when the two premises are particular judgments or when both are negative judgments. *Maybe these are the cases in which their level of dissimilarity with any of the valid syllogisms is extremely high, and, therefore, an inadequate assumed dynamic deductive schema for a valid syllogism is less likely to be wrongly actualized*. But even in those cases, there are persons who err, deriving a positive conclusion. A hypothetical reason for that is that they specifically interpret only the relations stated in the premises and not the meaning of the syllogistic terms, especially when more stable elementary relational dynamical schemas are actualized by the given information[38].

In conclusion, it is to be expected *a validity effect* based on the assumption that valid syllogisms are more important cognitively than the invalid ones.

[38] Therefore, they may interpret that a particular judgment states that there is a weak relationship between two mental objects corresponding to the unanalyzed syllogistic terms. With two such weak relations, linked by a common point (object), a transitivity deductive schema may be elicited, deriving a weak relation between the two extreme points of the transitive chain. It is as if having a weak relationship with another object is a transitive property of those objects, by transforming the asymmetry of the initial syllogistic relationship, into a symmetrical one. The same thing may happen in the case of two negative premises, when not having a relationship with another object becomes also a transitive property.

3. A comparison between the dynamic schema-based model and mental models theory in what respects the main expected effects

a) Knowledge and content effects *in mental models theory vs. dynamic schema-based model*

Until now, the ***cognitive function, the intensional and pragmatic aspects that were discussed above have been almost completely ignored in the syllogistic reasoning research, the focus being on the extensional and formal aspects***.

The dominant theory in the syllogistic reasoning research (there is no developed mental logic model to date for the syllogistic reasoning), i.e. *the mental models theory*, is one in which it is assumed in its *classical version* that:

- The *information given in the premises is interpreted exclusively extensionally*, by abstract symbolic tokens as instances of classes or categories. The mental models theory is semantic only to the degree in which it is referring to the truth of a model, using the same principle as the truth tables from the semantic logic.
- The *semantic meaning and the existing knowledge* in what respects the information given in the premises (for example, the status of subject or predicate of the syllogistic terms) *is supposedly used only in order to build that extensional model* (an initial one or a counterexample), having *no relevance for the proper inferential step*.
- The ability to build mental models is principally developed by learning through the language understanding (Johnson-Laird & Byrne, 1991). ***But what is learned is the way to give an extensional meaning (representing concepts by an arbitrary number of representative members) to the abstract concepts and their logical properties, and not their intensional meaning in order to use it in the inferential processes.***
- *No distinction is made between the logical or the pragmatic meaning (determining the cognitive function) of the syllogistic terms as abstract concepts or of the syllogistic relations in what respects their relevance in building such extensional models.*

- It is assumed that *knowledge may serve only in determining the initial implicit model and in updating that model* with its explicit information when building a counterexample. Specifically, it serves *to position the tokens into the model in the right places or to add new ones if needed*[39].

[39] But other than that, there are no specific hypotheses regarding the dynamics of the explicitation process or no stated specific factors that are important in eliciting or driving it, or determining what should be explicit or implicit in the initial model, why the initial model is built in the way in which it is built. The hypothesis of an initial implicit model seems more like an ad hoc hypothesis, since no very clear reasons for its structure, other than the assumed limits in the processing capacity, and no clear factors determining its content are provided in the traditional versions of the mental models theory. So far, the gathered evidence (Newstead, Handley & Buck, 1999) has suggested that people do not build counterexample models most of the time not because they do not have sufficient available processing resources, but because they are unwilling to use them, and they do not even try to do it. Even if people do generate alternative models, Johnson-Laird and Byrne (1991, p.214) recognize that nothing is known for certain in what concerns the way they are generated, and the way their generation is terminated. In the case of the conditional reasoning, Johnson-Laird and Byrne (2002) have acknowledged the role of knowledge in guiding the flashing-out of the explicit information and in generating alternative models for the conditional reasoning stating what they call the *principle of semantic modulation* and the *principle of pragmatic modulation*. In accordance with the semantic modulation principle, formulated for the conditional reasoning, meanings of the antecedent and consequent term, and their coreferential link "can add information to models, prevent the construction of otherwise feasible models of the core meaning and aid the process of constructing fully explicit models" (p. 658). In accordance with the pragmatic modulation principle, the context of the deductive task eliminates possible models. Therefore, knowledge determines the models that are retained in the final representation. But beyond these general principles, no specific information is provided in what respects the type of information that is capable to modulate the process of building mental models, and nothing is stipulated concerning the extension of those principles at the syllogistic reasoning case. As Handley and Feeney (2007) have noticed, "simply describing a model set for the assertion, as Johnson-Laird and Byrne did, does not constitute an adequate analysis of the pragmatics" (p. 36) of a conditional assertions. In their view, "it simply redescribes our intuitions about the meaning of such statements." (p. 36). In addition of that, the very principle of explaining the difficulty of a reasoning task by the required number of mental models is undermined if the influence of knowledge and context would mean that not all the possible mental models are built due to their restraining power. But such an interpretation is unlikely in the theoretical framework of the standard mental models theory, because it would make it incoherent. That is why, in Johnson- Laird and Byrne's (2002) work, the implied idea should be that knowledge and content serve

- *Knowledge learned through experience used for building models is a general knowledge that is useful for every syllogism*, no matter its type. So, ***it is expected, from this point of view, that the performance for all the syllogisms to be improved by experience,*** *but the most for the (valid or invalid) multiple model syllogisms and figure 3 syllogisms.*
- The *essential explicative principle remains* the fact that, *out of a limited (potential or actual) processing capacity, the subjects are not able to explore all the necessary possibilities in order the give a correct solution*. Currently, in that theory, the knowledge has no specified role in restraining the range of the possibilities (models) to be considered in order to give the expected conclusion. At most, knowledge may be important in restraining the explicit information considered in the initial model of the premises (though this hypothesis is not explicitly stated in the standard versions of the theory).
- *Knowledge may rather expand the range of the considered possibilities in order that the correct logical answer to be given, favoring the search for a counterexample*. Therefore, *it should be expected* that the semantic information or knowledge acquired by ***learning to have beneficial effects especially for those syllogisms requiring the expansion of the searched possibilities, eliciting their search. Such syllogisms are those requiring more than one mental model in order to be solved, the most***

more to eliminate the *already built models* that are not relevant for a particular situation. Otherwise, the necessity of a derived conclusion could not be ascertained. By stating in the same time that knowledge could "prevent the construction of otherwise feasible models" they are ambiguous in what respects the meaning of the term "prevent", and do not specify what kind of process would be the one capable to prevent the building of alternative models by explicitation. It seems to be an incoherent statement, since even they have admitted, based on the gathered evidence, that people (without a training in formal logic) usually build alternative models by explicitation in abstract tasks (when there is no influence from knowledge) predominantly when they are prompted or encouraged somehow to do that. So, the process of finding counterexamples by explicitation is not something that has to be prevented, as long as it usually does not exist at all.

difficult ones. And since all the invalid syllogisms have more than one model, knowledge acquired by learning should be beneficial especially for them[40].

In comparison, *in the dynamic schema-based model of the syllogistic reasoning*, centered on the idea of cognitive function, the assumptions are that:

– *The role of knowledge is primarily one of restraining the possibilities needed to be considered* in order to give the expected conclusion. By learning a pragmatic dynamic schema, the state space of all the possibilities is contracted. Therefore, **a lower performance** is explained

[40] Several observations could be made in order to distinguish the role of knowledge and context for the deductive reasoning in the mental models theory from their function attributed in the proposed model. In the case of the *mental models theory*, they have the role to adjust a general procedure to particular conditions, not in the inferential process as such. Their influence leads to pragmatic answers that do not coincide any more with the logical ones, the ones obtained by a decontextualized meaning. In general, such knowledge is conceived to be a concrete or factual one. In fact, the two appendix principles (of semantic and pragmatic modulation) are an extension of the idea that the information explicitated in the initial model, even for abstract formal tasks, is somehow determined by the previous experiences, but this is not stated clearly in the theory. On the other hand, in the proposed *dynamic model*, knowledge is essential as such in the inferential process, representing the base on which the deductive schemas emerge. Such knowledge is of an abstract type, representing typical deductive situations (whether more concrete or more abstract). If adequately actualized, those emerged schemas should lead to a correct answer from a logical point of view. They do not inadvertently reduce the possibilities to be searched and considered, out of limited cognitive resources or out of the influence of some factual memorized knowledge (when the answer is practically a recollection of a specific memory, so that building mental models would be a superfluous process). Therefore, *knowledge and context are meant to explain the logically correct answers from the beginning, not the errors made by people or the correction of those errors*. So, that is why I have supposed that in order that a correct conclusion to be obtained in the case of syllogisms, a hypothetical involved knowledge should expand the searched possibilities of counterexamples in order to correct the errors made because of a faulty initial mental model. This idea has been supported also by Handley and Feeney (2007), who believe that "pragmatic modulation involves adding a single model of background knowledge about more plausible relationships to the initial representation of the assertion" (p. 39). Similarly, Barrouillet and Grosset (2007) cites the opinion of Markovits (1993) that the knowledge from LTM (Long Term Memory) "makes it possible to construct additional models" for conditional reasoning, representing the antecedent and the consequent not as constants, as it is the case for children, but as variables with multiple values.

mainly not by a failure to search in the entire state space, but ***by a failure to use knowledge (when there is one) in order to restrain the searching space, impeding the combinatorial explosion***. The ***errors occur when the state space is restrained too much***, by the constraining power of wrongly actualized schemas or when there is no actualized schema.

– *Knowledge acquired through learning and semantic information should be detrimental for the invalid syllogisms, by illicitly restraining the search space* through an *"illusory recognition" of a dynamic deductive schema based on some of the provided information*. In comparison, *for the valid syllogisms having also more than one mental model, their effect should be rather a beneficial one* if they have an important cognitive function.

<u>*Differential prediction*</u>

In the *dynamic schema-based model*:

– ***A difference of performance for the syllogisms with more than one mental model*** *is expected to occur, in certain conditions,* ***especially in what respects the role of learning and of the semantic information from the premises***. It is predicted that *they should lead to a direct improvement of the syllogistic performance more for the valid syllogisms than for the invalid ones*.

– Syllogistic performance in usual circumstances should be ***favored by an intensional intensional or, especially, a mixed semantics***.

– ***A positive correlation between the level of argumentative experience (knowledge) and the performance only for the valid syllogisms should occur, in general***.

In the *mental models theory*:

– If knowledge and learning have indeed a role in generating counterexamples, they should lead ***more probably to a performance improvement for the invalid syllogisms than for the valid ones***. From the point of view or knowledge role, ***no difference is expected, generally, between the multiple model valid syllogisms and the invalid syllogisms***, no matter the context and the type of syllogistic task.

– Syllogistic performance in usual circumstances, in general, no matter the type of syllogism, should be ***favored exclusively by an extensional semantics***.

– ***No correlation***, or, at most, ***a positive correlation should occur between the level of performance for all the syllogisms, in general, no matter their validity***.

b) *The validity effect* *in the mental models theory vs. dynamic schema model*

The above mentioned differential predictions are important also in explaining the *general validity effect*: the performance is higher for the valid syllogisms in comparison with the invalid ones.

<u>*Mental models theory*</u>

It accounts for that effect using the fact that solely the valid syllogisms can be solved with one mental model. *Invalid syllogisms require always more than one model*.

<u>*Dynamic schema-based model*</u>

The effect is justified by the fact that *the cognitive importance of the valid syllogisms is greater than the cognitive importance of the invalid ones*.

<u>*Differential prediction*</u>

As there are valid syllogisms with more than one mental model, then it results that the two theoretical models could be assessed by comparing the results obtained in solving them with the results obtained in solving the invalid syllogisms.

In the framework of the *mental models theory*:

- it would be expected that *no such difference to occur*, no matter the context, as it was stated before, since the same number of models are required to be built in order to give a correct conclusion;
- *alternatively*, if the figural effect (the effect of the position of the middle term) is taken into consideration, then *the performance for the invalid syllogism should be higher than the performance for the valid syllogisms with more than one model*. The latter ones are almost exclusively figure 2, and especially, figure 3 syllogisms. But, in accordance with Johnson-Laird and Byrne (1991), due to the position of the middle term, for these two symmetric figures it is the hardest to build an initial model. The reason is that they require supplementary operations of switching the representa-

tion of a premise (in what respects the order of the syllogistic terms in the model) and the renewal of the interpretation of a premise in order to bring the two middle terms in contiguity. Consequently, for them, the frequency with which the answer "no valid conclusion" is given should increase, no matter if that answer is correct or not. For the valid syllogisms, that answer is an incorrect one and that is why their performance should be decreased. But for the invalid syllogisms it happens to coincide with the correct answer. So, the performance for the invalid figure 2 and figure 3 syllogisms should be increased. Therefore, it may be that the performance for them is higher than the one for the valid syllogisms having more than one mental model.

In the framework of the *dynamic schema-based model*:

- on the contrary, due to their higher cognitive function, it is expected, in favorable conditions, a *higher performance (a real one, not obtained by coincidence) for the multiple-model valid syllogisms than the one for the invalid syllogisms*.

***c) The figure effects** in the mental models theory vs. dynamic schema model*

The case of <u>*mental models theory*</u>

In the mental models theory**,** there are *three types of figure effects*, differentiated by their presumed causes:

1) the figure effect generated by the fact that the *percentage of the valid syllogisms with one mental model (and, correlatively, the percentage of the valid syllogism with more than one mental model) is notably different in the three syllogistic figures*. Therefore, the order of the difficulty for the three syllogistic figures should be: figure 1 < figure 2 < figure 3.

2) the *position of the middle term in the premises*. More operations are needed to build an initial model for the figure 3 than for the figure 2 syllogisms, and more for the figure 2 in comparison with the figure 1 syllogisms, respectively. Therefore, the order of the difficulty for the three syllogistic figures should be: a) figure 1 < figure 2 < figure 3 for the valid syllogisms, and b) figure 1 > figure 2 > figure 3 for the invalid syllogisms (because, when no model is built, the correct answer "no

valid conclusion is more probably given). Since there are more operations to be made in that respect for the figure 3 than for the figure 2 syllogisms, then it is expected that the figure 3 syllogisms to be the most difficult ones. But, although the Johnson-Laird and Bara's (1984, as cited in Johnson-Laird and Byrne, 1991) empirical results are invoked to support such a difference, their careful analysis reveals that it may not be that case. Indeed, there is a difference of performance in what respects the valid conclusions favoring the figure 2 syllogisms (35% in comparison with 22% for the figure 3 syllogisms). But, in what respects the percentage of the erroneous "no valid conclusion" responses, no significant difference occurs (it is 34% both for the figure 2 and figure 3 syllogisms), as it would have been expected if the initial model had been harder to be built for the figure 3 syllogisms. That expectation is based on the hypothesis that a "no valid conclusion" response is given when a failure in building an initial model occurs. In fact, even Johnson-Laird and Byrne (1991) seem not to expect such a difference since they do not make a difference between them when they state that the invalid figure 2 and figure 3 syllogisms alike are easier than the invalid figure 1 ones. On the other part, the cited difference in the case of the valid conclusions could be explained by the fact that there are more figure 3 syllogisms with more than one mental model than figure 2 syllogisms of this type.

There are some empirical findings that contradict the idea of the importance of bringing the middle terms into contiguity in order to explain the figure effects. Gamez and Marrero (2000) have shown in a series of experiments that causal-agency behavioral content biases the deductive process towards a pragmatic conclusion in opposition to the figural effect. Their conclusion is that "bringing the middle terms into contiguity is not a cognitive operation involved in the process of drawing a pragmatic conclusion".

3) *position of the extreme terms in the premises*, determining their order in the conclusion when it is freely generated. In what respects this third type of figural effect, mental models theory hypothesizes that it could be explained by a functional principle of the working memory:

"first in, first out" (Broadbent, 1958, Johnson-Laird & Byrne, 1991), In other words, the information that enters first in the working memory issues first. So, the extreme term that enters first in the working memory will be the subject in the resulted conclusion.

The case of the *dynamic schema-based model*

The *order of the performance is expected to be, in general, the same for the valid syllogisms, as the one predicted by the mental models theory*, both for the valid and invalid syllogisms.

A) The *first type of figure effect* is considered to be the *consequence of the*:

- *difference in what respects the importance of the cognitive function*s of the syllogistic figures (assumed to be positively associated with the stability of the corresponding dynamic reasoning schemas);
- *dynamic competition for actualization, dependent on context, between more or less stable syllogistic schemas that are similar in what respects the information needed to trigger their actualization*;

B) The *second and third types of figure effects* are accounted in the same way: *the similarity of the ordinal organization of the provided information with the ordinal organization of a syllogistic schema*. So, if both the middle term and the extreme terms occupy in premises the same position as in the required schema, they should facilitate the actualization of the correspondent dynamic syllogistic schema and, therefore, the performance. It is hypothesized that the temporal order of the syllogistic terms is particularly important only for the two versions of the figure 1 valid syllogisms (in which the position of the middle term is changed), since its syllogistic schema is very similar with a transitivity schema. The figure effects occurring for the other two syllogistic figures for valid syllogisms, or for all the figures of the invalid syllogisms are accounted instead mainly through their differential cognitive importance, and, respectively, by higher chances of "illusory recognitions" of inadequate schemas. The temporal order similarity may be important only to account for an increased chance that such "illusory recognitions" to occur.

Differential prediction

In the framework of the *mental models theory*:

– To my knowledge, there are *no specified predictions* regarding the conditions (nature of task, semantic content, and context) in which the predicted figural order of the performance could be changed.

– Still, it could be inferred that *if there are such conditions, the valid and invalid syllogisms of a syllogistic figure should be similarly affected*, in the same direction: positively or negatively

– There is no specified way in which the semantic information *could be differentially beneficial or detrimental in what respects the proper building of the mental models*. Changes could be expected, at most, if that semantic information influences the building of the mental models. In that that case, the figure 3 valid and invalid syllogisms should be the most advantaged, since they have the greatest number of syllogisms with more than one mental model and the greatest number of operations in building an initial model. But it is hard to determine hypothetically what kind of semantic information would promote a mental model building in the syllogistic reasoning.

– As it was discussed in the previous section, for the valid syllogisms, there should be a) no *differential correlation of the level of the argumentative performance* with the performance for a syllogistic figure, or b) *at most, a higher positive correlation with the performance for the figure 2 syllogisms, and, especially, with the one for the figure 3 syllogisms,* since they need more experience in building alternative models, having a higher proportion of multiple model syllogisms.

– There are *no specific predictions of the mental models theory regarding the figure effects within the class of the valid syllogisms with one mental model*, or, respectively, *within the class of the valid syllogisms with more than one mental model*. Still, in accordance with the mental models theory, it is *to be expected* that the *valid figure 1 syllogisms with one mental model should be easier than the valid figure 2 syllogisms of the same type*. In the same vein, it is expected that the *valid figure 1 syllogisms with more than one mental model should be easier than the valid figure2 syllogisms of the same type, and they, in their turn, should be easier than the valid figure 3 syllogisms with more than one mental model*.

In the framework of the *dynamic schema-based model*:

– It is expected that *there are exceptions* from the general order in what respects the difficult of the three syllogistic figures (for all of them, or within the valid, invalid, one model, or multiple model syllogisms), and that the figure effect might be *changed contextually*, by manipulating the factors that are able the influence differentially the different syllogistic dynamic schemas in the three syllogistic figures. Such factors are supposed to be, for example, the semantic information provided in the premises or a previous deductive task in which dynamic syllogistic schemas were actualized differentially (a case discussed in the following section, dedicated to the order effects)[41].

– It is expected that the level *of the argumentative experience to correlate differentially with the performance for the syllogisms of the three syllogistic figures*.

– The *more stable the dynamic schemas for the valid syllogisms of a certain syllogistic figure are, the more chances are that they are actualized "accidentally" for the invalid syllogisms, predominantly of the same figure, by "illusory recognitions*" (recruiting/constraining the interpretation of the information from the premises into their frame), leading to a wrong answer. Since it is assumed that the dynamic schemas should be the most stable for valid figure 1 syllogisms, then the most affected should be the invalid figure 1 syllogisms. The same reason holds for the cases of figure 2, and, respectively, figure 3 syllogisms.

d) The task format effects *in the mental models theory vs. dynamic schema model*

Until now, the syllogistic reasoning has been studied in only three main types of task formats, similar with the ones encountered in the logic handbooks. *For all the three types, the information of the two premises is verbally provided. They differ in what respects the required answer*. Some of them demand the truth assessment of a given conclusion, some

[41] If the semantic information is more similar in a particular context with the semantic information contained by the dynamic syllogistic schema of a type of syllogisms, then the performance for them may be boosted up in comparison with the one for other syllogisms that may have, generally, a more important cognitive function.

demand that the reasoner to generate by herself/himself a conclusion, and some demand that the reasoner to choose the correct conclusion out of a set of several possible alternatives.

But these types of tasks are not the most frequent formats of a syllogistic task that a person is likely to encounter in her/his daily experience, i.e. they are not ecological tasks. Most of the time people reason syllogistically in a different way. *They start with a conclusion and then they will find the premises that logically warrant its truth.* Usually, these premises are not even explicitated, and only the involved middle term, or only a premise is stated as an argument for that conclusion (as it is in an enthymeme). For example, such an argumentation would be "Mercury is a metal because it conducts electricity". Didilescu and Botezatu (1976) sustained also that this is the natural thinking stream in the syllogistic reasoning. In their opinion, beginning with Aristotle, to reason syllogistically has meant to find the middle term, the one that mediates the relation between the two given extreme terms.

In its standard version, *mental models theory* does not provide procedures for finding the answer for such a task format, since in its case the idea of an initial model obtained by integrating the models built for premises does not make any sense. The theory is built on the assumption that the reasoning proceeds from premises to the conclusion. However, some authors (Morley et al., 2004, as cited in Stupple & Ball, 2007) have proposed a version of the mental models theory in which the reasoning process can start from the conclusion toward premises. The assumed purpose is to find out a mental model of the premises that is compatible with the model of the conclusion. Such kind of process is supposedly involved especially in the task format in which a given conclusion is assessed. However, this distinction has been contested based on empirical findings (Stupple & Ball, 2007).

Instead, the performance in such an ecological task could be naturally interpreted in the *dynamic schema-based model* as a process of pattern completion, too, but one in which more information misses. That is why this process would be more similar with a memory recall task based on a given clue than with a recognition task, as it is in the traditional format. Therefore, the *performance in such a task is expected to be lower than in a traditional task. Only the most stable deductive dynamic schemas would be actualizable*, presumably those of the valid figure 1 syllogisms. Such a task has the advantage that decreases the probability that a correct answer to be given by chance, as it is the case for the traditional format.

f) ***The order effects*** *in the mental models theory vs. dynamic schema model*

The order effects considered in the deductive reasoning research, in general, as well as in the syllogistic reasoning research, in particular, are almost exclusively the ones related with the temporal order of the information from the premises. As it was shown before, in a previous section, in the syllogistic research that temporal order was used to explain figure effects. I am aware of only one exception, a research carried out by Hawkins, Pea, Glick, and Scribner (1984), in which a changed temporal order of three successive syllogistic tasks with a different semantic content has lead to different results in what respects their performance. Investigating the syllogistic ability of the preschool children (4-5 years old), they used three kinds of syllogistic problems having a different content: fantasy problems (with no link with the experience and knowledge), congruent problems (with a content congruent with the actual experience), and incongruent problems (with a content incongruent with the actual experience). The order in which the three types of syllogistic problems were presented was changed, resulting three types of sequences. Hawkins et al. (1984) have found an order effect linked with the three types of sequences, in the sense that the temporal context acts as a setting condition that influences the interpretation of the task requirements. The initial presentation of the congruent or incongruent problems would determine a set that "tends to elicit empirically biased reasoning". But when fantasy problems were presented first, the children "could use unfamiliar information in premises in deductively correct ways and used some different response strategies than the other groups of children in the remainder of the task."(Hawkins et al., 1984, p. 592).

In a _dynamical theoretical framework_, order effects of the above mentioned type are expected to occur as natural consequences of its fundamental assumptions. It is expected that such effects should occur when the previously presented information *brings the underlying dynamic system closer to or further away from the state space region associated with a deductive schema* involved in a syllogistic task. Such order effects are expected to be not only general, but *to be differentially beneficial or detrimental for different types of syllogisms*.

In comparison, _mental models theory_ predicts nothing in this respect. The reason may very well be that in its standard theoretical framework there is no way to justify a prolonged effect of building a particular mental model for a syllogism, as mental models are ad hoc representations that supposedly totally vanish after a conclusion is generated.

g) ***The individual differences effect*** *in the mental models theory vs. dynamic schema model*

There is relatively little research for the effect of some personality (attitudinal or aptitudinal) traits or other stable individual differences on the syllogistic performance. The most important studies of that kind are those of Stanovitch and West (2000). No integrated theoretical account was given for the obtained empirical findings showing significant associations between such individual traits and the syllogistic performance.

Although in the _mental models theory_ it is assumed that the syllogistic ability is linked with some individual differences such as the *working memory span, flexibility, ability to maintain simultaneously representations for contradictory information* (Buciarelli & Johnson-Laird, 1999), not very much has been done in order to document these assumptions. A reason for that may be the fact that such relations with the personality traits seem to have a peripheral importance for this theory.

In a _dynamic approach_ of the syllogistic reasoning such individual differences effects are expected, too, but *they receive a more fundamental theoretical grounding*. Assuming that the deductive reasoning processes are essentially dynamic ones, and that they are dynamically coupled with the entire psychological system and with it subsystems, it follows that the states of those systems should have an influence on their dynamics. *Personality traits might be like order parameters* describing at a level with a reduced dimensionality the behavior of the subjacent dynamic system. They might be also control parameters for the subordinate dynamic systems. Therefore, *individual differences are assumed to be like control parameters for the assumed dynamics of the syllogistic processes*.

XII. Conclusion

The proposed dynamic model of the deductive processes was conceived at three levels.

1) The *general level*: Deductive processes are assumed to imply the evolution in time of several interacting dynamic variables linked with the meaning of the syllogistic concepts and judgments. Deriving a conclusion is seen as a process of completing an abstract dynamic pattern (dynamic deductive schema) that synthesizes the experience with a class of argumentative experiences having a common cognitive goal.

2) The *intermediate level*: The general types of deductive schemas (spatio-temporal, pragmatic, or combinatorial) are specified based on the general level of abstractness of their characteristic cognitive goals. They are assumed to be emergent on different levels of organization of the subjacent dynamic structures and to be in permanent interaction from this reason. Several expected dynamic effects and phenomena are stipulated: content, order, task format effects, stabilizing and destabilizing factors.

3) The *particular level*: Particular models were elaborated for the conditional and syllogistic reasoning in the case of the reasoners without training in formal logic, by specifying the possible cognitive functions of theirs various types and of the semantic content of their assumed deductive schemas.

Partial empirical validation of the dynamic schema-based model on the syllogistic reasoning case

In order to check some of the predictions of the proposed general dynamic schema-based model in what respects the expected type of effects enumerated previously, I carried out a series of empirical studies. In the same time, these studies are aimed to verify some of the presumed relationships from the dynamic schema-based model of deductive reasoning in the particular case of the syllogistic reasoning.

The investigated relationships from the scheme presented in figure 1

1. *Autonomous style of thinking – the level of performance for a specific type of syllogisms – the level of stability of a dynamic syllogistic schema*

Learning effects and individual differences effects are intended to be investigated indirectly studying this relationship.

a. It is expected that *an autonomous style of thinking* (through its social interaction style and its cognitive subcomponent of learning specific reasoning skills) measure to *correlate positively with the performance for valid syllogisms independently of the general intellectual ability, and the level of motivation for autonomy,* indicating that such a thinking style is associated with a separate deductive competence.

b. In order to get evidence suggestive in what respects the source of the above-mentioned deductive competence[1], *the relationship between the main types of syllogisms* (valid or invalid, of different syllogistic figure) and *the level of autonomous thinking* was studied. In that respect, a series of predictions were made:

A. It was expected that the association between the level of autonomous thinking measure and the syllogistic performance (accuracy) to vary with the type of syllogisms. A significant positive association would suggest either that there are specific innate syllogistic competences promoting an autonomous thinking or simply co-occurring with such a style of thinking, or that specific syllogistic competences were acquired through learning, by encountering the correspondent specific types of experiences favored by an autonomous style of thinking.

B. If the latter alternative is the case, then a higher association between the measure of the autonomous thinking and the performance for a certain type of syllogisms is assumed to indicate a higher frequency of encountering argumentative experiences (learning opportunities) linked with the specific deductive competence acquired through learning to solve that type of syllogisms.

C. The level of association between the autonomous thinking measure and the performance for a certain type of syllogisms is presumably indicative for the level of basic stability of the assumed correspondent dynamic syllogistic schema. The supposition is made considering two other assumptions:

− In accordance with the connectionist theory, learning increases the level of stability of an emerged dynamic structure with representational properties in the state space.

− A dynamic structure (named dynamic syllogistic schema) emerges by encountering a class of argumentative experiences.

D. Assuming that the different types of syllogisms have different levels of cognitive importance based on the level of informativeness of their conclusion, a positive association should occur between the cogni-

[1] In other words, the problem is if that deductive competence is at least partially acquired through learning by encountering specific types of argumentative situations and through the emergence of deductive schemas centered on characteristic cognitive goals.

tive importance of a type of syllogisms and the frequency of the learning experiences that are important for the emergence of particular syllogistic skills for that type of syllogisms.

E. It is expected a positive association between the level of relationship between the autonomous thinking measure and the performance for the considered types of syllogisms (presumably indicating the level of opportunities for learning their solving) and the level of cognitive importance ascribed to those types of syllogisms. Such an association would support the hypothesis that the cognitive function of a type of syllogisms is associated with the level of learning to solve that specific type of syllogisms. So, in the hypothesis that learning contributes to emergence of deductive schemas, those schemas are associated with cognitive goals having different levels of pragmatic importance.

2. *Level of the basic stability of a deductive schema acquired trough learning – reduced quantity of specific information, resistance at the destabilizing effects of noise, winning of the competition with other deductive schemas, reduced sensitivity to the particular context of a deductive task – variation of the context and content of the deductive task – level of stability in the performance of a type of syllogisms correspondent to that dynamic schema*

Content effects, task format effects, figure effects, and order effects are all important in the investigation of this relationship. The rationale of its exploration is based on a series of intervening relationships, hypotheses and predictions.

The intervening relationships are: *variation of the context and content of the deductive task – variation of the quantity of specific and unspecific (irrelevant) information involved in the actualization of an assumed dynamic deductive schema – variation of the performance for a type of syllogism presumed to be associated with that dynamic deductive schema – level of cognitive importance ascribed to that type of syllogism – level of basic stability of the dynamic syllogistic schema having that cognitive function*

The predictions are:

– it is expected a differential variation (degree of constancy) in the level of performance for different types of syllogisms obtained by varying the context of solving a syllogistic task (temporal context, task format, semantic content);

– it is expected that the level of stability (correlatively, of variation) in the performance for a type of syllogisms to be positively associated with the ascribed level of its cognitive importance, assuming that that level of cognitive importance is positively associated with the basic stability of a presumed correspondent dynamic syllogistic schema.

3. *Level of the basic stability of a deductive schema acquired trough learning – winning of the competition with other deductive schemas – level of performance of a deductive task*

In order to investigate these relationships *learning, validity/figural effects, individual differences effects, and order effects* were useful.

Its exploration was based on the following predictions:

– It is expected a *negative association between the average performance for valid syllogisms of a certain type (having ascribed the same level of cognitive importance) and the average level of performance for invalid syllogisms of the same type.* The reason for this prediction is based on the following assumptions. Since there are no stable deductive schemas for invalid syllogisms, the chances that a competing dynamic deductive schema of a valid syllogism, actualizable based on a figure similarity, for example, to win the competition are increased. So, an incorrect answer will be given for the invalid syllogism, when, otherwise, the more probable guessed correct answer would have been: "no valid conclusion". But the chances that the dynamic schema of a correspondent valid syllogism to be wrongly actualized are increased when that schema has an increased basic stability. And that basic stability is supposed to be associated with the level of cognitive importance and, correlatively, with the syllogistic figure.

– It is expected that the *above mentioned association to be more salient in experimental conditions that favor the actualization of the assumed dynamic deductive schemas* (increased similarity of content, preceding task with increased similarity content). Also, it is expected *a higher performance in what respects the invalid syllogisms for syllogistic tasks that do not favor the actualization of the involved dynamic syllogistic schemas of the valid syllogisms in comparison with that performance for syllogistic tasks that favor the actualization of the involved dynamic syllogistic schemas of the valid syllogisms*.

– It is expected a *negative association between the level of autonomous thinking measure and the performance for invalid syllogisms*. The level of this correlation should be inversely proportionally related with the level of cognitive importance ascribed to their syllogistic figure. This prediction is based on three assumptions. The first one is that the basic stability of a valid dynamic syllogistic reasoning is supposedly associated with the level of autonomous thinking. The second one is that the more stable is a dynamic deductive schema, the more chances are for it to win the actualization competition with other deductive dynamic schemas. A final assumption is that the basic stability of a schema of a syllogism is positively related to its ascribed level of cognitive importance.

– It is expected *that the above mentioned negative association to be dependent on the level of the general intellectual ability*. The prediction is based on the assumption that the level of learning by encountering a class of argumentative opportunities on the stability of a corresponding syllogistic schema is mediated by the level of general intellectual ability. The higher the intellectual ability, the more stable should be the dynamic deductive schema emerged based on the same level of specific argumentative experiences.

– It is expected that *the performance for a syllogism of a syllogistic figure associated with a low level of cognitive importance to be detrimentally affected by the solving of a preceding syllogism of a different syllogistic figure, with a higher ascribed cognitive importance, which has the same types of judgments as premises*.

4. *The average level of stability of the subordinate patterns from which the dynamic deductive schema emerged by learning – the average performance in a syllogistic task*

In order to investigate such a relationship, the *individual differences effects* are relevant. The average level of stability of the subordinate patterns from which the dynamic deductive schema emerged by learning is considered to be like a control parameter governing the basic stability of an emerged syllogistic schema. The level of performance in a deductive task will be influenced trough this basic stability of the corresponding dynamic deductive schema.

The specific prediction is:

– It is expected a *nonlinear relationship between the average level of stability of the subordinate patterns from which the dynamic deductive schema emerged by learning and the average performance in a series of deductive tasks*. The maximum level of performance will be for an intermediate level of stability of the subordinate patterns. The theoretical argumentation for such a prediction was presented in a previous section, the one in which the general model was presented.

The investigated relationships from the scheme presented in figure 2

1. *Higher level of similarity* between the *semantic information contained in the premises* and the semantic information contained in the adequate dynamic deductive schema – increased chances for an *actualization and maintenance of the adequate dynamic deductive schema* – *higher expected performance* in a deductive task

These relations were studied investigating mainly the *content effects and task format effects.*

A. Content effects

Four ***types of contents*** *were used in the current series* of empirical studies. The type of content was reflected in the way the judgments involved in the syllogistic task were formulated, providing different semantic information, at *different levels of abstractness*, and of *similarity* with the kind of semantic information assumed to be contained in the considered dynamic syllogistic schemas.

Therefore, syllogisms have four types of formulation of their judgments:

– **Abstract traditional with a pure symbolic format (N)**, in which the syllogistic terms were noted with the symbols: S. P (for the two extreme terms), and M (for the middle term). It is considered to be *rather a neuter kind of formulation, with a maximum of ambiguity in what respects the semantic clues needed for the actualization of different types of dynamic syllogistic schemas.*

– **Abstract with a symbolic format and supplementary logical semantic information (L)**, in which the syllogistic terms were noted by symbols as in the traditional formulation, and the abstract logical semantic information consisted in specifications of the logical status of the syllogistic terms (*individual case, subclass, class, or property*) and of their relationship (*intensional*: between the members of a class and a property, or *extensional*: between members of two classes). The specifications were made in accordance with the demands of the mixed semantics interpretation (intensional-extensional) of the syllogism proposed by Didilescu and Botezatu (1976).

A) For the **figure 1 syllogism**:

- *first premise* is intensional (relationship between a category and a property)
- *second premise* is extensional (relationship between an individual or subcategory and a category)
- *conclusion* is intensional (relationship between an individual or subcategory and a property).

B) For the **figure 2 syllogism**:

- *first premise* is intensional (relationship between a category and a property)
- *second premise* is intensional (relationship between an individual or subcategory and a property)
- *conclusion* is extensional (relationship between an individual or subcategory and a category).

C) For the **figure 3 syllogism**:

- *first premise* is extensional (relationship between an individual or subcategory and a category)
- *second premise* is intensional (relationship between an individual or subcategory and a property)
- *conclusion* is intensional (relationship between a category and a property).

– **Concrete centered on attributes (A)**, in which the linguistic formulation of the syllogistic terms is assumed to favor their *interpretation as attributes (properties), and their relations as intensional ones*.

– **Concrete centered on classes (C),** in which the linguistic formulation of the syllogistic terms is assumed to favor their *interpretation as classes, and their relations as extensional ones*.

The following **general predictions** were made:

– It is expected that the performance for all valid syllogisms to be higher for a syllogistic task of the **L** type than the one for a task of the **N** type. Instead, the performance for all invalid syllogisms should be higher for a task of the **N** type than the one for a task of the **L** type, assuming a lost competition with the dynamic schemas of the similar valid syllogisms.

– It is expected that the performance for all valid syllogisms to be higher, in general, for a syllogistic task of the **A** type than the one for a task of the **C** type. However, it is to be expected that there is no such difference for the figure 2 syllogisms, dependent on the type of task.

B. <u>Task format effects</u>

Two *types of task formats* were used in the current series of studies

– **A traditional format task** with *two given premises*, and the answer to be chosen from five alternatives (the four types of judgments having the extreme terms in the same order, and the "no valid answer"). It was symbolized with **PPC**.

– **A "natural" format task** with a given conclusion, and the two premises to be found by choosing each one from its correspondent set of eight judgments, representing all the possible combinations with the two corresponding syllogistic terms (one of the extreme terms and the middle term). It was symbolized with **CPP**.

The following *prediction* was made:

- The performance should be higher for the **PPC** task than for the **CPP** task, given that the quantity of given information and the chances for guessing are higher in the **PPC** task than in the **CPP** task.

2. *No competing stable dynamic deductive schemas were recently actualized* – increased chances for an *actualization and maintenance of the adequate dynamic deductive schema* – *higher expected performance* in a deductive task

These relations were studied mainly in the form of the *order effects*.

The following *predictions* were made:

– It is expected that *the performance for an **A** task to be lower when it is preceded by a **C** task than when it is not*, given that the dynamic deductive schemas actualized by an **A** task compete with the dynamic deductive schemas actualized by a **C** task.

– It is expected that the *performance of a syllogism of a figure associated with a low level of cognitive importance to be detrimentally affected by solving a preceding syllogism of a different syllogistic figure*, with a higher ascribed cognitive importance, which has the same types of judgments as premises.

3. *Recent actualization of the same deductive schema* in a previous deductive task - increased chances for an *actualization and maintenance of the adequate dynamic deductive schema - higher expected performance* in a deductive task

These relations were studied mainly in the form of the *order effects*.

The following *predictions* were made:

– It is expected that the *performance with a **C** task to be higher when it is preceded by an **A** task than when it is not*, given that the dynamic deductive schemas actualized by an **A** task facilitate (by cooperation, through a phenomenon like priming or of mind set) the actualization of the adequate dynamic deductive schemas in the **C** task.

– It is expected that *the performance at a **PPC** task to be higher when it is preceded by a **CPP** task than when it is not*. There are several reasons for this prediction. In a CPP task, the cognitive functions of the syllogisms having stable deductive schemas are assumed to be more salient. Therefore, a dynamic deductive mental set is presumed to emerge. By cooperation, through a phenomenon like the conceptual priming, the actualization of the adequate dynamic deductive schemas in the **PPC** task should be facilitated.

Methodological considerations

1. The **main objective**

The main objective of the empirical research was *the prediction of the effects of a certain task format, content, argumentative context or individual difference on the performance of a deductive task*, rather than a post facto explanation of some obtained frequencies of the correct and incorrect answers, without paying much attention to the conditions in which they were obtained. Such a methodological strategy can be encountered occasionally, in the deductive reasoning research, but without a systematic and principled grounding.

2. Inherent **difficulties in the deductive reasoning research**

– *Deductive tasks*, especially those in a formal format, are *notoriously difficult for the majority of the people* who do not have special training in logics.

– *The level of motivation in completing deductive tasks and in respecting the given instructions* is rather low.

– It is *hard to find people willing to complete such tasks voluntarily, especially when their completion takes a lot of time*. That is why a lot of studies from the deductive reasoning research have rather small samples of subjects. I had, too, an extremely limited access to subjects, particularly for testing them for time intervals longer than two hours.

3. The **general design of the present empirical research**

Given the above mentioned difficulties, I chose a general strategy with several studies with small samples of subjects, in which several hypotheses were tested, instead of a strategy with only one or two experiments with larger samples of subjects, testing a lower number of hypotheses. Furthermore, in the same time, some of the tested hypotheses were double checked in multiple studies in different experimental conditions, with the purpose to secure the consistency of the findings not by a large sample, but by their constancy in different small samples.

4. **Conclusion**

Maybe, taken separately, the individual studies do not provide strong enough evidences, because of the methodological difficulties that have occurred as a result of many pragmatic constraints. But my opinion is that, together, they are building a case for a dynamic schema-based model for syllogisms, with results that could be extended in order to support a dynamic schema-based model for deductive reasoning, in general. It is to be noted, also, that it is highly improbable that it could be proved beyond any doubt, purely through experimental methods, that mental representations exists in a certain format, specifically in a dynamic one, as in the present case. Empirical data obtained through such experimental methods could be useful only to bring support and incline the balance towards one alternative over the other. As it is known, it is not possible to definitely prove a theory, but only, at most, to falsify its current version (Popper, 1981).

Study 1

I. Purpose and hypotheses

Purpose

The main objective of this study was to reveal the *assumed individual differences effects* concerning two of the general personality traits included in the diagram presented in the Figure 1: autonomous thinking and general intellectual ability, by investigating their association with the syllogistic performance. In this study, there were also explored indirectly the assumed learning effects for the syllogistic performance through the expected individual differences effects and their hypothetical link with the level and type of the argumentative experiences of a reasoner.

The secondary objective was to document the occurrence of *validity effects* (mainly regarding the difference between the performance for valid multiple model syllogisms and the performance for invalid ones), and *figure effects* that are also relevant in the context of the comparison of the proposed model for the syllogistic reasoning with the mental models theory.

Preliminary comments

Definition for autonomous thinking

Autonomous thinking is shortly defined here as a complex personality trait having two interrelated components: a cognitive one, and an attitudinal-motivational one. It is conceived like an interactional style of thinking, expressing a tendency/preference of a person to gather and process independently the information needed in order to attain her/his goals and solve problems, without the undue help or the interference of others, being aware that she/he has the resources to do this by herself/himself. Plainly speaking, it is a trait of the persons who like, are willing to make the effort, have faith that they have the needed resources and are able to solve problems, make decisions and evaluations, form opinions by themselves, by using their personal thinking abilities (see for details Faiciuc, 2004). At a social behavior level, these persons tend to be assertive, defending their conclusions, their judgments, and resisting to external influences intended to persuade them to change their mind if those influences are assessed by them as unconvincing. The cognitive component of the autonomous thinking is referring mainly to the available cognitive and metacognitive resources, which offer the foundation on which autonomous thinking is built. It includes: general intellectual ability, general learning ability, specific thinking and reasoning skills, working memory span etc. At the metacognitive level, there are placed the ability to reflect upon and to assess the level of the personal cognitive resources and its relationship with the ability to attain the desired goals. The attitudinal-motivational component includes: a) the value attributed by a person to an autonomous thinking and the respect for the truth that justify the effort invested into the goal of having such a style of thinking; b) a presumed fundamental need for autonomy that brings a feeling of satisfaction in pursuing it (Deci & Ryan, 1995); c) a need to succeed in thinking tasks (presumably linked with the success obtained previously in such task) expressed by a more intense effort and a longer time dedicated to them; d) the level of self-confidence, self-efficacy etc. As it is the case in general, the two components are logically interrelated. On the one hand, an innate need or/and the adopted high value of the autonomous thinking as a goal lead to efforts to improve the needed personal cognitive resources and place a person into situations in which she/he uses those resources or in which it is necessary to defend her/his autonomy. On the other hand, the awareness of the availability of the needed cognitive resources in order to attain the desired goals encourages a person to think autonomously, brings her/him self-confidence, and the feeling of satisfaction that it is competent, valuable as a person.

The link between the autonomous thinking
and the syllogistic performance

Although it is hard to disentangle the two components, it is reasonable to assume that a person with a higher level of autonomous thinking should have a higher desire to improve her/his reasoning skills, inclusively the deductive reasoning skills. Also, she/he inevitably may have encountered more frequently situations in which she/he was constrained to use those skills, in order to attain a goal or to defend a personal position. Therefore, it is presumed that the level of autonomy in thinking should be positively linked with the level of the argumentative experiences needed in order to learn deductive skills, inclusively syllogistic skills. Assuming that that learning involves, in a dynamic interpretation, the emergence of dynamic structures centered on specific cognitive goals, named here dynamic deductive schemas, which have a basic stability that depends on the level of learning, then, it should be expected, in general, a positive association between the level of autonomous thinking and the performance in deductive tasks, at least or particularly in those tasks for which pragmatic deductive schemas are likely to be developed.

In the case of the level of the motivational component of the autonomous thinking, it expected that its positive association with the syllogistic performance should hold for any deductive task, because it is linked with an increased effort to complete correctly that task, no matter the available resources. In the theoretical frameworks that assume general deductive mechanisms (mental logic or mental models theories), this prediction should be valid without exceptions. In a dynamic model instead, where the deductive performance depends more on the particular experiences with certain types of deductions or on context, exceptions are possible. For the cognitive component of the autonomous thinking, its part linked with general intellectual abilities should lead to a positive association between the level of autonomous thinking and the performance in any deductive task. But its part linked with the specific deductive skills developed through learning should lead to a positive association of the level of autonomous thinking only with those deductive tasks that are related more tightly with argumentative experiences likely to be encountered in one's daylily or professional life. In fact, at the level of specific deductive skills, the two components of the autonomous thinking are the most intricate, since learning is promoted by motivation. But the encountered experiences make that the effect of the motivation component of the autonomous thinking to be in this case differential. Moreover, the presumed effects of the learning of specific deductive skills are assumed to be modulated by the component referring to the general intellectual abilities. In other words, less argumentative experience may be needed to learn specific deductive skills at a certain level of proficiency for those with a higher level of nonverbal intelligence than for those with lower levels.

The rationale for choosing measures of the autonomous thinking as a personality trait and of the general intellectual ability for studying the assumed learning effects in the performance of syllogistic reasoning

Since the goal of the present work was to investigate the usual syllogistic reasoning of the persons untrained in formal logic, or who have no experiences in that respect given their professional activity (centered on pragmatic syllogistic schemas), I was interested to indirectly find out what kind of deductive experience may be obtained through learning in the conditions of a normal life. That information was important in order to determine the general pragmatic importance of different types of syllogisms, and to see if that pragmatic importance is linked with a) their cognitive importance ascribed based on the informativeness of their conclusion, and b) with the effects indicating the level of stability of the assumed dynamic deductive schemas through the level and the context dependency of a specific syllogistic performance.

That is why it was important that learning effects to be explored not only in specific learning experiences (offered by a special training, by a special education or professional activity), but also in the context of the general available argumentative experiences. A special domain of activity requiring a high level of deductive skills is assumed to distort the general pragmatic importance of the different types of syllogisms and it would involve the development of new types of dynamic syllogistic schemas, competing with the usual ones (and, thus, changing the syllogistic processes).

It is extremely difficult to assess directly the usual level of argumentative experiences relevant for developing deductive reasoning skills for a person untrained in formal logic. Difficulty resides, in the first place, in obtaining a representative sample of such relevant experiences and, then, an assessment instrument for them that could be easily applied. In the second place, giving reasoning tasks, in order to check the level of previously encountered argumentative experiences, leads to a circular undertaking, since the purpose was to investigate the association between those argumentative experiences and the performance in reasoning tasks.

Therefore, I had to use an indirect measure in that respect. In my opinion, it is reasonable to believe that the trait of autonomous thinking incorporates in itself, implicitly, a component representing simultaneously a) the level of argumentative experiences to which a person is likely to be exposed through having such a trait, and b) the level of learning of specific syllogistic skills based on those experiences and on her/his motivation and ability to learn from them. Therefore, having at my disposition acceptable instruments for measuring autonomous thinking that can be administered easily, I chose them as indirect self-report measures of the level of argumentative experiences. One of them is centered on measuring predominantly the motivational component of the personal autonomy, the other one includes also, more saliently, the cognitive component through its manifestation at a behavioral level.

The measures used for the motivational component of the personal autonomy and for the general intellectual ability were thought to be useful in separating the part of the autonomous thinking linked specifically with the learning of particular reasoning skills. They had to be taken into consideration because the two variables could be confounded variables in what respects the assumed association between the level of argumentative experiences (measured indirectly through a personality questionnaire measuring autonomous thinking) and syllogistic performance. Also, the general intellectual ability is assumed to be a moderator variable in what respects the relationship between the assumed level of encountered argumentative experiences and the level of learning specific deductive skills (and implicitly the level of performance in syllogistic tasks).

Concluding comments

The study was correlational in nature. The important variables were:

- The *level of autonomous thinking*, measured with the autonomous thinking scale (AT scale) of the A/H questionnaire (elaborated by Monica Albu, Ioan Berar, Dragoş Cârneci, Cîmpian Erika, Lucia Faiciuc, Florea Marius, and Elena Geangu);
- The *level of motivation for autonomy*, measured with GCOSA, the Autonomy Orientation scale of the General Causality Orientations Scale (Deci & Ryan, 1995);
- The *level of general intellectual ability/nonverbal intelligence*, measured with the Raven Standard Progressive Matrices;
- The *level of syllogistic performance,* measured with a syllogistic task with 24 items;
- The *level of argumentative experiences* hypothetically operationalized through the level of autonomous thinking indicated by the AT scale.

Hypotheses

Main hypotheses

1) It is expected a positive partial correlation between the scores obtained for the autonomous thinking scale (AT scale) of A/H and the correctness for valid syllogisms, the controlling variables being the scores for Raven test and for GCOSA.

2) It is expected a negative partial correlation between the scores obtained for the autonomous thinking scale of A/H and the correctness for invalid syllogisms, the controlling variables being the scores for Raven test and for GCOSA (assuming that for a neuter abstract symbolic task, the average stability of the actualized syllogistic schemas is not able to promote the necessary distinction between the similar valid and invalid syllogisms).

3) It is expected a higher average correctness for the valid syllogisms with more than one mental model than the average correctness for the invalid syllogisms.

Secondary hypotheses

1) It is expected a positive association between the scores obtained for GCOSA and the scores obtained for the autonomous thinking scale of A/H.

2) It is expected a positive association between the scores obtained for Raven test and the scores obtained for the autonomous thinking scale of A/H.

3) It is expected a positive association between the scores obtained for Raven test and the correctness of syllogisms, no matter of their type.

4) It is expected a significant correctness difference between the valid syllogisms of the three syllogistic figures; the presumed order of their correctness would be: figure 1 > figure 2 > figure 3 (given the assumed order of their cognitive importance).

5) It is expected a correctness difference between the invalid syllogisms of the three syllogistic figures; the presumed order of their correctness would be: figure 3 > figure 2 > figure 1 (given the assumed chances of confusions through the inadequate actualization of the pragmatic deductive schemas for the similar valid syllogisms).

II. Method

Participants

Forty-eight (48) high school students of 10th grade, with an average age of 16 (29 girls, and 19 boys), having an elementary training in formal logic completed both the syllogistic reasoning task and the A/H questionnaire. Only forty-one (41) of them completed also the Raven test (standard version), and thirty-five also GCOSA questionnaire. The syllogistic task and all the three psychometric instruments were completed by 29 students.

Materials

– A *traditional syllogistic reasoning task* (see Annex 1) with neuter abstract symbolic content named syllogistic task of type **N**. Two premises are given and the task is to choose the correct answer from five given alternatives (the four types of judgments: A, E, I, O, with the extreme terms in the same order, and "no valid answer"). The order of the alternatives was the same for all syllogisms. The task includes 24 syllogisms: 12 valid syllogisms (having a valid conclusion), 12 invalid (not having a valid conclusion). They are ordered in such a way that no regularity exists in what respects the succession of the valid and invalid syllogisms. Of the 24 syllogisms, eight (8) are figure 1 syllogisms, eight (8) are figure 2 syllogisms, and eight (8) are figure 3 syllogisms. The syllogisms of the same figure are presented together, in blocks, in the following order: figure 1, figure 2, and figure 3. Of the 12 valid syllogisms, six (6) are one model syllogisms (AA1A, AI1I, EA1E, AE2E, EA2E, AI3I, corresponding to the items 1, 3, 5, 10, 13 and 19 from the syllogistic task), and six (6) are multiple model syllogisms (the remaining valid syllogisms). Of the eight figure 1 syllogisms, three (3) are one model syllogisms. For the figure 2 syllogisms, two (2) are one model syllogisms, and for the figure 3 syllogisms, one (1) is a one model syllogism. The syllogisms were presented in the same order for all the subjects.

– *Raven Standard Progressive Matrices* (standard version), shortened here as Raven test.

– *The Autonomous Thinking (AT) Scale (with 21 items, see Annex 2) of the Questionnaire for Personal Autonomy A/H* (elaborated by Monica Albu, Ioan Berar, Dragoş Cârneci, Cîmpian Erika, Lucia Faiciuc, Florea Marius, and Elena Geangu). Psychometrical data indicate an acceptable level of internal consistency of the entire questionnaire for a sample of over 300 high school students (Albu, 2007). The autonomous thinking scale has the highest level of internal consistency (Albu, 2002).

– *The Autonomy Orientation scale of the General Causality Orientations Scale (17 items, see Annex 2): GCOSA* (Deci & Ryan, 1995), adapted for high-school students. A previous study (Faiciuc, 2005) on 81 high-school students indicated a high internal consistency (Cronbach's alpha value was 0.8599, higher than the one reported by Deci and Ryan for a sample of adults: 0.744).

Procedure

The task and the three psychometric instruments were administrated in the same session, with no time limit. The syllogistic task was administrated individually, on the computer, using the MediaLab program, without a training phase. It was preceded by a written instruction in which it is explained what is a syllogism by using an example and what it means to infer a valid necessary conclusion. The two premises were simultaneously presented.

III. Results

The chosen statistical significance threshold was of $p = .05$.

Almost all the variables involved in the study had an asymmetrical distribution, departing significantly from the normal distribution. Appling the Kolmogorov-Smirnov test of normality, the following values were obtained:

- for AT scale: 0.092, $p = .200$
- for Raven test: .219, $p = .000$
- for GCOSA: .170, $p = .02$
- correctness of valid syllogisms: .132, $p =.035$
- correctness of invalid syllogisms: .170, $p = 001$

Because the distribution of almost all the measured variables was asymmetric, and since the sample is relatively small, with few exceptions, nonparametric statistical tests and correlation coefficients were used.

The statistical values for the main variables involved in the study are found in Table 2 from Annex 3.

No significant gender differences occurred.

Results regarding the secondary hypotheses

1), 2) The following rank correlations between the *two questionnaires and the syllogistic task* were obtained:

- Spearman correlation coefficient for *GCOSA scores* and *AT scale scores* was: $\varrho = .414$, ($p = . 008$, one-tail);
- Spearman correlation coefficient for *AT scale scores* and *Raven test scores* was: $\varrho = .304$, ($p = . 288$, one-tail).

No significant association was obtained between *GCOSA scores* and *Raven test scores*.

3) In what respects the *correlations between the Raven test score and several syllogistic performance scores*, the present results indicate that, as it was expected, Raven scores correlate positively significantly with the correctness of both valid and invalid syllogisms ($\varrho = .594$, $p = . 000$, for the valid syllogisms, and $\varrho = .320$, $p = .014$, for the invalid syllogisms).

Analyzing the association of the Raven test sores with the correctness for the syllogisms of every syllogistic figure, the results indicated that only for the figure 3 syllogisms (no matter if they are valid or not) a significant positive association was not obtained (see Annex 4a).

4) Comparing the *correctness of the valid syllogisms for the three syllogistic figures*, using the Wilcoxon test, the following results were obtained:

- There was no significant difference of correctness between the figure 1valid syllogisms in comparison with those of figure 2.
- There was a significant difference of correctness between the figure 2 valid syllogisms in comparison with those of figure 3: $z = -4.928$, $p = .000$, the level being higher for the figure 2 valid syllogisms.
- There was a significant difference of correctness between the figure 1 valid syllogisms in comparison with those of figure 3: $z = -4.78$, $p = .000$, the level being higher for the figure 1 syllogisms.

So, the order of their level of correctness was figure 1 = figure 2 > figure 3.

5) Comparing the *correctness of the invalid syllogisms for the three syllogistic figures*, using the Wilcoxon test, no significant difference between them was obtained.

6) Applying the Wilcoxon test, there was a significant difference between the correctness for valid syllogisms and the invalid ones ($z = -3.674$, $p = .000$), as it was expected, in accordance with what it is known in this respect: the correctness was higher for the valid ones.

Results for the main hypotheses

Since partial correlation is a parametric association measure, and almost all the variables involved in the study had an asymmetrical distribution, its use in what follows is considered to have only an exploratory value.

1) The *partial correlation between the AT scale scores and the correctness for the **valid** syllogisms*, controlling for the variables measured with Raven test and GCOSA (general intellectual ability, and the motivational component of the autonomy) was positive and significant: $r = .443$, $p = .007$, as it was expected.

2) The *partial correlation between the AT scale scores and the correctness for the* ***invalid*** *syllogisms*, controlling for the variables measured with Raven test and GCOSA was negative, as it was expected, but did not reach the statistical significance threshold, being only close to it: $r = -.239$, $p = .101$.

Since the use of the parametric methods of data analysis as ANOVA, partial correlation, or regression analysis were not warranted in our study, another way to disentangle the independent role of the variables measured by Raven test and GCOSA in the associations predicted in the main hypotheses was needed for several reasons. It was obvious from the previously presented results that Raven scores and AT scales scores correlated positively with each other, although not at a statistically significant level. Also, Raven test scores correlated positively with the correctness for the syllogistic task. The same positive correlation was found between the GCOSA scores and AT scales scores. The only available solution was to separate the sample of subjects into groups based on the extreme values of the two variables that should be controlled in what respects their influence over the association between the AT scale scores and the correctness for different types of syllogisms. But, because the sample was small, this procedure was not possible simultaneously, for both of the variables that are to be controlled. Therefore, it was applied separately for each one of them. So, the association between the AT scale scores and the correctness for the various types of syllogisms considered in the hypotheses was analyzed separately on two different levels of the Raven scores, and, respectively, on two different levels of the GCOSA scores. It is a common procedure for dealing with moderator variables, used here as an approximate method instead of the parametric methods. The obtained results can be consulted in the Annex 4b, and Annex 4c. In what follows a short summary of them is given.

In the *case of the split of the sample based on the Raven test scores*, the cut point was the mean value for the Raven test scores: 52.5. There was a significant difference between the two groups in what respects the Raven score (Mann-Whitney test $U = 0$, $p < .001$). The group with lower scores (noted with LR) had 25 participants, and the group with higher scores (noted HR) had 16 participants.

In what respects the *association between AT scale scores and the correctness for different types of valid syllogisms*, the obtained results were the following (see Annex 4b):

- For the *association between AT scale scores and the correctness for all the valid syllogisms,* a significant *positive association* was obtained, as it was predicted, only for those from the *LR group* (ϱ = .482, p = .007, one-tail).
- *Only* for the *participants from the LR group* a significant *positive association* was obtained for the *valid syllogisms of figure 1* (Kendall tau-b = 0.387, p = .007, one-tail), and *valid syllogisms of figure 2* (Kendall tau-b = 0.405, p = .005, one-tail), but *no significant positive association* for the *valid syllogisms of figure 3*.
- *Only* for the *LR grouped* occurred a significant *positive association* for the *valid one model syllogisms* (ϱ = .446, p = .013, one-tail), but not a statistically significant one for the *multiple model valid syllogisms*.
- Within the type of *one model valid syllogisms*, also, *only* for the *LR group*, significant *positive associations* were found for the *figure 1 syllogisms* (Kendall tau-b = 0.367, p = .011, one-tail) and for the *figure 2 syllogisms* (Kendall tau-b = 0.438, p = .004, one-tail), but not for the figure 3 syllogisms.

In what respects the *association between AT scale scores and the correctness for different types of invalid syllogisms*, the obtained results were the following:

- For the *association between AT scale scores and the correctness for all the invalid syllogisms,* a significant *negative association* was obtained, as it was predicted, only for those from the *HR group* (ϱ = -.495, p = .026, one-tail).
- *Only* for the *participants from the HR group* a significant *negative association* was obtained for the *figure 3 invalid syllogisms* (Kendall tau-b = -0.565, p = .003, one-tail), and *figure 2 invalid syllogisms* (Kendall tau-b = -0.413, p = .022, one-tail), but *no significant negative association* for the *figure 1 invalid syllogisms*.

In the *case of the split of the sample based on the GCOSA scores*, the cut point was the mean value for the GCOSA scores: 93.69. There was a significant difference between the two groups in what respects the GCOSA score ($U = 0$ $p = .000$). The group with lower scores (noted with LM) had 13 participants, and the group with higher scores (noted HM) had 20 participants. The results indicated that there was a significant positive correlation between GCOSA scores and the correctness for all the valid syllogisms ($\varrho = .520$, $p = .034$, one-tail) and one at the limit of the statistical significance for the correctness of the invalid syllogisms ($\varrho = 472$, $p = .052$, one-tail) for those from the LR group. For those from the HR group, the positive correlation was only somewhat close to the statistical significance threshold ($\varrho = .313$, $p = .119$, one-tail) for the valid syllogisms.

In what respects the *association between AT scale scores and the correctness for different types of valid syllogisms*:

- A significant *positive association* was obtained, as expected, for *all valid syllogisms*, and for *all their types*, for those from the *group LM* (see Annex 4c).
- For those from the *group HM*, a significant *positive association* was obtained, as expected, only for *all valid syllogisms* ($\varrho = .433$, $p = .028$, one-tail), and from them only particularly for the *one model syllogisms* (Kendall tau-b = .398, $p = .015$, one-tail). For the valid figure 1 and figure 2 syllogisms, the value of the positive correlations were very close to the significance threshold.

In what respects *association between AT scale scores and the correctness for different types of invalid syllogisms*, *no significant negative associations* were obtained.

3. Applying the Wilcoxon test, the results indicated that the mean correctness of *valid multiple model syllogisms* was significantly *higher* than the one for *invalid syllogism*s only in the HR group ($z = -2.401$, $p = .016$), for the LR group the difference being only close to the significance threshold ($z = -1.747$, $p = .081$).

IV. Discussions

Preliminary notes

Because the report of the results would have been more complicated than it already is, no reference was made to the level of the performance that it would be obtainable by chance, with a pure strategy of a random guessing. Anyway, that level is hard to be computed for each type of syllogism, given the fact that the alternative options were provided in a fixed order and people may have preferences when trying to guess the correct answer.

Main hypotheses

1), 2) Because of methodological problems, the first two main hypotheses could not be verified in the form they were formulated. Still, the results obtained by calculating the partial correlation coefficients were, in part, the expected ones (one of them only approaching the statistical significance threshold). But they have to be considered with caution. If there were some chances that these results are not significantly vitiated by the problems with the non-normal distribution of the involved variables, then it would mean that through the AT scale is measured something that is associated with the syllogistic performance, which is different from (not related with) the general intellectual ability or autonomous motivation. *My hypothesis, supported by theoretical and intuitive arguments, was that that something may well be the level of learning specific syllogistic skills by encountering particular classes of argumentative experiences that are centered on a certain important cognitive goal (function). Therefore, implicitly, through that something may be measured also the level of the chances to encounter those argumentative experiences*.

The results obtained by trying to disentangle that something from the AT scale from other cognitive components or from the motivational components measured through it by other data analysis methods point, in general, in the same direction, emphasized in the previous paragraph. However, they bring supplementary information and suggestions regarding the role in the dynamics of the syllogistic processes of the other two individual differences (assumed to have the status of control parameters), linked with motivation and the general intellectual ability.

So, by trying to partially control the general intellectual ability (measured with the Raven test) separately, through the split of the sample in two groups defined by the level of the Raven test scores, the *predicted result of a significant positive association between the correctness for the valid syllogisms and AT scale scores* was found *only for the LR group*, i.e. the one with lower scores for the Raven test. Analyzing in more detail the source of this association, it was obtained that, for this group, the global result is due mainly to significant positive associations between AT scale score and the performance for valid figure 1 and, respectively, figure 2 syllogisms, on the one part, and, within them, mainly to the significant positive association between AT scale scores and the performance for one model syllogisms, on the other part. This figure effects occurred only for the LR group. In the case of the *predicted result of a significant negative association between the correctness for the invalid syllogisms and AT scale scores*, the expected result was obtained *solely for the HR group*. Analyzing in more detail the source of this global negative association, it was obtained that, for this group, the global result is due mainly to significant negative associations between the AT scale score and the performance for the invalid figure 2 and figure 3 syllogisms, respectively. It is a result that seems to not be compatible with the current version of the mental models theory. Intuitively, one reason for this would be that an autonomous style of thinking should promote the search for alternative models out of a higher desire to reason correctly or out of a higher desire to defend one's standpoint in the face of an opponent. Therefore, a positive correlation of the AT scale score should occur particularly with the correctness of the multiple model syllogisms, as the invalid syllogisms are, and not a negative one.

It is to be noted that the reversed pattern of results for the valid syllogisms in comparison with the one obtained for the invalid syllogisms in what respects the significant associations between the AT scale score and the performance for each syllogistic figure is a figural effect expected to occur given the theoretical assumption of a competition between the presumed more stable dynamic schemas for valid syllogisms and the less stable dynamic (probably of a combinatorial nature) schemas for invalid syllogisms, or of a recruitment phenomenon when no such schemas could be developed for the invalid syllogisms (a case in which the neutral, ambiguous formulation of the invalid syllogisms from the **N** format task encourages such a recruitment, through a biased interpretation of the given information). This figural effect of an inverse pattern of results for the valid and invalid syllogisms may be more salient in the case of the association between the AT scale sore and syllogistic performance than when comparing only the order of the performance for the three syllogistic figures for valid and invalid syllogisms for the following reasons:

– In the first place, it may be that this particular case of a symbolic neuter formulation (in the **N** format task) does not provide sufficiently favorable conditions for a highly stable actualization of the dynamic schemas for the valid syllogisms with an important cognitive function. Therefore, their power to influence the answer for the invalid syllogisms is decreased.

– In the second place, is to be noted that for the HR group the pattern of results for the valid and invalid syllogisms is reversed. For the valid syllogisms, the figure effects of a difference of performance occur, but not the figural effect of a differential association between the AT scale score and the performance of a syllogistic figure. Instead, for the invalid syllogisms, there is no traditional figure effect of a difference of performance between the syllogistic figure, but there occurs instead a negative differential correlation between the AT scale score and the performance for different syllogistic figures. A hypothetical explanation in the theoretical framework proposed here for this state of affairs would be that, for those from the HR group, it is more saliently emphasized the assumed dissociation between the level of argumentative experiences provided by an environment and by a particular style of interaction with that environment (the style defined by the tendency toward an autonomous behavior) and the level of learning of a dynamic syllogistic schema reflected in its basic stability. Assuming that the Raven test is successful in measuring a general intellectual ability (nonverbal intelligence) that facilitates learning, then, that nonverbal intelligence is supposed to be a moderator variable between the level of available argumentative experiences and the level of learning syllogistic skills (correlatively, the stability of some emergent dynamic syllogistic schemas). Therefore, for the same level of stability of a syllogistic schema, it is assumed that fewer argumentative experiences are needed for those with a high level of nonverbal intelligence than for those with low levels of that trait. Or, correlatively, the same level of argumentative experiences is exploited differently in what respects the learning efficiency, leading, presumably, to more stable dynamic schema for those from the HR group. But this does not change the level of stability for a dynamic syllogistic schema that is presumably dependent on its cognitive function. In other words, no matter the absolute level of the argumentative experiences of a certain type, their relative order of cognitive importance and of the chances to be encountered remains the same.

– Taken into consideration the theoretical argument from the previous paragraph, then, for those from the HR group, for the *valid syllogisms*, the syllogistic figure differences in what respects the performance that are dependent on their fundamental cognitive function should continue to exist, as in the case of those from the LR group. But, for them, because they may be quick learners, a higher level of chances to encounter, for example, the typical argumentative experiences needed for the emergence of a dynamic schema for figure 1 valid syllogisms might not be so important for the basic stability of that schema, reflected into the general absolute level of the performance in a correspondent syllogistic task. Instead, it might be important for its relative stability in comparison with the stability of the dynamic schemas of other figures of the valid syllogisms for a certain individual. So, it is to be expected that the level of chances to encounter a particular type of argumentative experience as a consequence of an individual favoring factor (as the autonomous thinking trait may be) becomes more important, leading to a differential association between the level of the available argumentative experiences and the correspondent syllogistic performance, as the level of cognitive importance of the syllogisms is decreased, and, implicitly, the general level of the availability of such argumentative experiences is decreased, too, because it is not dependent on the availability presumably determined by a personality trait as it is the autonomous thinking. Given the eventuality that through AT scale is measured indirectly particularly the accessibility to argumentative experiences determined by the style of the interaction with the environment (by measuring a cognitive – behavioral style that favors their occurrence through the interaction with the surrounding informational environment), it is to be expected then that, for those from the HR group, the level of the importance of that kind of experiences to be ordered inversely than the one for the LR group. The less chances are that the general information environment to provide the needed argumentative experiences for the emergence of a dynamic schema of a particular syllogistic figure, the more important may be the level of argumentative experiences of that type of experiences secured by a particular interactional style. Therefore, for the HR group, the correlation between the AT scale score and the syllogistic performance should be higher for the figure 3 valid syllogisms than the one for the figure 2 valid syllogisms, and that correlation for the latter type of syllogisms to be higher than the one for the figure 1 syllogisms, if only the individually determined accessibility to the relevant argumentative experiences would count. But, in the same time, the advantages offered by such an individually secured access to the informational environment will provide general accessibility for all the cognitive experiences that are equally relevant for all the syllogistic figures. Therefore, the level of stability of the dynamic schemas of the most important valid syllogisms that already have emerged would be increased. Therefore, from this point of view, the correlation between the AT scale score and the syllogistic performance should be the highest for the figure 1 syllogisms, at an intermediate level for the figure 2 valid syllogisms, and the lowest for the figure 3 valid syllogisms. So, the order is reversed in comparison with the previous one. That might be the reason why, ultimately, no correlation occurs between the AT scale score and the valid syllogisms of different figures for the HR group.

– For the *invalid syllogisms*, in the case of the HR group, the situation is changed in comparison with that for the valid syllogisms. For the invalid syllogisms, it is less probable to exist performance differences between syllogistic figures based on their general cognitive function. The differences of performance between them are explainable in the proposed theoretical framework predominantly by the relative stability of the dynamic schemas for the valid syllogisms and by the similarity of their structure (especially when they are in a correspondent syllogistic figure) with such schemas for valid syllogisms, which could enter in competition with the more evolved deductive schema needed in order to solve efficiently the invalid syllogisms, or could project themselves onto the ambiguous and disorganized information found in the premises through a recruiting phenomenon, when the more evolved deductive schema is absent. It is reasonable to assume that there are increased chances that, in comparison with the participants from the LR group, the participants from the HR group are able to develop more advanced syllogistic schemas, of a combinatorial type, which would be helpful in solving all the invalid syllogisms, no matter their syllogistic figure. Therefore, it is to be expected that, for those from the HR group, their rate of success in solving invalid syllogisms would depend on the rate at which such more evolved deductive schemas win the competition with the pragmatic dynamic schemas of the valid syllogisms. Higher chances are that they can win that competition for those syllogistic figures that have a general basic stability of their dynamic schemas of the valid syllogisms lower than that of the others. In other words, that should happen for figure 2 and, especially, for figure 3 invalid syllogisms. As the basic stability of the syllogistic schemas for the valid syllogisms is assumed to be directly related with the level of access to the relevant argumentative experiences, then, indirectly, for the correspondent invalid syllogisms, the rate of success in their solving should be inversely related to that level of access to the relevant argumentative experiences for the emergence of the dynamic schemas of the similar valid syllogisms. If AT scale score measures indirectly that level of access to the relevant argumentative experiences, then it is understandable its negative association with the performance for the figure 3, and figure 2 invalid syllogisms, but not with the figure 1 invalid syllogisms.

With the intention to control partially the motivational component through the *GCOSA measure*, by splitting the sample in two groups with two different levels of the GCOSA scores, the expected result of a *significant positive association between the AT scale score and the performance for the valid syllogisms* was obtained in all the considered cases for the LM group, and, generally, only for the global score, and for the one model syllogisms, in the case of the HM group. The expected result of a significant negative association between the AT scale score and the performance for the invalid syllogisms was not obtained neither in general, nor in particular, for a certain type of invalid syllogism, for any of the two groups: LM, or HM.

In conclusion, the current data suggest that there is an association between what AT scale measures and the syllogistic performance in an abstract symbolic neuter task, but that this association is dependent on other individual differences measured by GCOSA and Raven test, and on the type of the considered syllogisms (valid or invalid, or with a particular syllogistic figure).

The obtained significant partial correlation offers a hint that, in spite of its unwarranted use in partially improper conditions, the AT scale, by its association with the syllogistic performance, may indicate an aspect important for the syllogistic performance that is not reducible to the motivational and cognitive aspects assumed to be related with the GCOSA, and Raven test, respectively. Proceeding by exclusion, intuitively, and using theoretical arguments, my suggestion is that that aspect could very well be the learning of particular syllogistic skills by encountering specific argumentative experiences. More precisely, that aspect is the level of combined general and individual access to the cognitive experiences (needed for the emergence of some dynamic syllogistic schemas during the learning of those skills) allowed by a particular style of interaction with the informational environment.

The general pattern of the findings is that the positive association between AT scale score and the syllogistic performance in the **N** format task is more salient:

- in the conditions in which the assumed positive influence of the other two considered individual differences (motivation and nonverbal intelligence) is decreased: LR group, and LM group, respectively;
- for those types of syllogisms that are generally characterized by a higher level of performance, particularly for the LR group.

Since it was not possible to control both the variable measured by GCOSA and the variable measured by the Raven test, there remains the possibility that the correlations obtained by controlling only one of them are accountable exclusively by the remaining uncontrolled variable. But there are reasons to not support such an alternative.

In the first place, it is reasonably to presume that the influence of the factors measured by the Raven test and GCOSA should have a relatively uniform positive influence (e.g., no matter the type of syllogisms, or the level of the other factor) over the performance of any cognitive task. Therefore, generally, a uniform pattern of positive correlations should have been expected if such an uncontrolled factor were to totally account for the obtained correlations when the other factor was controlled. But this was not the case when the factor measured by the Raven test was controlled, nor when the factor measured by GCOSA was controlled.

In the case when the controlled factor was the one measured by GCOSA, the support for the idea that the factor measured by the Raven test is not able to explain only by itself the obtained data pattern is more salient for the HM group. If only the general factor measured by the Raven test were important, then the positive correlation between AT scale score and the syllogistic performance should have occurred especially for those valid syllogisms that are generally characterized by a lower performance. But the results showed that it was the other way around, the expected positive associations being significant only for those syllogisms characterized generally by a higher performance. Therefore, it is likely that these associations are accounted for by a factor specifically linked with the AT scale, and not with the other two considered measures. Since

a) the positive associations are significant specifically for the syllogisms that generally have a higher level of performance, and b) assuming that they are syllogisms that have a higher chance to be learned by most of the people, the intuitive inference would be that that factor specifically associated with the AT scale is an aspect linked with learning, particularly the level of accessible cognitive experiences.

In the case when the controlled factor was the one measured by the Raven test, the support for the idea that the factor measured by GCOSA is not able to explain only by itself the obtained data pattern was apparent in both groups: LR, and HR. For the LR group, a positive association between the AT scale score and the syllogistic performance did not occur for all the syllogisms, as it would have been expected if the factor measured by GCOSA were the only one important. Instead, that association occurred, again, only for those syllogisms with a higher general performance. For the HR group, similarly, by considering only the possible role of the factor measured by GCOSA, by its link with AT scale, then no associations or positive associations between AT scale and the syllogistic performance should have occurred for all the types of syllogisms (assuming that, in this case, the nonlinear relationship between motivation and performance is not relevant). In fact, this is the only condition in which negative associations occurred for some of the invalid syllogisms, but not for the valid ones. But these negative associations are not accountable only by a factor linked with learning, too, because it is reasonable to believe that its influence should have been positive, also.

That is why, I suggested that a dynamic hypothesis could be helpful in interpreting the obtained pattern of findings through the:

- idea of dynamic competition between dynamic syllogistic schemas;
- the idea of a basic stability of such dynamic schemas that is dependent on their general cognitive function, on the intellectual and motivational factors, as well as on styles of interaction with the informational environment favoring the occurrence of relevant cognitive experiences;

– the idea that beyond a certain level of stability, the link of the stability of a syllogistic schema with the performance in a correspondent syllogistic task is not perceptible any more (as it is the case, also, with the recognition of an overlearned pattern).

I am not aware how the entire presented pattern of results could be accounted in the theoretical framework of the mental models theory. As it was shown above, there are particular results where the current predictions of the mental models theory are in contradiction with the obtained results.

3) The obtained result of a higher level of performance for the valid multiple model syllogisms than for invalid syllogisms (particularly for the HR group), although both are multiple model syllogisms, cannot be accounted by the current mental models theory. If the figure effect (the position of the middle term) were to be invoked besides the number of models factor, then the reverse result should have been the case. In the mental models theoretical framework, it would be harder to build an initial model for the figure 3, than for figure 2 valid syllogisms, and for the latter ones it would be harder than for the figure 1 valid syllogisms. A further assumption made in the mental models theory is that not building an initial model leads to the "no valid conclusion" answer. That answer is an incorrect one for the valid syllogisms, but it happens to coincide with the correct one for the invalid syllogisms. Therefore, the performance should have been higher for the invalid syllogisms than for the valid multiple model syllogisms. That was not the case. Instead, in the theoretical framework proposed in this work, the obtained difference is explained by a higher pragmatic and cognitive importance of the valid syllogisms than the one of the invalid syllogisms. The expected difference is assumed to be more salient in this study particularly given the abstract symbolic format of the task, since it is presumed that such an ambiguous format is not especially advantageous for the performance of the invalid syllogisms. The fact that this result is notable particularly for those with higher scores at the Raven test may reflect the assumed higher stability of the supposed dynamic syllogistic schema for the multiple model valid syllogisms in their case in comparison with the one of those having lower scores at the Raven test. It is a result offering another clue in what respects the presumed importance of a higher level of intellectual ability in learning deductive schemas with higher levels of stability.

Secondary hypotheses

The results obtained in relation with the secondary hypotheses (included because of their role in the investigation and the interpretation of the main hypotheses or in order to certify well known results for this particular sample) were in general the expected ones.

1), 2) By studying the correlations between the instruments used in this research, it was certified that the Raven test measures something different than GCOSA, which is in line with the intention of the authors of the GCOSA scale. It was meant to measure the orientation toward autonomy from a motivational point of view. So, it should correlate positively with the assumed motivational component from the AT scale, a result that actually was obtained. But, as it is assumed that the AT scale should include also a cognitive component linked with the intellectual activity (presumably innate or acquired by learning cognitive resources, reflecting indirectly the nature of the informational environment that made possible their acquisition), the AT scale scores should also correlate positively with the Raven test scores. This result was obtained, too. In this way, a support was gained for the idea that AT scale has a mixed structure, reflecting the mixed nature of the construct of autonomous thinking, supposedly measured by it.

3) The results concerning the significant positive correlations between the Raven scores and the performance for all the syllogisms, with the exception of valid and invalid figure 3 syllogisms, bring support to the following two conclusions. The first one is that the syllogistic activity might involve a factor linked with what is conceived to be the general intellectual ability (as measured through the Raven scores), which is a rather intuitive, obvious assertion. The other one is that the syllogistic reasoning processes are, the most likely, not reducible to that factor, since there is a class of syllogisms for which the level of performance does not vary with the Raven score. For the standard mental models theory, the other missing explicative factors would be predominantly the span of the working memory (which is still supposedly linked with the presently used measure of the general intellectual ability) and the general knowledge or experience in building initial models and alternative mental models. For the proposed dynamic schema-based model, the other missing explicative factor would be the specific knowledge or argumentative experiences, and, indirectly, learning, with all the factors influencing it. The knowledge factor would refer, here, not only particularly or exclusively to concrete, pragmatic, argumentative experiences, but also to other cognitive situations defined by other abstract cognitive goals or functions, as it is the case, for example, with the categorization daily task, which seems to be the most tightly linked with the syllogistic deductive reasoning. Other possible cognitive tasks also molding the syllogistic reasoning processes could be envisioned: to combat an opposing view by finding exception cases, to check the consistency of an argument, etc.

4), 5) In the present study, there were checked also the figure effects currently acknowledged in the scientific literature, and the figure effects that were anticipated based on some intuitive measure of the informativeness of a syllogistic conclusion that was assumed to be linked with its cognitive or pragmatic importance. The obtained results were only partially the expected ones.

For the *valid syllogisms*, in this particular context, there was no significant difference between the performance for the figure 1 syllogisms in comparison with the one for the figure 2 syllogisms. This result is more easily accommodated in the terms of the proposed dynamic syllogistic model, in my opinion, than in the terms of the standard mental models theory.

One reason is that, principally, if solving a syllogistic task involves a type of dynamic syllogistic schema, no matter its basic stability (presumably dependent on the general importance of the cognitive goal on which it is centered), its actualization should depend on contextual factors that could be more beneficial for a particular syllogistic schema than for another one. Therefore, it may be that, in this case, the abstract neuter symbolic format of the given syllogistic information had a lower power to actualize the adequate dynamic syllogistic schemas. The reason might be an assumed dissimilarity between the informational content of this format and the specific logical semantic content required by the presumed dynamic syllogistic schemas, particularly for the figure 1 valid syllogisms. This reason will be discussed at large in a future study, but here it suffices to say that it is linked with the mixed intensional-extensional model of the syllogism interpretation proposed by Didilescu and Botezatu (1976). Instead, it is possible that such a symbolic abstract format would favor an exclusive extensional interpretation of the information, in terms of relations between classes. Therefore, it might presumable favor more the actualization of the assumed schemas for the figure 2 valid syllogisms (given the same mixed intensional-extensional model of the syllogism interpretation). So, the expected difference between the correctness for the figure 1 and figure 2 valid syllogisms should decrease because of the abstract symbolic format.

Another possible reason for the lack of the difference between the correctness of the figure 1 and figure 2 valid syllogisms is that the difference regarding the level of intuitive informativeness between their conclusions seems to be lower than the one expected and lower than the one between the informativeness of their conclusions and the one for the figure 3 valid syllogisms conclusions. As it was shown before, figure 3 conclusions could be only particular judgments, whereas conclusions of the figure 1 and figure 2 syllogisms could be also universal judgments. It is assumed that only in special and rare circumstances, a particular conclusion could be cognitively and pragmatically more important than a universal one.

For the standard mental models theory, the invoked explicative factors are less sensitive to particular contexts or circumstances. As it is known, the figure effects are assumed to depend principally on the constant factor of a different percentage of one model syllogisms in each syllogistic figure and on the constant factor of the number of operations to be executed in order to build an initial model. Therefore, it is hard to imagine what other factors could affect differentially the syllogisms of a certain figure and not all of them alike, which would annul the effect of the objective factors. So, the solution at hand would be to declare that such a result might be an accidental one, obtained by chance, especially given that, in the mental models theory, too, the difference between the level of the cognitive "work" for the figure 1 in comparison with the figure 2 syllogisms is lower than the one between their levels and the level of the cognitive "work" for the figure 3 syllogisms. But, then, the results cited by Johnson-Laird and Byrne (1991) should be declared also as accidental, because there was no difference between the invalid figure 2 and figure 3 syllogisms in what respects the number of "no valid answers", as it should have been expected if the invoked factors really were to matter. It is a result similar with the one in which, in general, no significant difference has been found between the performance for the syllogisms requiring two mental models and the one of those requiring three mental models (Bucciarelli & Johnson-Laird, 1999). That result made Johnson-Laird and Byrne (1991) to think and admit that it is possible that alterative models are not built at all, at least in normal situations, but only in special circumstances. It is as if a threshold of a one model is set, and few are willing to make the effort to surpass it. But then, the explicative value of the number of mental models factor looses from its power.

In general, the same considerations from the precedent paragraph are applicable also for the case of the invalid syllogisms, where no significant differences in what respects the performance were obtained for the syllogistic figures. It may be, from the point of view of the proposed model, that the result is partially linked with the results obtained for the valid syllogisms. If their assumed dynamic syllogistic schemas have presumably a less stable actualization in this particular context of an abstract symbolic format, then, their "recruiting" power (through which they lead to "illusory recognitions" and, consequently, to incorrect answers for the invalid syllogisms) would be decreased.

6) The obtained validity effect was the one expected, certifying a robust (less dependent on particular conditions) result, constantly occurring in the syllogistic research literature, but generally ignored in what respects its significance and interpretation.

V. Conclusion

The obtained results revealed a complex data pattern, reflecting several possible interactions between the involved variables. Because of the methodological limits of the study, it was not possible to investigate properly all this interactions. But several promising directions for the future research are opened.

From the investigation of the associations of the three personality factors (measured with the Raven test, GCOSA and AT scale, respectively) with the syllogistic performance, data were obtained that offer suggestions in what respects the possible role played in the syllogistic processes by the probability to encounter relevant cognitive experiences and to draw benefits from them by learning. The dependence of the investigated associations between the three personality traits and the syllogistic performance on the type of syllogism (characterized be a specific informational content and cognitive function) and not only on the level of the other traits pleads for the existence of another factor associated with the syllogistic performance that was studied here only implicitly, not explicitly. It is a factor assumed to be linked simultaneously with the informational content of the different types of syllogisms, the general availability of cognitive experiences associated with that content and with an individual difference measuring an interactional style that promotes the access to such cognitive experiences. Data and theoretical arguments support the view that such a factor may be implicitly measured by the AT scale.

The link between the syllogistic performance and an individual difference referring to the level of argumentative experiences is important in the perspective of the dynamic theoretical framework proposed in order to model the syllogistic processes. Its fundamental assumption is that syllogistic tasks are solved by dynamic syllogistic schemas that are centered on some characteristic cognitive goals and are learned by encountering relevant cognitive experiences in the informational environment. They have a dynamic property (stability) on which their functionality depends, and which is changed by encountering relevant experiences. The syllogistic performance is assumed to be dependent on the level of the stability of one or more competing or cooperating such dynamic deductive schemas involved in a syllogistic task. But the basic stability of a deductive schema as a dynamic representational structure is presumed, taking into consideration the tenets of the connectionist paradigm with dynamic networks, to depend on a learning process allowing the emergence of stable dynamic structures having simultaneously representational and processing functions. So, from a dynamic point of view, both the general and the individual patterns of data regarding the syllogistic performance should be linked with the general and individual characteristics of the informational environment. The characteristics of the informational environment are important in the emergence both of the dynamic deductive schemas and of those individual differences (with a role of control parameters) that are linked with the efficiency of the learning processes. It was presumed that autonomous thinking is such an individual difference. It can offer indirect indices in what respects not only the characteristics (as content type and level) of the argumentative experiences of an individual, but also the characteristics of the informational environment that define the general probabilities with which such argumentative experiences could be encountered. Such general probabilities should be related with the cognitive importance of the different types of syllogisms. That kind of data are needed in order to link the general pattern of the results from the scientific literature with the proposed dynamic schema-based model for the syllogistic reasoning. Obviously, in the future, it would be important to study also the role of the learning in the emergence of the assumed deductive schemas not only on a general level, indirectly, but also at a particular level, directly. In that way, information would be gathered about how specific controlled argumentative experiences offered in a training phase might influence the syllogistic performance on a test phase in the way predicted by the dynamic schema-based model.

The proposed dynamic hypothesis was useful in suggesting an interpretation for the significant negative association between the AT scale score and the syllogistic performance for the invalid syllogisms at the HR (with high scores at the Raven test) group. It is a result for which the standard mental models theory was not relevant in order to find an explanation.

Finally, secondary results were obtained documenting more or less known validity and figure effects. The most important one, which directly contradicts the predictions of the standard mental models theory, is the strong tendency toward a higher performance for the valid multiple model syllogisms in comparison with the one for the invalid syllogisms.

Study 2

I. Purpose and hypotheses

Purposes

The *main purpose* of the study was to investigate the content, task, and order effects that are important in what respects the *general hypotheses* that, in the syllogistic reasoning, there are involved pattern completion dynamic processes based on deductive schemas with specific cognitive goals.

More precisely, the objective was to bring evidence that distinct categories of cues offered by the type of concrete content, the type of the task format, or by the temporal context (represented by the recently solved deductive tasks) of a syllogism lead to a significantly different syllogistic performance. Those cues were presumed to be recognition and distinction signs for the assumed available dynamic deductive schemas. The expected evidence was that the general data pattern regarding the syllogistic performance should be in accordance with the predictions made in the dynamic schema-based model of the syllogistic reasoning. In this model, it is assumed a characteristic link between a particular category of cues and a hypothetic type of syllogistic schema with a typical level of cognitive importance. The expected evidence is to be interpreted taking into consideration the fact that the manipulated factors are irrelevant and neutral in what respects the syllogistic performance from the point of view of a standard version of the mental models theory. To my knowledge, there are no other explicit predictions in its theoretical framework regarding such kinds of experimental manipulations than the implicit one that they are rather unimportant. However, in what concerns the content effect, it was considered the possibility to derive a hypothetical prediction taking in view the extensional semantics of the mental models theory.

So, *one of the secondary purposes* was to compare the proposed model with the mental models theory based on the obtained results. *Another secondary purpose* was to investigate if the validity, and figure effects from the previous study could be reproduced in the new conditions and how they are influenced by the experimental conditions.

Preliminary comments

The specific hypotheses were formulated within the following general theoretical framework, defined by several general assumptions.

1) Syllogistic reasoning may involve different pragmatic dynamic deductive schemas for each syllogistic figure centered on a characteristic cognitive goal;

2) The content of those schemas has a mixed semantics (intensional and extensional), including the logical meaning of the syllogistic terms, and of their relationships that is relevant for achieving the goals of those schemas;

3) That logical meaning is an abstract one, referring to: a) a general category in which each syllogistic term can be included: class, individual or subclass, or property; b) the general type of relationship between the syllogistic terms: 1) extensional (class order) or intensional (relationship between a class or individual and a property)[2]; 2) affirmative or negative; d) integrative (an extensional relationship of subsummation), determinative (an intensional relationship through which an individual or a subclass is defined, determined by a property) or delimitative (an intensional relationship in which a property is stated to be accidentally related with a category)[3].

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[2] See Didilescu and Botezatu (1976)

[3] See Noica (1995)

4) A syllogistic schema is presumed to integrate the abstract semantic features linked with the above mentioned logical meaning into a pattern emerged based on the experience with a class of deductive situations having a certain cognitive goal.

5) Linguistic, semantic cues, task context cues, or the information previously actualized may be beneficial or detrimental in what respects the recognition of the informational pattern of a syllogistic schema. Their influence will depend, also, on the basic and relative stability of that syllogistic schema.

6) Choosing as syllogistic terms common nouns representing classes of fictive plants (for example, ophidees, siderines, palmats, as in the present research) would favor an extensional interpretation, and would be detrimental for an intensional interpretation of the information given for a syllogistic task.

7) Choosing as syllogistic terms expressions with attributive value (for example, "has hepatosis", "has a high level of bilirubin in blood", "has red spots on hands") would favor an intensional interpretation, and would be detrimental for an extensional interpretation of the information given for a syllogistic task.

8) A "natural" format task with a given conclusion and the two premises to be found would be beneficial in actualizing the general cognitive goal of the syllogistic schemas, but detrimental in actualizing them, because a bigger part of the schema is missing than in the traditional task (with two given premises and a missing conclusion) and there is no context to constrain the resulting indeterminacy.

The content effects

In the present experiment, a *comparison* is made, in the first place, *between* the general syllogistic performance in *an experimental condition in which the content of the syllogistic task is of a type* **A** (**concrete, centered on attributes)** *and* the one *in an experimental condition in which the content of the syllogistic task is of a type* **C** (**concrete, centered on attributes)**. The comparison will be made for four distinct situations: when the task format is of a **PPC** type (traditional, with two given premises and the to be derived conclusion), administered *before* or *after* a **CPP** task, or when the task format is of a **CPP** type ("natural", with a given conclusion and the two to be derived premises), administered *before* or *after* a **PPC** task. Also, the comparison will be made for the valid and invalid syllogisms. Because no clear, uncomplicated, effects are expected when that comparison is made a) on the three types of syllogistic figures, or, respectively, for the **CPP** format, on the types of conclusion judgments (A, E, I, or O), and b) on the type of syllogisms in what respects the number of mental models (one or multiple model syllogisms), the correspondent analyses will not be included in the present study.

So far, *in the scientific literature dedicated to the syllogistic research*, the empirical findings have suggested that there is a difference of performance when the syllogistic task has a concrete, familiar, content, in comparison with the situation when the content is abstract, unfamiliar, or symbolic. The content effect has been known from the very beginning of the syllogistic research (Wilkins, 1928, as cited in Dominowski & Bourne, 1994). Although the difference is, generally, in the favor of the concrete content, the direction of the difference depends on the type of syllogisms and the type of the content: for example, its believability, the desirability of a particular conclusion (Morgan & Morton, 1944, as cited in Dominowski & Bourne, 1994), the level of factual knowledge linked with a concrete content. But, in the studies carried on so far, only a concrete factual content was compared with an abstract one.

In my study, the comparison will be made, *for the first time*, *between two types of concrete, nonfactual, contents*. Those contents were chosen so that no specific, factual knowledge about the syllogistic terms or relations to be possible. They refer to fictive cases or stated relationships. However, they are considered to be partially familiar, because they call upon plausible types of concrete argumentative situations that are likely to be encountered in the everyday cognitive activity: classification of a plant, and diagnosing an illness, respectively. Therefore, the level of abstractedness and the factual knowledge as factors known to be important for the syllogistic performance were controlled by including only concrete, nonfactual information. The purpose was to show that, in the concrete content of the everyday syllogistic tasks, in fact, semantic indices at an abstract level, with logical meaning, are important for the deductive process, favoring the recognition of an abstract dynamic deductive pattern. It was assumed that those indices are semantic features linked with a certain class of argumentative experiences or cognitive situations.

The standard *mental models theory* does not specifically predict that the status of attributes or as classes of the syllogistic terms would be important in building the needed mental models. But the mental models theory is an extensional one, interpreting the information from the premises by abstract tokens representing individuals of spatially related classes. Therefore, it would be reasonable to assume that a content of **C** type would be favorable for such an information codification, and this effect should be beneficial for all the syllogisms (valid or invalid, with one model or with multiple mental models, of different syllogistic figure). The same expectation for a beneficial effect of the **C** type content could be supported by the fact that, in the **A** type content, there are more words to be processed and, therefore, the supplementary load of the working memory should be detrimental for the syllogistic performance.

In the *dynamic schema-based model* instead, the information is assumed to be predominantly intensionally coded for the pragmatic dynamic syllogistic schemas and maybe extensionally for the higher level combinatorial schemas. Also, it is presumed that the pragmatic schemas are likely to be more stable and, therefore, to be used (by winning the dynamic competition with other existing deductive schemas) for those syllogisms having a higher assumed cognitive importance (presumably, figure 1, or figure 2 valid syllogisms). In order that those pragmatic schemas to be actualized and to be stable, it is, too, considered to be important that the given information to offer semantic cues in what respects the general status of the syllogistic terms, as adequate role fillers for those schemas (which supposedly include such general specifications). Moreover, that information might be helpful in eliciting the cognitive goal of an assumed pragmatic schema, besides the more traditional indices offered by the position of the middle term, the quantifiers, or negations.

But the effect of that facilitative information is expected to be dependent on the effect of other factors, particularly the basic and relative stability of a considered schema or whether such schema exists at all. If the stability of a schema is excessive, the contribution of the facilitative cues might not be notable at the level of the performance for those syllogisms for which that schema is adequately "recognized". Their effect would be, in this case, more notable at the level of the performance for the similar syllogisms that have less stable schemas, which could be defeated by the excessive stable ones. For them, such facilitative cues may actually lead to a decreased performance. If there is no learned schema at all (probably the case of the invalid syllogisms), the effect of such facilitative cues would be only an indirect one. It should be dependent on their role in facilitating (by an excessive relative stability) or impeding confusions or "illusory recognitions" (by enhancing the relatively low stability of some schemas, making possible an optimal distinction of the appropriate triggering cues for a syllogistic schema).

Therefore, for the *valid syllogisms* (no matter the task format), for which it is more likely to exist pragmatic deductive schemas of the type specified in the proposed model, the performance in the **A** type task should be *generally higher* than the performance in the **C** type task. The prediction is made for the situation in which the tasks are administered in the first position, when no order effects could affect the content effect. Given the presumed complex interactions between the assumed schemas of the different syllogistic figures, dependent on their contextual stability, no specific predictions were made regarding the interaction between the content effect and the figure effect (or, respectively, the type of judgment for the **CPP** task). However, it is probable that the difference between the **A** type task and the **C** type task in what respects performance in their solving to be the clearest one for the figure 1 valid syllogisms.

For the *invalid syllogisms*, since the manipulated factor is expected to have contrary effects dependent on particular conditions, no predictions were made, too.

The task and order effects

I am not aware of previous data from the scientific literature that indicate the kinds of effects expected in this experiment.

In the first place, a **CPP** task format has never been used before. Beyond the purpose of studying the content effects in its case, in the present study, this task format was introduced in order to study order effects, too. It was assumed that such a task format, through its "ecological" value[4], would be able to facilitate the actualization of the existing stable syllogistic schemas by its power to suggest their usual cognitive goals. In that way, their presumed relative stability is raised, so that they would be more able to influence the organization of the future incoming information, from the second administered syllogistic task. Because it was expected that the task performance to be lower in the **CPP** format than in the **PPC** format[5] anyway, it was not possible to investigate that presumed order effect at the level of an improvement from a **CPP** task to a **PPC** task. Therefore, the order effect was expected rather at the level of the difference between the performance for the valid syllogisms at the **A** type task and the one for the **C** type task in the **PPC** format, when it is administered after the **CPP** format. Because of a possible ceiling effect (due to the cumulative influences of the content, task, and order effects), it was predicted that that improvement[6] might be less notable or almost negligible for the **A** type task in comparison with the one expected for the **C** type task. Correspondingly, if the difference between the performance for the valid syllogisms at the **A** task and the one for the **C** task in the case when the **PPC** task is not preceded by the **CPP** task does occur as expected, it should disappear when the **PPC** task follows the **CPP** task.

[4] This value is presumably conferred by its similarity with the format in which categorical syllogisms are embedded usually in the everyday argumentative flux.

[5] The reasons are that the chances of guessing the correct answer are decreased and there are many syllogistic schemas that could be activated for some of the given conclusions, the missing part being bigger than in the traditional format.

[6] The improvement is considered to be a virtual one, in comparison with the situation in which the **PPC** task would have been not preceded by the **CPP** task.

The order effects were expected also to appear by comparing the syllogistic performance for a task with the same type of content and format when that task is administered before or after a task with another format. Because of an assumed ceiling effect, it might be less likely that a significant performance difference to occur *for the* **A** *type task* in the format **PPC** when it is administered before or after the task in **CPP** format. For the **A** type task, it might be more probable that this effect to occur for the **CPP** format, since, in its case, the presumed syllogistic schemas are assumed to be less stable and, therefore, more sensible to destabilizing or stabilizing effects. But no specific prediction was made in that respect. It may be that a **PPC** task format to have a disruptive effect through its frame, encouraging a more "combinatorial" approach, centered on combining possibilities, than the one required by a successful completion of the **CPP** task. In the **CPP** task, the performance would be supposedly facilitated by a strategy in which the given conclusion is used as a cue for recalling learned syllogistic schema, and not by one in which an analysis of the possible combinations of the given judgments is made. *For the* **C** *type task*, it is likely that the possible disruptive effect of the **PPC** task to be not so salient when the **CPP** task is administered after it. Instead, order effects are to be expected especially for the **PPC** task when it is administered after a **CPP** task, given the cognitive goal cues offered by such a task format, useful in actualizing the existing syllogistic schemas.

In the theoretical framework of the mental models theory, such order effects are not expected at all, especially combined with content effects. The most important reason is the fact that solving a syllogism is primarily dependent on an ad hoc mental model built from abstract tokens that are not subsequently memorized. Speculations could be made in what respects the way the mental models theory could predict something in this respect, especially taking in view the role of the previous knowledge and learning in building initial and alternative models. But in the standard mental models theory, that role is too vague, being underspecified. I see no reason for which the experience with a **CPP** task would improve the performance for a subsequent **PPC** task from the perspective of the mental models theory. It may be rather the other way around, in case that specific combinations of premises with their corresponding conclusion are somehow memorized in the **PPC** format, facilitating their recollection in the **CPP** format.

Instead, as it was argued in the theoretical section of this work, order effects are expected in the case of the dynamic syllogistic schemas, through their power to organize new incoming stimuli and to enter in competition or cooperation with other existing syllogistic schemas supported by them. In a dynamic model, the value taken by a cognitive variable at a certain moment has cognitive significance for the state of the cognitive system in a future moment.

Figural effects

In the standard mental models theory, there are no specified reasons for which the figural effects predicted in its theoretical framework should be dependent on the type of the concrete content of the task or on the order of the two used task formats. The content effect could, at most, change the predicted order of difficulty of the syllogistic figures only in the sense that the expected differences might be annihilated in the unlikely hypothesis that certain syllogistic contents improve either the generation of alternative models, or the initial model building, preferentially, only for some of the syllogisms. In that way, they might be brought, at most, at the same level of performance with the previously easier syllogisms.

Instead, in accordance with the proposed *dynamic schema-based model*, a partial reversal of the order of the performances for the three syllogistic figures in comparison with the one from a neuter abstract symbol type of task, as a consequence of the content, task or order effects is more likely to be expected. The reason is that the actualization of the assumed syllogistic schemas linked with their relative stability is presumed to be context dependent. So, beyond the hypothetical, virtual hierarchy of the syllogistic figures based on their putative cognitive significance (information gain), it might be possible that particular conditions (content, task format, temporal context) to change that hierarchy. Because many factors are involved that are hard to be controlled, no specific hypotheses were made in that respect. Therefore, this part of the study will have mostly an exploratory character.

Validity effects

As it was argued in a previous section, it is assumed a nonlinear relationship between the level of stability of a syllogistic schema and the performance for those syllogisms that have no corresponding schema, but which have cues that could trigger that inadequate schema. The reason is that an intermediate level of stability of a schema is supposed to be optimal for the distinction of those syllogisms for which that schema is actualized adequately. The extreme levels of stability lead presumably to higher rates of confusions or "illusory recognitions" by projections. Invalid syllogisms are such kinds of syllogisms that probably do not have a pragmatic syllogistic schema. At most, for their majority, combinatorial schemas would be the most adequate. So, the performance for them should be dependent on the stability level of the assumed schemas of the similar valid syllogisms. The effect of an excessive or too low stability of the assumed valid syllogisms schemas should be detrimental for the performance obtained for the invalid syllogisms. Instead, an intermediate level of that stability should have a beneficial effect for the performance obtained for the invalid syllogisms. So, as the expected effects in what respects the invalid syllogisms might be in both directions (i.e., detrimental or beneficial effects) and as no direct measure is available for the stability level of the pragmatic syllogistic schemas, no determinate predictions were possible for the invalid syllogisms. However, because in the present study the syllogistic content, especially in the case of the type **A** task, is not ambiguous as in the case of the abstract symbolic format from the previous study, the chances for a correct distinction of an inappropriate use of a valid syllogism schema for an invalid syllogism are supposedly higher. Therefore, it is expected that the performance for the invalid syllogisms should be raised, too, by the content of a type **A** task. Consequently, no significant difference between the performance for the multiple models valid syllogisms and the one for the invalid syllogisms for the **A** type tasks in a **PPC** format is likely to be expected.

Concluding comments

The study was an experimental one, with a mixed 3-way factorial design. The **manipulated independent variables** were:

- the *type of content of the syllogistic task* (centered on attributes: **A** vs. on classes: **C**);
- the *type of task format* (traditional: **PPC** vs. "natural" **CPP**);
- the *order of the administration of the two types of task formats*: **PPC** then **CPP** (symbolized with **VN** or **PPCCPP**), or **CPP** then **PPC** (symbolized with **NV** or **CPPPPC**);
- the *position in the administration order*: first vs. second.

The **dependent variable** was *the level of correctness*, at the global level or for different types of syllogisms.

The *syllogistic figures, validity, and the number of mental models* were additional independent variables, which were not manipulated.

Hypotheses

Main hypotheses

1) It is expected the following **content effect**: the *correctness for the A type task should be higher than the one for the **C** type task*, at least for the following configuration of conditions: *valid syllogisms*, **PPC** *task format, the order of administration* **VN**.

2) It is expected the following **order effect**: *no statistically significant difference* between the *correctness (total or for valid or invalid syllogisms) for the A type task* and the *one for the **C** type task* in the following configuration of conditions: *valid syllogisms*, **PPC** *task format, the order of administration* **NV.**

3) It is expected the following **order effect**: a *higher correctness for the valid syllogisms from the* **A** *type task in the format* **CPP** *when it is administered before the* **A** *type task in the* **PPC** *format than when it is administered after the* **A** *type task in the* **PPC** *format.*

4) It is expected the following **order effect**: a *higher correctness for the valid syllogisms from the* **C** *type task in the format* **PPC** *when it is administered after the* **C** *type task in the* **CPP** *format than when it is administered before the* **C** *type task in the* **CPP** *format*.

Secondary hypotheses

1) There should be *changes in the figure effects dependent on the experimental condition* in comparison with the ones obtained in the previous study with an abstract symbolic neuter task.

2) *No significant correctness differences between the multiple model valid syllogisms and invalid syllogisms from the **A** type tasks in the format **PPC*** should occur.

Presumed predictions of the mental models theory

1) *No difference* or, at most, the *correctness for the **C** type task should be higher than the one for the **A** type task*, for *all the syllogisms*, in the **PPC** *task format, no matter the order of administration.*

2) *No difference* or, at most, the *precedence of a task of the **PPC** format should have a beneficial effect on a subsequent task in the **CPP** format*, not the other way around, no matter the syllogistic content.

3) *No changes in the figural and validity effects dependent on the experimental conditions*.

II. Method

Participants

The participants at the study were 86 students at the Social Work Faculty (75) of the "Babeş-Bolyai" University and Law Faculty of the "Dimitrie Cantemir" University (11). They were in their first, second or, respectively, third year of college, having a mean age of 21 years. Of them, 66 were female students, 14 male students and 6 participants did not disclose their gender. Since of the 86 students not all managed to complete all the administered tasks (for example, they arrived later at the seminar hour or for other reasons), in the results section, for each statistical analysis, where it will be relevant, the number of participants taken into consideration will be specified.

Material

The following syllogistic tasks were used:

– A **CPP** format task, when a conclusion is given and the derivation of the premises is required, with a concrete content centered exclusively on classes (**C** type content). It had five items (see Annex 5), correspondent to the four possible types of judgments and to the “no valid conclusion” answer. The classes were fictive classes of plants.

- A **CPP** format task, when a conclusion is given and the derivation of the premises is required, with a concrete content centered exclusively on attributes (**A** type content). It had five items (see Annex 6), correspondent to the four possible types of judgments and to the “no valid conclusion” answer. The attributes were fictive symptoms of a rare disease.
- A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with a concrete content centered exclusively on attributes (**A** type content). It had 24 items distributed on types and ordered as in the task used in the preceding study that had a neuter abstract symbolic content (see Annex 7). The attributes were fictive symptoms of a rare disease.
- A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with a concrete content centered exclusively on classes (**C** type content). It had 24 items distributed on types and ordered as in the task used in the preceding study that had a neuter abstract symbolic content (see Annex 8). The classes were fictive classes of plants.

Each type of task was preceded by an instruction in which the argumentative situation was explained with reference to its specific concrete content and through which the modality of answer was described. There were no trial tasks or trial syllogisms within a task.

Procedure

The syllogistic tasks were administered collectively, during the same session, at the seminar hours, without other time limit than the length of those 2 hours. The participants were allowed to give a pseudonym instead of their name in order to discourage the tendency to copy the answers from their neighbors, by securing the confidentiality of their performance.

The participants were included in the four experimental groups by a random selection, taking into consideration their arrangement in the seminar room (were selected the rows of chairs for a given experimental group). The first experimental group (**A** type task and the order **CPPPPC**) had 18 participants. The second experimental group (**A** type task and the order **PPCCPP**) had 14 participants. The third experimental group (**C** type and the order **CPPPPC**) had 16 participants. The fourth experimental group (**C** type and the order **PPCCPP**) had 19 participants.

III. Results

Given that a) the majority of the variables involved in the study had a distribution significantly departed from normality (with the exceptions of the total correctness and the correctness for the valid syllogisms), b) the sample of participants was relatively small, and c) the variance homogeneity for the experimental groups was not secured in all the relevant situations, I was constrained to use nonparametric statistical tests (Mann-Whitney test for the between-subjects comparisons and Wilcoxon test for the within-subjects comparisons). They only partially succeeded in replacing the parametric tests and ANOVA.

The statistical description of the most important variables involved in the study for each of the four experimental groups is included in the Annex 9.

The chosen statistical significance threshold was of $p = .05$.

Preliminary results

With only an exception (the group with **C** type task and **VN** administration order), which had a lower age in comparison with the remaining groups, no other statistically significant age and gender differences existed between the experimental groups. Still, the age difference was not reflected in a significant difference in what respects the score at the short version of the Raven Advanced Progressive Matrices Test (APM) (12 items), nor at two cognitive autonomy tests (AT scale of A/H questionnaire and cognitive or values scale at CA questionnaire, elaborated by Monica Albu, 2007). Since the presumed variables measured by the two instruments are important for the syllogistic performance, and no differences were obtained between the four experimental groups in their respect, it is assumed that it is unlikely that the obtained results concerning that experimental group to be accounted by its age difference. Still, it is not a totally excluded possibility.

Main hypotheses

1) Applying t-test in order to compare the ***correctness of the valid syllogisms*** *for the* ***A*** *type task with the one for the* ***C*** *type task* in the **PPC** format and the administration order **VN,** no significant difference was obtained, which is not the expected result.

Supplementary results

However, a significant difference was obtained for the **total correctness** of the ***A*** *type task,* which was higher than the total correctness of the ***C*** *type task* for the **PPC** format and the administration order **VN** (t = -2.335, df = 25, p = .031).

Also, the **correctness for the figure 1 syllogisms** of the **A** type task was significantly higher in comparison with the one for the ***C*** *type task* for the **PPC** format and the administration order **VN** (U = 37, p = .039)**.**

2) *No statistically significant differences* were obtained between the *correctness (total, or for valid or invalid syllogisms) for the* ***A*** *type task* in comparison with the *one for the* ***C*** *type task* in the following configuration of conditions: **PPC** *task format, the order of administration* **NV**, as it was expected.

3) No significantly *higher correctness for the* ***valid syllogisms*** *of the* **A** *type task in the* **CPP** *format when it was administered before than when it was administered after the* **A** *type task in the* **PPC** *format* was obtained, which is not the expected result.

Supplementary result

However, the correctness was significantly higher for the **multiple model syllogisms** of the **A** *type task in the format* **CPP** *when it was administered before than when it was administered after the* **A** *type task in* **PPC** *format* (Mann-Whitney test U = 53.5, p = .009).

4) No significantly *higher correctness for the* ***valid syllogisms*** *of the* **C** *type task in the format* **PPC** *when it was administered after than when it was administered before the* **C** *type task in* **CPP** *format* was obtained, which is not the expected result.

Supplementary results

However, the **total correctness** was significantly higher *for the* **C** *type task in the format* **PPC** *when it was administered after than when it was administered before the* **C** *type task in the* **CPP** *format* (Mann-Whitney test U = 20.5, p = .004).

Also, a significantly higher performance was obtained for the **valid figure 1 syllogisms** *of the* **C** *type task in the format* **PPC** *when it was administered after than when it was administered before the* **C** *type task in the* **CPP** *format* (Mann-Whitney test U = 33.5, p = .027).

Secondary hypotheses

1) The complete results and the values obtained for the comparisons in what respects the figure effects are presented in the tables from the Annex 10.

For the PPC format:

The most consistent result was the higher correctness for the *valid figure 1 syllogisms* than the one for the *valid figure 3 syllogisms* for all experimental groups. Instead, the significant difference between the valid figure 2 syllogisms and the valid figure 3 syllogisms (with a higher performance for the figure 2 syllogisms) disappeared in three of the four experimental groups (the exception is the experimental condition of a **C** type task, in the format **PPC**, with the **NV** administration order).

In the case of the *invalid syllogisms*, a higher performance for the figure 3 syllogisms than the one for the figure 1 syllogisms (the result predicted by the mental models theory) was obtained only for the experimental group with the **A** type task and the **VN** administration order. In accordance with the mental models theory, it should have been more likely to occur for a **C** type task. Similarly, the predicted correctness difference between the figure 2 and 3 invalid syllogisms, in the favor of the figure 3 invalid syllogisms, occurred for two of the four experimental groups, both in an **A** type task, but with different order of administration.

Since, in the mental models theory, figural effects are accounted not only through the percentage of the one model syllogisms in a syllogistic figure, but also through the middle term position in the premises, a separate analysis of the figure effects was made for the two categories of syllogisms: one model and multiple model valid syllogisms. The hierarchy of the difficulty of the syllogistic figures predicted by the mental models theory was not obtained as expected. For the *one model syllogisms*, only three significant differences occurred. There was a significant difference between the figure 1 and 2 syllogisms, in the favor of the figure 1 syllogisms, only for two of the experimental groups: a) **A** type task with the **VN** administration order; b) **C** type task with the **NV** administration order. The difference between the figure 2 and 3 syllogisms, in the favor of the figure 2 syllogisms, was significant only for the group with the **C** type task and **NV** administration order. For the valid *multiple model syllogisms*, a significantly higher correctness for the figure 1 syllogisms than the one for the figure 3 syllogisms occurred for the **A** type task and the **C** type task only when the order of administration was **NV**. A significantly higher correctness occurred, also, for the figure 2 multiple model syllogisms in comparison with the one for the figure 3 multiple model syllogisms in three of the experimental conditions. The only exception was the **C** type task in the **PPC** format at its administration in the first position.

For the CPP format:

Significant differences occurred between the figure 1 and figure 3 syllogisms, favoring the figure 1 syllogisms, only for the two experimental groups with the **A** type task. Also, a significantly higher correctness was obtained for the figure 1 syllogisms in comparison with the one for the figure 2 syllogisms in the group with the **A** type task and **VN** administration order. The same result was at the limit of the statistical significance threshold for the group with the **A** type task and **NV** administration order.

2) *No significant differences* occurred *for the **A** type tasks in the **PPC** format between the correctness of the valid multiple model syllogisms and the one of the invalid syllogisms*, as it was expected.

IV. Discussion

Preliminary notes

As in the first study, because the report of the results would have been more complicated than it already is, no reference was made to the level of the performance that it would be obtainable by chance, with a pure strategy of a random guessing. Anyway, that level is hard to be computed for each type of syllogism, given the fact that the alternative options were provided in a fixed order and people may have preferences when trying to guess the correct answer.

Main hypotheses

1) The expectation of the first hypothesis of a higher level of performance for the task centered on attributes (**A**) in comparison with the one for the task centered on classes (**C**) in the **PPC** format was not obtained specifically for the valid syllogisms. But it occurred for the total performance (valid and invalid syllogisms together), and for the figure 1 valid syllogisms, in particular. The obtained results could be interpreted to mean that, for this sample, a content centered on attributes might have helped especially the actualization of the assumed syllogistic schemas for the figure 1 syllogisms, presumably the ones having the highest stability in these conditions, given their higher assumed cognitive importance. But the semantic cues of the intensional meaning were not so powerful in what respects the actualization of the unstable schemas for the syllogisms with lower cognitive importance. For some of the cases, especially the figure 3 valid syllogisms, these schemas may not exist at all. Moreover, for the figure 2 valid syllogisms, as it was explained in a previous section, an exclusive intensional content might not be as beneficial as it may be for the figure 1 and figure 3 valid syllogisms, being the only syllogistic figure for which the conclusion has an extensional meaning. All these three reasons offer an explanation for the fact that the expected difference did not occur separately for all the valid syllogisms. It may be that the improvement through the content effect in what respects the relative stability of the assumed schemas for the valid syllogisms was at an intermediary level that should have increased the chances that the argumentative situations of the invalid syllogisms to be more easily distinguished in comparison with the argumentative situations of the valid syllogisms. So, maybe that is the reason for which the performance for the invalid syllogisms brought a contribution, too, to the total difference induced by the content effect. But, in their case, also, the improvement could not be noticed separately, only for them.

2) When the **PPC** task was administered in the second position, after a correspondent **CPP** task having the same type of content, order effects were expected especially for the **C** type task. So, no difference was probably to occur between the performance at the task with a content centered on attributes and the one at the task centered on classes, due to a presumed more salient improvement in the second case through an order effect. In the situation with an **A** type content, this improvement may not be so notable, given the presumed ceiling effect: adding a new stabilizing factor, which favors the recognition of an existing schema (order effect), might not have much of a supplementary contribution after another stabilizing factor. Its presence is likely to be superfluous, as it is the case also for the recognition of a human face, for example. When the minimum level of the necessary elements in order to recognize it is attained, supplementary cues are superfluous. The obtained result supported this hypothesis.

3) The presumed detrimental effect of a **PPC** format task for a subsequent **CPP** task with an **A** type content (centered on attributes) was not obtained for all the valid syllogisms, as it was expected, but only for the multiple model syllogisms, the ones having the lowest presumed cognitive importance, and, implicitly, less stable assumed schemas. It is reasonable to assume that, for them, a detrimental influence should be more notable than for the syllogisms with more stable schemas, resistant to the influence of such unfavorable contexts.

4) As in the case of the content effect of the first hypothesis, the order effect expected to occur for a **C** type task as a consequence of the precedence of an assumed facilitator **CPP** task was not notable for all the valid syllogisms separately, but only for those of figure 1, or for the total performance. The interpretation of this result is presumed to be a similar one.

Secondary hypotheses

1) Standard mental models theory predicts a strict order of the difficulty of the syllogistic figures in the absence of the factual knowledge that may distort that order. In my experiment, there is no factual knowledge, since the syllogistic terms are fictive names of plants, or fictive symptoms of a rare disease. So, the predicted order should have been found no matter the experimental condition. Instead, no difference was found between the performances of the figure 1 and figure 2 syllogisms in the **PPC** format. Also, for the figure 2 and figure 3 syllogisms in the **PPC** format, a performance difference was obtained only for one of the experimental conditions: **C** type task, **PPC** format, in the **CPPPPC** order. The obtained results could be interpreted by taking into consideration the content effects that were manifested as tendencies when comparing the **A** type task with **C** type task in the **PPC** format administered in the first, and, respectively, in the second position.

For the *condition **A** type task in the **PPC** format administered in the first position*, no significant difference occurred between the performances for the figure 2 and figure 3 valid syllogisms, probably because there was a more salient improvement for the figure 3 valid syllogisms. For the **PPCCPP** order of administration, there occurred a tendency of a higher performance for the figure 3 valid syllogisms in the **A** type task than the one in the **C** type task ($U = 41$, $p = .066$). Also, the absence of a performance difference between the figure 1 and figure 2 valid syllogisms in this condition may be accounted by the fact that there are more multiple model syllogisms (with presumably less stable schemas) in the syllogistic figure 2 than in the syllogistic figure 1. But there was a tendency that a content centered on attributes (**A** type task) to lead to a more salient improvement in performance, in comparison with the **C** type task, exactly for the multiple model syllogisms (the ones presumed to have less stable schemas) for the **PPCCPP** order of administration ($U = 42$, $p = .06$). Therefore, figure 2 valid syllogisms should be favored more by a content centered on attributes than figure 1 valid syllogisms. In that way, it is explained, also, the lack of a significant performance difference between the figure 2 and figure 3 valid syllogisms.

For the *condition **A** type task in the **PPC** format administered in the second position,* the fact that the only significant performance difference between the syllogistic figures was the one between the figure 1 and figure 3 valid syllogisms may be explained in the same way as for the previous condition. The same tendency for a better performance in the case of the **A** type task than in the case of the **C** type task at their administration in the second position occurred particularly for the multiple model syllogisms ($U = 59$, $p = .057$). Since the syllogistic figures 2 and 3 have more such multiple model syllogisms, they may benefit more from a content centered on attributes and, so, the differences between the syllogistic figures should be decreased.

For the *condition **C** type task in the **PPC** format administered in the first position*, it may be that the concrete unfamiliar, exclusively extensional, type of content is more similar with the neuter abstract symbolic content of the syllogistic task used in the previous experiment. That is why the figural effects were similar, too. Such content may not favor particularly the actualization of the assumed schemas for the figure 1 and figure 3 valid syllogisms, i.e. their relative stability. Therefore, the performance in their case would be accounted predominantly by the basic stability of their assumed schemas. But the differences in what respects the basic stability of the presumed schemas for the syllogistic figures might be probably rather small. Therefore, there may be less likely that such differences to lead to statistically significant differences in performance between neighboring syllogistic figures. Only for the extreme syllogistic figures: 1 and 3 this difference is likely to be notable.

For the *condition **C** type task in the **PPC** format administered in the second position*, the fact that it is the only condition in which a significant performance difference occurred between the figure 2 and figure 3 valid syllogisms may be accounted based on an order effect, given the precedence of the **CPP** task format. An extensional type of content might be the most beneficial for a conclusion of a figure 2 valid syllogism, since it is the only syllogistic figure having an extensional conclusion in accordance with the mixed semantics model of Didilescu and Botezatu (1976). The **CPP** task format gives a conclusion for which the correspondent premises are to be found. So, this task format should favor the actualization of those assumed syllogistic schemas for which the meaning of the conclusion is similar with the meaning (intensional or extensional) of the given conclusions. For a **C** type task in the **CPP** format, the schemas of the figure 2 valid syllogisms should be favored. This preferential actualization is likely to be reflected, then, through an order effect in the subsequent **PPC** task. Furthermore, the assumed preferential actualization may explain why a significant higher performance was obtained for the one model syllogisms in the **C** type task than the one obtained in the **A** type task, when they are administered after a **CPP** task ($U = 54$, $p = .038$). Since figure 1 valid syllogisms are presumed to have the most stable schemas and to require an intensional conclusion, it is less likely that they could benefit significantly from the precedence of a **C** type task in the **CPP** format. Figure 3 valid syllogisms are assumed to have rather unstable schemas or to not have schemas at all and to require intensional conclusions, and, therefore, their benefit from the precedence of a **C** type task in the **CPP** format may be small, too. As a consequence, figure 2 valid syllogisms may be the principal beneficiaries of the precedence of a **C** type task in the **CPP** format. In fact, a significant performance difference occurred in that direction.

For the *invalid syllogisms*, the predictions of the mental models theory were generally not supported by data. In fact, the only performance differences that were obtained in their support occurred not in the **C** type task, the extensional one, as it should have been if extensional mental models were built, but only in the **A** type task. This result suggests that the figure effects for the invalid syllogisms may not be due to the position of the middle term, as it is assumed in the mental models theory, but to the presumed influences from the assumed schemas of the valid syllogisms. The argument behind this affirmation is the fact that the performance differences between the invalid syllogisms of different syllogistic figures occurred only for the intensional **A** type of content, presumed to be able to favor the actualization of the assumed schemas for the valid syllogisms.

The fact that the position of the middle term may not be important in the way envisioned by the standard mental models theory is supported also by the results of the analysis of the figure effects obtained separately for the one model and, respectively, multiple model valid syllogisms. These results offer a powerful suggestion that both an intensional content (**A** type task) and a **CPP** task format (actualizing the cognitive goals of the syllogistic schemas) might have a more salient influence only for those syllogistic figures that have assumed schemas with high stability. So, for the first time in my research, there occurred a performance difference between the figure 1 and figure 2 valid syllogisms, but only in the case of the *one model syllogisms* and only for an **A** type task administered in the first position or a **PPC** format task preceded be a **CPP** format task for a **C** type task. This difference did not occur for an **A** type task administered in the second position probably because of the concurrent action of the intensional content and of the precedent **CPP** format task on the performance for the figure 2 valid syllogisms. It might have been raised more saliently than the performance for the figure 1 valid syllogisms. For the latter ones, it may be apparent a ceiling effect, because their basic stability is the highest, and adding actualizing cues is rather superfluous. For the *one model syllogisms from the **C** type task in the **PPC** format administered in the first position* no performance differences occurred between the syllogistic figures probably because no facilitative cues were present (they were not provided by a preceding CPP task format or an intensional content).

For the *multiple model valid syllogisms* that are assumed to have rather unstable schemas, figure 2 syllogisms might be favored the most by the putative facilitative factors (intensional content and the precedence of a **CPP** format task). The reason is that their assumed schemas may have an intermediate level of basic stability and they are more likely to exist than in the case of the figure 3 multiple model valid syllogisms. That is why, in this situation, a significant performance difference did not occur between the figure 1 and figure 2 multiple model valid syllogisms. Instead, the performance difference between the figure 2 and figure 3 multiple model valid syllogisms was significant for three of the experimental conditions, the ones in which at least one of the assumed facilitative factors occurred. The only exception was for the condition with a **C** type task administered in the first position, in which there was no facilitative factor. For the figure 1 and figure 3 multiple model syllogisms, a significant performance difference (favoring figure 1 syllogisms) occurred for the two experimental groups in which the administration order was **CPPPPC**, no matter the content of the task. A similar tendency, close to the significance threshold, occurred for the **A** type task administered in the first position. So, again, only in the experimental condition in which the facilitative factors were absent, the figure effect was absent, too, contrary to what the standard mental models theory would predict.

For the **CPP** task format, figure effects occurred only for the type of content centered on attributes (**A** type task), no matter the order of administration, when the facilitative factor of the content presumably favored predominantly the performance for the figure 1 syllogisms, i.e. the ones assumed to have schemas with the highest probability and with the highest stability. The only exception was the condition with the **A** type task for the **CPPPPC** administration order, in which the performance difference between the figure 1 and figure 2 syllogisms was very close to the statistical significance threshold. These results may be understood in the light of the difficulty of the **CPP** task format in comparison with the **PPC** task format. Since less information is given, the actualization of an adequate schema is harder, less probable, and more information has to be completed with lower chances of guessing. So, only the syllogisms with the schemas assumed to have the highest basic stability, those of figure 1 type, had a chance to be actualized and favored by an intensional content (**A** type task).

2) The results support the idea that, in this case, when, presumably, the actualization of the assumed schemas for the multiple model valid syllogisms is at an intermediate level of stability, the content effects and order effects favor a higher performance not only for the valid syllogisms, but also for the invalid ones. The hypothetical reason may be the facilitation of the distinction between the argumentative situations of the two types of multiple model syllogisms.

V. Conclusion

Of the four main *hypotheses*, only one was entirely supported, and three of them were partially supported, in the sense that the expected performance differences did not occur specifically for all the valid syllogisms, but only for the figure 1 valid syllogisms and for all the syllogisms (valid and invalid ones together). The obtained results are still in accordance with the proposed model and in contraction with the predictions of the mental models theory. The differences were explained through the particular conditions of this experiment (characteristics of the sample, type of content, the assumed level of stability of the syllogistic schemas) and taking in view the results that were close to the statistical significance threshold.

From a global point of view, there was a *content effect*, the intensional **A** type of task tending to favor the syllogistic performance either globally or particularly, for the figure 1 valid syllogisms, cases in which the syllogistic performance in the **A** type of task was higher than the correspondent performance in the extensional **C** type of task, as it was expected.

Also, there was an *order effect* combined with a *task format effect* through which the precedence of a task with a certain format influenced the performance for the subsequent task, having another format. This result did not occur specifically for all the valid syllogisms as it was expected, but only for certain types of valid syllogisms (multiple model or figure 1 valid syllogisms), depending on the experimental condition, or for all the syllogisms (an option that was not, in fact, excluded when the hypotheses were formulated). These data could be explained in the theoretical framework of the proposed model, but they are in contradiction with the hypothetical predictions of the standard mental models theory. Also, the detrimental effect of the precedence of a **PPC** format task for the performance in an **A** type task is not accountable based on the traditional notion of priming. Such results are more compatible with the idea of a dynamic cognitive system that is placed in its state space farther away from the region corresponding to an adequate assumed dynamic syllogistic schema.

Both secondary hypotheses were supported by data. The pattern of the results for the *figure effects* indicates that the manipulated factors affected differently the performance for the three syllogistic figures. Generally speaking, figure 1 valid syllogisms, assumed to have schemas with the highest level of stability and cognitive importance, benefited the most in almost all the experimental conditions. The exceptions were the conditions in which either there was no facilitative factor or both facilitative factors were present, occurring a ceiling effect in the recognition of their assumed schemas. Instead, the performance for the figure 2 syllogisms, which have presumably less stable schemas, and, therefore, for them, a ceiling effect is less probable, was facilitated the most in the condition with an intensional content and the precedence of the **CPP** format task.

The fact that for the **CPP** format task, there was no performance difference between figure 2 and figure 3 valid syllogisms and that the performance for the figure 1 valid syllogisms was significantly higher than the performance for them supports the idea that the assumed syllogistic schemas for the figure 1 valid syllogisms are the most stable. They could be actualized even in the impoverished situation of a **CPP** task format. Still, their salient actualization was not possible without the help of an intensional **A** content type.

The pattern of the results for *the invalid syllogisms* is complicated, but a clear result was that it varied with the experimental condition and that the expected figure effects for them were not obtained as predicted by the standard mental models theory. The data offer a suggestion that for the A type of task, with intensional content, the stability of the assumed syllogistic schemas was raised at a level required for an optimal distinction between the argumentative situations of the valid syllogisms and those of the invalid syllogisms. This conclusion is supported predominantly by a higher total performance in the case of an intensional A type of content or in the case of the precedence of a **CPP** task format.

Study 3

I. Purpose and hypotheses

Purposes

The *general purpose* of this study remains the same as the one from the previous study. All general considerations in what respects the intention to bring evidence to support the dynamic schema-based model of the syllogistic reasoning are valid in this case, too.

The *main purpose* of the present study was to investigate the *order effects* when the two types of tasks with different content: **A** and, respectively, **C** are administered at the same subject in a different order. Such order effects could be interpreted to mean that some abstract mental representations actualized by an **A** type task are able to organize the syllogistic processes in the **C** type task. It was assumed that such abstract mental representations have the defining properties of a dynamic cognitive schema.

The *secondary purposes* were to find out if the results obtained in the previous study in what respects the content effects remain the same or not. Also, the validity and figure effects are studied again to see their consistency in relation with the results obtained in the two previous studies, in the new experimental conditions.

Preliminary comment

In the previous study, it was not pragmatically possible to compare the performance for the two types of tasks with different concrete content: **A** and **C** when they are administered to the same subject. That comparison is expected to be important given the fact that an order effect is anticipated. In the antecedent study, the results indicated a content effect in what respects the syllogistic performance favoring the **A** type task in comparison with the **C** type task, as it was anticipated on theoretical grounds. Therefore, I presumed that the facilitative features that are present in an **A** type task might extend in time their beneficial influence through a dynamic phenomenon to a subsequent different task, with a content less adequate for the syllogistic performance, as the **C** type task is assumed to have. This presumption was supported also by the order effects suggested by the data from the previous study in which the **CPP** task format had such beneficial valences. Also, in the precedent study, order effects were obtained when a task format, presumed to be less adequate for the actualization of the pragmatic syllogistic schemas, was administered before another task format, considered to be more adequate in that respect. Therefore, in the present study, there were expected order effects indicating a deterioration of the performance for an **A** type task when it is preceded by a **C** type task. Also, it should be expected a higher performance for the **C** type task when the **A** type task is administered before than after it. As a consequence, in the hypothesis in which there occurs the expected difference between the performance for the **A** type task and for the **C** type task when they are administered in the first position, in the situation in which they are administered in the second position, no such performance difference is likely to occur.

The expected order effects are *interpreted dynamically*, based on the theoretical assumption that an actualized assumed dynamic schema is able to influence the interpretation and organization of the subsequently received information. It could enter in competition or cooperation relations with other existing schemas that could be triggered by that information.

Mental models theory does not make any specific predictions regarding the expected main order effects. As it was stated before, too, the order effects are not consistent with the idea of ad hoc mental models that, after a syllogistic task, dissolve themselves for good. Moreover, if a beneficial effect is still to be expected, within the framework of the mental models theory, as a consequence of an administration order, it would be more plausible to be one in which the performance for a subsequent **A** type task is improved as a consequence of a precedent extensional **C** type of task than one in which the performance for a subsequent **C** type task is improved as a consequence of a precedent intensional **A** type of task, as it is predicted by the theoretical model proposed in this work. A higher performance for the **C** type task than the one for the **A** type task could be supported by the fact that, in the **A** type task, there are more words to be processed and, therefore, the supplementary load of the working memory should be detrimental for the syllogistic performance.

The preliminary general comments regarding the expected content, validity, figure or number of mental models effects from the previous studies remain valid for the present one, too.

Concluding comments

The study was an experimental one, with a mixed 2-way factorial design. The **manipulated independent variables** were:

- the *type of content of the syllogistic task* (centered on attributes: **A** vs. on classes: **C**);
- the *administration order of the two types of task*: **A** then **C** (symbolized with **AC**) or **C** then **A** (symbolized with **CA**)
- the *position in the administration order*: first vs. second.

The **dependent variable** was *the level of correctness*, at the global level, or for different types of syllogisms.

The *syllogistic figures, validity, and the number of mental models* were additional independent variables, which were not manipulated.

Hypotheses

Main hypotheses

1) It is expected the following order effect: At least *for the valid syllogisms*, the *correctness should be higher for the* ***A*** *type task when it is administered in the first position than when it is administered after the* ***C*** *type task*.

2) It is expected the following order effect: At least *for the valid syllogisms*, the *correctness should be higher for the* ***C*** *type task when it is administered after the* ***A*** *type task than when it is administered in the first position.*

3) It is expected the following order effect: At least *for the valid syllogisms*, there should be no significant difference between the *correctness for the* ***A*** *type task and the one for the* ***C*** *type task* when they are administered in the second position.

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Secondary hypotheses

1) It is expected the following content effect: the *correctness for the **A** type task should be higher than the one for the **C** type task*, at least for the following configuration of conditions: *valid syllogisms, administration in the first position.*

2) There should be *changes in the figure effects dependent on the experimental condition* and in comparison with the ones obtained in the first study, which had an abstract symbolic neuter task.

3) *No significant performance difference* should occur *between the multiple model valid syllogisms and invalid syllogisms for the **A** type task when it is administered in the first position*.

Presumed predictions of the mental models theory

1) *No order effects* or, at most, *a beneficial effect of the precedence of the **C** type task for the subsequent **A** type task*.

2) *No content effects* or, at most, the *correctness for the **C** type task should be higher than the one for the **A** type task*, for *all the syllogisms, no matter the administration order.*

3) *No changes in the figure and validity effects dependent on the experimental conditions*.

II. Method

Participants

The participants at the study were 43 high school students (23 girls and 20 boys) of 10^{th} and 11^{th} grade, with a specialization in mathematics and physics. The mean age was of 17 years. Only 31 of them completed all the items for the tasks administered in the first position, and only 24 of them completed all the items for the tasks administered in the second position. In the section for results, the number of participants involved in each comparison will be specified.

Material

The following syllogistic tasks were used:

– A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with a concrete content centered exclusively on attributes (**A** type content). It had 24 items distributed on types and ordered as in the task used in the first study that had a neuter abstract symbolic content (see Annex 7). The attributes were fictive symptoms of a rare disease.

– A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with a concrete content centered exclusively on classes (**C** type content). It had 24 items distributed on types and ordered as in the task used in the first study that had a neuter abstract symbolic content (see Annex 8). The classes were fictive classes of plants.

Each type of task was preceded by an instruction in which the argumentative situation was explained with reference to its specific concrete content and through which the modality of answer was described. There were no trial tasks or trial syllogisms within a task.

Procedure

The syllogistic tasks were administered collectively, at the class hours, in the same session, without other time limit. The order of the syllogisms of a task was the same for all the participants, no matter the type of the syllogistic task. There were no trial task or trial syllogisms given the administration conditions (the time limited to a class hour and the content constraints). The participants were allowed to give a pseudonym instead of their name in order to discourage the tendency to copy the answers from their neighbors, by securing the confidentiality of their performance.

Participants were included in the two experimental groups by a random selection, taking into consideration their arrangement in the classroom (each row of chairs was assigned to one of the two experimental conditions). The first experimental group (the administration order **AC**) had 16 participants for the first task, and 13 participants for the second one. The second experimental group (the administration order **CA**) had 15 participants for the first task, and 11 for the second one.

III. Results

Given that a) the majority of the variables involved in the study had a distribution significantly departed from normality (with the exceptions of the total correctness and the correctness for the valid syllogisms), b) the sample of participants was relatively small, and c) the variance homogeneity for the experimental groups was not secured in all the relevant situations, I was constrained to use nonparametric statistical tests (Mann-Whitney test for the between-subjects comparisons and Wilcoxon test for the within-subjects comparisons). They only partially succeeded in replacing the parametric tests and ANOVA.

The statistical description of the most important variables involved in the study for each of the four experimental groups is included in the Annex 11.

The chosen statistical significance threshold was of $p = .05$.

Preliminary results

No statistically significant age and gender differences existed between the experimental groups.

Comparing globally (for all the syllogisms of both tasks) the correctness for the two experimental groups, no significant performance difference occurred between the first administered task and the second one. The comparison on types of syllogisms, using the Wilcoxon test, indicated that the only significant difference was for the correctness of the invalid syllogisms ($z = -2.083$, $p = .037$), their correctness being significantly lower at the second administered task in comparison with the first one. Analyzing to see if this significant difference occurred for both experimental groups, the results indicate that it was significant only for the group with the administration order AC ($z = -.2.207$, $p = .027$, $N = 13$).

Main hypotheses

1) A significantly lower performance for the valid syllogisms in the **A** type task at its administration after the **C** type task than the one obtained at its administration before the **C** type task was obtained ($U = 48$, $p = .043$, $N = 27$), as it was expected.

2) The expected difference for the correctness of the valid syllogisms from the **C** type task between the situation in which it was administered in the first position and the one in which it was administered in the second position was only close to the statistical significance threshold (Mann-Whitney test $U = 61.5$, $p = .098$) for a two-tailed comparison, but it was statistically significant for a one-tailed comparison (which here is warranted, given the unidirectional prediction). The correctness was higher when the **C** type task was administered after the **A** type task, as it was expected.

3) No statistically significant difference occurred between the *correctness for the **A** type task and the one for the **C** type task* when they were administered in the second position, as it was expected.

Supplementary result: No statistically significant performance differences between the two experimental groups were obtained, also, when the above-mentioned comparison was made on types of syllogisms (of different validity, syllogistic figure, or number of mental models).

Secondary hypotheses

1) Comparing with the Mann-Whitney test the correctness for the two tasks administered in the first position: **A** and **C**, a significant difference was obtained only for the valid syllogisms ($U = 70.5$, $p = .044$, $N = 31$), in the expected direction: performance for the **A** type task was higher than the one for the **C** type task.

Supplementary result: The improvement in the performance for the **A** type task did not refer to particular types of valid syllogisms, because no statistically significant differences between the two experimental groups occurred in that respect.

2) The complete results and the values obtained for the comparisons in what respects the figure effects are presented in the tables from the Annex 12.

For valid syllogisms

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 2 syllogisms was obtained for all four experimental conditions, no matter the type of task content or the administration order.

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 3 syllogisms was obtained for all four experimental conditions, no matter the type of task content or the administration order.

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 3 syllogisms was obtained for three of the experimental conditions. The only exception was for the **A** type task, in the **CA** administration order.

For invalid syllogisms

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 1 syllogisms was obtained for three of the experimental conditions. The only exception was for the **A** type task, in the **AC** administration order.

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 3 syllogisms was obtained for only one experimental condition: **C** type task, in the **AC** administration order.

For one model syllogisms

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 2 syllogisms was obtained for only one experimental condition: **C** type task, in the **CA** administration order.

For multiple model valid syllogisms

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 3 syllogisms was obtained for all four experimental conditions, no matter the type of task content or administration order.

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 3 syllogisms was obtained for three of the experimental conditions. The only exception was for the **A** type task, in the **CA** administration order.

3) *There occurred no statistically significant difference between the correctness for the multiple model syllogisms and the one for the invalid syllogisms from the **A** type task when it was administered in the first position,* as it was expected.

IV. Discussion

Preliminary notes

Because the report of the results would have been more complicated than it already is, no reference was made to the level of the performance that it would be obtainable by chance, with a pure strategy of a random guessing. Anyway, that level is hard to be computed for each type of syllogism, given the fact that the alternative options were provided in a fixed order and people may have preferences when trying to guess the correct answer.

The possibility that the expected order effects to be accounted by learning and transfer from the previously administered task, or through a general deterioration of the performance due to tiredness was not supported by data. By comparing globally the correctness for the two experimental groups together, no statistically significant difference occurred between the first administered task and the second one.

Main hypotheses

1) There occurred, as it was expected, an order effect in which the precedence of the **C** type task had a detrimental effect for the performance of the subsequent **A** type task. This result is not expected to occur in the standard mental models theory, in which, hypothetically, it should have been the other way around, given the extensional nature of the mental models. Also, the result is not accountable using the traditional notion of priming. It is considered to be more compatible with the dynamic idea that the cognitive system is placed in its state space through a **C** type task in a region that is farther away from the regions of the adequate assumed dynamic syllogistic schemas. So, their recognition, when the **A** type task is administered, should be affected by the precedence of the **C** type task. It might be a suggestion that different dynamic mental sets are implied by the two types of tasks. The phenomenon might be similar with the one discussed in the traditional cognitive psychology in what respects the costs involved in task switching (Walther & Fei-Fei, 2007). They are generically explained by some unclearly specified top down influences, labeled "task-set reconfiguration". Wylie, Javitt, and Foxe (2003) note that the changing of a task set "relies on 'executive control' processes" and that "despite extensive efforts to detail the nature of these processes, there is little consensus as to how the brain achieves this critical function" (p. 667). They suggested a dynamic mechanism, centered on the idea of competition. Based on obtained empirical data, their view was that "preparing to switch task may not be a separate (control) process per se, but rather, the beginning of a competition between the potentially relevant tasks, a competition that is ultimately resolved during the switch trial." (Wylie et al., 2003, pp. 667). Such an idea is in accordance with the notion of competition between dynamic schemas of organization of the input stimuli, as the one advanced in this work in what respects the interactions between dynamic deductive schemas. The phenomenon is similar, also, with the familiar situation when it is harder to recognize, for example, a face if, previously, another face was presented.

2) At least for the investigated sample of participants, the facilitative effect of the precedence of an **A** type task, with intensional content, seems to be not as powerful as the one of the precedence of a **CPP** task format, as in the previous study, for a **C** type task. The expected order effect was only close to the significance threshold in a two-tailed comparison, although, in the one-tailed comparison, warranted by the unidirectional prediction, was statistically significant. The obtained result may be explained taking into consideration also the fact that an exclusively intensional content is not expected to have positive effects for all the syllogisms, and that an exclusively extensional content is also not expected to have detrimental effects for all the syllogisms. Moreover, in the **C** type task, the names for the fictive classes of plants could be easily interpreted as attributes also, not only as classes, resulting that the **C** type task might be not, in fact, purely extensional. Therefore, it is likely that the expected difference of performance to be not so notable.

3) No difference occurred at the administration of the two tasks in the second position between the performance for the **A** type task, with intensional content, and the one for the **C** type task, with a predominantly extensional content, as it was expected, due to the combined effects of the previously two order effects. So, the performance difference between the two tasks at their administration in the first position might have been annihilated through the obtained order effects.

Secondary hypotheses

1) For this sample of participants, the expected difference between the task with intensional concrete content (**A** type task) and the one predominantly with extensional content (**C** type task) administrated in the first position occurred in the predicted way, specifically for the valid syllogisms. The obtained *content effect* seems to be the result of a cumulative contribution of all the valid syllogisms. The difference between the results obtained in this study and the results in this respect obtained in the previous study may be due to the differences between the investigated samples. A comparison with the Mann-Whitney test of the two samples concerning the global performance and the performance for the two types of syllogisms (valid or invalid) indicated a significant performance difference, no matter the type of content of the task. So, a higher performance was obtained for this high school sample than the one for the college students' sample for the **A** type of task at its administration in the first position ($U = 419.5$, $p < .001$, for the total correctness, $U = 491.5$, $p < .001$, for the correctness of the valid syllogisms, $U = 669$, $p = .01$, for the correctness of the invalid syllogisms, $U = 409.5$, $p < .001$, for the one model syllogisms). The two samples were similar only in what respects the multiple model valid syllogisms in the **A** type task, where no significant difference occurred. A higher performance was obtained also for this high school sample than the one for the college students' sample for the **C** type of task at its administration in the first position for all types of syllogisms ($U = 520$, $p < .001$, for the total correctness, $U = 760.5$, $p < .001$, for the correctness of the valid syllogisms, $U = 776.5$, $p = .001$, for the correctness of the invalid syllogisms, $U = 843.5$, $p = .002$, for the one model syllogisms, $U = 870.5$, $p = .003$, for the multiple model syllogisms). Such results may suggest that, for this sample of high school students with a special training in the mathematics and physics, the basic stability of the assumed schemas for valid syllogisms might be at a higher level and the presumed schemas for the figure 2 and figure 3 valid syllogisms might exist in a higher proportion than in the case of the college students with a special training in social sciences. This difference may be reflected in a higher performance of the high school sample than the one of the college sample for every type of syllogisms in the **C** type task, in spite of its putative extensional unfavorable content. But this high stability of the assumed schemas for valid syllogisms may be excessive for the **A** type task, so that it is possible that this type of task to have a detrimental effect over the performance for those syllogisms with no schemas or less stable schemas. This effect might be reflected into the absence of a performance difference for the invalid syllogisms between the **A** and **C** type task at their administration in the first position. It is to be noted that only for the **A** type task there is no performance difference between the two samples in what respects the multiple model syllogisms, the ones assumed to have less stable syllogistic schemas. So, it may be that an **A** type task is a facilitative factor especially for these syllogisms.

2) In this study, the expected figure effects in the order predicted both by the proposed dynamic model as well as the mental models theory occurred more clearly than in the previous studies. For the valid syllogisms, there was a higher performance for the figure 1 syllogisms than the one for the figure 2 and, respectively, figure 3 syllogisms, no matter the type of the experimental condition. Also, with the exception of only one experimental condition, a higher performance was obtained for the figure 2 syllogisms than the one for the figure 3 syllogisms. The exception may be due to the detrimental effect of the precedence of a **C** type task particularly for the performance at the figure 2 syllogisms of a subsequent **A** type task. The clearer performance difference between all the three syllogistic figures in this study than the one obtained in the previous study may be due also to the characteristics of this sample, to a presumed higher basic stability for the assumed schemas for all valid syllogisms, in accordance with their cognitive importance. But, as there was indicated by the results obtained for the figure effects by taking into consideration the number of mental models, the difference in stability may be more salient for the syllogisms with lower cognitive function, since the figure effects occurred in this sample predominantly for the valid multiple model syllogisms. This affirmation, explaining the difference not through the number of mental models or the position of the middle term, may be supported also by the fact that, for the invalid syllogisms, the obtained figure effects were not the ones expected by the standard mental models theory. The results did not indicate that the figure 3 invalid syllogisms had the highest performance, as it should have been in accordance with the mental models theory. Instead, for this sample and type of tasks, figure 2 invalid syllogisms had the highest performance. The result may be understood given the fact that the assumed syllogistic schemas for the figure 2 valid syllogisms may benefit the most when both the intensional and extensional influences are present in the condition of a **C** type task following an **A** type task. Therefore, due to their relatively higher stability, less confusion with the corresponding invalid syllogisms is to be expected.

3) In this study, too, no significant performance difference occurred between the multiple model syllogisms and invalid syllogisms for the **A** type task when it was administered in the first position, as it was expected. The reason is the same with the one mentioned in the study 2: higher chances for the distinction of the appropriate argumentative situations for the valid syllogisms schemas in the case of a content centered on attributes than in the case of a content centered on classes.

V. Conclusion

All the *main hypotheses*, regarding the order effects, and the *secondary hypotheses* were supported by the data.

The results showed a more salient content effect of the intensional type of task (**A** type task) than the one obtained in the previous study. Also, they indicated a detrimental effect of the precedence of an extensional task (**C** type task) for the performance in a subsequent intensional type of task (**A** type task). It may be that the interpretation of a syllogistic task as referring exclusively to relations between classes makes harder its intensional interpretation in a subsequent task, involving a dynamic competition between syllogistic schemas placed on different organization levels. For this sample, the intensional content did not have the same facilitative effect as the precedence of a **CPP** task format in the previous study. The obtained results are not the ones hypothetically predicted by the mental models theory.

Study 4

I. Purpose and hypotheses

Purposes

The *general purpose* of this study remains the same as in the previous studies. All general considerations in what respects the intention to bring evidence to support the dynamic schema-based model of the syllogistic reasoning are valid in this case, too.

The *main purpose* of the study was to investigate the content and order effects occurring in two types of tasks with a different abstract symbolic content (type **N**: neuter and type **L**: specifying the logical meaning of the syllogistic terms). The comparison of the syllogistic performance in the two types of tasks is important in order to support the hypothesis that abstract semantic cues (features) have significance in the syllogistic process, not the concrete meanings as such, i.e. factual knowledge, or some purely formal, syntactic features.

The *secondary purpose* was to find out if the results obtained in the previous studies in what respects the validity, order and figure effects occur also in the new experimental conditions.

Preliminary comments

The results obtained in the previous studies on a concrete content were encouraging regarding their interpretation based on the hypothesis that the semantics of the syllogisms is a mixed one. It was presumed that it includes not only an extensional component, but also a more important intensional one, defining the content of the pragmatic syllogistic schemas. The findings supported the idea that a task content centered exclusively on attributes leads to a higher global performance than the one obtained in a task centered exclusively on classes. Also, given the fictive nature of the concrete content of the A and C type tasks, these results could be interpreted to mean that in the concrete content of the everyday syllogistic tasks there are semantic features at an abstract level, with logical meaning, which are important for the syllogistic processes. But those findings may have an ambiguous interpretation in what respects the source of the obtained difference. A possible alternative explanation to be considered is that the concrete content as such of the two types of tasks was important (i.e., the classification or the diagnosing situation), not the type of linguistic and semantic cues favoring a classial or attributive interpretation. Moreover, given that, with a concrete content, it is hard to design syllogistic tasks with veridical situations and in accordance with the requirements of a mixed semantics[7], a comparison for tasks with a concrete mixed content was not possible. Therefore, an abstract symbolic content was used instead. Only that, in comparison with the traditional abstract symbolic tasks, the general logical status of the syllogistic terms and of their relationship was explicitly stated using determinative abstract specifications. For example, the **A** type judgment in the new abstract symbolic version is: All members of the class **S** have the property **P**. The new version of the syllogistic task (**L**) was compared with the traditional abstract symbolic version (**N**). That version may be considered to be neuter or ambiguous in what respects the logical semantics, but, still, it seems that it generally encourages a classial (extensional) interpretation.

It was assumed that the performance for a **L** type task should be generally higher than the one for a **N** type task in the case of the valid syllogisms, based on approximately the same dynamic reasons for which it was presumed that an **A** type task should lead to higher performances than a **C** type task in that respect. Also, order effects were expected when the **L** and **N** tasks are administered successively at the same subject, supported by the same theoretical dynamic argumentation as in the case of the predicted ordered effects for the **A** and **C** tasks in the previous study.

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[7] It is the kind of semantics proposed by Didilescu and Botezatu (1976).

It was expected, also, that the validity and figure effects should remain relatively the same in the new experimental conditions, especially for those syllogisms that have the highest cognitive function. However, changes in the validity and figure effects may occur as a consequence of the level of the assumed relative stability for the less stable syllogistic schemas of the syllogisms with a lower importance of their cognitive goal. Specifically, those changes were expected especially for the figure 2 valid syllogisms and for the invalid syllogisms (for reasons stated before, in the precedent studies).

For the current study, a specific figure effect was expected to occur due to the fact that the participants had to choose between an intensional and an extensional version of the same possible conclusion. For each syllogistic figure, only one of the two versions is predicted to occur if the mixed semantics of the syllogisms is valid for the pragmatic syllogistic schemas. For the figure 1 and figure 3 valid syllogisms, the intensional version of the conclusion should be the preferred one. For the figure 2 valid syllogisms, the extensional version of the conclusion should be preferred instead. The order of the concordance between the correct chosen answer and the one predicted based on the mixed semantics should be the same with the order of the cognitive importance of the syllogistic figures. In other words, it was expected a higher concordance between the correct chosen answer and the one expected based on the assumed syllogistic mixed semantics model (i.e., if the intensional or the extensional version of the conclusion is chosen) for both administration orders at least for the figure 1 valid syllogisms in comparison with the figure 2 and, respectively, figure 3 valid syllogisms.

For the expected results, in this case, too, the mental models theory of reasoning does not have any specific predictions. Nowhere is it stipulated that the interpretation of the syllogistic terms as classes or attributes or of their relationship as intensional or extensional should matter for the syllogistic performance. It is to be presumed only that, since mental models are extensional representations (as it also noted by Barrouillet in 2011, who affirms that mental models theory “favors an extensional approach based on the representation of possibilities”), the content with an explicit intensional meaning may not be, in general, beneficial for the syllogistic performance. Moreover, since in the **L** version there are more words to be processed, the supplementary load of the working memory should be detrimental for the syllogistic performance. The **L** type task should be harder, also, than the **N** type task because it has more answer options to be analyzed (9 options for the **L** type task in comparison with 5 options for the **N** type task). Also, no validity or figure effects are expected to be changed by such a semantic manipulation in a very clear manner. There is no reason, too, for which there should be figure differences in what respects the chosen version of the conclusion: intensional or extensional.

Concluding comments

The study was an experimental one, with a mixed 2-way factorial design. The **manipulated independent variables** were:

- the *type of abstract content of the syllogistic task* (neuter: **N** vs. mixed logical semantics **L**);
- the *administration order of the two types of tasks*: **N** then **L** (symbolized with **NL**) or **L** then **N** (symbolized with **LN**);
- the *position in the administration order*: first vs. second.

The **dependent variable** was *the level of correctness*, at the global level, or for different types of syllogisms.

The *syllogistic figures, validity, and the number of mental models* were additional independent variables, which were not manipulated.

Hypotheses

Main hypotheses

1) It is expected the following **content effect**: the *correctness for the **L** type task should be higher than the one for the **N** type task*, at least for the following configuration of conditions: *valid syllogisms, administration in the first position*.

2) It is expected the following **order effect**: At least *for the valid syllogisms*, the *correctness should be higher for the **L** type task when it is administered in the first position than when it is administered after the **N** type task*.

3) It is expected the following **order effect**: At least *for the valid syllogisms*, the *correctness should be higher for the **N** type task when it is administered after the **L** type task than when it is administered in the first position.*

4) It is expected the following **order effect**: At least *for the valid syllogisms*, there should be no significant difference between the *correctness for the **L** type task and the one for the **N** type task* when they are administered in the second position.

5) It is expected a particular **figure effect**: *For both administration orders*, there should be a *higher concordance between the correct chosen answer and the one expected based on the assumed syllogistic mixed semantics model* (i.e. if the intensional or the extensional version of the conclusion is chosen) *for the figure 1 valid syllogisms than the one for the figure 2 syllogisms and, respectively, figure 3 valid syllogisms.*

Secondary hypotheses

1) There should be *changes in the figure effects dependent on the experimental condition*.

2) *No significant performance difference between the multiple model valid syllogisms and invalid syllogisms for the **L** type task when it is administered in the first position* should occur.

Presumed predictions of the mental models theory

1) *No order effect*s

2) *No correctness difference* or, at most, the *correctness for the **N** type task should be higher than the one for the **L** type task*, for *all the syllogisms*, *no matter the administration order*.

3) *No changes in the figure and validity effects dependent on the experimental conditions*.

4) No differences of *concordance between the correct chosen answer and the one expected based on the assumed syllogistic mixed semantics model* (i.e. if the intensional or the extensional version of the conclusion is chosen) between the syllogistic figures. Moreover, at most, due to the extensional nature of the mental models theory, the preferred chosen answer should be, for all the cases, the extensional version of the conclusion.

II. Method

Participants

The participants at the study were 51 high school students (49 girls and 2 boys) of 10th and 11th grade, with a specialization in mathematics and physics. The mean age was of 17 years. Of them, 50 completed all the items for the tasks administered in the first position, and only 43 of them completed all the items for the tasks administered in the second position. In the results section, the number of participants involved in each comparison will be specified.

Material

The following syllogistic tasks were used:

- A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with an abstract symbolic neuter content (**N** type task). It was the same with the task of 24 items from the first study (see Annex 1)
- A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with an abstract symbolic content having a mixed semantics (Didilescu & Botezatu, 1976), in which the logical meaning of the syllogistic terms as classes or as properties, as well as of the syllogistic judgments was specified (**L** type task). It had 24 items distributed on types and ordered as in the task used in the first study that had a neuter abstract symbolic content (see Annex 13). There were nine alternatives from which the answer could be chosen. For each of the four types of judgment, an intensional and an extensional version were provided. The answer "no valid conclusion" was added to these eight alternatives.

Each type of task was preceded by an instruction in which, this time, only a very short explanation of the task was given, assuming an implicit understanding of the task.

For the **L** task, the correctness was computed in two ways. The one used in most of the analyses did not consider the extensional or intensional version chosen for a given conclusion. The other one considered that an answer is correct only if it corresponds with the requirements of the mixed semantics.

Procedure

The syllogistic tasks were administered collectively, at the class hours, in the same session, without time limit. The order of the syllogisms was the same for all the participants, no matter the type of syllogistic task. There were no trial task or trial syllogisms given the administration conditions (the time limited to a class hour and the content constraints). The participants were allowed to give a pseudonym instead of their name in order to discourage the tendency to copy the answers from their neighbors, by securing the confidentiality of their performance.

Participants were included in the two experimental groups by a random selection, taking into consideration their arrangement in the classroom (each row of chairs was assigned to one of the two experimental conditions). The first experimental group (the administration order **NL**) had 26 participants for the first task, and 22 for the second task. The second experimental group (the administration order **LN**) had 22 participants for the first task, and 24 for the second task.

III. Results

Given that a) the majority of the variables involved in the study had a distribution significantly departed from normality (with the exceptions of the total correctness and the correctness for the valid syllogisms), b) the sample of participants was relatively small, and c) the variance homogeneity for the experimental groups was not secured in all the relevant situations, I was constrained to use nonparametric statistical tests. They only partially succeeded in replacing the parametric tests and ANOVA.

The statistical description of the most important variables involved in the study for each of the four experimental groups is included in the Annex 14.

Preliminary results

No statistically significant age and gender differences existed between the experimental groups.

Comparing globally the correctness for the two experimental groups (for all the syllogisms of both tasks), no significant difference occurred between the first administered task and the second one. The comparison on the two experimental groups (with two types of administration order) and on types of syllogisms indicated the following results. Applying the Wilcoxon test, for the **NL** administration order, the only statistically significant difference was for the correctness of the multiple model valid syllogisms ($z = -2.239$, $p = .025$). There was a higher performance for the multiple model valid syllogisms at the **L** type task than the one for the **N** type task. For the **LN** administration order, the only statistically significant difference was for the correctness of the figure 3 valid syllogisms ($z = -2.053$, $p = .025$). There was a higher performance for figure 3 valid syllogisms at the **L** type task than the one for the **N** type task.

Main hypotheses

1) A higher correctness for the **L** type task than the one for the **N** type task, for valid syllogisms, for the tasks administrated in the first position, was obtained ($U = 186$, $p = .013$), as it was expected.

Supplementary results

The full analysis on types of syllogisms and on the two types of administration order is presented in the Annex 15.

Synthesizing, the results *for the tasks administered in the first position* indicated:

- a significantly higher correctness for the *invalid syllogisms* at the **N** type task than the one at the **L** type task;
- a significantly higher correctness for the *multiple model valid syllogisms* at the **L** type task than the one at the **N** type task;
- a significantly higher correctness for the *figure 1 valid syllogisms* at the **L** type task than the one at the **N** type task;
- a significantly higher correctness for the *figure 3 invalid syllogisms* at the **N** type task than the one at the **L** type task.

2) There was no significantly higher performance for the **L** type task when it was administered in the first position than the one obtained when it was administered after the **N** type task. So, the expected result was not obtained.

3) A significantly higher correctness was obtained (U = 175.5, p = .02) for the **N** type task when it was administered after the **L** type task in than the one obtained when it was administered in the first position, as it was expected.

Supplementary results

The analysis on types of syllogisms indicated that, within the *valid syllogisms*:

- The correctness was significantly higher (U = 186.5, p = .033) for the **N** type task when it was administered after the **L** type task than the one obtained when it was administered in the first position only for the *multiple model valid syllogisms*;
- For the *one model syllogisms*, the difference favoring the **N** type task at its administration in the second position was only relatively close to the significance threshold (U = 214, p = .122, two-tail);
- For the *figure 1 valid syllogisms*, the correctness was significantly higher (U = 162.5, p = .005) for the **N** type task when it was administered after the **L** type task than the one obtained when it was administered in the first position; for the *figure 2 valid syllogisms*, there was only a tendency that their correctness to be higher (U = 203.5, p = .077) for the **N** type task when it was administered after the **L** type task than the one obtained when it was administered in the first position, in a two-tailed comparison (but in a one-tailed comparison, warranted by the unidirectional prediction, the result was statistically significant);
- For the *invalid syllogisms*, in a two-tailed comparison, there was only a tendency that their correctness to be higher (U = 201.5, p = .076) when the **N** type task was administered before **L** type task than the one obtained when it was administered after the **L** type task (but in a one-tailed comparison, warranted by the uni-directional prediction, the result was statistically significant).

4) There was no statistically significant difference between the *correctness for the valid syllogisms of the* ***L*** *type task and the one for the valid syllogisms of the* ***N*** *type task* when they were administered in the second position, as it was expected.

Supplementary result

There was a significantly *higher correctness for the figure 1 valid syllogisms at the **L** type task than the one at the **N** type task* ($U = 171$, $p = .038$) at their administration in the second position.

5) Applying the Wilcoxon test, the following results were obtained:

- Significantly *more concordant answers* were obtained *for the figure 1 valid syllogisms* than the ones for the figure 2 valid syllogisms in the **NL** administration order ($z = -2.867$, $p = .004$), and in the **LN** administration order ($z = -3.495$, $p < .001$), as it was expected.
- Significantly *more concordant answers* were obtained *for the figure 1 valid syllogisms* than the ones for the figure 3 syllogisms in the **NL** administration order ($z = -3.745$, $p = .000$), and *in* the **LN** administration order ($z = -3.972$, $p < .001$), as it was expected.

Secondary hypotheses

1) The complete results and the values obtained for the comparisons in what respects the figure effects are presented in the tables from Annex 16.

For valid syllogisms

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 2 syllogisms was obtained for all four experimental conditions, no matter the type of task content, or the administration order.

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 3 syllogisms was obtained for all four experimental conditions, no matter the type of task content, or the administration order.

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 3 syllogisms was obtained for three of the experimental conditions. The only exception was for the **L** type task, in the **LN** administration order.

For invalid syllogisms

A significantly higher correctness for the figure 2 invalid syllogisms than the one for the figure 1 invalid syllogisms was obtained for only one of the experimental conditions: **N** type task, in the **NL** administration order.

A significantly higher correctness for the figure 3 invalid syllogisms than the one for the figure 1 invalid syllogisms was obtained for two of the experimental conditions: the **NL** administration order for the **L** type task, and, respectively, for the **N** type task.

A significantly higher correctness for the figure 2 invalid syllogisms than the one for the figure 3 invalid syllogisms was obtained for two of the experimental conditions: **L** type task in the **NL** administration order, and, respectively, **N** type task, in the **LN** administration order.

For one model syllogisms

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 2 syllogisms was obtained for only two of the experimental conditions: **L** type task, and, respectively, **N** type task, in the **LN** administration order.

A significantly higher correctness for the figure 1 syllogisms than the one for the figure 3 syllogisms was obtained for only one of the experimental conditions: **L** type task, in the **NL** administration order.

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 3 syllogisms was obtained for only one of the experimental conditions: **N** task, in the **LN** administration order.

For multiple model valid syllogisms

A significantly higher correctness for the figure 1 than the one for the figure 3 syllogisms was obtained for all four experimental conditions, no matter the type of task content, or the administration order.

A significantly higher correctness for the figure 2 syllogisms than the one for the figure 3 syllogisms was obtained for all four experimental conditions, no matter the type of task content, or the administration order.

2) For the **LN** administration order, a *significantly higher correctness* was obtained for the multiple model valid syllogisms than the one for the invalid syllogisms, both in the **L** type task ($z = -3.761$, $p = .000$), and the **N** type task ($z = -3.629$, $p = .000$). It was not the expected result.

Supplementary result

For the **NL** administration order, a *significantly higher correctness* was obtained for the multiple model valid syllogisms than the one for the invalid syllogisms in the **L** type task ($z = -3.051$, $p = .002$).

IV. Discussion

Preliminary notes

Because the report of the results would have been more complicated than it already is, no reference was made to the level of the performance that it would be obtainable by chance, with a pure strategy of a random guessing. Anyway, that level is hard to be computed for each type of syllogism, given the fact that the alternative options were provided in a fixed order and people may have preferences when trying to guess the correct answer.

The possibilities that the expected order effects to be accounted by a general improvement of the performance at the syllogistic task administered in the second position by learning and transfer from the previous task, or through a general deterioration of the performance due to tiredness or boredom are not supported by data. By comparing globally the correctness for the two experimental groups together, no significant correctness difference occurred between the first administered task and the second one. The regression to the mean is, also, less likely an explanation for the order effects, because they were not the same for the valid and invalid syllogisms.

The obtained content effects are not accountable exclusively through the assumption that the **L** format might discourage illicit conversions by its intensional meaning for some of the syllogistic judgments. In order to prove that, there was not made here a complete analysis for all the syllogisms for which the illicit conversion might play a role in their solving (see Dickstein, 1981). Only the case of the EA3O syllogism is considered here, the only one from this syllogistic task for which an erroneous conclusion (**E** judgment) occurs through an illicit conversion, in both of its versions (see Dickstein, 1981): conversion by addition or by substitution. If the **L** format was able to successfully discourage illicit conversions, then the erroneous conclusion **E** for the EA3O syllogism should be significantly less frequent in the syllogistic task administered in the first position in the **LN** group (i.e., for the **L** format task) than in the **NL** group (i.e., for the **N** format task). Applying the chi-square test, such a statistically significant performance difference in the above-mentioned direction between the two experimental groups was not obtained.

Main hypotheses

1) The *content effect* was the expected one. The result is notable especially taking in view the fact that for the **L** task more words had to be processed, and more options were given for the choice of the answer. So, the **L** task should have been harder than the **N** task in all four experimental conditions. Moreover, the supplementary results showed a clear effect of the mixed semantics content both on the syllogisms with the highest assumed cognitive importance (figure 1 syllogisms) and on those with lower cognitive importance (which are, in general, multiple model syllogisms, with the lowest performance). Instead, this time (in comparison with the previous study), the performance for the invalid syllogisms was lowered by the mixed semantics content. A possible explanation is the extreme level of stability of the schemas of the valid syllogisms.

2) The fact that no order effect occurred in what respects the precedence of a **N** type task over the performance in the **L** type task may be interpreted in two ways. On the one hand, in comparison with a **C** type task, a **N** type task has, presumably, a more neuter interpretation in what respects the extensionality of the syllogistic terms. On the other hand, it may be also that the relative stability of the syllogistic schemas in this sample in the case of the **L** type task was so high that any effect from the precedence of a **N** task could not be a notable one.

3) The above-mentioned interpretation may be supported by the order effect obtained by the precedence of the **L** task on the performance for the subsequent **N** task. In comparison with the previous study, when an exclusively intensional task did not have a statistically significant influence on the performance in a subsequent exclusively extensional one, here, a mixed semantics (extensional and intensional) type of task had a statistically significant positive influence on the performance in the subsequent neuter type of task.

4) For the first time, a content effect was obtained when comparing the tasks administered in the second position, the performance for the figure 1 valid syllogisms from the **L** task being higher than the one for the figure 1 valid syllogisms from the **N** task. But, in this comparison, there was no difference for the total correctness, a result supporting the expected order effect.

5) The idea of a mixed semantics for the syllogistic task is supported by the results indicating a greater concordance between the chosen conclusion and the one expected based on this semantics for the figure 1 syllogisms (the ones assumed to have the highest cognitive importance and syllogistic schemas with the highest stability) than the one for the figure 2 and, respectively, figure 3 syllogisms.

Secondary hypotheses

1) As in the previous study, the figure effect for the *valid syllogisms* was, in general, the one expected in accordance with the order of their assumed cognitive importance. However, there occurred an exception: the lack of a performance difference between the figure 2 and figure 3 syllogisms for the **L** type task, in the **LN** administration order. It may be that this result is caused to the effect of the mixed semantics of the **L** task, favoring the actualization of the syllogistic schemas with lower assumed stability. For the *invalid syllogisms* of the three syllogistic figures, the results did not support the performance order predicted hypothetically by the mental models theory. There were two experimental conditions in which the figure 2 invalid syllogisms had a better performance than the figure 3 invalid syllogisms. It seems that this occurred in those situations in which there was a combined effect of the mixed semantics and of the extensional interpretation of the **N** task. The order hypothetically predicted by the mental models theory was partially respected particularly for the experimental condition when the **N** type task is administered in the first position. In other words, it is the situation in which an exclusively extensional interpretation was favored the most.

For the *one model syllogisms*, the figure effect was not very obvious, which is not what a mental models theory would predict. A performance difference between the figure 1 and figure 2 one model syllogisms occurred only for the **L** and **N** type task, in the **LN** administration order, maybe as an effect of the mixed semantics content. The expected performance difference between the figure 1 and figure 3 one model syllogisms, as well as the one between the figure 2 and figure 3 one model syllogisms, occurred only in one experimental condition, in each case. It may be that the stability of the figure 3 one model syllogisms in a L type task is affected by the precedence of a **N** task and that is why the performance difference between the figure 1 and figure 3 syllogisms became notable. Instead, the figure 2 one model syllogisms in a **N** type task might have been favored by the precedence of a L type task, and that is why the performance difference between the figure 2 and figure 3 one model syllogisms occurred only for this case.

For the *multiple model syllogisms*, the expected performance differences in what respects the figure effects occurred more clearly, maybe because, in their case, the ceiling effect induced by the mixed semantics type of task was less likely to occur. That ceiling effect was indicated only by the absence of a performance difference between the figure 1 and figure 2 multiple model valid syllogisms in all four experimental conditions. Instead, the other two figure differences (figure 1 - figure 3, and figure 2 - figure 3) in what respects the performance for the multiple model syllogisms occurred without exception in all four experimental conditions.

An explanation based on the position of the middle term is not possible for these results.

2) In this study, there occurred, in fact, a clear performance difference between the multiple model valid syllogisms and the invalid syllogisms for both administration orders, which it is not the result predicted by the mental models theory. It could be explained in the model proposed in this work based on the idea that the mixed semantics content was able to favor preferentially the performance for the multiple model valid syllogisms because they are more likely to have syllogistic schemas that could be activated by such content than the invalid syllogisms. In other words, the invalid syllogisms were not advantaged from this point of view. Moreover, they may have been disadvantaged by the extreme relative stability of some of the assumed schemas for the valid syllogisms having either the highest cognitive performance, or the lowest cognitive performance, which might have promoted the confusion of those valid syllogisms with the similar invalid syllogisms, and not their distinction, as it was expected. It may be that the above-mentioned distinction was favored only for those invalid syllogisms that are similar with valid syllogism having an intermediary relative stability of their assumed schemas (and, correlatively, an intermediary cognitive importance).

V. Conclusion

Of the five main hypotheses, four were supported by data. Of the two secondary hypotheses, only one was supported by the obtained results. However, the failure to support the two hypotheses is accountable in the proposed model, but not in the mental models theory. A clear content effect was obtained, favoring the **L** type task, in spite of its difficulty regarding the number of to be processed words and the number of the given options for an answer. This effect is also notable considering that it refers to the performance in two tasks with an abstract symbolic formulation. The effect of the mixed semantics was reflected also in the order effect in which the precedence of the **L** type task had a beneficial effect for the performance in the subsequent **N** task. Support for the mixed semantics was also obtained from the figure effect occurring for the concordance between the chosen conclusion and the one predicted through this mixed semantics. Also, the effect of the mixed semantics content was revealed by the significant higher performance for the multiple model valid syllogisms than the one for the invalid syllogisms. The expected figure effects occurred, too, especially for the multiple model syllogisms, in all four experimental conditions. The results are clearer in this respect than the ones from the previous studies.

Study 5

I. Purpose and hypotheses

Purpose

The *main purpose* of the study was the investigation of an order effect involving two syllogisms with the same type of content and similar premises but with a different assumed cognitive importance (valid vs. invalid) that were administered in a different order.

Preliminary comment

In the three previous studies, the order effects were investigated globally, and between syllogisms in different task formats, or with different types of semantic content. Their results supported the theoretical general hypothesis that the assumed dynamic schemas previously actualized in another syllogistic task are able to influence the performance and the syllogistic processes in a subsequent syllogistic task. It was assumed that such influences could be dynamically accounted by dynamic processes a) of cooperation, competition, recruitment, or b) of bringing the cognitive system closer or farther away in what respects the region from its state space corresponding to an adequate dynamic schema. Also, in all the previous studies, the performance for the invalid syllogisms was dynamically accounted by presuming that the assumed dynamic schemas of some valid syllogisms might be able to influence the answers for the similar invalid syllogisms (and even the answers for other similar valid ones). The supposition was that the dynamic schemas with an excessive stability, presumably those for the valid syllogisms having the highest cognitive importance and those that have been recently actualized, should have the highest influence in what respects the occurrence of their illusory recognitions, both for the valid and invalid syllogisms. On the other part, the dynamic schemas with the lowest level of stability may also favor the confusions (illusory recognitions of incorrect syllogistic schemas) in particular conditions (especially for the invalid syllogisms or for the figure 3 valid syllogisms), due to higher levels of overlap with the information given for other similar syllogisms that do not have stable schemas. It was presumed that only at an intermediate level of stability the dynamic schemas of the valid syllogisms might have beneficial effects on the performance of both the valid and the invalid syllogisms. This level of stability of the dynamic schemas was considered to favor the distinction between their adequate syllogistic situation and other similar situations. In the same time, it is not high enough in order to "project" their template onto the ambiguous elements of other similar syllogistic situations.

In the present study, two pairs of syllogisms in a traditional task format, with abstract symbolic neuter content, were chosen. Each pair contained a valid and an invalid syllogism. The first pair contained a valid syllogism (AA1A) with an assumed cognitive significance higher than the cognitive importance of the valid syllogism from the second pair (AE2E). The invalid syllogisms were chosen in such a way that they were identical with the correspondent valid syllogism with which they were paired in what respects the type of judgments of the premises and their order, but different from those correspondent valid syllogisms in what respects their syllogistic figure. Also, their modal incorrect answer from the previous studies had to be the correct conclusion of the correspondent valid syllogism. So, the valid syllogism AA1A was paired with the invalid syllogism AA2N (where **N** symbolizes the answer "no valid conclusion"). The valid syllogism AE2E was paired with the invalid syllogism AE3N. There were two experimental groups, for which the syllogisms from the two pairs were presented in the two possible administration orders.

By presenting the syllogisms from the two pairs in a different order, it was expected that the presumed relative stability of their assumed dynamic schemas would be manipulated. But their basic stability, defined predominantly by their cognitive importance, was assumed to remain the same.

In the first place, there was predicted an *order effect: the performance for the valid syllogism from the first pair should be higher when it is presented in the first position in the pair than when it is presented in the second one*. In the previous studies, detrimental effects occurred when a syllogistic task presumed to not favor the actualization of the assumed dynamic syllogistic schemas preceded a syllogistic task presumed to be favorable for such an actualization. A similar phenomenon was expected here. However, in this case, it was assumed that the precedence of an invalid (or other valid) syllogism may move away the cognitive system from the region of its state space corresponding to an assumed adequate syllogistic schema.

In what respects the *performance for the invalid syllogism*, the direction of the influence of a preceding valid syllogism is less predictable, since it depends on the stability of the assumed syllogistic schema of that valid syllogism. As it was noted above, only if that stability were at an intermediate level, the performance for the subsequent invalid syllogism should be increased as an effect of the precedence of the valid syllogism. Since the assumed dynamic schema for the AA1A syllogism, in spite of its abstract symbolic content, might have a rather high stability, it was expected that for the *AA2N syllogism to occur a higher performance when it is not preceded by the AA1A syllogism than when it is preceded by it*. As AE2E syllogism is presumed to have a lower cognitive importance and, correspondingly, a lower basic stability of its assumed dynamic schema, it was considered more likely that *its precedence will not have a notable effect over the performance for the subsequent AE3N syllogism*. It may be, also, that the stability of the AE2E assumed schema is at an intermediate level, favoring the distinction of its appropriate situation from the syllogistic situation of the AE3N syllogism. Thus, in the case of this pair, the precedence of the valid syllogism may have a beneficial effect over the performance of the subsequent invalid syllogism.

The influence of the preceding valid syllogism from a pair may be reflected also at the level of the frequency of the incorrect answers for the subsequent invalid syllogism. From that perspective, the percentage of the answer **A** for the AA2N syllogism should be higher when it is preceded by the AA1A syllogism than when it is not. Such a result is expected to occur only if the relative stability of the assumed dynamic schema for the AA1A syllogism will be sufficiently stable in the traditional abstract symbolic format used in this study. A similar result might be less likely to occur for the AE3N case, for the same reasons for which its performance might be less likely to be negatively influenced by the precedence of the AE2E syllogism.

The mental models theory in its standard version does not predict the expected differences. I see no reason for which building models for the AA2N syllogism should negatively influence in a significant manner the building of the initial model for the AA1A syllogism.

Concluding comments

The study was an experimental one, with a mixed 2-way factorial design. The **manipulated independent variables** were:

- The *order of the valid and invalid syllogisms in a pair*;
- The *type of syllogisms chosen for each pair* (valid vs. invalid, with high cognitive importance vs. with medium cognitive importance).

Hypotheses

Main hypothesis

1) It is expected an **order effect**: the *correctness for the AA1A syllogism should be higher when it is presented in the first position in its pair than in the second position*.

Tentative hypotheses

1) It is more likely the following **order effect**: the *correctness for the AA2N syllogism should be higher when it is presented in the first position in its pair than in the second position.*

2) It is more likely the following **order effect**: the *percentage of the A judgment answer for the AA2N syllogism should be higher when it is presented in the second position in its pair than in the first position.*

II. Method

Participants

The participants at the study were 30 high school students (20 girls and 10 boys) of 10^{th} grade, having as their specialty mathematics and physics. The mean age was of 16.5 years.

Material

Two versions of a task with four syllogisms formulated in an abstract symbolic neuter manner were used (see Annex 17). The two syllogisms from the first pair were AA1A (a figure 1 valid syllogism having as conclusion an A judgment), and AA2N (a figure 2 invalid syllogism, where N symbolize that the correct answer is "no valid conclusion"). The two syllogisms of the second pair were: AE2E (a figure 2 valid syllogism having as conclusion an E judgment), and AE3N (a figure 3 invalid syllogism, where N symbolize that the correct answer is "no valid conclusion"). In the first version of the task, the valid syllogism from each pair was presented in the first position of the pair (the **VN** version). In the second version of the task, the valid syllogism from each pair was presented in the second position of the pair (the **NV** version).

Each version of the task was preceded by an instruction in which only a very short explanation of the task was given, assuming an implicit understanding of the task.

Procedure

The syllogistic tasks were administered collectively, at the class hours, in the same session, without time limit. There were no trial task or trial syllogisms, given the purpose of the experiment (the study of an order effect). The participants were allowed to give a pseudonym instead of their name in order to discourage the tendency to copy the answers from their neighbors, by securing the confidentiality of their performance.

Participants were included in the two experimental groups by a random selection, taking into consideration their arrangement in the classroom (each row of chairs was assigned to one of the two experimental conditions). The first experimental group (the administration order **VN**) had 16 participants. The second experimental group (the administration order **NV**) had 14 participants.

III. Results

Preliminary results

By applying the Mann-Whitney test, no significant differences were obtained between the two experimental groups in what respects the total correctness. There occurred, using the Wilcoxon test, a tendency that the correctness for the AA1A syllogism to be higher than the one for the AE2E syllogism ($z = -1.667$, $p = .096$) in a two-tailed comparison. The correctness difference between the two syllogisms was statistically significant in a one-tailed comparison, which is warranted given the initial unidirectional prediction from the theoretical section that the syllogisms AA1A should have a higher cognitive importance and, correlatively, a higher performance than the ones of the AE2E. The correctness for the syllogism AE3N was significantly higher than the one for AA2N ($z = -2.6464$, $p = .008$).

Main hypothesis

By applying the chi-square test, a significantly lower correctness ($\chi2(1) = 5.275$, $p = .022$) was obtained for the AA1A syllogism when it was presented in the first position in its pair than in the second position, as it was expected.

Supplementary result

No significant difference between the two experimental groups was obtained for the AE2E syllogism.

Tentative hypotheses

1) It was not possible to verify this hypothesis because in the studied sample only one correct answer was given for the AA2N syllogism.

2) The chi-square test was applied for the 21 participants who answered with the **A** judgment at the AA2N syllogism. Only a tendency of a lower percentage [$\chi2(1) = 3.087$, $p = .079$] of the **A** responses was obtained for the case when the AA2N syllogism was presented in the second position in its pair than in the first position. So, the expected difference was only close to the chosen statistical significance threshold.

IV. Discussion and conclusion

The result of this study indicate that order effects could occur also between two successive syllogisms, in the condition in which there is a significant difference in their cognitive importance (valid vs. invalid), and the first syllogism in a pair is not preceded by other syllogisms. There was a detrimental effect of the precedence of an invalid syllogism over the performance for a subsequent valid syllogism. The obtained effect is not accountable by a priming phenomenon. It is also not predicted by the standard mental models theory. I see no reason for which building models for an invalid syllogism should disturb the building of the initial model for a subsequent valid syllogism. Instead, from a dynamic point of view, such a result is interpretable as a displacement of a subjacent dynamic cognitive system to a region farther away from the one corresponding to the assumed syllogistic schema for the valid syllogism. The obtained result is not explainable by a general difference in the reasoning competence between the two experimental groups, as long as no significant differences between them occurred for the global performance.

Tentative hypotheses

1) The hypothesis that the precedence of the valid syllogism should have a detrimental effect on the performance for the subsequent invalid syllogism having similar premises could not be tested, because of the extreme difficulty of the AA2N invalid syllogism.

2) However, the possibility of the above-mentioned influence was indicated by the tendency that the precedence of the valid syllogism AA1A to lead to a higher percentage of the incorrect answer **A** for the subsequent AA2N syllogism. Dynamically, this would mean the possibility that the assumed dynamic schema for the valid syllogism was inadequately recognized in the case of the two similar premises of the subsequent invalid syllogism, generating confusion. This confusion might have lead to the incorrect answer of the judgment corresponding to the correct answer for the AA1A syllogism.

Future research with other pairs of syllogisms and with larger samples of participants are needed in order to elucidate the order effects that are possible between successive syllogisms dependent on their similarity and assumed cognitive importance.

Study 6

I. Purpose and hypotheses

Purpose

The purpose of the study was to investigate the relationship between an individual difference presumably indicating the average general stability of the abstract mental representations of an individual and the syllogistic performance. More precisely, the objective was to test the nonlinear relationship between the average level of stability of the subordinate representational patterns and the stability of the superordinate assumed dynamic deductive schema predicted and theoretically argued in the theoretical section of this work.

Preliminary comments

In the present study, it was hypothesized that the average general stability of the abstract mental representations could be assessed by using a task of free number generation. This task was chosen for the following reasons. Numbers, through their abstract, symbolic character are similar with the symbols or the general concepts of the syllogistic terms involved in a syllogistic task, as representations on lower levels of organization than the one of a dynamic syllogistic schema. Moreover, from a pragmatic point of view, for them it is easier to apply the data analysis methods needed in order to obtain the estimated value for the relevant individual difference.

In the free number generation task conceived by me (Faiciuc, 2003), the participants had to generate a series of 400 numbers using the natural numbers from 1 to 9. Each element of the generated series was required to be that number that passes through their mind at the moment of its generation, no matter whichever is. In a series of studies, I obtained data suggesting that, through such a task, stable individual characteristics of the dynamics of the free actualization of the mental representations could be estimated. The stability in time of such individual characteristics and their significant association with the performance in creativity tasks were documented in these previous studies (Faiciuc, 2008b; Faiciuc, 2003).

A first assumption was that the choice of one element of the series is influenced by the choices made for the previously generated elements.

A second assumption of mine was that the average level of influence between the chosen numbers depends on their basic stability as dynamic mental representations. The presumed reason is that the chances of a dynamical transition between a number and a subsequent one depend on the resistance at destabilization of the first one, i.e. on its stability. Moreover, the chances of a destabilized system to arrive into the attractive region of the dynamic representation of another number and to remain there depend also on the power of attraction of that number. Therefore, again, the transition is presumed to depend on the stability of the subsequent number. The transition is assumed to be dependent also on the distance from the state space between the two attractive regions corresponding to the two considered mental representations. It should be at a relatively medium level in order that a destabilized system to move into another attractive region and to remain there. If it is too small, the chances of the system to return back to the region of the first number before it gets stabilized into another one are supposedly increased. If that distance is too long, the chances of the destabilized system to get into a neighborhood of an attractive region are presumably decreased. By considering all the ten given numbers, their average level of mutual influences between them should depend on the average level of stability of their assumed dynamic representations.

The third assumption was that a rough estimation of the average level of mutual influences between the ten numbers could be the sum of the absolute values of the coefficients of interaction from the model of the series obtained by applying an autoregressive analysis.

Autoregressive analysis is a method to study autocorrelation in a temporal series and, therefore, its internal dynamics. If, in a classical regression analysis, the values of a variable are predicted by the weighted sum of the values of other variables, in an autoregressive analysis, the value of a variable is predicted by itself, i.e. by the weighted sum of some of its previous values. More precisely, the autoregressive analysis tries to determine a model through which the value of a series element is best predicted by a weighted linear or nonlinear combination of the values of some previously occurred elements. In other words, if such a model is obtained and it has a good fit with the data, that would mean that an element of a series does not follow randomly, but its generation is constrained by an internal dynamics of the series, by the previously occurred numbers. The number of previously chosen elements that still have an influence on the choice of a future element is said to be the order of the found model. A model is described by an equation of the following kind (Bourke, 1998):

$$x_t = \sum_{i=1}^{N} a_i x_{t-i} + \varepsilon_t$$

In the equation, a_i are the autoregression (interaction) coefficients, x_t is the series under investigation, and **N** is the order (length) of the model. The noise term or residue, epsilon in the equation, is generally assumed to be the Gaussian white noise. Intuitively, the equation means that the current term of a series can be estimated by a linear weighted sum of previous terms in the series. The weights are the autoregression coefficients or interaction coefficients, as they are also named. It was assumed that, by summing the absolute values of the autoregression coefficients, a rough estimation of the level of interaction between the numbers from the model could be obtained. The researcher Iarinca Luiza from Physics Institute from Cluj-Napoca helped me to obtain the autoregressive models for the series generated by the participants. With only three exceptions, a model of order 9, that is with nine interaction coefficients, was considered to be the best fit for the remaining series.

That means that the choice of a number is influenced in a significant manner by the last nine chosen numbers, and every interaction coefficient represents the level of influence of a number over the choice of the future numbers.

Concluding comments

The uncontrolled *independent variable* was the sum of the absolute values of the interaction coefficients (ICS).

The *dependent variable* was the correctness of the valid syllogisms.

Hypothesis

Given all the above considerations, the general main hypothesis was that a nonlinear relationship between the correctness of the valid syllogisms and the sum of the absolute values of the interaction coefficients (ICS) should occur. More precisely, the maximum syllogistic performance should be for the intermediate values of the sum of the absolute values of the interaction coefficients.

II. Method

Participants

The participants at the study were 33 college students (30 girls and 3 boys) in the first or the second year at the Social Work Faculty of the "Babeş-Bolyai" University, who were participants also in the second study. Their mean age was of 21 years.

Material

The following syllogistic tasks were used:

- A **CPP** format task, when the conclusion is given and the derivation of the premises is required, with a concrete content centered exclusively on classes (**C** type content). It had five items (see Annex 5), correspondent to the four possible types of judgments and to the "no valid conclusion" answer. The classes were fictive classes of plants.
- A **CPP** format task, when a conclusion is given and the derivation of the premises is required, with a concrete content centered exclusively on attributes (**A** type content). It had five items (see Annex 6), correspondent to the four possible types of

judgments and to the “no valid conclusion” answer. The attributes were fictive symptoms of a rare disease.

- A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with a concrete content centered exclusively on attributes (**A** type content). It had 24 items distributed on types and ordered as in task used in the study 1 that had a neuter abstract symbolic content (see Annex 7). The attributes were fictive symptoms of a rare disease.
- A **PPC** format task, when the premises are given and the derivation of the conclusion is required, with a concrete content centered exclusively on classes (**C** type content). It had 24 items distributed on types and ordered as in task used in the study 1 that had a neuter abstract symbolic content (see the Annex 8). The classes were fictive classes of plants.

Each type of task was preceded by an instruction in which the argumentative situation was explained with reference to its specific concrete content and through which the modality of answer was described. There were no trial tasks or trial syllogisms within a task.

Also, a free number generation task (see Annex 18) was administered, requiring to the participants to generate a series of 400 numbers using the natural numbers within the interval from 1 to 9.

Procedure

The free number generation task was administered collectively, in the same session with the syllogistic tasks administered in the second study, as the last task.

III. Results

Preliminary analysis

The participants were separated into three relatively equal groups (with 12, 9, and, respectively, 12 participants) using the ICS value, at the following cut points: 0.13 and 0.44. Applying the t test in order to see if there was a significant difference between them in what respect the ICS value, the following results were obtained. A significant difference occurred between the middle group and the two extreme groups: $t(29) = -8.619$, $p < .001$, and, respectively, $t(37) = -7.414$, $p < .001$.

Nonparametric tests were used because the distribution for the correctness of the valid syllogisms departed significantly from the normal distribution.

Given the small sample, the analyses were made by ignoring the type of content of the syllogisms and the administration order of the task formats.

Main hypothesis

In the first phase, applying the Kruskal-Wallis test for the three obtained groups in order to see if there is a difference concerning the correctness for the valid syllogisms, a significant value was obtained only for the **CPP** task: $\chi 2(2)= 6.426$, $p = .04$.

In the second phase, a separate comparison for each possible pair of groups was carried on by applying the Mann-Whitney test. The following results were obtained:

- the correctness for the valid syllogisms was higher for those with intermediate values of the ICS than the one for those with lower values of the ICS ($U = 22$, $p = .023$);
- the correctness for the valid syllogisms was higher for those with intermediate values of the ICS than the one for those with higher values of the ICS ($U = 25$, $p = .036$).

Supplementary results

Applying the Kruskal-Wallis test, a statistically significant difference between the three groups was obtained also for the *one model syllogisms*: $\chi 2(2) = 6.529$, $p = .038$. By applying the Mann-Whitney test, the following results were obtained:

- the correctness for the one model valid syllogisms was higher for those with intermediate values of the ICS than the one for those with lower values of the ICS ($U = 23.5$, $p = .016$);
- the correctness for the one model valid syllogisms was higher for those with intermediate values of the ICS than the one for those with higher values of the ICS ($U = 26.5$, $p = .037$).

IV. Discussion and conclusion

The predicted nonlinear relationship between the ICS of the numeric series generated in a free number generation task and the syllogistic performance occurred in the case of a **CPP** task, with aggregate scores, no matter the type of content. The performance was the highest for the intermediate values of the ICS, as it was expected, based on the idea that that sum might be a rough measure of the average stability of the abstract mental representations of an individual. It is a result for which the mental models theory is not able to provide an explanation. Instead, as it was argued in the theoretical section of this work, from a dynamic point of view, such a result is accountable given the presumed optimal condition for the emergence of superordinate patterns (schemas) from subordinate patterns. The fact that this result could be linked with the emergence of such assumed syllogistic schemas for the valid syllogisms is indicated by the supplementary result that the expected nonlinear relationship occurred especially for the one model syllogisms. Such syllogisms are presumed to have, in fact, the highest cognitive importance and the highest chances to have stable syllogistic schemas.

The expected nonlinear relationship did not occur in the case of a **PPC** task format. One possible reason for such a result may be the assumption that, in a **PPC** task, the proportion of the correct answers that were lucky guesses may have been significantly higher than the one for the **CPP** task. So, the presumed nonlinear relationship may be less notable because of this assumed high error in the measurement of the syllogistic competence through a **PPC** task format. Another possible reason is the fact that, in a **PPC** task format, the actualization of the assumed syllogistic schemas might be favored by the higher level of information supplied in the premises than the one supplied in the given conclusion from a **CPP** task format. So, it might be possible that, in such favorable conditions, less stable schemas are actualized. Therefore, it would be harder to reveal the expected nonlinear relationship because of the influence of such less stable schemas.

More research is needed in the future, on larger samples, and on different types of syllogistic tasks, having also an abstract symbolic content, in order to investigate more thoroughly the assumed nonlinear relationship. Also, this relationship should be studied in relation with other individual differences in order that its significance to be properly understood.

General discussion and conclusions

The series of six empirical studies brought indirect, compatible, evidences in the favor of the proposed schema-based dynamic model. In comparison, the present predominant explicative theory for the syllogistic performance, the mental models theory, does not have predictions or it has generally hypothetical opposite predictions than the ones of the proposed model in what respects the investigated phenomena. Many of the stated hypotheses were formulated as tentative guesses, being aware that the results are, because of the dynamic nature of the proposed model, highly dependent on particular contexts and circumstances that provide certain intervals of variation for the involved variables. Those hypotheses were formulated having in mind the idea of stability of a syllogistic schema, but the level of its stability and the dynamic effects deriving from it were assumed to be dependent on contextual factors, being relative also to the stability of other involved syllogistic schemas. In my studies, unfortunately, there were no available means to measure directly such a property, i.e. the stability of a dynamic schema. Therefore, it was hard to formulate clear hypotheses that would take into account all the involved factors, particularly in the situation in which no direct data were available in what regards their relative values.

In the first and the sixth studies *the association between some individual differences and the syllogistic performance* was documented for the first time in the scientific literature. In the first experiment, a positive *association between a measure of the autonomous thinking*, as an interactional style concerning the cognitive activity, and the performance for the valid syllogisms in the case of the participants with low scores at the Raven test was documented. The obtained result was the one envisioned in the proposed model, and it was dynamically interpreted to mean that it may reflect the effect of a higher argumentative experience presumably favored by such an interactional style over the emergence and stability of the assumed syllogistic schemas for the valid syllogisms, the ones having the greatest cognitive importance. Such an influence may be not so notable in the case of the participants with higher scores at the Raven test, due to an assumed ceiling effect for the stability of the assumed schemas for the valid syllogisms. It was supposed that the participants from this category learn more efficiently from the available argumentative experiences than the ones with lower scores at the Raven test, so that they may have in a higher proportion valid syllogisms with an excessive stability of the assumed syllogistic schemas, for which a ceiling effect is likely to occur, than the participants with lower scores at the Raven test. Such an excessive stability of the assumed syllogistic schemas for the valid syllogism is presumed to be reflected also in the negative association obtained in the case of the participants with higher scores at the Raven test between their performance for the invalid syllogisms and the measure for the autonomous thinking. That result was interpreted to mean that a high level of experiences with some syllogisms may have a negative effect on the performance for the syllogisms that are rarely encountered in the everyday life, for which, presumably, no schemas or less stable schemas exist. Such an interpretation is compatible with a similar interpretation for the figure effects encountered for the invalid syllogisms. In their case, the higher performance was usually obtained in almost all the studies from this work for the figure 3 syllogisms, not for the figure 1 syllogisms, as it was the case for the valid syllogisms.

In the sixth experiment, data suggesting a nonlinear relationship between a hypothetical and rough measure of the *average level of stability of the dynamic abstract mental representations and the syllogistic performance* in a **CPP** format task was obtained, as it was stipulated in the proposed dynamic theoretical model. It is a remarkable result such an association between the performances in two tasks so different in nature: a free generation task with abstract numeric representations, and a syllogistic task involving verbal, concrete mental representations. The result was interpreted dynamically as indicating the possible influence of an order parameter describing a general characteristic of the cognitive system as a dynamic system (the average level of stability of the mental representations at a rather abstract level, which might be analogous with the temperature parameter for a physical system) that controls the dynamics at the level of the syllogistic processes, particularly the average stability level of the assumed syllogistic schemas.

Content, task format and *order effects* were studied in the second, third, fourth, and the fifth experiments, separately, or in combination.

For the first time in the scientific literature there were obtained results indicating *a performance difference between syllogistic tasks with two different concrete unfamiliar contents, or between two different abstract symbolic contents*. So far, only comparisons between the syllogistic performance for an abstract and a familiar concrete content were made. The findings of my studies were interpreted to mean that there might be some abstract semantic features embedded in the usual syllogistic concrete content that should be advantageous or disadvantageous for the recognition of the abstract semantic pattern of the assumed dynamic syllogistic schemas. They support the idea that the semantic content of those assumed schemas might be mixed, involving both extensional and intensional meanings. Therefore, the maximum syllogistic performance and differentiation between the syllogistic figures should be obtained particularly for a content emphasizing such a mixed semantics. The data were compatible with this prediction. In the first place, the performance for those syllogistic tasks having an exclusively intensional content was usually higher in the expected conditions than the performance for the tasks having a presumably exclusively extensional content, as the mixed model would predict. Such a model involves two intensional relationships between the syllogistic terms, and only a single extensional one. In the second place, a clearer performance difference than the above-mentioned one was obtained between a syllogistic task with an abstract symbolic mixed content and one with an abstract neuter content, in the favor of the first task. Moreover, in this latter comparison, a higher concordance between the chosen conclusion and the one predicted by the mixed semantics model was obtained for those valid syllogisms assumed to have schemas with the highest stability due to their high cognitive importance than the one obtained for those valid syllogisms assumed to have schemas with the lowest stability due to their low cognitive importance. This result also supports the idea of a mixed semantics at the level of the assumed dynamic pragmatic syllogistic schemas. The obtained results regarding the content effect are notable especially taking in view that for the exclusively intensional task (**A** type task) and the mixed semantics abstract symbolic task (**L** type task) the number of words to be processed and, in the latter case, the number of given options for an answer, was higher than the ones for the exclusively extensional task (**C** type task) or the abstract neuter task (**N** type task). The fact that the results found with the concrete material might not be due to the peculiarities (for example, a higher familiarity) of one of the two particular argumentative situations but to some embedded abstract features was supported by the similar results obtained with the abstract symbolic material. The assumption that the results in the two above-mentioned cases are not exclusively attributable to a putative supplementary distinctiveness of the syllogistic terms in the tasks with the highest performance was supported by the findings regarding the figure effect for the concordance between the chosen conclusion and the conclusion predicted by the mixed semantics model. The general results regarding the content effect are not accountable in the standard framework of the mental models theory.

In what regards *the two task formats*, it was notable the fact that in a **CPP** format the performance might be relatively lower than the performance in a **PPC** format, although no direct comparison could be made. There seems that a **CPP** format decreases the chances of lucky guesses and supplies less information for the recognition of the assumed syllogistic schemas. That is why it may provide a more accurate indication of the real syllogistic competence of a reasoner than a **PPC** format task. This idea is supported by the fact that the syllogisms assumed to have the highest cognitive importance (figure 1 valid syllogisms) were the only ones having a notable performance in this format.

The obtained *order effects* for the valid syllogisms were of several types and occurred in all four experiments, although their existence depended on the particular sample of participants and the particular experimental condition.

The first type of order effects was the one in which the predicted content effect for the administration of the considered tasks in the first position disappeared at their administration in the second position due to order effects in opposite directions for the two involved tasks. This order effect was obtained in the second, third, and forth experiments.

The second type of order effects was the one in which the precedence of a task with a format or a content supposedly disadvantageous for the activation of the assumed dynamic schemas was expected to have a detrimental effect for the performance in the subsequent task with presumed advantageous characteristics in that respect. It is an effect that is not accountable either by the priming phenomena, or by the standard mental models theory. Dynamically, it was interpreted to mean that a subjacent dynamic cognitive system is placed in its state space in a region farther away from the one needed in order to give an adequate answer. This order effect was supported partially in the second experiment, and entirely in the third experiment. In the fourth experiment it was not obtained, presumably because of the higher level of stability of the assumed syllogistic schemas when the content has a mixed semantics, considered to be the optimal one.

In the sixth experiment a similar order effect was obtained, but, this time, between two successive syllogisms, one presumably without a syllogistic schema (an invalid syllogism), and the other one having such dynamic schema (a valid syllogism).

The third type of order effects was the one in which the precedence of a task with an assumed advantageous format or content for the activation of the assumed dynamic schemas was expected to have a beneficial effect for the performance in a subsequent task with a presumed disadvantageous format or content in that regard. In the second experiment, partial evidence was obtained for this type of order effects in the case of the task format (predominantly for figure 1 syllogisms). In the third experiment, a significant difference in what respects this type of order effects was obtained only in a one-tailed comparison. The results found in the fourth experiment supported entirely the idea of such an order effect. The data pattern is interpretable dynamically, but not in the theoretical framework of the standard mental models theory. The expected order effect occurred in the clearest manner only in the fourth experiment maybe because only there a content with a mixed semantics was involved, i.e. the content presumed to be the most advantageous for the actualization of the assumed syllogistic schemas.

In what regards the *figure and validity effects*, the performance order for the valid and invalid syllogisms varied dependent on the experimental condition and the characteristics of the sample and it was not constant as the standard mental models theory would predict. The general pattern of results indicated that the combination of several presumed advantageous factors led to a ceiling effect in the solving of the figure 1 syllogisms or of the one model syllogisms, supposedly having the highest stability of their assumed dynamic schemas. Consequently, their performance was not so notably improved by the presumed advantageous factors as the one for the syllogisms with assumed less stable schemas (figure 2 and figure 3, or multiple model syllogisms). Therefore, in such conditions, the figure effect was changed by a leveling of the performance differences between the syllogistic figures. In the case of the figure effects, there might be an interplay between the assumed basic stability of the syllogistic schemas for each syllogistic figure, dependent predominantly on its general cognitive importance, and their relative stability, dependent on the contextual factors (task format, content, administration order). Such an interplay may account for the variation of the figure effects. It might indicate that the figure effect is essentially semantic in nature rather than syntactic or procedural as it is thought to be in the standard mental models theory. In that theory, it is linked with the number of transformations required in order to build a mental model and the number of models to be built in order to certify the necessity of a conclusion. More research, on a more detailed level of analysis, is needed in order to bring more substantial data in explaining the results regarding the obtained figure effects. For now, it seems that, in what respects the basic stability, presumably reflected the most in the neuter abstract symbolic task (**N** task) and the one with exclusively extensional concrete content (**C** type task), there was no notable stability difference between the figure 1 and figure 2 valid syllogisms. The most consistent stability difference was the one between the basic stability of the assumed schemas for the figure 1 and figure 3 syllogisms. Through the influence of the presumed advantageous factors in the **A** and **L** type tasks, there seems that the stability differences between the assumed schemas of the syllogistic figures became more salient, due to a supplementary relative stability, especially for the figure 1 valid syllogisms. Such a supplementary stability was reflected in the higher performance for the valid multiple model syllogisms than the one for the invalid multiple model syllogisms in the most favorable conditions of the **L** type task. This result is unexpected and unexplainable within the framework of the standard mental models theory.

It would have been preferable that more direct evidence to be brought in order to support the proposed theoretical model. But such evidence it would have required tasks individually administered in special conditions, which was not possible because of pragmatic constraints. Also, only some of the segments of the schema-based model for the syllogistic reasoning were tackled in this series of studies. Numerous experimental manipulations suggested by the proposed theoretical framework remain for the future research to be carried on.

The general pattern of the results is rather complicated and complex, reflecting the involvement of numerous factors together with their suggested interaction. Those results seem only to scratch, with rudimentary methods, at the surface of the dynamic phenomena occurring during the syllogistic processes. The above-mentioned methods had a limited efficiency in comparison with the ones needed in order to reveal directly more characteristic dynamic phenomena (for example, hysteresis) than the ones suggested by a simple order effect. Standard mental models theory, which is still the predominant theory in explaining the syllogistic reasoning, offers, in my opinion, a too simplistic and rigid interpretative framework in order to account for the complex data obtained not only in this series of studies, but also in other studies from the scientific literature. The explicative power of the central variables in that theory: the number of mental models and the position of the middle term may stem from their possible status of confounded variables. My assumption is that both are confounded partially with the cognitive importance of the syllogisms. That is why, the mental models theory is able to partially account for the data regarding the difficulty of the syllogisms. But, in our studies, there are contexts in which there are syllogisms with the same number of mental models and even the same syllogistic figure but for which the performance is significant different (for example, in the **L** type task, the multiple model valid syllogisms have a higher performance than multiple model invalid syllogisms). The existing empirical data in what respects the categorical syllogisms are neither conclusive in supporting the mental models theory, or, in general, the symbolic computationalist theories, nor univocally interpretable based on such theoretical positions.

In this work, the proposed model does not have a substantial empiric support for other types of deductive tasks and other types of deductive schemas than the pragmatic ones. In order to investigate such types of schemas, future experiments are needed, with new manipulations, using a content that would favor their actualization, and with samples of special participants (with a very high or very low syllogistic competence).

Final conclusion

For the schema-based dynamic model of the deductive reasoning proposed in this work, two lines of arguments were presented.

There were presented empirical arguments for the categorical syllogistic reasoning case, documenting content, task format, and order effects as well as an association between the syllogistic performance and the interactional style of the autonomous thinking. They indicate a series of phenomena similar with the ones occurring in the pattern recognition at the perceptual level, suggesting the existences of some schematic representations organizing the syllogistic input and conclusion generation based on the previous experiences with classes of argumentative situations. The content of such schematic representations appears to involve implicit abstract semantic features with logical meaning (classes, members of classes, properties, and intensional, or extensional relations). Data indicate through the order effects that the actualization of such assumed schemas in a syllogistic task has effects on the performance in subsequent syllogistic tasks for a relatively long period of time. It is relatively less likely that such effects to be accountable partially or entirely through priming phenomena (Becker et al., 1997). Instead, they are attributed to some dynamic characteristics (stability, attractive power) of such schemas as dynamic mental representations. They are capable to continually influence the organization of the incoming stimuli through their status of attractor structures, constantly interacting (through competition or cooperation) with other attractor structures. The documented *content effects* suggest, from a dynamical point of view, that the deductive reasoning might be dependent on the abstract logical meaning of the concepts involved in it and that the process is not exclusively a formal one (as it is in the mental logic theories) or a procedural one, based only on truth tables (as in the standard mental models theory). However, data support the view that it is not exclusively based on concrete meanings, either. Also, the content effects suggest that the assumed syllogistic schemas may have a mixed semantics: intensional and extensional. The *task effects* bring evidence that those schemas may be centered on the cognitive goal defined by the type of the to-be-proven conclusion. They indicate, too, that stability, as a dynamic property of the assumed schemas, may be associated with the cognitive importance of such a goal, linked with the general frequency with which that goal could be encountered in the everyday cognitive activity. The data concerning *the differential association between the performance for certain syllogistic figures and the autonomous thinking*, as an interactional style, bring evidence in the same direction. Also, the *nonlinear association between the performance at such different tasks as the free number generation task and the syllogistic task* with concrete content in a **CPP** format indicate that there may be some general characteristics of the mental representations involved in both of them that are relevant in explaining such an association. It was presumed that such characteristics are dynamic ones, referring to the average stability of the mental representations of an individual.

There was presented also a line of theoretical argumentation concentrated on bringing reasons for which the idea of cognitive schema and other connected constructs (priming, activation) are more compatible and coherent, through their properties inferred from the empirical data, with a dynamic theoretical background than with a symbolic computationalist one. These reasons are, in my opinion, all the more compelling as they suggest the possibility that the classic concepts of the symbolic paradigm (as it is the rule construct) could be dynamically reinterpreted and linked with the subjacent dynamic neurophysiologic and perceptual processes. I admit that the construct of dynamic schema is currently underspecified. But, in this incipient phase of a dynamic research of the deductive reasoning and of the general knowledge in cognitive sciences, it may serve as a heuristic means in order to generate hypotheses to be empirically tested, as it was also the case of the previously presented empirical studies. It is a way to indicate with a more familiar term and concept a general distinction between its format of representation, able to have an intrinsic processing function, and other more static representational formats (mental models, or rules). It also suggests the semiabstract status of the representations involved in the deductive reasoning processes, originating in the condensation of some argumentative situations that have a common cognitive goal. The process of their emergence is considered to be similar with the one in which scenarios are abstracted from common successions of events, only that, in the deductive reasoning, these events happen in a more abstract mental environment, involving interactions with different kinds of mental, abstract objects.

In the theoretical part, a general theoretical framework is proposed for a dynamic understanding of the deductive processes, no matter their type or the level of the deductive competence of the reasoners. Its basic idea is that there are different types of deductive schemas, centered on different cognitive goals, learned by interaction with specific classes of argumentative experiences, and emergent on different levels of organization that are, permanently, in mutual reciprocal interaction. Conclusions are generated, whether the expected correct ones or not, based on a process of pattern completion, when a subjacent dynamic system is stabilized in the schema that has won the competition with other schemas partially compatible with a given input.

So, synthetically speaking, the present work brings a contribution primarily at a theoretical level, by identifying the general principles and ideas on which a dynamic approach of the deductive reasoning could be grounded, and by applying those principles on the particular cases of the conditional, and especially the categorical syllogistic deductive reasoning. It also indicates theoretical contributions through which such a dynamic approach could be linked and could integrate concepts or the existing theories from the cognitive psychology that are related with the deductive reasoning. In my opinion, a dynamic approach might be useful in solving also to conundrum of the deductive reasoning mentioned in the introductory part. It suggests that the deductive tasks usually used in experiments are so difficult and they are approached by participants with a low motivation despite the fact that the deductive reasoning is an important part of their cognitive activity because they might not correspond with the format and the content of their daily deductive activity. More precisely, the daily deductive activity is considered to be centered only on some specific deductive goals and to be, in general, based on several pragmatic deductive schemas organized around those goals. Usually, it should not involve general deductive mechanisms or the assumed combinatorial schemas, and it is less likely to require frequently a proof that nothing follows from the given information. Also, the deductive processes from our usual life are not decontextualized or separated from the factual or logical knowledge, and, generally, their direction might be rather from a to-be-proven conclusion to the supporting premises than the other way around.

Through the presented empirical studies, beyond the evidence suggesting the validity of the proposed model, new lines of experimental manipulations for the future research of the deductive reasoning are revealed. Also, new kinds of tasks (**A**, **C**, **L**, **CPP** type of tasks) were elaborated through which new aspects of the syllogistic processes could be studied.

The theoretical and the empirical results from this work may be also useful from a pragmatic point of view.

In the first place, they could be helpful in designing training programs for developing deductive competencies. Here are some general tentative recommendations. They should be grounded on the deductive goals needed to be attained in the everyday life or in a specific domain of activity. In the categorical syllogism case, the accent may be initially placed on the pragmatic deductive schemas for the valid syllogisms. The risk of overlearning such schemas should be avoided, because, then, the schemas of a higher level, the combinatorial ones, would emerge with difficulty and they would be presumably less stable. The development of such combinatorial schemas should be done especially by exercising with invalid deductions or rather unfamiliar deductions, with lower cognitive function, the ones used to reveal exceptions, for example. In the case of the categorical syllogistic reasoning, it may be possible that the tasks with mixed semantics to be helpful in learning the required pragmatic deductive schemas. In learning deductive schemas, it would be also important that the order effects to be taken into consideration. Consequently, it would be recommendable not to use syllogistic tasks presumed to have disadvantageous characteristics for the actualization of the assumed deductive schemas, especially not before learning a syllogistic task with presumed advantageous properties in that respect.

In the second place, in what regards the measuring of the deductive competencies, the obtained results suggest that, in conceiving instruments with that purpose, it may be important to take into consideration what level of the assumed deductive schemas is envisioned, and which are the goals of the measurement. Furthermore, in designing such instruments, it would be important to take into consideration the content, format, and order effects documented in the present research.

The present work represents only the first step of a more systematic and extended possible program of research in what regards the application of the dynamic approach from the cognitive psychology to the problematic of the deductive reasoning. It may be considered not as a competitor for the existing theoretical approaches, but rather an integrative alternative, bringing complementary perspectives over the dynamic aspects of the deductive reasoning and new interpretations of the traditional concepts.

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Annexes

Annex 1

Romanian version of the N type task

În cele ce urmează sunt prezentate premisele pentru 24 de silogisme. Spre deosebire de exemplul dat mai înainte, premisele lor au o formulare mai abstractă, cei trei termeni ai silogismului fiind simbolizați prin înlocuirea lor cu trei litere majuscule: **S**, **M** si **P**.

Vi se cere ca pentru fiecare silogism să găsiți o soluție, alegând unul dintre enunțurile care sunt prezentate sub fiecare dintre ele, bifând acea literă (A, B, C, D, sau E) care se află în dreptul enunțului ales printr-o apăsare pe butonul stâng al mouse-ului în timp ce săgeata cursorului este așezată pe pătrățelul în care se află acea literă (adică dând un click de mouse pe acea literă).

Enunțurile care sunt prezentate sub fiecare silogism sunt:

A. Toți **S** sunt **P**.
B. Toți **S nu** sunt **P**.
C. Unii **S** sunt **P**.
D. Unii **S nu** sunt **P**.
E. **Nu** se poate deduce nici o concluzie necesară.

După ce ați ales enunțul pe care îl considerați corect pentru un silogism, treceți la următorul, dând un click de mouse pe spațiul unde scrie "**Continuă**". În caz că, înainte de a trece la următorul silogism, vă dați seama că răspunsul pe care l-ați ales este unul greșit, puteți să-l deselectați dând un click de mouse pe pătrățelul din dreptul lui, adică pe cel pe care l-ați selectat înainte. Apoi selectați un nou răspuns, pe cel pe care îl considerați potrivit, dând un click de mouse pe pătrățelul din dreptul lui. După ce ați trecut la un nou silogism nu mai puteți să vă întoarceți să-l corectați pe cel anterior.

Nu treceți mai departe, până când nu ați înțeles bine instrucțiunile de până acum, pentru că nu vă veți putea întoarce să le recitiți.

1. Toți **M** sunt **P**. Concluzie: ________________________
   Toți **S** sunt **M**.
2. Toți **M** sunt **P**. Concluzie: ________________________
   Toți **S nu** sunt **M**.
3. Toți **M** sunt **P**. Concluzie: ________________________
   Unii **S** sunt **M**.
4. Toți **M** sunt **P**. Concluzie: ________________________
   Unii **S nu** sunt **M**.
5. Toți **M nu** sunt **P**. Concluzie: ________________________
   Toți **S** sunt **M**.
6. Toți **M nu** sunt **P**. Concluzie: ________________________
   Toți **S nu** sunt **M**.
7. Toți **M nu** sunt **P**. Concluzie: ________________________
   Unii **S** sunt **M**.
8. Toți **M nu** sunt **P**. Concluzie: ________________________
   Unii **S nu** sunt **M**.

9. Toți **P** sunt **M**. Concluzie: ________________________
Toți **S** sunt **M**.
10 Toți **P** sunt **M**. Concluzie: ________________________
Toți **S** **nu** sunt **M**.
11. Toți **P** sunt **M**. Concluzie: ________________________
Unii **S** sunt **M**.
12. Toți **P** sunt **M**. Concluzie: ________________________
Unii **S** **nu** sunt **M**.
13. Toți **P** **nu** sunt **M**. Concluzie: ________________________
Toți **S** sunt **M**.
14. Toți **P** **nu** sunt **M**. Concluzie: ________________________
Toți **S** **nu** sunt **M**.
15. Toți **P** **nu** sunt **M**. Concluzie: ________________________
Unii **S** sunt **M**.
16. Toți **P** **nu** sunt **M**. Concluzie: ________________________
Unii **S** **nu** sunt **M**.
17. Toți **M** sunt **P**. Concluzie: ________________________
Toți **M** sunt **S**.
18. Toți **M** sunt **P**. Concluzie: ________________________
Toți **M** **nu** sunt **S**.
19. Toți **M** sunt **P**. Concluzie: ________________________
Unii **M** sunt **S**.
20. Toți **M** sunt **P**. Concluzie: ________________________
Unii **M** **nu** sunt **S**.
21. Toți **M** **nu** sunt **P**. Concluzie: ________________________
Toți **M** sunt **S**.
22. Toți **M** **nu** sunt **P**. Concluzie: ________________________
Toți **M** **nu** sunt **S**.
23. Toți **M** **nu** sunt **P**. Concluzie: ________________________
Unii **M** sunt **S**.
24. Toți **M** **nu** sunt **P**. Concluzie: ________________________
Unii **M** **nu** sunt **S**.

English version of the N format task

Response options:

A. All S are P.
B. All S are not P.
C. Some S are P.
D. Some S are not P.
E. It is not possible to derive a necessary logical conclusion.

Syllogisms

1. All M are P.
   All S are M.
2. All M are P.
   All S are not M.
3. All M are P.
   Some S are M.
4. All M are P.
   Some S are not M.
5. All M are not P.
   All S are M.
6. All M are not P.
   All S are not M.
7. All M are not P.
   Some S are M.
8. All M are not P.
   Some S are not M.
9. All P are M.
   All S are M.
10. All P are M.
    All S are not M.
11. All P are M.
    Some S are M.
12. All P are M.
    Some S are not M.
13. All P are not M.
    All S are M.
14. All P are not M.
    All S are not M.
15. All P are not M.
    Some S are M.
16. All P are not M.
    Some S are not M.
17. All M are P.
    All M are S.
18. All M are P.
    All M are not S.
19. All M are P.
    Some M are S.
20. All M are P.
    Some M are not S.
21. All M are not P.
    All M are S.
22. All M are not P.
    All M are not S.
23. All M are not P.
    Some M are S.
24. All M are not P.
    Some M are not S.

Annex 2

Items for AT scale of A/H questionnaire

Romanian version

20. Îmi apăr punctul de vedere chiar și atunci când majoritatea celor din jurul meu gândesc altfel.
22. Dacă mi se cere să decid ceva, mă străduiesc să descopăr singur cum trebuie să acționez.
23. Îmi pun întrebări în legătură cu ceea ce citesc.
26. Prefer să trag concluziile de unul singur decât să mă consult cu ceilalți.
34. Mi-e greu să îmi formez singur o opinie în legătură cu un eveniment controversat.
35. Îmi place să adun cât mai multă informație pentru a nu greși în deciziile mele.
38. Când nu știu ceva, prefer să aflu singur, fără să-i întreb pe alții.

English version

20. I defend my point of view even when the majority of the people around me think differently.
22. If I am asked to decide something, I try hard to find out by myself how I should act.
23. I ask myself questions in what regards the read information.
26. I prefer to draw conclusions by myself than to consult other people for that purpose.
34. It is hard for me to arrive to a personal opinion regarding a controversial event.
35. I like to gather as much information as I can in order to not err in my decisions.
38. When I do not know what to do, I prefer to find out by myself, and not to ask other people.

Scala generală a orientărilor cauzalității adaptată de Lucia Faiciuc, după scala cu același nume elaborată de Deci și Ryan (1985)

Veți găsi în paginile următoare o serie de texte scurte. Fiecare din ele descrie o situație pentru care sunt date trei modalități de răspuns. Vă rugăm să citiți textul pentru fiecare situație și apoi să evaluați răspunsurile care îi sunt date. Pentru a le evalua, trebuie să vă gândiți pentru fiecare din opțiunile de răspuns date la cât de probabil este ca voi să răspundeți în acel mod la situația descrisă. Toți răspundem în modalități diferite la aceeași situație și, probabil, fiecare răspuns din cele date are cel puțin o șansă, oricât de mică, de a fi adoptat de dvs. Dacă este foarte puțin probabil ca voi să răspundeți în modalitatea descrisă de o anumită opțiune de răspuns dată, atunci veți avea de selectat unul din numerele 1 sau 2. Dacă e în grad moderat probabil, veți avea de selectat unul dintre numerele plasate în partea de mijloc a intervalului dat (3, 4 sau 5); iar dacă este foarte probabil ca dvs. să răspundeți în modalitatea descrisă, veți avea de ales unul dintre numerele 6 sau 7. Vă rugăm să selectați câte un singur număr pentru fiecare dintre cele trei răspunsuri date pentru fiecare situație, notându-l pe foaia de răspuns, folosind ca reper următoarea scală

1	2	3	4	5	6	7
foarte puțin probabil		în grad moderat probabil			foarte probabil	

Itemii chestionarului încep pe pagina următoare.

1. **Ți se oferă o nouă funcție într-o organizație de tineri al cărei membru ești de câtva timp. Prima întrebare care e probabil să îți vină în minte este:**
   a. Ce se va întâmpla dacă nu pot face față noii responsabilități?
   b. Voi putea să mă bucur de mai multe avantaje personale în această nou funcție?
   c. Mă întreb dacă ceea ce trebuie să fac în noua funcție este ceva interesant.
2. **Ai participat la un interviu pentru obținerea unei burse cu câteva săptămâni în urmă. Primești prin poștă o scrisoare tip prin care ești informat că bursa a fost obținută de altcineva. E probabil să te gândești:**
   a. Nu e important ce cunoști, ci pe cine cunoști.
   b. Nu sunt probabil suficient de bun (bună) pentru acea bursă.
   c. Dintr-un anume motiv nu au considerat competențele mele ca potrivindu-se cerințelor bursei.
3. **Ai fost numit conducătorul unui cerc de studiu din instituția în care înveți, care e alcătuit din cinci persoane. Ați primit accesul la un laborator dotat cu echipamente foarte performante, dar în care nu pot lucra mai mult de două persoane simultan. Ai fost însărcinat cu alcătuirea programului de acces în acest laborator a membrilor cercului de studiu. Vei rezolva probabil problema:**
   a. Spunând membrilor cercului de studiu care e situația și invitându-i să găsiți împreună programarea potrivită a accesului la laboratorul în care vi s-a permis să lucrați.
   b. Pur și simplu repartizând perioadele de timp în care fiecare poate să se ducă să lucreze în laborator, evitându-se orice probleme.
   c. Aflând de la o persoană cu autoritate ce e de făcut sau cum s-a procedat în trecut.
4. **Tocmai ai primit rezultatele la un test care ți-a fost dat și afli că performanța ta a fost foarte scăzută. Reacția ta inițială este probabil să fie:**
   a. “Nu pot face nimic cum trebuie” și te simți nefericit.
   b. “Mă întreb ce s-a întâmplat de am obținut o performanță atât de scăzută” și te simți dezamăgit.
   c. “Acest test tâmpit nu demonstrează nimic” și te simți înfuriat.
5. **Când tu și prietenul (prietena) tău (ta) vă faceți planuri pentru sâmbătă seara, e probabil ca:**
   a. Să lași să fie așa cum vrea prietenul (prietena) tău (ta); el (ea) nu ar vrea probabil să facă ceea ce tu ai sugera.
   b. Fiecare dintre noi să facă sugestii și apoi ne decidem împreună pentru ceva ce amândoi avem chef să facem.
   c. Să-l convingi pe prietenul (prietena) tău (ta) să facă ceea ce tu vrei să faceți.
6. **Ai fost invitat la o mare petrecere unde cunoști foarte puțini dintre invitați. Gândindu-te la seara petrecerii, te aștepți probabil că:**
   a. Vei încerca să te adaptezi la orice se va întâmpla pentru a te simți bine și pentru a nu face o impresie neplăcută.
   b. Vei putea găsi câteva persoane cu care să poți comunica.
   c. Te vei simți probabil oarecum izolat și nebăgat în seamă.

7. **Ți se cere să planifici o masă la iarbă verde pentru tine și colegii tăi. Stilul în care vei aborda această sarcină ar putea fi caracterizat probabil ca:**
   a. Asumarea controlului: adică majoritatea deciziilor majore vor fi luate de tine.
   b. Luarea ca model a unui caz precedent: nu te ridici, de fapt, la nivelul cerințelor sarcinii date, așa că o vei îndeplini în modul în care a mai fost realizată înainte.
   c. Apelul la participarea celorlalți: primești sugestii de la alții care vor să le facă, înainte ca tu să alcătuiești planurile definitive.
8. **Recent, în instituția la care înveți se organizează o excursie gratuită în străinătate. Pentru că numărul locurilor e foarte limitat, s-a luat hotărârea ca din fiecare an de studiu, pe baza meritelor, să fie selectate doar câte cinci persoane de către un profesor responsabil. Tu nu ai fost selectat, deși erai printre cei care ar fi meritat să meargă. Apreciind situația, e probabil să te gândești că:**
   a. Nu te-ai așteptat de fapt să primești un loc în acea excursie; în mod frecvent ai fost neglijat atunci când s-au ivit ocazii de a-i răsplăti pe cei merituoși.
   b. Acei colegi care au fost selectați „erau bine puși" cu profesorul care a făcut selecția.
   c. Ar trebui să analizez factorii legați de propriile merite care au făcut să nu fiu și eu selectat.
9. **Ești pe cale să alegi o carieră. Ceea ce consideri a fi cel mai important este probabil:**
   a. Dacă solicitările ei sunt pe măsura puterilor tale.
   b. Cât de interesat ești de tipul de muncă cerut în acea carieră.
   c. Dacă există posibilități mari de avansare (în ceea ce privește câștigul material și statutul social).
10. **Ai fost ales șeful organizației care îi reprezintă pe colegii tăi în consiliul de conducere al instituției la care învățați. Una din colegele tale deține o funcție în această organizație și s-a achitat în general bine de sarcinile care i-au revenit. Totuși, în ultimele două luni, performanța ei nu a mai fost cea obișnuită și pare a fi mai puțin activ interesată în activitatea organizației. Reacția ta va fi probabil să:**
    a. Îi spui că activitatea sa e sub așteptări și că ar trebui să înceapă să se străduiască să se implice mai mult.
    b. O întrebi care e problema și îi spui că ești dispus să o ajuți să o rezolve.
    c. Te gândești că e greu să știi ce e de făcut pentru a o determina să se îndrepte și să își revină.
11. **Părinții tăi au reușit să obțină înscrierea ta la o instituție de învățământ extrem de renumită, dar care este situată într-un oraș aflat la mare distanță față de localitatea unde ai învățat până acum. Gândindu-te la mutare, probabil că:**
    a. Te vei simți interesat de noua provocare și în același timp puțin temător.
    b. Te vei simți încântat de statutul superior și de avantajele oferite de o astfel de instituție.
    c. Te vei simți stresat și neliniștit în ceea ce privește schimbările care vor surveni.
12. **Din cercul tău de prieteni, cel (cea) cu care alegi să îți petreci cel mai mult timp este:**

a. Cel (cea) cu care petreci cel mai mult timp schimbând idei și sentimente.

b. Cel (cea) care se bucură de cea mai mare popularitate.

c. Cel (cea) care are cel mai mult nevoie de tine ca prieten (prietenă).

13. Ai o soră mult mai mică decât tine, care merge la școală. Părinții, neavând timp, te însărcinează pe tine să urmărești performanța ei școlară. Verificându-i carnetul de note, observi că nu se descurcă prea bine la școală și nu pare să fie interesată de învățătură. E probabil ca tu să:

a. Discuți despre acest lucru cu sora ta pentru a înțelege mai bine care este problema.

b. O cerți și să speri că performanța ei se va îmbunătăți.

c. Te asiguri că își îndeplinește sarcinile date, pentru că tu crezi că trebuie să se străduiască mai mult.

14. Prietenul (prietena) ta are un obicei care te irită (deranjează) într-atât încât devii furios. Este probabil ca tu să:

a. Îi atragi atenția de fiecare dată când observi apariția obiceiului și astfel el (ea) va înceta să îl mai aibă.

b. Încerci să ignori acel obicei pentru că, discutând despre el, nu ajută la nimic, oricum.

c. Încerci să înțelegi de ce prietenul (prietena) îl are și de ce anume te deranjează atât de mult.

15. Un prieten apropiat al tău (de același sex) a fost prost dispus (cu toane) în ultima vreme și ,de câteva ori, s-a înfuriat pe tine fără motiv (pentru „fleacuri”). E probabil ca tu să:

a. Discuți cu el (ea) observațiile tale în ceea ce îl (o) privește și să încerci să afli ce se întâmplă cu el (ea).

b. Îl ignori, pentru că, oricum, tu nu poți face mare lucru în legătură cu problema sa.

c. Îi spui că ești dispus să vă petreceți timpul împreună doar dacă el (ea) face un efort mai mare pentru a se controla.

16. Sora mai mică a prietenului (prietenei) tău (tale) este în primul an de școală. Prietenul (prietena) tău (ta) vă spune că ea nu se prea descurcă și te întreabă ce ar trebui să facă în această situație. Tu îl (o) sfătuiești:

a. Să discute cu ea și să încerce sa afle ce se întâmplă cu sora sa.

b. Să nu-i atragă atenția; oricum, el (ea) nu ar putea face nimic în legătură cu această problemă.

c. Să-i spună că e important pentru ea să aibă o performanță bună și că ar trebui să se străduiască mai mult.

17. Simți că prietenul (prietena) tău (ta) nu e suficient de atent (atentă) cu tine. Probabil că tu:

a. Vei găsi o ocazie să-i explici de ce te deranjează acest lucru; el (ea) s-ar putea să nici nu își dea seama cât de mult te supără astfel.

b. Nu vei spune nimic; dacă el (ea) ține cu adevărat la tine ar trebui să înțeleagă cum te simți.

c. Îi vei cere prietenului (prietenei) tău (tale) să înceapă să îți acorde mai multă atenție, pentru că în caz contrar îi vei răspunde purtându-te la fel ca el (ea).

Foaie de răspuns
pentru
Scala generală a orientărilor cauzalității

1. a. _____	**2.** a. _____	**3.** a. _____	**4.** a. _____
b. _____	b. _____	b. _____	b. _____
c. _____	c. _____	c. _____	c. _____
5. a. _____	**6.** a. _____	**7.** a. _____	**8.** a. _____
b. _____	b. _____	b. _____	b. _____
c. _____	c. _____	c. _____	c. _____
9. a. _____	**10.**a. _____	**11.**a. _____	**12.**a. _____
b. _____	b. _____	b. _____	b. _____
c. _____	c. _____	c. _____	c. _____
13.a. _____	**14.**a. _____	**15.**a. _____	**16.**a. _____
b. _____	b. _____	b. _____	b. _____
c. _____	c. _____	c. _____	c. _____
17.a. _____			
b. _____			
c. _____			

Annex 3

The statistical values for the main variables involved in the study

	Number of cases		Mean	Median	Mode	Standard Deviation
	Valid	Missing				
AT scale	41	7	49.82927	51	44	9.34319
GCOSA	33	3	93.697	98	86	12.84884
Raven	47	1	52.46809	55	56	5.72125
Correctness for valid syllogisms	48	0	6.95833	7	7	2.23091
Correctness for invalid syllogisms	48	0	3.29167	2.5	0	3.45154
Correctness for valid one model	48	0	4.72917	5	5	1.39512
Correctness for valid multiple model syllogisms	48	0	2.22917	2	2	1.40273
Correctness for valid figure 1 syllogisms	48	0	2.875	3	3	1.08422
Correctness for invalid figure 1 syllogisms	48	0	1	1	0	1.27162
Correctness for valid figure 2 syllogisms	48	0	2.6875	3	3	1.07498
Correctness for invalid figure 2 syllogisms	48	0	1.14583	1	0	1.23753
Correctness for valid figure 3 syllogisms	48	0	1.39583	1	1	0.93943
Correctness for invalid figure 3 syllogisms	48	0	1.14583	1	0	1.30449

Annex 4a

The association of the Raven test sores with the correctness for the syllogisms of the three syllogistic figures

Syllogism type	Raven
Figure 1 valid syllogisms	ρ = .448, p = .001
Figure 1 invalid syllogisms	ρ = .381, p = .004
Figure 2 valid syllogisms	ρ = .572, p = .000
Figure 2 invalid syllogisms	ρ = .314, p = .016
Figure 3 valid syllogisms	ρ = .230, p = .06
Figure 3 invalid syllogisms	ρ = .117, p = .216

Annex 4b

The association between AT scale scores and the correctness for different types of valid syllogisms

	Low scores for standard Raven (N = 25)	**High scores for standard Raven (N = 16)**
	Score at AT scale	Score at AT scale
Correctness for valid syllogisms	ρ = **.482**, p = .007	–
Correctness for invalid syllogisms	–	ρ = **−.495**, p = .026
Correctness for one model syllogisms	ρ = **.446**, p = .013	–
Correctness for multiple model valid syllogisms	ρ = .240, p = .124	–
Correctness for figure1 valid syllogisms	Kendall tau–b = **0.387**, p = .007	
Correctness for figure1 invalid syllogisms		Kendall tau–b = −0.231, p = .126
Correctness for figure2 valid syllogisms	Kendall tau–b = **0.405**, p = .005	–
Correctness for figure2 invalid syllogisms	–	Kendall tau–b = **−0.413**, p = .022
Correctness for figure 3 valid syllogisms	–	–
Correctness for figure3 invalid syllogisms	–	Kendall tau–b = **−0.565**, p = .003
Correctness for figure1 one model syllogisms	Kendall tau–b = **0.367**, p = .011	–
Correctness for figure2 one model syllogisms	Kendall tau–b = **0.438**, p = .004	–
Correctness for figure3 one model syllogisms	–	–
Correctness for figure1 multiple model valid syllogisms	Kendall tau–b = **0.225**, p = .096	–
Correctness for figure2 multiple model valid syllogisms	Kendall tau–b = **0.186**, p = .139	–
Correctness for figure3 multiple model valid syllogisms	–	–

Annex 4c

The association between AT scale scores and the correctness for different types of valid syllogisms

	Low scores for GCOSA (N = 13)	**High scores for GCOSA (N = 20)**
	Score at AT scale	Score at AT scale
Correctness for valid syllogisms	ρ = **.712**, p = .003	ρ = **.433**, p = .028
Correctness for invalid syllogisms	–	–
Correctness for one model syllogisms	ρ = **.494**, p = .014	ρ = **.398**, p = .015
Correctness for multiple model valid syllogisms	ρ = **.607**, p = .003	–
Correctness for figure1 valid syllogisms	Kendall tau–b = **.626**, p = .003	Kendall tau–b = .251, p = .083
Correctness for figure 1 invalid syllogisms	–	–
Correctness for figure 2 valid syllogisms	Kendall tau–b = **.422**, p = .031	Kendall tau–b = .297, p = .053–
Correctness for figure2 invalid syllogisms	–	–
Correctness for figure 3 valid syllogisms	Kendall tau–b = **.543**, p = .009	–
Correctness for figure3 invalid syllogisms	–	–

Annex 5

Romanian version for the CPP format task centred on classes (C type)

Sarcină de investigare a raționamentului deductiv in format CPP

În cele ce urmează vi se prezintă tipul de sarcină pe care sunteți solicitați să o rezolvați.

Se pornește de la *o propoziție* în care se enunță *o anumită relație* dintre *două tipuri fictive de plante* (inventate pentru elaborarea acestei probe): **ofideele** și **siderinele**.

Se presupune că aceste două tipuri de plante pot avea *relații* cu *un alt tip de plantă fictivă*: **palmatele**.

Toate relațiile logic posibile între **palmate** și **ofidee** (sau, echivalent, între **ofidee** și **palmate**) sunt prezentate într-o listă de 8 propoziții:

1. Toate **palmatele** sunt **ofidee**.	**5.** Toate **ofideele sunt palmate.**
2. Toate palmatele nu sunt ofidee.	**6. Toate ofideele nu sunt palmate.**
3. Unele palmate sunt ofidee.	**7. Unele ofidee sunt palmate.**
4. Unele palmate nu sunt ofidee.	**8. Unele** ofidee **nu** sunt **palmate**.

La fel, toate relațiile logic posibile între **palmate** și **siderine** (sau, echivalent, între **siderine** și **palmate**) sunt prezentate într-o altă listă de 8 propoziții:

9. Toate **palmatele** sunt **siderine**.	**13.** Toate **siderinele sunt palmate.**
10. Toate palmatele nu sunt siderine.	**14. Toate siderinele nu sunt palmate.**
11. Unele palmate sunt siderine.	**15. Unele siderine sunt palmate.**
12. Unele palmate nu sunt siderine.	**16. Unele** siderine **nu** sunt **palmate**

Sarcina Dvs. este să găsiți

ce relație dintre **palmate** și **siderine** și
ce relație dintre **palmate** și **ofidee**
trebuie să fie *simultan adevărate* pentru ca *enunțul dat* la început (care se referă la *una dintre cele 5 relații logic posibile* dintre **ofidee** și **siderine)** să fie *adevărat în mod obligatoriu*, numai pe baze logice.

Cu alte cuvinte, este ca și cum ați fi în situația să argumentați logic cuiva că *una dintre relațiile posibile* dintre **ofidee** și **siderine** este adevărată, bazându-vă pe relațiile fiecăreia din cele două tipuri de plante cu cel de-al treilea tip: **palmatele**. În această situație, *ce cuplu* de propoziții ați alege (prin *selecția unui enunț* din cele din lista numerotată de la **1** la **8** și *selecția altuia* din lista numerotată de la **9** la **16**) *ca trebuind să fie adevărate* dintre cele care descriu relațiile **palmatelor** cu **ofideele** și cu **siderinele**?

Vă atenționăm că pentru *patru* din cele cinci enunțuri cu privire la relațiile dintre **ofidee** și **siderine** există *mai mult de o singură soluție*!! Adică, este posibil ca pentru *oricare* dintre cele patru enunțuri să existe *mai multe cupluri de propoziții* (formate prin alegerea uneia din lista numerotată de la **1** la **8** și a celeilalte din lista numerotată de la **9** la **16**) care, dacă ar fi adevărate, ar face ca și acel enunț să fie adevărat în mod logic necesar.

Pentru **soluțiile alternative**, notați *perechea de enunțuri* corespunzătoare *fiecărei noi soluții* găsite de Dvs. *în cele două spații marcate cu o liniuță*, mărginite de către o pereche de paranteze (trecând *în primul spațiu*, deasupra liniuței, *numărul corespunzător enunțului ales* dintre cele numerotate de la **1** la **8** și *în cel de-al doilea spațiu*, deasupra liniuței, *numărul enunțului ales* dintre cele numerotate de la **9** la **16**).

Vă mulțumim foarte mult pentru colaborarea la această cercetare! Fiind un studiu explorator, scopul nu este acela de a vă evalua abilitățile de gândire personale, ci de a investiga procesele raționamentului deductiv. De aceea, rezultatele obținute nu pot fi tratate ca o probă ale cărei rezultate să fie relevante în ceea ce privește măsurarea inteligenței Dvs.

English version for the CPP format task centred on classes (C type)

In what follows, the task to be solved is described.

In the start, a *statement* is given in which it is presented a *certain relationship* between *two fictive types of plants* (created especially for this task): **ophidees** and **siderines**.

It is presumed that these two types of plants can have relationships with another type of fictive plant: **palmats.**

All the possible logical relationships between **palmats** and **ophidees** (or, equivalently, between **palmats and ophidees**) are presented in the following list with 8 statements:

1. All **palmats** are ophidees**.**	5. **All** ophidees **are** palmats**.**
2. **All** palmats **are** not ophidees**.**	6. **All** ophidees **are** not palmats**.**
3. **Some** palmats **are** ophidees**.**	7. **Some** ophidees **are** palmats**.**
4. **Some** palmats **are** not **ophidees**.	**8.** Some **ophidees** are **not palmats**.

In the same way, *all the possible logical relationships* between **palmats** and **siderine**s (or, equivalently, between **palmats and siderines**) are presented in another list with 8 statements:

9. All **palmats** are siderines**.**	13. **All** siderines **are** palmats**.**
10. **All** palmats **are** not siderines**.**	14. **All** siderines **are** not palmats**.**
11. **Some** palmats **are** siderines**.**	15. **Some** siderines **are** palmats**.**
12. **Some** palmats **are** not **siderines**.	**16.** Some **siderines** are **not palmats**.

Your task is to find out:

what relationship between **palmats** and **siderines**
and
what relationship between **palmats** and **ophidees**
must be *simultaneously true* in order that the statement given in the beginning (referring to *one of the five logically possible relationships* between **ophidees** and **siderines**) to be *obligatorily true*, only on logical bases.

In other words, it is as if you would be in the situation to logically argue to someone that *one of the logically possible relationships* between **ophidees** and **siderines** is true, based on the relationships of each of the two types of plants with the third type of plant: **palmats**. In such a situation, what couple of statements would you choose from the statements describing the relationships of the **palmats** with the **ophidees** and **siderines** (by *selecting one of the two statements* from the list numbered from **1** to **8** and *the second statement* from the list numbered from **9** to **16**) as *having to be true*?

Be aware that for *four* of *the five logically possible relationships* between **ophidees** and **siderines** *more than a single solution is possible*!! In other words, for each of the four statements there is more than one couple of statements (formed through the selection of one of the two statements from the list numbered from **1** to **8** and of the another one from the list numbered from **9** to **16**) that, if they were true, would make true in a necessary logical way the considered statement given in the beginning.

For the **alternative solutions**, note the *pair of statements* chosen for *each new solution* found by you *in the two blank spaces marked with a small horizontal line* and framed between a pair of round parentheses (by noting *in the first blank space*, on the line, *the number of the corresponding statement* chosen from the list numbered from **1** to **8**, and *in the second blank space*, on the line, *the number of the corresponding statement* chosen from the list numbered from **9** to **16**).

Answer sheet for the Romanian version of the CPP format task centred on classes (C type)

FOAIE DE RĂSPUNS

1. Pentru ca să demonstrez în mod logic cuiva adevărul enunțului:

„Toate **ofideele** sunt cu certitudine **siderine.**"

ar trebui să știu că este adevărat enunțul cu numărul ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre cele numerotate de la **1** la **8**) și *simultan este adevărat* enunțul cu numărul ___ (notați deasupra liniuței numărul *corespunzător enunțului ales* dintre cele numerotate de la **9** la **16**).

Soluții alternative

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

2. Pentru ca să demonstrez în mod logic cuiva adevărul enunțului:

„Toate **ofideele nu** sunt cu certitudine **siderine.**"

ar trebui să știu că este adevărat enunțul cu numărul ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre cele numerotate de la **1** la **8**) și *simultan este adevărat* enunțul cu numărul ___ (notați deasupra liniuței numărul *corespunzător enunțului ales* dintre cele numerotate de la **9** la **16**).

Soluții alternative

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

3. Pentru *ca să demonstrez* în mod logic cuiva *adevărul enunțului*:

„*Unele* **ofidee** sunt cu certitudine **siderine.**"

ar trebui să știu că este adevărat enunțul cu numărul ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre cele numerotate de la **1** la **8**) și *simultan este adevărat* enunțul cu numărul ___ (notați deasupra liniuței numărul *corespunzător enunțului ales* dintre cele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

4. Pentru *ca să demonstrez* în mod logic cuiva *adevărul enunțului*:

„*Unele* **ofidee nu** sunt cu certitudine **siderine.**”

ar trebui să știu că este adevărat enunțul cu numărul ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre cele numerotate de la **1** la **8**) și *simultan este adevărat* enunțul cu numărul ___ (notați deasupra liniuței numărul *corespunzător enunțului ales* dintre cele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

5. Pentru *ca să demonstrez* în mod logic cuiva *adevărul enunțului*:

„*Nu se poate stabili nimic cu certitudine* privire la relația dintre **ofidee** și **siderine.**”

ar trebui să știu că este adevărat enunțul cu numărul ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre cele numerotate de la **1** la **8**) și *simultan este adevărat* enunțul cu numărul ___ (notați deasupra liniuței numărul *corespunzător enunțului ales* dintre cele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

Evaluați cât de mult ați înțeles sarcina, alegând prin încercuire una din opțiunile de mai jos:

1. Deloc
2. Puțin.
3. Așa și așa.
4. Mult.
5. Complet.

Answer sheet for the English version of the CPP format task centred on classes (C type)

1. In order to *logically demonstrate* to someone the truth of the statement:

“All **ophidees** are with certainty **siderines.”**

I should know that it is true the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and, *simultaneously*, that *it is true* the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

2. In order to *logically demonstrate* to someone the truth of the statement:

"All **ophidees** are **not** with certainty **siderines.**"

I should know that it is true the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and, *simultaneously*, that *it is true* the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

3. In order to *logically demonstrate* to someone the truth of the statement:

"Some **ophidees** are with certainty **siderines.**"

I should know that it is true the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and, *simultaneously*, that *it is true* the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

4. In order to *logically demonstrate* to someone the truth of the statement:

"Some **ophidees** are **not** with certainty **siderines.**"

I should know that it is true the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and, *simultaneously*, that *it is true* the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

5. In order to *logically demonstrate* to someone the truth of the statement:

"*Nothing can be established with certainty* in what regards
the relationship between **ophidees** and **siderines**."

I should know that it is true the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and, *simultaneously*, that *it is true* the statement with the number ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

Assess how much you understood the task, by encircling the chosen option from the ones presented below:

1. Nothing at all.
2. A little.
3. Moderately.
4. A lot.
5. Completely.

Annex 6

Romanian version for the CPP format task centred on attributes (A type)

Sarcină pentru investigarea raționamentului deductiv

Sunteți solicitați să rezolvați un tip de sarcină asemănătoare celei cu care doctorii se confruntă atunci când încearcă să vadă care sunt legăturile dintre simptoame și boli.

În cele ce urmează este vorba de cazul unui grup de medici care au studiat *relațiile* dintre o *boală* rară a ficatului: **hepatoza**, și *semnele sale posibile la nivelul pielii*: **apariția unor pete roșii în palme**, pentru ca să știe câtă importanță să dea acelor pete.

Relațiile logic posibile puteau fi următoarele:

A. Toți **cei bolnavi de hepatoză** au **pete roșii în palmă** din cauza bolii.

B. Unii **din cei bolnavi de hepatoză** au **pete roșii în palmă** din cauza bolii.

C. Toți **cei bolnavi de hepatoză nu** au **pete roșii în palmă** din cauza bolii.

D. Unii dintre **cei bolnavi de hepatoză nu** au **pete roșii în palmă** din cauza bolii.

E. Nu se poate spune nimic cert despre legătura dintre **hepatoză** și **petele roșii din palmă**.

Pentru a determina care dintre cazurile de mai sus este cel adevărat, ei s-au gândit să studieze *legătura* dintre **apariția petelor roșii** și *un alt simptom posibil* al bolilor de ficat: **nivelul bilirubinei în sânge**.

Sarcina Dvs. este să descoperiți *ce*:

- *ar trebui să știe* medicii despre legătura dintre **hepatoză** și **nivelul crescut al bilirubinei în sânge** și
- ce *ar trebui să descopere* în urma investigațiilor pe care urmau să le facă privitor la relația dintre apariția **petelor roșii în palmă** și **nivelul crescut al bilirubinei**

pentru *ca să stabilească pe cale logică* adevărul *uneia dintre cele cinci relații logic posibile* dintre **hepatoză** și **apariția petelor roșii în palmă** (de la **A** la **E**) prezentate mai sus.

Pentru *a vă ușura găsirea și notarea răspunsului*, puteți *alege dintre variantele* de mai jos.

Trebuiau să știe că în ceea ce privește legătura dintre **hepatoză** și **nivelul crescut al bilirubinei în sânge** este *adevărat că*:

1. Toți **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**.
2. Unii dintre **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**.
3. Toți **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**.
4. Unii dintre **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**.
5. Toți **cei cu un nivel crescut de bilirubină în sânge** sunt **bolnavi de hepatoză**.
6. Unii din **cei cu un nivel crescut de bilirubină în sânge** sunt **bolnavi de hepatoză**.
7. Toți **cei cu un nivel crescut de bilirubină în sânge nu** sunt **bolnavi de hepatoză**.
8. Unii din **cei cu un nivel crescut de bilirubină în sânge nu** sunt **bolnavi de hepatoză**.

Trebuiau să descopere în urma investigațiilor pe care urmau să le facă privitor la relația dintre apariția **petelor roșii în palmă** și **nivelul crescut al bilirubinei în sânge** că *este adevărat că*:

9. Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**.
10. Unii dintre **cei cu un nivel ridicat bilirubină în sânge** au **pete roșii în palmă**.
11. Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**.
12. Unii dintre **cei cu un nivel ridicat bilirubină în sânge nu** au **pete roșii în palmă**.
13. Toți **cei care au pete roșii în palmă** au **un nivel crescut de bilirubină în sânge**.
14. Unii din **cei care au pete roșii în palmă** au **un nivel crescut de bilirubină în sânge**.
15. Toți **cei care au pete roșii în palmă nu** au **un nivel crescut de bilirubină în sânge**.
16. Unii din **cei care au pete roșii în palmă nu** au **un nivel crescut de bilirubină în sânge.**

Atenție!! Vă rugăm să întoarceți foaia pentru a citi continuarea instrucțiunilor!

Observație:

Dacă medicii știu sau descoperă că **doar unii** pacienți au unul din cele două simptoame (*pete roșii în palmă* sau *nivelul crescut de bilirubină în sânge*) sau boala *hepatoză*, înseamnă că cele constatate de ei *sunt certe* pentru *cel puțin o parte* dintre pacienții care *au putut fi investigați*. Este însă **posibil**, *dar nu cert*, ca ele să fie valabile *și pentru* **toți** *pacienții,* adică *și pentru cei care au putut fi investigați și pentru cei care* (din diverse motive) **nu** *au putut fi investigați*.

Dacă medicii știu sau descoperă că **toți** pacienții au *cu certitudine* unul din cele două simptoame (*pete roșii în palmă* sau *nivelul crescut de bilirubină în sânge*) sau boala *hepatoză*, înseamnă că *toți* pacienții *au putut fi investigați*.

Vă avertizăm că pentru *patru* dintre relații dintre **hepatoză** și **apariția petelor roșii în palme** sunt posibile *mai multe căi logice* de a afla dacă ele sunt adevărate sau nu, adică alegând alte *perechi de variante* (*una* dintre cele numerotate de la **1** la **8**, iar *alta* dintre cele numerotate de **9** la **16**).

Pentru **soluțiile alternative**, notați *perechea fiecărei noi soluții* găsite de Dvs. *în cele două spații marcate cu o liniuță*, mărginite de către o pereche de paranteze **(**trecând *în primul spațiu*, deasupra liniuței, *numărul corespunzător variantei alese* dintre cele numerotate de la **1** la **8** și *în cel de-al doilea spațiu*, deasupra liniuței, *numărul corespunzător variantei alese* dintre cele numerotate de la **9** la **16)**.

Vă mulțumim foarte mult pentru colaborarea la această cercetare! Fiind un studiu explorator, scopul nu este acela de a vă evalua abilitățile de gândire personale, ci de a investiga procesele raționamentului deductiv. De aceea, rezultatele obținute nu pot fi tratate ca o probă ale cărei rezultate să fie relevante în ceea ce privește măsurarea inteligenței Dvs.

English version for the CPP format task centred on attributes (A type)

You are required to solve a task similar to the one with which physicians are confronted when they try to find the relationship between symptoms and diseases.

In what follows, it is discussed the fictive case of a group of physicians who have studied the *relationships* between a rare liver *disease*: **hepatosis** and its *possible* skin *symptoms***: the occurrence of some red spots on palms**, in order to see how important those red spots are in diagnosing that rare disease.

The possible logical relationships considered by them are the following ones:

A. All **people ill with hepatosis** have **red spots on palms** because of the disease.

B. Some **people ill with hepatosis** have **red spots on palms** because of the disease.

C. All **people ill with hepatosis** do **not** have **red spots on palms** because of the disease.

D. Some **people ill with hepatosis** do **not** have **red spots on palms** because of the disease.

E. Nothing certain can be stated about the relationship between **hepatosis** and the **red spots on palms**.

In order to see which of the above-mentioned cases is true, their thought was to study the *relationship* between the **occurrence of the red spots** and *another possible symptom* of the liver diseases: **the blood level of the bilirubin**.

Your task is to discover:

- *what* the physicians *should know* about the relationship between **hepatosis** and **the blood level of the bilirubin**

and

- *what* the physicians *should discover* through their investigations in what regards the relationship between the **occurrence of the red spots** and the **blood level of the bilirubin**

in order to establish in a logical way the truth of one of the five possible logical relationships between **hepatosis** and the **red spots on palms (**from **A** to **E)** presented above.

In order *to make easier the finding of the answer and its notation*, you *can choose from the following alternatives*.

The physicians *should know* in what regards the relationship between **hepatosis** and **the high bilirubin blood level** that *it is true that*:

1. All **people ill with hepatosis** have a **high bilirubin blood level**.

2. Some **people ill with hepatosis** have a **high bilirubin blood level**.

3. All **people ill with hepatosis** do **not** have a **high bilirubin blood level**.

4. Some **people ill with hepatosis** do **not** have a **high bilirubin blood level**.

5. All people with a **high bilirubin blood level** are **ill with hepatosis**.

6. Some people with a **high bilirubin blood level** are **ill with hepatosis**.

7. All people with a **high bilirubin blood level** are **not ill with hepatosis**.

8. Some people with a **high bilirubin blood level** are not **ill with hepatosis**.

The physicians *should discover* through their investigations in what regards the relationship between **the occurrence of the red spots** and **the high bilirubin blood level** that *it is true that*:

9. All people with a **high bilirubin blood level** have **red spots on palms**.

10. Some people with a **high bilirubin blood level** have **red spots on palms**.

11. All people with a **high bilirubin blood level** do **not** have **red spots on palms**.

12. Some people with a **high bilirubin blood level** do **not** have **red spots on palms**.

13. All people with **red spots on palms** have a **high bilirubin blood level**.

14. Some people with **red spots on palms** have a **high bilirubin blood level**.

15. All people with **red spots on palms** do **not** have a **high bilirubin blood level**.

16. Some people with **red spots on palms** do **not** have a **high bilirubin blood level**.

Note:

If physicians know or discover that **only some** of the patients have one of the two symptoms (*red spots on palms* and a *high bilirubin blood level*) or *hepatosis*, it means that what they have come to know *is certain* for *at least a part* of the *patients whom they were able to investigate*. However, it is **possible**, *but not certain*, that what they have come to know is true *for* **all** *the patients*, i.e. *also for the patients that*, out of various reasons, *were not investigated*, not only for those that were investigated.

If physicians know or discover that **all** patients have with *certainty* one of the two symptoms (*red spots on palms* and a *high bilirubin blood level*) or *hepatosis*, it means the physicians *were able to investigate all patients*.

Be aware that for *four* of the five possible logical relationships between **hepatosis** and the **occurrence of the red spots** there are *multiple logical ways* to find out if they are true or not, by choosing *other pairs of alternatives* (*one* from the list numbered from **1** to **8**, and *the other one* from the list numbered from **9** to **16**).

For the **alternative solutions**, note *the pair of statements for each new solution* found by you in the *two blank spaces marked with a small horizontal line*, and framed between a pair of round parentheses (by noting *in the first blank space*, on the line, *the number of the corresponding statement* chosen from the list numbered from **1** to **8**, and *in the second blank space*, on the line, *the number of the corresponding statement* chosen from the list numbered from **9** to **16**).

Answer sheet for the Romanian version of the CPP format task centred on attributes (A type)

FOAIE DE RĂSPUNS

1. Pentru ca medicii să determine că

„Toți **cei bolnavi de hepatoză** au **pete roșii în palmă** din cauza bolii."

ei *trebuiau să știe* că *e adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **1** la **8**) și *trebuiau să descopere* că *este adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

2. Pentru ca medicii să determine că

„Unii **din cei bolnavi de hepatoză** au **pete roșii în palmă** din cauza bolii."

ei *trebuiau să știe* că *e adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **1** la **8**) și *trebuiau să descopere* că *este adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

3. Pentru ca medicii să determine că

„Toți **cei bolnavi de hepatoză nu** au **pete roșii în palmă** din cauza bolii."

ei *trebuiau să știe* că *e adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **1** la **8**) și *trebuiau să descopere* că *este adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

4. Pentru ca medicii să determine că

„Unii dintre **cei bolnavi de hepatoză nu** au **pete roșii în palmă** din cauza bolii."

ei *trebuiau să știe* că *e adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **1** la **8**) și *trebuiau să descopere* că *este adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

5. Pentru ca medicii să determine că

„Nu se poate spune nimic cert despre legătura dintre **hepatoză**
și **petele roșii din palmă**."

ei *trebuiau să știe* că *e adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **1** la **8**) și *trebuiau să descopere* că *este adevărat că* ___ (notați deasupra liniuței *numărul corespunzător enunțului ales* dintre variantele numerotate de la **9** la **16**).

Soluții alternative

(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __),
(__ , __) , (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __), (__ , __)

Evaluați cât de mult ați înțeles sarcina, alegând prin încercuire una din opțiunile de mai jos:

1. Deloc
2. Puțin.
3. Așa și așa.
4. Mult.
5. Complet.

Answer sheet for the English version of the CPP format task centred on attributes (A type)

1. In order that the physicians to determine that

"All **people ill with hepatosis** have **red spots on palms** because of the disease."

they *should know that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and *they should discover that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

2. In order that the physicians to determine that

"Some **people ill with hepatosis** have **red spots on palms** because of the disease."

they *should know that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and *they should discover that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

3. In order that the physicians to determine that

"All **people ill with hepatosis** do **not** have **red spots on palms** because of the disease."

they *should know that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and *they should discover that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

4. In order that the physicians to determine that

"Some **people ill with hepatosis** do **not** have
red spots on palms because of the disease."

they *should know that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and *they should discover that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

5. In order that the physicians to determine that

"Nothing certain can be stated about the relationship between **hepatosis** and the **red spots on palms**."

they *should know that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **1** and **8**) and *they should discover that it is true* that ___ (note on the small line *the number of the corresponding statement chosen* from the list numbered between **9** and **16**).

Alternative solutions

(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _),
(_ , _) , (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _), (_ , _)

Assess how much you understood the task, by encircling the chosen option from the ones presented below:

1. Nothing at all.
2. A little.
3. Moderately.
4. A lot.
5. Completely.

Annex 7

Romanian version of the PPC format task centred on attributes (A type)

Sarcină pentru investigarea raționamentului deductiv

În cele de mai jos vi se cere să rezolvați o sarcină de raționament deductiv, ca cele pe care doctorii le folosesc zi de zi atunci când încearcă să vadă care sunt legăturile dintre anumite simptome și anumite boli.

Este vorba în cele ce urmează de cazul unui grup de medici care au studiat relațiile dintre o boală rară a ficatului: *hepatoza*, și semnele sale posibile la nivelul pielii: *apariția unor pete roșii în palme* și la nivelul compoziției sângelui: prezența în sânge a unei *concentrații ridicate dintr-o substanță numită bilirubină*. Mai precis, doreau să știe ce relație există între *petele roșii din palmă* și boala de ficat numită *hepatoză*, pentru ca să știe câtă importanță să dea acelor pete în stabilirea diagnosticului. Relațiile logic posibile puteau fi următoarele:

A. Toți **cei bolnavi de hepatoză** au **pete roșii în palmă** din cauza bolii.

B. Unii din **cei bolnavi de hepatoză** au **pete roșii în palmă din cauza bolii**.

C. Toți **cei bolnavi de hepatoză nu** au **pete roșii în palmă** din cauza bolii.

D. Unii dintre **cei bolnavi de hepatoză nu** au **pete roșii în palmă** din cauza bolii.

E. Nu se poate spune nimic *cert* despre legătura dintre **hepatoză** și **petele roșii din palmă**.

În cele de mai jos vi se dau 24 de combinații posibile între ceea ce *ei puteau ști* în ceea ce privește legătura dintre **hepatoză** și **nivelul crescut al bilirubinei în sânge** și ceea ce ei *puteau descoperi* în urma investigațiilor pe care urmau să le facă privitor la relația dintre **apariția petelor roșii în palmă** și **nivelul crescut al bilirubinei**. Sarcina Dvs, este să stabiliți pentru fiecare combinație posibilă la care dintre cele 5 concluzii posibile de mai sus (în ceea ce privește relația dintre **petele roșii din palmă** și boala de ficat numită **hepatoză**) trebuiau să ajună pe cale logică medicii.

Observație:

- În situațiile în care medicii știu sau descoperă că **toți** pacienții au unul din cele două simptoame (*pete roșii în palmă* sau *nivelul crescut de bilirubină în sânge*) sau boala *hepatoză*, înseamnă că **toți** pacienții aflați la dispoziția lor, sub observație, *au putut fi investigați* de către ei.
- În situațiile în care medicii știu sau descoperă că **doar unii** pacienții au unul din cele două simptoame (*pete roșii în palmă* sau *nivelul crescut de bilirubină în sânge*) sau boala *hepatoză*, înseamnă că **doar o parte** dintre pacienții aflați la dispoziția lor, sub observație, *au putut fi investigați* de către ei. Prin urmare, cele constate de medici în privința lor *sunt certe* pentru *unii dintre potențialii pacienți*, adică pentru *cel puțin o parte* dintre cei investigați. Este însă **posibil** (*dar nu cert*, ca în situațiile menționate mai sus, când toți pacienții au putut fi investigați) ca ele să fie valabile *și pentru restul pacienților*, cei care nu au putut fi investigați din diverse motive.

Vă mulțumim foarte mult pentru colaborarea la această cercetare! Fiind un studiu explorator, scopul nu este acela de a vă evalua abilitățile de gândire personale, ci de a investiga procesele raționamentului deductiv. De aceea, rezultatele obținute nu pot fi tratate ca o probă ale cărei rezultate să fie relevante în ceea ce privește măsurarea aptitudinilor intelectuale.

English version of the PPC format task centred on attributes (A type)

You are required to solve a deductive reasoning task, as the ones encountered by physicians in their daily activity when they try to find the relationship between some symptoms and certain diseases.

In what follows, it is discussed the fictive case of a group of physicians who studied the *relationships* between a rare liver *disease*: **hepatosis** and its *possible* skin *symptoms*: **the occurrence of some red spots on palms,** and blood *symptoms*: **a high bilirubin blood level**. More precisely, they wanted to know <u>what relationship is</u> between the *red spot on palms* and *hepatosis*, in order to see how important those red spots are in diagnosing that rare disease. The possible logical relationships considered by them are the following ones:

A. All **people ill with hepatosis** have **red spots on palms** because of the disease.

B. Some **people ill with hepatosis** have **red spots on palms** because of the disease.

C. All **people ill with hepatosis** do **not** have **red spots on palms** because of the disease.

D. Some **people ill with hepatosis** do **not** have **red spots on palms** because of the disease.

E. Nothing certain can be stated about the relationship between **hepatosis** and the **red spots on palms**.

Below, you are given 24 possible combinations between what *they might have known* in what regards the relationship between **hepatosis** and **the blood level of the bilirubin** and *what they might have discovered* through their investigations in what regards the relationship between the **occurrence of the red spots** and the **blood level of the bilirubin**. Your task is to establish for each possible combination the conclusion derived in a logical way with necessity by the physicians from the information supposedly known by them by choosing the corresponding option from the above-mentioned five conclusions (in what regards the relationship between the **red spot on palms** and **hepatosis**).

Note:

- If physicians know or discover that **only some** of the patients have one of the two symptoms (*red spots on palms* and a *high bilirubin blood level*) or *hepatosis*, it means that what they have come to know *is certain* for *at least a part* of the *patients whom they were able to investigate*. However, it is **possible**, *but not certain*, that what they have come to know is true *for* **all** *the patients*, i.e. *also for the patients that*, out of various reasons, *were not investigated*, not only for those that were investigated.
- If physicians know or discover that **all** patients have with *certainty* one of the two symptoms (*red spots on palms* and a *high bilirubin blood level*) or *hepatosis*, it means the physicians *were able to investigate all patients*.

Answer sheet for the Romanian version of the PPC format task centred on attributes (A type)

FOAIE DE RĂSPUNS

1. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

2. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

3. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

4. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

5. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

6. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

7. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

8. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

9. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Toți **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

10. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Toți **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

11. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

12. Dacă

- *au descoperit că*: „Toți cei care **au pete roșii în palmă** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

13. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă nu** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Toți **cei bolnavi de hepatoză** au un **nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

14. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă nu** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Toți **cei bolnavi de hepatoză nu** au un **nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

15. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă nu** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia __________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

16. Dacă

- *au descoperit că*: „Toți **cei care au pete roșii în palmă nu** au **un nivel crescut de bilirubină în sânge**."
- și *știau că*: „Unii din **cei bolnavi de hepatoză nu** au **un nivel crescut de bilirubină în sânge**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

17. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei cu un nivel crescut de bilirubină în sânge** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

18. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei cu un nivel crescut de bilirubină în sânge nu** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

19. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei cu un nivel crescut de bilirubină în sânge** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

20. Dacă

- au *descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei cu un nivel crescut de bilirubină în sânge nu** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia _________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

21. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei cu un nivel crescut de bilirubină în sânge** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia ________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

22. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Toți **cei cu un nivel crescut de bilirubină în sânge nu** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia ________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

23. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei cu un nivel crescut de bilirubină în sânge** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia ________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

24. Dacă

- *au descoperit că*: „Toți **cei cu un nivel ridicat de bilirubină în sânge nu** au **pete roșii în palmă**."
- și *știau că*: „Unii din **cei cu un nivel crescut de bilirubină în sânge nu** sunt **bolnavi de hepatoză**."

atunci în mod necesar medicii trebuiau să deducă logic

concluzia ________________ (notați *deasupra liniei litera* de la **A** la **E** corespunzătoare enunțului potrivit)

Answer sheet for the English version of the PPC format task centred on attributes (A type)

1. If

- they *discovered that*: "All people with a **high bilirubin blood level** have **red spots on palms**."
- and *knew that*: "All **people ill with hepatosis** have a **high bilirubin blood level**.",

then, with necessity, the physicians must logically derive the

conclusion ________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

2. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “All **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the *conclusion* __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

3. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “Some **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the *conclusion* __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

4. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “Some **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the *conclusion* __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

5. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “All **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the *conclusion* __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

6. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “All **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the *conclusion* __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

7. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “Some **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

8. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “Some **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

9 If

- they *discovered that*: “All people with **red spots on palms** have a **high bilirubin blood level**.”
- and *knew that*: “All **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

10. If

- they *discovered that*: “All people with **red spots on palms** have a **high bilirubin blood level**.”
- and *knew that*: “All **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

11. If

- they *discovered that*: “All people with **red spots on palms** have a **high bilirubin blood level**.”
- and *knew that*: “Some **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

12. If

- they *discovered that*: “All people with **red spots on palms** have a **high bilirubin blood level**.”
- and *knew that*: “Some **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

13. If

- they *discovered that*: “All people with **red spots on palms** do **not** have a **high bilirubin blood level**.”
- and *knew that*: “All **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

14. If

- they *discovered that*: “All people with **red spots on palms** do **not** have a **high bilirubin blood level**.”
- and *knew that*: “All **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

15. If

- they *discovered that*: “All people with **red spots on palms** do **not** have a **high bilirubin blood level**.”
- and *knew that*: “Some **people ill with hepatosis** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

16. If

- they *discovered that*: “All people with **red spots on palms** do **not** have a **high bilirubin blood level**.”
- and *knew that*: “Some **people ill with hepatosis** do **not** have a **high bilirubin blood level**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

17. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “All people with a **high bilirubin blood level** are **ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

18. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “All people with a **high bilirubin blood level** are **not ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

19. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “Some people with a **high bilirubin blood level** are **ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

20. If

- they *discovered that*: “All people with a **high bilirubin blood level** have **red spots on palms**.”
- and *knew that*: “Some people with a **high bilirubin blood level** are **not ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

21. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “All people with a **high bilirubin blood level** are **ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

22. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “All people with a **high bilirubin blood level** are **not ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

23. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “Some people with a **high bilirubin blood level** are **ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

24. If

- they *discovered that*: “All people with a **high bilirubin blood level** do **not** have **red spots on palms**.”
- and *knew that*: “Some people with a **high bilirubin blood level** are not **ill with hepatosis**.”,

then, with necessity, the physicians must logically derive the

conclusion __________________ (note *on the line the letter* from **A** to **E** that corresponds to the adequate statement).

Annex 8

Romanian version of the PPC format task centred on classes (C type)

Sarcină pentru investigarea raționamentului deductiv

În cele ce urmează vi se prezintă tipul de sarcină pe care sunteți solicitați să o rezolvați.

Se pornește de la *două propoziții* (premise) în care sunteți informați despre *o parte* dintre *relațiile presupuse ca adevărate* dintre *trei tipuri fictive* (inventate pentru elaborarea acestei probe) *de plante*: **ofidee**, **siderine** și **palmate**. Mai precis, într-una dintre propoziții se *va presupune ca adevărată* o anumită *relație* dintre **palmate** și **siderine** (sau, echivalent, între **siderine** și **palmate**). În cealaltă propoziție *se va presupune ca adevărată* o anumită relație dintre **palmate** și **ofidee** (sau, echivalent, între **ofidee** și **palmate**).

Prin urmare, *presupunând că cele două propoziții date sunt adevărate*, vi se cere să deduceți logic *ce anume rezultă cu necesitate* cu privire la *relația* dintre **ofidee** și **siderine**, cea despre care nu vi s-a prezentat nici o informație.

Pentru aceasta, va trebui *să alegeți o propoziție* dintre cele cinci de mai jos, *trecând litera din dreptul său în spațiul marcat* în partea dreaptă a foii(deasupra liniei care urmează după „Concluzia logică este:").

A. Toate **ofideele** sunt **siderine**.

B. Toate **ofideele nu** sunt **siderine**.

C. Unele **ofidee** sunt **siderine**.

D. Unele **ofidee nu** sunt **siderine**.

E. **Nu** se poate deduce cu certitudine nimic precis cu privire la relația **ofideelor** cu **siderinele**.

Vă mulțumim foarte mult pentru colaborarea la această cercetare! Fiind un studiu explorator, scopul nu este acela de a vă evalua abilitățile de gândire personale, ci de a investiga procesele raționamentului deductiv. De aceea, rezultatele obținute nu pot fi tratate ca o probă ale cărei rezultate să fie relevante în ceea ce privește măsurarea inteligenței Dvs.

English version of the PPC format task centred on classes (C type)

In what follows, the type of task that you are required to solve is presented.

In the start there are given *two statements* (premises) in which you are informed about *a part* of the *relationships that are assumed to be true* about *three fictive types of plants* (created especially for this task): **palmats, siderines** and **ophidees**. More precisely, in one of the two statements *it is assumed to be true* a certain relationship between **palmats** and **siderines** (or, equivalently, between **siderines** and **palmats**). In the other statement *it is assumed to be true* a certain relationship between **palmats** and **ophidees** (or, equivalently, between **ophidees** and **palmats**).

Therefore, *assuming the two statements are true*, you are required to logically *determine what can be inferred with necessity* in what regards the *relationship* between the **ophidees** and **siderines**, the one for which no information was presented.

In order to do that, you are required *to choose a statement* of the following five statements from below, *by noting the letter placed before that statement in the blank space* marked with a line in the right side of the sheet (on the line that follows after "The logical conclusion is:")

A. All **ophidees** are **siderines.**

B. All **ophidees** are **not siderines**.

C. Some **ophidees** are **siderines**.

D. Some **ophidees** are **not siderines**.

E. **Nothing** can be established with certainty in what regards the relationship between **ophidees** and **siderines**.

Answer sheet for the Romanian version of the PPC format task centred on classes (C type)

FOAIE DE RĂSPUNS

1. Dacă e adevărat că:
   „Toate **palmatele** sunt **siderine**." și că Concluzia logică este: ____________
   „Toate **ofideele** sunt **palmate**."
2. Dacă e adevărat că:
   „Toate **palmatele** sunt **siderine**." și că Concluzia logică este: ____________
   „Toate **ofideele nu** sunt **palmate.**"
3. Dacă e adevărat că:
   „Toate **palmatele** sunt **siderine**." și că Concluzia logică este: ____________
   „Unele **ofidee** sunt **palmate**"
4. Dacă e adevărat că:
   „Toate **palmatele** sunt **siderine**." și că Concluzia logică este: ____________
   „Unele **ofidee nu** sunt **palmate**."
5. Dacă e adevărat că:
   „Toate **palmatele nu** sunt **siderine**." și că Concluzia logică este: ____________
   „Toate **ofideele** sunt **palmate**."
6. Dacă e adevărat că:
   „Toate palmatele **nu** sunt **siderine**." și că Concluzia logică este: ____________
   „Toate **ofideele nu** sunt **palmate**."
7. Dacă e adevărat că:
   „Toate **palmatele nu** sunt **siderine**." și că Concluzia logică este: ____________
   „Unele **ofidee** sunt **palmate**."
8. Dacă e adevărat că:
   „Toate **palmatele nu** sunt **siderine**." și că Concluzia logică este: ____________
   „Unele **ofidee nu** sunt **palmate**."

9. Dacă e adevărat că:
„Toate **siderinele** sunt **palmate**.” și că
„Toate **ofideele** sunt **palmate**.”
Concluzia logică este: ____________

10. Dacă e adevărat că:
„Toate **siderinele** sunt **palmate**.” și că
„Toate **ofideele nu** sunt **palmate**.”
Concluzia logică este: ____________

11. Dacă e adevărat că:
„Toate **siderinele** sunt **palmate**.” și că
„Unele **ofidee** sunt **palmate**.”
Concluzia logică este: ____________

12. Dacă e adevărat că:
„Toate **siderinele** sunt **palmate**.” și că
„Unele **ofidee nu** sunt **palmate**.”
Concluzia logică este: ____________

13. Dacă e adevărat că:
„Toate **siderinele nu** sunt **palmate**.” și că
„Toate **ofideele** sunt **palmate**.”
Concluzia logică este: ____________

14. Dacă e adevărat că:
„Toate **siderinele nu** sunt **palmate**.” și că
„Toate **ofideele nu** sunt **palmate**.”
Concluzia logică este: ____________

15. Dacă e adevărat că:
„Toate **siderinele nu** sunt **palmate**.” și că
„Unele **ofidee** sunt **palmate**.”
Concluzia logică este: ____________

16. Dacă e adevărat că:
„Toate **siderinele nu** sunt **palmate**.” și că
„Unele **ofidee nu** sunt **palmate**.”
Concluzia logică este: ____________

17. Dacă e adevărat că:
„Toate **palmatele** sunt **siderine**.” și că
„Toate **palmatele** sunt **ofidee**.”
Concluzia logică este: ____________

18. Dacă e adevărat că:
„Toate **palmatele** sunt **siderine**.” și că
„Toate **palmatele nu** sunt **ofidee**.”
Concluzia logică este: ____________

19. Dacă e adevărat că:
„Toate **palmatele** sunt **siderine**.” și că
„Unele **palmate** sunt **ofidee**.”
Concluzia logică este: ____________

20. Dacă e adevărat că:
„Toate **palmatele** sunt **siderine**.” și că
„Unele **palmate nu** sunt **ofidee**.”
Concluzia logică este: ____________

21. Dacă e adevărat că:
„Toate **palmatele nu** sunt **siderine**.” și că
„Toate **palmatele** sunt **ofidee**.”
Concluzia logică este: ____________

22. Dacă e adevărat că:
„Toate **palmatele nu** sunt **siderine**.” și că Concluzia logică este: ____________
„Toate **palmatele nu** sunt **ofidee**.”
23. Dacă e adevărat că:
„Toate **palmatele nu** sunt **siderine**.” și că Concluzia logică este: ____________
„Unele **palmate** sunt **ofidee**.”
24. Dacă e adevărat că:
„Toate **palmatele nu** sunt **siderine**.” și că Concluzia logică este: ____________
„Unele **palmate nu** sunt **ofidee**.”

Answer sheet for the Romanian version of the PPC format task centred on classes (C type)

1. If it is true that:
„All **palmats** are **siderines**.” and that The logical conclusion is: ____________
„All **ophidees** are **palmats**.”
2. If it is true that:
„All **palmats** are **siderines**.” and that The logical conclusion is: ____________
„All **ophidees** are **not palmats**.”
3. If it is true that:
„All **palmats** are **siderines**.” and that The logical conclusion is: ____________
„Some **ophidees** are **palmats**.”
4. If it is true that:
„All **palmats** are **siderines**.” and that The logical conclusion is: ____________
„Some **ophidees** are **not palmats**.”
5. If it is true that:
„All **palmats** are **not siderines**.” and that The logical conclusion is: ____________
„All **ophidees** are **palmats**.”
6. If it is true that:
„All **palmats** are **not siderines**.” and that The logical conclusion is: ____________
„All **ophidees** are **not palmats**.”
7. If it is true that:
„All **palmats** are **not siderines**.” and that The logical conclusion is: ____________
„Some **ophidees** are **palmats**.”
8. If it is true that:
„All **palmats** are **not siderines**.” and that The logical conclusion is: ____________
„Some **ophidees** are **not palmats**.”
9. If it is true that:
„All **siderines** are **palmats**.” and that The logical conclusion is: ____________
„All **ophidees** are **palmats**.”

10. If it is true that:
„All **siderines** are **palmats**." and that — The logical conclusion is: ____________
„All **ophidees** are **not palmats**."
11. If it is true that:
„All **siderines** are **palmats**." and that — The logical conclusion is: ____________
„Some **ophidees** are **palmats**."
12. If it is true that:
„All **siderines** are **palmats**." and that — The logical conclusion is: ____________
„Some **ophidees** are **not palmats**."
13. If it is true that:
„All **siderines** are **not palmats**." and that — The logical conclusion is: ____________
„All **ophidees** are **palmats**."
14. If it is true that:
„All **siderines** are **not palmats**." and that — The logical conclusion is: ____________
„All **ophidees** are **not palmats**."
15. If it is true that:
„All **siderines** are **not palmats**." and that — The logical conclusion is: ____________
„Some **ophidees** are **palmats**."
16. If it is true that:
„All **siderines** are **not palmats**." and that — The logical conclusion is: ____________
„Some **ophidees** are **not palmats**."
17. If it is true that:
„All **palmats** are **siderines**." and that — The logical conclusion is: ____________
„All **palmats** are **ophidees**."
18. If it is true that:
„All **palmats** are **siderines**." and that — The logical conclusion is: ____________
„All **palmats** are **not ophidees**."
19. If it is true that:
„All **palmats** are **siderines**." and that — The logical conclusion is: ____________
„Some **palmats** are **ophidees**."
20. If it is true that:
„All **palmats** are **siderines**." and that — The logical conclusion is: ____________
„Some **palmats** are **not ophidees**."
21. If it is true that:
„All **palmats** are **not siderines**." and that — The logical conclusion is: ____________
„All **palmats** are **ophidees**."
22. If it is true that:
„All **palmats** are **not siderines**." and that — The logical conclusion is: ____________
„All **palmats** are **not ophidees**."

23. If it is true that:

„All **palmats** are **not siderines**." and that „Some **palmats** are **ophidees**."

The logical conclusion is: ____________

24. If it is true that:

„All **palmats** are **not siderines**." and that „Some **palmats** are **not ophidees**."

The logical conclusion is: ____________

Annex 9

Tabel 1
Administration order **CPPPPC** for the **PPC** task format

	Correctness for A type task	Correctness for valid syl-logisms at A type task	Correctness for invalid syllogisms at A type task	Correctness for C type task	Correctness for valid syl-logisms at C type task	Correctness for invalid syllogisms at C type task
N Valid	11	11	11	18	18	18
N Missing	1	1	1	0	0	0
Mean	8.4545	5.3636	3.0909	9.3333	6.0000	3.3333
Median	8.0000	5.0000	3.0000	10.0000	6.0000	3.0000
Mode	8.00	5.00	1.00(a)	10.00	8.00	3.00(a)
Standard deviation	2.29624	2.11058	1.86840	2.42536	2.40098	2.05798

Tabel 2
Administration order **PPCCPP** for the **PPC** task format

	Correctness for A type task	Correctness for valid syl-logisms at A type task	Correctness for invalid syllogisms at A type task	Correctness for C type task	Correctness for valid syl-logisms at C type task	Correctness for invalid syllogisms at C type task
N Valid	19	19	19	8	8	8
N Missing	0	0	0	0	0	0
Mean		5.3684	3.2632	5.6250	4.1250	1.5000
Median		5.0000	2.0000	5.0000	4.0000	1.0000
Mode		3.00(a)	2.00	5.00	3.00	.00
Standard deviation		2.47679	2.66338	2.72226	1.95941	1.69031

Tabel 3
Administration order **CPPPPC** for the **CPP** task format

	Correctness for A type task	Correctness for valid syl-logisms at A type task	Correctness for invalid syllogisms at A type task	Correctness for C type task	Correctness for valid syl-logisms at C type task	Correctness for invalid syllogisms at C type task
N Valid	11	12	11	16	16	16
N Missing	1	0	1	2	2	2
Mean		1.9167	2.0000	4.0000	1.6250	2.3750
Median		1.0000	1.0000	3.5000	1.5000	1.0000
Mode		1.00	1.00	1.00	.00	1.00
Standard deviation		2.02073	2.44949	3.20416	1.66833	2.60448

Tabel 4
Administration order **PPCCPP** for the **CPP** task format

	Correctness for A type task	Correctness for valid syllogisms at A type task	Correctness for invalid syllogisms at A type task	Correctness for C type task	Correctness for valid syllogisms at C type task	Correctness for invalid syllogisms at C type task
N Valid	16	16	16	8	8	8
N Missing	3	3	3	0	0	0
Mean		1.0625	1.9375	3.0000	1.2500	1.7500
Median		1.0000	1.5000	3.0000	1.0000	2.0000
Mode		1.00	1.00	2.00(a)	.00	2.00
Standard deviation		.92871	1.48183	.92582	1.48805	1.38873

Annex 10

Table 1
PPC task format

	Administration order CPPPPC		Administration order PPCCPP	
	A type task (N = 12)	**C type task (N = 18)**	**A type task (N = 19)**	**C type task (N = 8)**
Comparison between figure **1** and **2** *valid* syllogisms	$z = -1.552$ $p = .121$ (greater correctness for figure 1 ones)	$z = -1.897$ $p = .058$ (greater correctness for figure 1 ones)	$z = -1.908$ $p = .056$ (greater correctness for figure 1 ones)	
Comparison between figure **1** and **3** *valid* syllogisms	$z = \mathbf{-1.988}$ $p = .047$ (greater correctness for figure 1 ones)	$z = \mathbf{-3.499}$ $p = .000$ (greater correctness for figure 1 ones)	$z = \mathbf{-2.481}$ $p = .013$ (greater correctness for figure 1 ones)	$z = \mathbf{-1.897}$ $p = .058$ (greater correctness for figure 1 ones)
Comparison between figure **2** and **3** *valid* syllogisms		$z = \mathbf{-3.022}$ $p = .003$ (greater correctness for figure 2 ones)		-
Comparison between figure **1** and **2** *invalid* syllogisms	-			
Comparison between figure **1** and **3** *invalid* syllogisms	-		$z = \mathbf{-2.332}$ $p = .02$ (greater correctness for figure 3 ones)	
Comparison between figure **2** and **3** *invalid* syllogisms	$z = \mathbf{-2.913}$ $p = .004$ (greater correctness for figure 2 ones)		$z = \mathbf{-2.321}$ $p = .02$ (greater correctness for figure 3 ones)	

Table 2
PPC task format

	Administration order CPPPPC		Administration order PPCCPP	
	C type task (N = 18)	**A type task (N = 19)**	**C type task (N = 18)**	**C type task (N = 18)**
Comparison between figure **1** and **2** *one model* syllogisms	z = −1.592 p = .111 (greater correctness for figure 1 ones)	z = **−2.420** p = .016 (greater correctness for figure 1 ones)	z = **−2.866** p = .004 (greater correctness for figure 1 ones))	
Comparison between figure **1** and **3** *one model* syllogisms	-	z = −1.461 p = .144 (greater correctness for figure 1 ones)	-	
Comparison between figure **2** and **3** *one model* syllogisms	z = −1.643 p = .108 (greater correctness for figure 2 ones)	z = **−2.101** p = .036 (greater correctness for figure 2 ones)	z = −1.567 p = .117 (greater correctness for figure 2 ones)	
Comparison between figure **1** and **2** *multiple model valid* syllogisms	-	-	-	
Comparison between figure **1** and **3** *multiple model valid* syllogisms	z = **−2.303** p = .021 (greater correctness for figure 1 ones)	z = **−2.598** p = .009 (greater correctness for figure 1 ones)	z = −1.853 p = .064 (greater correctness for figure 1 ones)	
Comparison between figure **2** and **3** *multiple model valid* syllogisms	z = **−2.192** p = .028 (greater correctness for figure 2 ones)	z = **−3.567** p = .000 (greater correctness for figure 2 ones)	z = **−2.068** p = .039 (greater correctness for figure 2 ones)	

Tabel 3
CPP task format

	Administration order CPPPPC		Administration order PPCCPP	
	A type task (N = 12)	**C type task (N = 18)**	**A type task (N = 19)**	**C type task (N = 8)**
Comparison between figure **1** and **2** *valid* syllogisms	z = −1.933 p = .053 (greater correctness for figure 1 ones)		z = −2.673 p = .008 (greater correctness for figure 1 ones)	
Comparison between figure **1** and **3** *valid* syllogisms	z = **−2.226** p = .026 (greater correctness for figure 1 ones)		z = **−2.53** p = .011 (greater correctness for figure 1 ones)	
Comparison between figure **2** and **3** *valid* syllogisms				
Comparison between figure **1** and **4** *valid* syllogisms	z = **−1.994** p = .046 (greater correctness for figure 1 ones)		z = **−2.714** p = .007 (greater correctness for figure 1 ones)	

Annex 11

Table 1

	Correctness for the task administered in the first position	Correctness for valid syllogisms at the task administered in the first position	Correctness for invalid syllogisms at the task administered in the first position	Correctness for the task administered in the second position	Correctness for valid syllogisms at the task administered in the second position	Correctness for invalid syllogisms at the task administered in the second position
N Valid	31	31	31	24	24	24
N Missing	0	0	0	7	7	7
Mean		7.8710	5.5161	11.7917	7.5417	4.2500
Median		8.0000	5.0000	12.0000	8.0000	4.5000
Mode		8.00	5.00	9.00	7.00	.00
Standard deviation		1.74627	3.04271	4.96053	2.91889	3.26043

Table 2

	Correctness for A type task	Correctness for valid syllogisms at A type task	Correctness for invalid syllogisms at A type task	Correctness for C type task	Correctness for valid syllogisms at C type task	Correctness for invalid syllogisms at C type task
N Valid	27	27	27	28	28	28
N Missing	4	4	3	3	3	0
Mean		5.0370	12.5714	7.6786	4.8929	5.3871
Median		5.0000	12.0000	8.0000	4.5000	6.0000
Mode		5.00	12.00	7.00	4.00	6.00
Standard deviation		3.25200	4.12246	2.43514	3.15453	.88232

Annex 12

Tabel 1

	Administration order AC		**Administration order CA**	
	A type task (N = 16)	**C type task (N = 13)**	**C type task (N = 15)**	**A type task (N = 11)**
Comparison between figure **1** and **2** *valid* syllogisms	z = **−2.401** p = .016 (greater correctness for figure 1 ones)	z = **−1.511** p = .031 (greater correctness for figure 1 ones)	z = **−3.017** p = .003 (greater correctness for figure 1 ones)	z = **−2.137** p = .033 (greater correctness for figure 1 ones)
Comparison between figure **1** and **3** *valid* syllogisms	z = **−3.602** p = .000 (greater correctness for figure 1 ones)	z = **−2.913** p = .004 (greater correctness for figure 1 ones)	z = **−3.373** p = .001 (greater correctness for figure 1 ones)	z = **−2.754** p = .066 (greater correctness for figure 1 ones)
Comparison between figure **2** and **3** *valid* syllogisms	z = **−2.846** p = .004 (greater correctness for figure 2 ones)	z = **−2.197** p = .028 (greater correctness for figure 2 ones)	z = **−2.299** p = .022 (greater correctness for figure 2 ones)	-
Comparison between figure **1** and **2** *invalid* syllogisms	-	z = **−2.06** p = .039 (greater correctness for figure 2 ones)	z = **−2.490** p = .013 (greater correctness for figure 2 ones)	z = **−2.142** p = .032 (greater correctness for figure 2 ones)
Comparison between figure **1** and **3** *invalid* syllogisms	-	-	-	z = −1.633 p = .103 (greater correctness for figure 3 ones)
Comparison between figure **2** and **3** *invalid* syllogisms	-	z = **−2.232** p = .026 (greater correctness for figure 2 ones)	z = −1.574 p = .115 (greater correctness for figure 2 ones)	z = −1.513 p = .130 (greater correctness for figure 2 ones)

Tabel 2

	Administration order AC		Administration order CA	
	A type task (N = 16)	**C type task (N = 13)**	**A type task (N = 16)**	**Proba A (N = 11)**
Comparison between figure **1** and **2** *one model* syllogisms	z = −1.512 p = .131 (greater correctness for figure 1 ones)	-	z = **−2.585** p = .01 (greater correctness for figure 1 ones)	z = −1.761 p = .078 (greater correctness for figure 1 ones)
Comparison between figure **1** and **3** *one model* syllogisms	-	-	-	z = −1.414 p = .157 (greater correctness for figure 1 ones)
Comparison between figure **2** and **3** *one model* syllogisms	-	-	z = −1.897 p = .058 (greater correctness for figure 2 ones)	z = −1.857 p = .063 (greater correctness for figure 2 ones)
Comparison between figure **1** and **2** *multiple model valid* syllogisms	z = −1.473 p = .141 (greater correctness for figure 1 ones)	-	-	z = −1.718 p = .086 (greater correctness for figure 1 ones)
Comparison between figure **1** and **3** *multiple model valid* syllogisms	z = **−3.093** p = .002 (greater correctness for figure 1 ones)	z = **−2.754** p = .006 (greater correctness for figure 1 ones)	z = **−2.198** p = .028 (greater correctness for figure 1 ones)	z = **−2.539** p = .011 (greater correctness for figure 1 ones)
Comparison between figure **2** and **3** *multiple model valid* syllogisms	z = **−2.152** p = .031 (greater correctness for figure 2 ones)	z = **−2.431** p = .015 (greater correctness for figure 2 ones)	z = **−2.002** p = .045 (greater correctness for figure 2 ones)	-

Annex 13

Romanian version for the L type task

Instrucțiuni pentru proba de raționament silogistic

În cele ce urmează sunt prezentate **24 de probleme de raționament logic,** numit **raționament silogistic.**

Vi se cere să găsiți soluția pentru fiecare dintre ele, deducând **concluzia logic necesară** care decurge din *informația* prezentată în cele *două premise* (judecăți) ale unei probleme *dacă se presupune că această informație este adevărată*.

Pentru a da răspunsul, va trebui să alegeți unul dintre enunțurile de mai jos și să notați în spațiul rezervat, în dreptul concluziei, litera corespunzătoare (**A**, **B**, **C**, **D**, **E, F, G, H** sau **I**) enunțului ales:

A. Toți membrii clasei **S** au proprietatea **P**.

B. Toți membrii clasei **S** sunt și membrii ai clasei **P**.

C. Toți membrii clasei **S** **nu** au proprietatea **P**.

D. Toți membrii clasei **S** **nu** sunt și membrii ai clasei **P**.

E. Unii membri ai clasei **S** au proprietatea **P**.

F. Unii membri ai clasei **S** sunt și membri ai clasei **P**.

G. Unii membri ai clasei **S** **nu** au proprietatea **P**.

H. Unii membri ai clasei **S** **nu** sunt și membri ai clasei **P**.

I. **Nu** se poate deduce nici o concluzie logic necesară.

1. Toți membrii clasei **M** au proprietatea **P**. Concluzie: ________________
   Toți membrii clasei **S** sunt membri și ai clasei **M**.
2. Toți membrii clasei **M** au proprietatea **P**. Concluzie: ________________
   Toți membrii clasei **S** **nu** sunt membri și ai clasei **M**.
3. Toți membrii clasei **M** au proprietatea **P**. Concluzie: ________________
   Unii membri ai clasei **S** sunt membri și ai clasei **M**.
4. Toți membrii clasei **M** au proprietatea **P**. Concluzie: ________________
   Unii membri ai clasei **S** **nu** sunt membri și ai clasei **M**.
5. Toți membrii clasei **M** **nu** au proprietatea **P**. Concluzie: ________________
   Toți membrii clasei **S** sunt membri și ai clasei **M**.
6. Toți membrii clasei **M** **nu** au proprietatea **P**. Concluzie: ________________
   Toți membrii clasei **S** **nu** sunt membri și ai clasei **M**.
7. Toți membrii clasei **M** **nu** au proprietatea **P**. Concluzie: ________________
   Unii membri ai clasei **S** sunt membri și ai clasei **M**.
8. Toți membrii clasei **M** **nu** au proprietatea **P**. Concluzie: ________________
   Unii membri ai clasei **S** **nu** sunt membri și ai clasei **M**.
9. Toți membrii clasei **P** au proprietatea **M**. Concluzie: ________________
   Toți membrii clasei **S** au proprietatea **M**.

10 Toți membrii clasei **P** au proprietatea **M.** Concluzie: _______________
Toți membrii clasei **S nu** au proprietatea **M**.

11. Toți membrii clasei **P** au proprietatea **M.** Concluzie: _______________
Unii membri ai clasei **S** au proprietatea **M**.

12. Toți membrii clasei **P** au proprietatea **M.** Concluzie: _______________
Unii membri ai clasei **S nu** au proprietatea **M**.

13. Toți membrii clasei **P nu** au proprietatea **M**. Concluzie: _______________
Toți membrii clasei **S** au proprietatea **M**.

14. Toți membrii clasei **P nu** au proprietatea **M**. Concluzie: _______________
Toți membrii clasei **S nu** au proprietatea **M**.

15. Toți membrii clasei **P nu** au proprietatea **M**.. Concluzie: _______________
Unii membri ai clasei **S** au proprietatea **M**.

16. Toți membrii clasei **P nu** au proprietatea **M**. Concluzie: _______________
Unii membri ai clasei **S nu** au proprietatea **M**.

17. Toți membrii clasei **M** au proprietatea **P**. Concluzie: _______________
Toți membrii clasei **M** sunt și membri ai clasei **S**.

18. Toți membrii clasei **M** au proprietatea **P**. Concluzie: _______________
Toți membrii clasei **M nu** sunt și membri ai clasei **S**.

19. Toți membrii clasei **M** au proprietatea **P**. Concluzie: _______________
Unii membri ai clasei **M** sunt și membri ai clasei **S**.

20. Toți membrii clasei **M** au proprietatea **P**. Concluzie: _______________
Unii membri ai clasei **M nu** sunt și membri ai clasei **S**.

21. Toți membrii clasei **M nu** au proprietatea **P**. Concluzie: _______________
Toți membrii clasei **M** sunt și membri ai clasei **S**.

22. Toți membrii clasei **M nu** au proprietatea **P**. Concluzie: _______________
Toți membrii clasei **M nu** sunt și membri ai clasei **S**.

23. Toți membrii clasei **M nu** au proprietatea **P**. Concluzie: _______________
Unii membri ai clasei **M** sunt și membri ai clasei **S**.

24. Toți membrii clasei **M nu** au proprietatea **P**. Concluzie: _______________
Unii membri ai clasei **M nu** sunt și membri ai clasei **S**.

English version for the L type task

Response options:

A. All members of the class **S** have the property **P**.

B. All members of the class **S** are also members of the class **P**.

C. All members of the class **S** do **not** have the property **P**.

D. All members of the class **S** are **not** also members of the class **P**.

E. Some members of the class **S** have the property **P**.

F. Some members of the class **S** are also members of the class **P**.
G. Some members of the class **S** do **not** have the property **P**.
H. Some members of the class **S** are **not** also members of the class **P**.
I. It is **not** possible to derive a necessary logical conclusion.

1. All members of the class **M** have the property **P**.
   All members of the class **S** are also members of the class **M**.
2. All members of the class **M** have the property **P**.
   All members of the class **S** are **not** also members of the class **M**.
3. All members of the class **M** have the property **P**.
   Some members of the class **S** are also members of the class **M**.
4. All members of the class **M** have the property **P**.
   Some members of the class **S** are **not** also members of the class **M**.
5. All members of the class **M** do **not** have the property **P**.
   All members of the class **S** are also members of the class **M**.
6. All members of the class **M** do **not** have the property **P**.
   All members of the class **S** are **not** also members of the class **M**.
7. All members of the class **M** do **not** have the property **P**.
   Some members of the class **S** are also members of the class **M**.
8. All members of the class **M** do **not** have the property **P**.
   Some members of the class **S** are **not** also members of the class **M**.
9. All members of the class **P** have the property **M**.
   All members of the class **S** have the property **M**.
10. All members of the class **P** have the property **M**.
    All members of the class **S** do **not** have the property **M**.
11. All members of the class **P** have the property **M**.
    Some members of the class **S** have the property M**.**
12. All members of the class **P** have the property **M**.
    Some members of the class **S** do **not** have the property **M**.
13. All members of the class **P** do **not** have the property **M**.
    All members of the class **S** have the property **M**.
14. All members of the class **P** do **not** have the property **M**.
    All members of the class **S** do **not** have the property **M**.
15. All members of the class **P** do **not** have the property **M**.
    Some members of the class **S** have the property **M**.
16. All members of the class **P** do **not** have the property **M**.
    Some members of the class **S** do **not** have the property **M**.
17. All members of the class **M** have the property **P**.
    All members of the class **M** are also members of the class **S**.

18. All members of the class **M** have the property **P**.
    All members of the class **M** are **not** also members of the class **S**.
19. All members of the class **M** have the property **P**.
    Some members of the class **M** are also members of the class **S**.
20. All members of the class **M** have the property **P**.
    Some members of the class **M** are **not** also members of the class **S**.
21. All members of the class **M** do **not** have the property **P**.
    All members of the class **M** are also members of the class **S**.
22. All members of the class **M** do **not** have the property **P**.
    All members of the class **M** are **not** also members of the class **S**.
23. All members of the class **M** do **not** have the property **P**.
    Some members of the class **M** are also members of the class **S**.
24. All members of the class **M** do **not** have the property **P**.
    Some members of the class **M** are **not** also members of the class **S**.

Annex 14

Table 1

	Correctness for the task administered in the first position	Correctness for valid syllogisms at the task administered in the first position	Correctness for invalid syllogisms at the task administered in the first position	Correctness for the task administered in the second position	Correctness for valid syllogisms at the task administered in the second position	Correctness for invalid syllogisms at the task administered in the second position
N Valid	50	50	50	44	44	44
N Missing	1	1	1	7	7	7
Mean		6.7400	2.3800	9.3182	7.1136	2.2045
Median		7.0000	2.0000	9.0000	7.0000	2.0000
Mode		7.00	2.00	11.00	7.00	2.00
Standard deviation		2.28402	1.91546	2.81005	1.99086	1.94792

Table 2

	Correctness for N type task	Correctness for valid syllogisms at N type task	Correctness for invalid syllogisms at N type task	Correctness for L type task	Correctness for valid syllogisms at L type task	Correctness for invalid syllogisms at L type task
N Valid	48	48	48	46	46	46
N Missing	3	3	3	5	5	5
Mean		6.6458	2.5417	9.2391	7.1957	2.0435
Median		7.0000	2.0000	9.0000	7.0000	2.0000
Mode		7.00	2.00	10.00	7.00	2.00
Standard deviation		2.18787	2.10327	2.37753	2.09358	1.69910

Annex 15

Table 1

	Administration in the first position (N = 50)	**Administration in the second position (N = 44)**
Comparison between **N** type task and **L** type task regarding the correctness of *valid* syllogisms	U = **186** p = 013 (greater correctness for **L** type task)	–
Comparison between **N** type task and **L** type task regarding the correctness of *invalid* syllogisms	U = **204.5** p = 034 (greater correctness for **N** type task)	–
Comparison between **N** type task and **L** type task regarding the correctness of *one model* syllogisms	–	U = 169 p = 077 (greater correctness for **L** type task)
Comparison between **N** type task and **L** type task regarding the correctness of *multiple model valid* syllogisms	U = **173** p = 006 (greater correctness for **L** type task)	–
Comparison between **N** type task and **L** type task regarding the correctness of *figure 1 valid* syllogisms	U = **224** p = 043 (greater correctness for **L** type task)	U = **171** p = 038 (greater correctness for **L** type task)
Comparison between **N** type task and **L** type task regarding the correctness of *figure 1 invalid* syllogisms	–	–
Comparison between **N** type task and **L** type task regarding the correctness of *figure 2 valid* syllogisms	U = 236.5 p = 087 (greater correctness for **L** type task)	–
Comparison between **N** type task and **L** type task regarding the correctness of *figure 2 invalid* syllogisms	U = 237 p = 078 (greater correctness for **N** type task)	–
Comparison between **N** type task and **L** type task regarding the correctness of *figure 3 valid* syllogisms	U = 226.5 p = 08 (greater correctness for **L** type task)	–
Comparison between **N** type task and **L** type task regarding the correctness of *figure 3 invalid* syllogisms	U = **200.5** p = 022 (greater correctness for **N** type task)	–

Annex 16

Table 1

	Administration order NL		Administration order LN	
	N type task (N = 26)	**L type task (N = 22)**	**L type task (N = 22)**	**N type task (N = 24)**
Comparison between figure **1** and **2** *valid* syllogisms	z = **−2.329** p = .017 (greater correctness for figure 1 ones)	z = **−2.221** p = .026 (greater correctness for figure 1 ones)	z = **−2.575** p = .01 (greater correctness for figure 1 ones)	z = **−3.244** p = .001 (greater correctness for figure 1 ones)
Comparison between figure **1** and **3** *valid* syllogisms	z = **−4.051** p = .000 (greater correctness for figure 1 ones)	z = **−3.832** p = .000 (greater correctness for figure 1 ones)	z = **−3.555** p = .006 (greater correctness for figure 1 ones)	z = **−4.102** p = .000 (greater correctness for figure 1 ones)
Comparison between figure **2** and **3** *valid* syllogisms	z = **−3.033** p = .002 (greater correctness for figure 2 ones)	z = **−2.816** p = .005 (greater correctness for figure 2 ones)	z = −1.835 p = .067 (greater correctness for figure 2 ones)	z = **−3.157** p = .002 (greater correctness for figure 2 ones)
Comparison between figure **1** and **2** *invalid* syllogisms	z = **−2.236** p = .025 (greater correctness for figure 2 ones)	–	–	–
Comparison between figure **1** and **3** *invalid* syllogisms	z = **−2.236** p = .025 (greater correctness for figure 3 ones)	z = **−2.324** p = .02 (greater correctness for figure 3 ones)	–	z = −1.801 p = .072 (greater correctness for figure 3 ones)
Comparison between figure **2** and **3** *invalid* syllogisms	–	z = **−2.966** p = .003 (greater correctness for figure 2 ones)	–	z = **−3.310** p = .001 (greater correctness for figure 2 ones)

Table 2

	Administration order NL		Administration order LN	
	N type task (N = 26)	**L type task (N = 22)**	**N type task (N = 26)**	**L type task (N = 22)**
Comparison between figure **1** and **2** *one model* syllogisms	z = −1.624 p = .104 (greater correctness for figure 1 ones)	z = −1.909 p = .056 (greater correctness for figure 1 ones)	z = **−2.687** p = .007 (greater correctness for figure 1 ones)	z = **−2.842** p = .004 (greater correctness for figure 1 ones)
Comparison between figure **1** and **3** *one model* syllogisms	z = −1.431 p = .152 (greater correctness for figure 1 ones)	z = **−2.861** p = .004 (greater correctness for figure 1 ones)	z = −1.710 p = .087 (greater correctness for figure 1 ones)	–
Comparison between figure **2** and **3** *one model* syllogisms	–	–	–	z = **−2.345** p = .019 (greater correctness for figure 2 ones)
Comparison between figure **1** and **2** *multiple model valid* syllogisms	–	–	z = −1.5 p = .134 (greater correctness for figure 1 ones)	–
Comparison between figure **1** and **3** *multiple model valid* syllogisms	z = **−2.850** p = .004 (greater correctness for figure 1 ones)	z = **−2.130** p = .033 (greater correctness for figure 1 ones)	z = **−3.765** p = .000 (greater correctness for figure 1 ones)	z = **−2.774** p = .006 (greater correctness for figure 1 ones)
Comparison between figure **2** and **3** *multiple model valid* syllogisms	z = **−2.089** p = .037 (greater correctness for figure 2 ones)	z = **−2.367** p = .018 (greater correctness for figure 2 ones)	z = **−3.642** p = .000 (greater correctness for figure 2 ones)	z = **−2.896** p = .004 (greater correctness for figure 2 ones)

Annex 17

Probă de raționament silogistic A

În cele ce urmează sunt prezentate **2 probleme de raționament logic,** numit **raționament silogistic.**

Vi se cere să găsiți soluția pentru fiecare dintre ele, deducând **concluzia logic necesară** care decurge din *informația* prezentată în cele *două premise* (judecăți) ale unei probleme *dacă se presupune că această informație este adevărată*.

Pentru a da răspunsul, va trebui să alegeți unul dintre enunțurile de mai jos și să notați în spațiul rezervat, în dreptul concluziei, litera corespunzătoare (**A**, **B**, **C**, **D** sau **E**) enunțului ales:

Toți **S** sunt **P**.

Toți **S nu** sunt **P**.

Unii **S** sunt **P**.

Unii **S nu** sunt **P**.

Nu se poate deduce nici o concluzie logic necesară.

Vă mulțumim pentru participare!

Probleme

1. Toți **M** sunt **P**. Concluzie: ______________________
   Toți **S** sunt **M**.
2. Toți **P** sunt **M**. Concluzie: ______________________
   Toți **S** sunt **M**.
3. Toți **P** sunt **M**. Concluzie: ______________________
   Toți **S nu** sunt **M**.
4. Toți **M** sunt **P**. Concluzie: ______________________
   Toți **M nu** sunt **S**.

Probă de raționament silogistic B

În cele ce urmează sunt prezentate **2 probleme de raționament logic,** numit **raționament silogistic.**

Vi se cere să găsiți soluția pentru fiecare dintre ele, deducând **concluzia logic necesară** care decurge din *informația* prezentată în cele *două premise* (judecăți) ale unei probleme *dacă se presupune că această informație este adevărată*.

Pentru a da răspunsul, va trebui să alegeți unul dintre enunțurile de mai jos și să notați în spațiul rezervat, în dreptul concluziei, litera corespunzătoare (**A**, **B**, **C**, **D** sau **E**) enunțului ales:

Toți **S** sunt **P**.

Toți **S nu** sunt **P**.

Unii **S** sunt **P**.

Unii **S nu** sunt **P**.

Nu se poate deduce nici o concluzie logic necesară.

Vă mulțumim pentru participare!

Probleme

1. Toți **P** sunt **M**. Concluzie: ________________________
   Toți **S** sunt **M**.
2. Toți **M** sunt **P**. Concluzie: ________________________
   Toți **S** sunt **M**.
3. Toți **M** sunt **P**. Concluzie: ________________________
   Toți **M** **nu** sunt **S**.
4. Toți **P** sunt **M**. Concluzie: ________________________
   Toți **S** **nu** sunt **M**.

Annex 18

Free number generation task

Probă de generare liberă de numere

Mai jos găsiți un tabel care are 400 de căsuțe. Sunteți solicitați să îl completați scriind în fiecare căsuță *oricare dintre numerele* de la **1** la **9** *vă vine în minte în momentul completării acelei căsuțe*. Nu trebuie să țineți cont de nimic altceva decât dacă acel număr este cel pe care îl aveți în minte atunci când începeți să completați căsuța. Cu alte cuvinte, *nu are importanță cum este el (dacă este același sau nu, de exemplu) în raport cu numerele cu care ați completat căsuțele precedente*.

Începeți completarea tabelului cu prima coloană, de sus în jos, apoi continuați cu următoarele. Pentru a nu fi influențați de numerele completate anterior vă recomandăm să acoperiți progresiv cu o bucată de hârtie căsuțele deja completate.

English version

Below, you are given a table with 400 cells. You are required to complete that table by noting in each cell *whichever number from the natural numbers* between **1** and **9** that *freely comes through your mind in the moment when you are about to complete that cell*. You are not supposed to take into consideration anything other than if that is the number from your mind in the moment you start to complete that cell. In other words, *it is not important what kind of number is that number in relationship with the numbers from other cells (e.g., if it is the same as the previous one)*.

Start the table completion with the first column, from above to below, and then continue with the following columns. In order to not be influenced by the numbers already completed, you are recommended to cover progressively, with a piece of sheet, the cells already completed.

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