The Influence of Semantic and Pragmatic Factors in Wason's Selection Task: State of the Art

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Abstract

One of the cognitive processes, which has generated more research within the framework of the Psychology of thinking, is human reasoning. Throughout the history of the Psychology of reasoning, one of the experimental tasks most frequently used to study how subjects reason, and why they make mistakes, is the Wason's selection task or the four card problem **(Wason, 1966, 1968)**. This work presents the current state of the experimental research on this task, using as a common thread the empirical studies which have highlighted the plasticity of reasoning towards semantic and pragmatic factors.

1. Introduction

One of the principal ways in the study of human thinking is the cognitive approach, within the framework of the information processing paradigm. In general terms, Cognitive Psychology aims to study the human cognitive system, its organization and functional principles, in order to explain the human behaviour (Valiña & Martín, 2015).

One of the cognitive processes, which has generated the most research within the framework of the Psychology of thinking, is human reasoning (see Evans, 2011; Evans & Frankish, 2009; Martín & Valiña, 2003, for a historical perspective on the study of thinking). Peter Wason (1924-2003) suggested many of the topics which have been the focus of attention of Cognitive Psychology researchers for the last fifty years. Among his first works is one of the experimental tasks which has generated the most research in the history of the Psychology of

reasoning: the Wason's selection task or the four card problem (Wason, 1966, 1968).

The task involves presenting the subjects with four cards which have a number (odd or even) written on one side and a letter (vowel or consonant) on the other side. Immediately afterwards, a conditional rule is presented: "*If a card has a consonant on one side then it has an odd number on the other side*". The subjects had to say which card or cards they must turn over in order to decide whether the rule is true or false.

Logical analysis indicates that conditional statement included in the task should be interpreted as a material implication and, therefore, the correct answer is the selection of the antecedent of the rule ("p") and the negation of its consequent ("not-q"). The results of this original abstract version indicated that less than 10% of subjects answered correctly. Furthermore, they systematically committed one of the following mistakes: they either selected the card which represented the antecedent of the rule (verification bias: Wason, 1968) or they selected the antecedent and the consequent of the same (matching bias: Evans, 1972, 1998). What are the reasons why intelligent adult subjects fail to solve it?

The selection task is a meta-inference problem which requires the understanding of a conditional "if… then", and the formulation and verification of hypotheses. On one hand, research on the conditional has reflected the polysemic and ambiguous character of this type of statement (Byrne & Johnson-Laird, 2009; Nickerson, 2015); on the other hand, hypothetical thinking is limited (Evans, 2007). In this sense, research with the selection task has tried to determine what factors can modulate both the understanding of the conditional rule included in the problem, as well as the limits of hypothetical thinking. The first factor studied was the abstract nature of the original task.

2. First Explanations on the Task: The Thematic Facilitation Effect

The first results obtained by Peter Wason lead him to present the human subject as a person who seemed irrational. In this way, "much of Wason's work became controversial because it apparently showed people as illogical or irrational" (Evans & Johnson-Laird, 2003: p. 180).

The early investigations focused the difficulty of the task on the abstract nature of the rule presented. With this hypothesis, empirical studies were begun to be designed in which the content was manipulated, ratifying the existence of a thematic facilitation effect (Wason & Johnson-Laird, 1972). Consequently, when the task included a concrete or thematic content, the subjects selected the correct cards more frequently than with those which had abstract content (Wason & Shapiro, 1971 or Johnson-Laird, Legrenzi, & Legrenzi, 1972. See Evans, Newstead, & Byrne, 1993: Chapter 4, for a review on the history of the thematic facilitation effect; see also Martín, Valiña, Seoane, & Leirós, 2008).

The hypothesis of thematic content facilitation was maintained until the end of the 1970's. Specifically, in 1979, Manktelow and Evans, using specific content with an arbitrary relationship ("If I eat haddock then I drink gin"), did not register any improvement in performance with respect to the original abstract version. According to the authors, the facilitation registered in the previous thematic versions could be related to the activation of the correct counterexample from the memory. In this sense, different researchers have highlighted the role of memory in performance with the selection task as one of the principal determiners of the content effect (see Feeney & Thompson, 2014, for a recent publication on the relationships between memory and reasoning).

One of the thematic versions which registered a good performance, was designed by Griggs and Cox (1982): the "drinking age rule". In this task, the subjects had to imagine that they were police officers on duty. Their jobs were to ensure that people conform the rule: "if a person is drinking beer, then the person must be over 19 years of age". The key to the results was not the thematic content, but the intra-experimental relationship between content and experience. This forms the basis of the "memory cueing hypothesis" proposed by the authors.

Since Peter Wason's failure in the original version of the problem, other versions of the selection task were designed which, on some occasions, differed substantially from the original abstract one, without this being contemplated on an experimental level. Some of these will be reviewed hereinafter.

3. Different Versions of the Selection Task or Different Selection Tasks?

3.1. The Deontic Selection Task

One of the first thematic versions in which the facilitation effect was registered, included a postal rule (Johnson-Laird et al., 1972). In this work subjects were asked to imagine that they were post office workers sorting letters

and testing the rule: "If a letter is sealed then it has a 50 lira stamp on it". They were given the following instruction: "to find out whether or not they violate the rule" (p. 397). According to the authors, the content of the problem improved the understanding of its logical structure. However, some changes had been included in this version with respect to the original, which could be key to explaining the results obtained, and that were not contemplated at that time. Later empirical research reflected the influence on reasoning of variables such as the inclusion of the task in a *scenario* (see for example Margolis, 1987 or Martín, Valiña, & Evans 1999) or the type of *experimental instructions* the subjects received (Griggs, 1984; Griggs & Jackson, 1990; Valiña, Seoane, Ferraces, & Martín, 1995, 1998; Yachanin, 1983, 1986; Yachanin & Tweney, 1982, among others).

Directly related to the scenario and the instructions, the importance of the deontic character of the statement as opposed to the indicative character of the original version was considered. In effect, most of the thematic versions in which facilitation had been registered, were contextualized in scenarios and included deontic statements. In these versions, the subjects' ability to make inferences about violations of rules made by the authorities or persons in charge in order to obtain benefits or avoid costs was analysed (see Evans & Over, 1996: Chapter 4; Manktelow & Over, 1995; or Beller, 2010, for a review of deontic reasoning). In general, deontic conditionals express obligation or permission and include explicitly or implicitly deontic modal terms such as "should", "must", etc. In one indicative version, the subjects are asked to falsify the rule while in deontic versions they are required to find violations. In this sense, they could be considered to be "two distinct forms of the Wason's selection task: indicative and deontic, depending on which kind of conditional and instructions is employed" (Evans & Over, 1996: p. 71).

The first to consider the question of the deontic nature of the selection task were Manktelow and Over (1991). The authors designed a research in which the subjects reasoned with the rule "if you tidy up your room, then you may go out to play". Half of the subjects were instructed to imagine they were a boy who had been given the rule by his mother and were asked to indicate which cards had to be turned over to determine whether the mother had broken the rule. The other half of the subjects were instructed to take the view of the mother and were asked to determine whether the son had broken the rule. According to the authors, this type of conditional statement has two parts: an agent and an actor, and each of them includes different preferences, which the selected cards will modulate ("p y not-q" for the "child" and "not-p and q" for the "mother"). Evans, Over and Manktelow (1993), generalized the previous explanation considering that people reason in order to support their decisions and achieve objectives, and they propose an explanation for the deontic reasoning based on decision theory. The subjective utilities and the perceived objectives are crucial pragmatic factors which modulate the selection of cards (see Kirby, 1994, who based himself on the subjective expected utility theory to explain performance in the selection task).

Similar results to those of Manktelow and Over (1991) were observed in the work of Politzer and Nguyen-Xuan (1992) and Gigerenzer and Hug (1992); the latter suggest the term "social perspective effect", which occurs when the subjects are induced to select "p and not-q" or "not-p and q", by varying the perspective from which they are reasoning.

In conclusion, the most effective versions of the selection task may be related to deontic forms as opposed to indicative forms. Does this mean that the subjects' responses are modulated exclusively by the deontic or indicative nature of the task? When we compare performance on indicative tasks with that on deontic tasks, does the subject transition from an inept reasoner being to a pragmatic virtuoso? (see Girotto, Kemmelmeier, Sperber, & van Der Henst, 2001). Some of the principal lines of research which have attempted to respond to these and other questions regarding deontic reasoning and the selection task will be presented hereinafter (see **Table 1**).

3.2. Is Deontic Reasoning "Special"?

When subjects are presented with a deontic version of the task, they generally select the cards that coincide with the formally correct ones. Sometimes this result has been interpreted as evidence that there is a special innate capacity underlying deontic reasoning. This is what is known as the "deontic advantage", defended by authors such as Cummins (1996a, 1996b, 2013), or Harris and Nuñez (1996). However, such an assertion has been questioned by other researchers, such as Astington and Dack (2013); Bucciarelli and Johnson-Laird (2000); Dack and Astington (2011); Veleiro, Peralbo and García-Madruga (1998), among others.

According to Cummins (1996a, 1996b) the differences in performance between deontic and indicative tasks have their origin in the type of specific control and innate strategies which are used in each of them. In particular,

Table 1. Empirical research on the importance of semantic and pragmatic factors in the selection task.

Authors	Rule-Example	Result-Explanation
Wason & Shapiro (1971)	"Everytime I go to Manchester I travel by car".	Facilitation of thematic content.
Johnson-Laird, Legrenzi, & Legrenzi (1972)	"If a letter is sealed, then it has a 50 lira stamp on it".	Facilitation of thematic content.
Manktelow & Evans (1979)	"If I eat haddock, then I drink gin".	No thematic facilitation in arbitrary relationship.
Griggs & Cox (1982)	"If a person is drinking beer, then the person must be over 19 years of age".	Facilitation by content-experience relationship.
Cheng & Holyoak (1985)	"If the form says ENTERING on one side, then the other side includes CHOLERA among the list of diseases".	Facilitation by activation of permission rules.
Cosmides (1989)	"If a man eats cassava root, then he has a tattoo on his face".	Facilitation by reformulation of the rule as cost-benefit and application of cheater-detector algorithm.
Asensio, Martín Cordero, García-Madruga, & Recio (1990)	"If a person is driving a car, then he must be over 18 years old".	Execution by double syntactic-semantic processing.
Manktelow & Over (1991)	"If you tidy up your room, then you may go out to play".	Selection of cards which breaks the rule. Child: "p and not-q". Mother: "not-p and q".
Gigerenzer & Hug (1992)	"If an employee works on the weekend, then that person gets a day off during the week".	Perspective effect and cheater-detector algorithm modulate the selection (employee: "p and not-q"; employer: "not-p and q").
Holyoak & Cheng (1995)	"If a car owner installs a new catalytic converter, then that person gets a subsidy".	Pragmatic Schemas Theory explains the role of content and context. Rights and duties: complementary terms.
Valiña, Seoane, Ferraces, & Martín (1995)	"If a Wasit card has A on one side, then it must have a 3 on the other side". "If a person is sitting in the front seat of a car, then that person must be over 12 years of age".	Better performance in thematic version. Facilitation of violation instructions. Individual differences
Love & Kessler (1995)	"If there are Xow, then there must be a force field".	The context: key if it suggests the activation of counterexamples.
Valiña, Seoane, Ferraces, & Martín (1998)	"If a person is riding a motorcycle then he must wear a helmet".	Interactive effect instructions and content. Superior logical indexes in deontic versions.
Stanovich & West (1998)	"If 'Baltimore' is on one side of the ticket then 'plane' is on the other side of the ticket".	Better performance in deontic version. Individual differences.
Martín, Valiña, & Evans (1999)	"If a card has a bricklayer written on one side, then it must have/has hard hat written on the other side".	Effect of scenario in deontic problems. Better performance in permission or obligation rules.
Staller, Sloman, & Ben-Zeev (2000)	"If a Hare Mantra child is at least 8 years old, then that child performs well the 8-years intelligence test".	Perspective effect does not require deontic context. Execution according to activation of counterexamples.
Valiña, Seoane, Ferraces, & Martín (2000)	"If a person is more than 18 years old, then he has the right to vote".	Facilitation of violation instructions. Better performance in thematic-obligation task. Individual differences.
Almor & Sloman (2000)	"If an employee gets a day off during the week, then that employee must have worked on the weekend".	Looks for rule-history coherence.
Girotto, Kemmelmeier, Sperber, & van der Henst (2001)	"If a person travels to any East African country, then that person must be immunized against cholera".	The context expressed in the text modulates the relevancy to make inferences.

Continued

Handley, Feeney, & Harper (2002)	"If a customer lives in Tavistock then they pay the reduced tariff". "If a customer lives in Plymouth/Totnes then they pay the reduced tariff".	Selection of cards influenced by presence of a second rule.
Ayal & Klar (2014)	"If you buy my miracle medicine for $12.50, you will be cured in less than ten days". "If you give me $60, then I will have the furniture delivered and assembled in your home".	Different cheating ploys modulate the selection. Key: necessity/sufficiency of the cost-benefit relationship.
Thompson, Plowright, Attance, & Caza (2015)	"If it is the first day of the month, then there must be pancakes for lunch". "If the child takes a cookie then the child must have earned a gold star sticker".	Interaction type of problem ("cheater or non cheater") and parental connection with the child (existent or non-existent).

in deontic tasks, search strategies are used to detect possible violations of the rule, while in indicative tasks, verification strategies are used (see, however, Veleiro, Peralbo, & García-Madruga, 1998, for a reply of Cummins (1996a), in which the authors did not register the confirmatory search strategy in indicative contexts). Using toys in place of cards and a simplified version of the Wason's selection task (RAST), Cummins (1996a) observed that 3 - 4-year-old children presented this innate capacity (see also Harris & Nuñez, 1996: Experiment 4). From a different perspective, Astington and Dack (2013), Dack and Astington (2011) have considered that it is the context, both linguistic and extralinguistic, which determines if a statement is interpreted as a rule, which may be obeyed or disobeyed, or as an inference, which may be true or false.

In a great majority of studies, the deontic selection task has provided little empirical evidence of deductive reasoning, as opposed to the indicative version. An alternative explanation comes from research on the study of individual differences (see for example, Stanovich & West, 1998). These authors have considered that subjects' ability to solve deontic versions was linked more to the influence of pragmatic, rapid and automatic processes, than to their intellectual ability or to the presence of innate strategies. Factors such as intelligence or cognitive style have proved good predictors of performance in indicative versions of the task, such as the original abstract version, which requires an explicit and conscious reasoning process (see Newstead, Handley, Harley, Wright, & Farelly, 2004; Stanovich & West, 1998; Valiña, Seoane, Ferraces, & Martín, 1995, 2000, for some studies on individual differences in reasoning with the selection task).

Some authors consider that the means to understanding the mechanisms and functions of reasoning, must be the context of the task (Osman, 2014). Different studies in which it was empirically ratified that this variable was a key modulating factor in the selection of cards will be presented hereinafter.

4. The Context Effect

There is an increasing number of authors who propose different pragmatic aspects as the keys which allow for an explanation of performance, both in indicative and in deontic versions of the task. In this sense, it appears that the mere presence of a verb such as "must" does not bestow a deontic nature to the statement, nor does it explain the differences between both versions. In effect, deontic conditionals may have a different role depending on the context in which they are proposed.

Authors such as Almor and Sloman (1996, 2000); Girotto et al. (2001); Staller, Sloman and Ben-Zeev (2000), among others, designed different empirical studies in which it was considered that the difference between correct and incorrect selection was modulated more by factors relating to context than by the mere deontic or indicative nature of the statement. Almor and Sloman (2000) designed research based on the "reversed-perspective paradigm", using narrative texts. They used the "day-off version", in which the following rule of permission was included: "If an employee gets a day off during the week, then that employee must have worked on the weekend". The task was contextualized in a story which described the obligation of a company to give an employee one week day off when he had worked at the weekend. The subjects constructed a representation of the problem with a rule that was compatible with the whole task and, in consequence, they processed it as an obligation. In effect, there was a tendency to increase the amount of information presented by using general knowledge and by searching for coherence in the text. In this sense, when the subject reads a text, they construct a rich and coherent representation which goes beyond the same (De Vega, 1998). See also Haigh and Stewart (2011); Martín, Valiña,

Seoane and Ferraces (1998); Valiña (1985); Valiña and De Vega (1988); Valiña, Martín, Gehring and Seoane (2015); Valiña, Seoane, Ferraces and Martín (1997), for other studies which analyse the role that the congruence or coherence of a text plays in subjects' reasoning in different deductive reasoning tasks.

Another empirical investigation along the same lines, is the work of Girotto et al. (2001), who propose that deontic rules may also have a descriptive claim. They used two deontic and two descriptive versions and the same rule in all of them: "If a person travels to any East African country, then that person must be immunized against cholera". They included this rule in a narrative text, changing the story in which the rule was contextualized and the cards presented, from one version to another. According to the relevance theory, linguistic comprehension processes determine intuitions of relevance, that modulate the card selection, and "these intuitions can be manipulated through alterations of content and context" (Girotto et al., 2001: p. 75).

Most research which has analysed the role of perspective in reasoning with the selection task, has included deontic conditionals and rules which reflect social contracts or conventions. However, studies have also been designed in which the effect of perspective on reasoning, using non-deontic rules, has been ratified (for example, causal rules: Beller & Spada, 2003, or Fairley, Manktelow, & Over, 1999, among others). According to Beller and Spada (2003), the key to explaining performance in this task lies in the difference between content competency and form competency. The former refers to the ability to reason in accordance with social or causal rules or conventions. The latter is the ability to reason in accordance with the rules of logic. The authors found evidence of both types of competency by using selection tasks based on violations of the rule, with both causal and deontic statements. Within the framework of deontic conditionals, Beller (2008) differentiates between two types: strong and weak deontic conditionals, depending on whether or not they consider social limits on behaviour, such as prohibitions and permissions respectively.

Other authors, such as Staller et al. (2000), have considered that "different modal operators exist to express necessity, possibility, certainty, probability, obligation and so on, and each supports different inferences" (p. 404). The authors analysed the effect of perspective in both versions of the problem, deontic and indicative, and observed that this effect was modulated by the elicitation of counterexamples based on descriptions of the task. Context was key to the differences between both types of conditionals. Other studies, in previous decades, highlighted the importance of the ability to activate counterexamples, as another key factor in indicative versions of the task (Green, 1995; Green & Larking, 1995 or Love & Kessler, 1995, among others). In effect, "the ability to understand the premises, together with the ability to find counterexamples, accounts for the ability to reason, both deontically and factually" (Bucciarelli & Johnson-Laird, 2000: pp. 227-228).

Therefore, these empirical studies appear to suggest that reasoning using deontic versions of the selection task were modulated by the same factors as in non-deontic versions, being the context of the problem a key variable in the selection of cards.

Another important pragmatic aspect is the relationship that the subject may activate based on the statement, relying on their conceptual system and on their experience. In this sense, different empirical studies have analysed the role of the perceived necessity and sufficiency implicit in the statement, in performance with the four card problem.

5. Necessity and Sufficiency in the Selection Task

The key to reasoning could lie in the condition of necessity or sufficiency inherent in the conditional statements. In a selection task, casting doubt on sufficiency of a condition, leads to a higher frequency of "p and not-q" responses, while questioning the necessity leads to "not-p and q" cards (see for example Thompson, 1995 or Fairley et al., 1999).

Ahn and Graham (1999: Experiment 1), used three thematic versions and one abstract version and they manipulated the necessity/sufficiency relationship by means of the story presented to the subjects and the modal verb used in the statement. They observed that the most frequent response was the normative, independently of the content of the rule (experiment 1) and without taking the subjects' perspective into account (experiment 2).

The discussion on the necessity/sufficiency of the conditional as a modulating factor in the selection of cards, was extended by Hilton, Kemmelmeier and Bonnefon (2005). The authors pointed out the pragmatic use of deontic conditionals as they called "conditional directives". This involves statements which are intended to influence the actions other people have in mind when they express them, for example, a promise, a threat, etc. (Evans & Twyman-Musgrove, 1998; Newstead, Ellis, Evans, & Dennis, 1997 or Valiña, Martín, & Seoane, 2014,

among others, analysed the effect of this type of statements by using other conditional reasoning tasks).

Therefore, the protagonists' beliefs, desires and intentions, inferred by the reasoner, seem to play a fundamental role in performance (see for example Haigh & Bonnefon, 2015, for a study on how readers infer intentions based on the desires and beliefs of others, via their eye-movements; see also Hilton, 2016; Hilton, Charalambides, & Hoareau, 2016).

The empirical research presented thus far has shown that when subjects reason over the selection task, the cards they select and, in short, the conclusions they produce, could be modulated by semantic and pragmatic factors. How has this question been dealt with based on the principal theories of human reasoning?

6. Semantic and Pragmatic Factors in the Selection Task: Main Theoretical Explanations

Some authors have considered that the facilitation effect in the selection task may occur in some contexts in which the subjects have no experience with the content of the problem. However, they do have experience in analogous contexts which allows them to activate a series of "abstract knowledge structures". This is the proposal defended by the Theory of Pragmatic Reasoning Schemas (Cheng & Holyoak, 1985, 1989; Cheng, Holyoak, Nisbett, & Oliver, 1986; Holyoak & Cheng, 1995) and the Social Contract Theory (Cosmides, 1985; 1989; Cosmides & Tooby, 1992).

From a different perspective, it is suggested that subjects reason elaborating semantic representations of objects and situations in the real world, which they construct based on the information given in the task and by using their knowledge of the world. This is the position defended by the Mental Models Theory (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991, 2002).

Finally, the Heuristic-Analytic Theory (Evans, 1984, 1989, 2006) proposes that subjects reason over information that they have previously selected in a non-conscious manner.

How reasoning on the selection task has been addressed from these theoretical approaches will now be explained.

6.1. The Theory of Pragmatic Reasoning Schemas

From this perspective, subjects reason by activating a series of "knowledge packages" learnt from experience or *pragmatic schemas*, which express permission, obligation or causal relationships. For Cheng and Holyoak (1985), the content effect in the selection task is related to the activation of the four production rules included in the permission schema, according to which, "If an action is to be taken then a precondition must be satisfied". For example, the thematic facilitation registered in the "drinking age rule" (Griggs & Cox, 1982) has been explained by these authors, based on the activation of permission schema. Specifically, "if a person is drinking beer (action) then they must be over 19 years of age (precondition)". In this context, breaking the rule would mean carrying out the action without fulfilling the precondition (and therefore selecting, in general terms, "p and not-q"). Cheng and Holyoak also produced a new version of the selection task, related to immigration rules at an airport: "If it says ENTER on one side, then the other side must include CHOLERA on the list of diseases". The task was presented to the subjects in two versions: rational, in which it was explained to them that "they should ensure that the passengers who entered were protected against the disease", and the non-rational version, which did not include this specification. The percentage of correct selections decreased from 90% in the first version to 60% in the second. Other researchers who have supported the facilitation effect with the permission schema are Girotto, Mazzocco and Cherubini, 1992; Griggs and Cox, 1993; Jackson and Griggs, 1990; Kroeger, Cheng and Holyoak, 1993, among others.

According to Evans and Over (2004), the pragmatic schema theory does not explain the role of deontic conditionals, but it was "simply designed to account for responses in the selection task" (p. 84). Another theoretical approach which has explained reasoning using specific domain rules, in this case innate, is the social contract theory.

6.2. The Social Contract Theory

According to Cosmides (1985, 1989); Cosmides & Tooby (1992, 2013); Fiddick, Cosmides, & Tooby (2000), subjects have a series of social contract algorithms which allow them to reason in social exchange contexts and

to detect the people who cheat. In particular, when subjects reason with the selection task, they try to reformulate the rule in terms of a social exchange: "if you take a benefit then you pay a cost". They immediately apply the "cheater detector algorithm", looking for those subjects who obtain the benefit without paying the cost; in general terms selecting "p and not-q" cards.

In the version about the behaviour of aboriginal people, devised by the author, the subjects received a text in which they were asked to imagine that they were a member of the polynesian culture and they were given the rule: "If a man eats cassava root then he has a tattoo on his face". In this version, 75% of the responses registered were correct compared to around 25% with a descriptive version. This result was explained based on the reformulation of the rule in terms of cost-benefit and the activation of the "cheater detector algorithm", which would mean "eating cassava root without having a tattoo on the face" (obtaining the benefit without paying the cost), that is selecting, in general, the "p and not-q cards".

In daily life, people can "cheat" and commit infractions for different reasons, which may be more or less serious. This type of pragmatic aspects have been analysed within the framework of the selection task. For example, Cosmides and Tooby (1992), or Fiddick (2004), observed that "cheat detection" improved when the scenario was related to intentional violations of the rule, as opposed to when the violation was presented as accidental. On the other hand, there are different types of cheating, depending on the necessity-sufficiency of the perceived relationship between cost-benefit, which could lead to different selections being made (Ayal & Klar, 2014; see **Table 1**).

However, people do not always "cheat"; on occasion, they are altruistic and carry out laudable actions in benefit of others, in spite of the personal cost to themselves. One particular line of research which has arisen in this context, has analysed the differences in performance with the selection task among altruistic and cooperative subjects (those who fulfil their obligations in a reciprocal exchange). In general, the subjects' task in these studies was to specify whether somebody was being cooperative or altruistic; see for example Fiddick and Elrich (2010) or Thompson, Plowright, Atance and Caza (2015).

In general terms, one of Leda Cosmides' principal critiques, revolves around the nature of the experiments she designs, in which she uses very long and complex verbal scenarios (Evans, 2007) and instructions which change the nature of the task, with regard to the original version (Sperber & Girotto, 2002). Likewise, from critical stances, it has been proposed that there other versions of the task which do not appear liable to be explained within the framework of the social contract theory (for example, the "hospital version", using the rule: "if you clear up spilt blood, then you must wear rubber gloves" (Manktelow & Over, 1990). This critique lead Fiddick, Cosmides and Tooby (2000), to propose a new schema for a new domain related to precautions. However, Manktelow and Over opted for an explanation that was closer to the mental models theory.

6.3. The Theory of Mental Models

For Johnson-Laird (1983); Johnson-Laird and Byrne (1991, 2002), subjects reason by elaborating semantic representations or mental models, which reflect the meaning of the premises. This theory proposes that there are several reasoning stages that subject go through in order to draw the conclusion in a reasoning problem. First, the comprehension stage, based on the interpretation of the problem content, derived from current experience and background knowledge, to understand its premises. This process give the subjects a set of mental models of the problem's elements. From this, the subject pass to the description stage, in which he try to draw a conclusion. Finally, he validate it by searching for alternative models that defeat it or counterexamples. If he do find out one, he go back to the previous stage and see if he can formulate a conclusion that is true in all of the models.

One of the basic principles of this theory is that subjects tend to represent as much implicit information as is possible, only reasoning over the models that are explicitly represented. In the case of the selection task, the conditional rule "if a card has a consonant on one side, then it has an odd number on the other side", carries the explicit initial representation:

$$[consonant] \qquad odd$$
$$...$$

where the three dots "…" represent the implicit models. Subjects could consider only the cards that are explicitly represented in their models of the rule, which could lead them to commit matching bias (selection of: consonant, odd).

In order to reach the correct conclusion, it is necessary that the three models of the conditional to be explicitly

represented (and therefore, the subjects will perceive the need to turn over the negated consequent):

consonant   odd
consonant   odd
consonant   odd

One of the general predictions of this theory is: "any manipulation that draws attention to counter-examples should improve performance" (Johnson-Laird & Byrne, 1991: pp. 80-81). Likewise, any manipulation which minimizes the load in the operative memory, should also improve performance (Johnson-Laird, 1995).

According to the models theory, subjects tend to represent what is true, but no what is false. However, in the selection task representing what is false is key to making the correct selection (Santamaría & Espino, 2006). In this sense, when what would be false in a factual relationship, or what would violate the rule in a deontic relationship is made explicit, this could improve performance in the selection task.

According to Johnson-Laird and Byrne (2002), indicative and deontic conditionals lead to equivalent semantic interpretations: the indicative conditionals describe physical possibilities and impossibilities and the deontic conditionals describe deontic possibilities and impossibilities, even though the empirical evidence seems to show that deontic statements make what is impossible more prominent than do factual ones (Bucciarelli & Johnson-Laird, 2000, 2005).

For years, one of the principal critiques of the mental model theory was the lack of specificity regarding what type of mechanism modulate the content and context effects on reasoning. In this sense, Johnson-Laird and Byrne (2002) have proposed semantic and pragmatic modulation mechanisms to explain the elaboration of alternative mental models or to block their construction (see Johnson-Laird, 2000, 2012, 2013 for reviews of this theory).

The following theory has its origins in the Wason's selection task: the Heuristic-Analytic theory.

6.4. The Heuristic-Analytic Theory

This theoretical approach has its origins in the dual process theory (Evans & Wason, 1976; Wason & Evans, 1975), which emerged precisely to explain the discrepancies in the Wason task between the subjects' introspective reports and the experimental evidence of bias. In its original form, the heuristic-analytic theory (Evans, 1984, 1989) considered two different phases in order to explain the reasoning process: an initial phase of heuristic processing, which leads to selecting the relevant information on what is to be reasoned in a second phase of reasoning or analytic phase. This initial selection is modulated by linguistic, semantic and/or pragmatic variables, which could lead subjects to make mistakes in the heuristic phase, focussing their attention on irrelevant aspects of the task or not considering relevant aspects. The second phase includes an unspecific reasoning mechanism, although closer to the elaboration of mental models than to the activation of formal rules.

The heuristic-analytic theory has been revised (Evans, 2006), to include the possible existence of bias in the analytic stage also. It would seem that both types of heuristic and analytic processing are influenced by beliefs, although in different ways (for a more detailed explanation, see Weidenfeld, Oberauer, & Hörnig, 2005).

This theoretical approach falls within the framework of the so-called double process theories (specifically, Evans & Over, 1996; Evans & Stanovich, 2013). Evans and Over (1996), propose the existence of two different cognitive systems: System 1, of an implicit type, which recovers and applies knowledge quickly and automatically, and System 2, or an explicit system, which supports hypothetical thinking. Both systems may be the origin of bias, which appears to especially affect subjects of lesser cognitive ability (Stanovich, 1999). See Evans, 2000, 2012, 2013 for reviews of this theoretical perspective.

According to Evans and Clibbens (1995), beliefs may lead subjects to focus their attention on particular cards, which are selected based on criteria of relevance, more so than on any logical reasoning process. In this sense, Sperber, Cara and Girotto (1995), propose the theory of relevance to explain performance on the selection task, and define what is relevant as that which involves low cognitive effort and high cognitive effect. According to the authors, reasoning on the task is modulated by the subjects' perspectives on what is relevant, depending on the content and context of the task (see Evans, 1995; Sperber, Cara, & Girotto, 1995).

One of the debates proposed within the context of this theory refers to the following question: When subjects are faced with the four-card task, "do they decide on which cards to select before they think about them?" (Evans, 1996) or, on the contrary, "do they think before making the selection?" (Handley, Newstead, & Neilens, 2011). In connection to this topic, in the past few decades a theoretical debate has been proposed regarding what measures would be the most ideal in order to go into depth into the study of reasoning. In particular, a series of

empirical works have been developed which propose new indices, such as the inspection times, eye-movements or neural correlates. Along these lines, see Ball (2011, 2014); Ball, Lucas, Miles and Gale (2003); Cutmore, Halford, Wang, Ramm, Spokes, & Shum (2015); Evans (1996); Evans and Ball (2010), Lucas and Ball (2005); Roberts (1998); Roberts and Newton (2001, 2011). In more general terms, see De Neys and Osman (2014), for a recent publication about new methods of research on reasoning.

7. Conclusion

Research on the effect of facilitation in the selection task has put forth two important issues: 1) it does not necessarily involve an improvement in logical performance, and 2) it is not simply thematic facilitation. The existence of a key factor in explaining performance is not defended, like what had occurred in the 1970's regarding the content of the rule. There are different variables which may interact and explain reasoning on this task. Furthermore, the degree of improvement varies considerably from research to research. In effect, "no manipulation yields perfect selections in one condition and wholly erroneous selections in another" (Johnson-Laird, 1995: p. 136). Perhaps because, as Beller and Spada (2003) propose, "the extent to which a content effect arises depends in part on task-specific factors" (p. 367). Already in the 90's, Asensio, Martín Cordero, García-Madruga and Recio (1990) had anticipated that the matter of the quality and intensity of the influence of the content was a problem that would take some time to solve.

The selection task requires understanding a conditional statement as well as elaborating and verifying hypotheses on what may be on the other side of each card. In particular, the conditional is ambiguous by nature and subjects on occasion interpreting it incorrectly. However, the material implication may not be the only problem, as the so-called "deductive illusions" also occur in other types of statements (Johnson-Laird & Savary, 1999; Santamaría & Johnson-Laird, 1998, 2000). According to Stanovich (2015) the key is: "When reasoning hypotheticallly, a person must be able to represent a belief as separate from the world it is representing" (p. 149).

An important part of empirical research on the selection task appears to indicate the plasticity of reasoning towards factors related to content, context and empirical knowledge. In this sense, allowing us to finish this study using the words of Byrne (2016) on counterfactual conditionals, for the conditional with the four-card problem: knowledge affects the plausibility of a conditional through the semantic and pragmatic modulation of the mental representation of alternative possibilities.

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