

FALSIFICATION AND THE ROLE OF THE THEORY OF MIND IN THE REDUCED ARRAY SELECTION TASK

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Abstract: The aim of the paper is an investigation into the contexts that facilitate young children in a "reduced array" selection. Our hypothesis is that such contexts, e.g. deontic, are facilitatory in that they require to take into account the others' mental states. In our experiment we compared a deontic and a factual selection task in two groups of participants: one group carried out standard reduced array selection tasks, and the other group carried out the selection tasks in the context of the possibility of a false belief. We expected to find out a facilitatory effect of the deontic context only in the standard tasks. The results of the experiment confirm our prediction for three years old children, but not for four and five year olds. Indeed, contrary to the results in the literature, four and five years olds perform equally with the two sorts of standard reduced array selection tasks.

Key words: Falsification, Theory of mind, Reduced Array Selection Task

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INTRODUCTION

Wason's selection task has been extensively used in the psychological literature to investigate into the ability to test hypotheses (Wason, 1966). In a typical version of the task, participants are asked to choose whichever of four cards should be turned over in order to find out whether a conditional assertion is true or false. The four cards have a number on one side and a letter on the other side, which the subjects know, and the cards are laid out on a table with A, B, 2, and 3 uppermost, and the conditional to be tested is:

If there is an 'A' on one side of a card, then there is a '2' on the other side.

Intelligent adults tend to select the A card, or the A and the 2 card, and they fail to select the 3 card. Thus, given a rule of the form: if p then q, they select p, but conspicuously fail to select not-q. An improvement in performance in the deontic selection task is accomplished merely by changing the conditional to a deontic one concerning what is permissible (Johnson-Laird, Legrenzi, & Legrenzi, 1972; Griggs & Cox, 1982; Cosmides, 1989). This improvement is also noteworthy in children (see e.g. Girotto, Light, & Colbourn, 1988).

In working with children, however, investigators typically use the "reduced array selection task" (RAST) in which the participants have to choose only between the q and not-q cards (Wason, 1968). Thus, Cummins (1996: Experiment 2) told three-year and four-year-old children stories about squeaky mice. The stories culminated either in a factual generalization:

All the squeaky mice are in the house

or a deontic obligation (created by the Queen of the mice):

All the squeaky mice must stay in the house.

The children tended to make the correct selection (of checking the mice who were not in the house) in the deontic case when they had to check that none of the mice were disobeying the Queen (62% of the three-year olds and 80% of the four-year olds), but they tended to err by selecting the mice in the house in the factual case when they had to check whether the experimenter was tricking the children when she made the general assertion (only 37% correct of the three-year olds and 30% correct of the four-year olds). These results accordingly replicated those of Girotto et al. (1988), but for much younger children.

Why people's performance in the selection task is better with deontic materials than with factual materials? Some theories argue that there might exist formal rules for deontic reasoning (Rips, 1994). Others claim that in the deontic version of the selection task individuals are guided by pragmatic reasoning schemas (e.g. Cheng & Holyoak, 1985). The "evolutionary psychologists" argue that there is an innate module for deontic reasoning (see Cosmides, 1989; Gigerenzer & Hug, 1992) and, in Cummins' (1996) view, the domain-specific reasoning module is in place by the age of three. An alternative hypothesis are mental models and their associated utilities (Manktelow & Over, 1991). Indeed, in a selection task with the deontic conditional 'If you tidy your room (p) then you may go out to play (q)', the adult subjects' selections depended on whose point of view they were asked to take, the mother or the child (see also Politzer & Nguyen-Xuan, 1992). Completely different are the perspectives adopted by Oaksford and Chater (1994) - who advance a rational analysis centered on decision making rather than on inference - and by Griggs and Cox (1982) and Reich and Ruth (1982) - who argue that memory factors account for a high falsification rate in the standard selection tasks.

Our own view is that individuals rely on mental models, but mental models tend to represent only what is true, not what is false (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). Thus, individuals who grasp the need to search for counterexamples — either factual or deontic — will perform more accurately in the selection task. It is entirely feasible that the grasp of this principle differs from one domain to another as a function of experience, and that this difference accounts for many of the phenomena. Likewise, any manipulation that helps individuals to consider false instances of the rule, should improve performance (see e.g. Green & Larking, 1995; Liberman & Klar, 1996; Love & Kessler, 1995; and Sperber, Cara, & Girotto, 1995). The effects of point of view tend to arise in cases where the conditional has the force of a biconditional:

If and only if p then q.

Such biconditionals are false in two cases:

$$\begin{array}{l} p \quad \neg q \\ \neg p \quad q \end{array}$$

and the participants' point of view focuses them on one counterexample or the other. With no specific point of view, however, they are prone to select all four cards (Politzer & Nguyen-Xuan, 1992).

Mental Model theory claims that people's performance in the selection task is better with deontic materials than with factual materials because the for-

mer make salient the false instances of a rule. However, the theory claims that any contexts of this sort can enhance reasoners' performance (Johnson-Laird & Byrne, 1991). Our further assumption is that deontic materials make salient the false instances of a rule by making salient the others' mental states, such as beliefs and expectations. In other words, they induce reasoners to use their theory of mind to conceive of alternative possibilities of the reality. In our experiment we tested two predictions on three, four and five years old children: factual and deontic versions of the task should be equally difficult to deal with in the context provided by the possibility of a false belief, but not in the standard context, where only the deontic task invites reasoners to consider the others' mental states.

The results fully confirm our expectations only for three years old children. Indeed, within the standard context, four and five year old children perform in the factual version of the task as in the deontic version. Thus, our results concerning the standard tasks replicate only partially the results obtained by Cummins (1996), which gave rise to the hypothesis of the existence of a deontic module. We analyze the implications of our results in the final discussion.

The role of the theory of mind in reasoning with the Reduced Array Selection task

The developmental literature has shown that deontic materials sort a facilitatory effect on young children's reasoning in the RAST. This evidence, as we said above, lead to the conclusion that there exist a module for deontic reasoning. In our view, a possible alternative explanation is that deontic materials invite children to consider the others' mental states such as beliefs and expectations, and therefore they invite to consider possible false instances of the rule. We argue that the understanding of deontic rules and theory of mind are domains closely interwoven in the child's mind (see also Nunez & Harris, 1998): children can not develop an understanding of rights and obligations that is separate from their developing theory of mind (but cfr. Jackendoff, 1996).

A first aim of our experiment was to replicate the results obtained by Cummins (1996), and therefore to find out that young children perform better with deontic materials than with factual materials in the standard versions of the RAST. Thus, in our experiment we used the same materials as in Cummins' study, but this time in a within subjects experimental design. Indeed, Cummins compared the performance of a group of children in the

indicative task with the performance of another group of children in the deontic task. However, a fair comparison requires children to deal with both tasks.

Also, our assumption leads to the prediction that reasoners' performance should improve in the context provided by the possibility of a false belief, independently on the fact that the task is factual or deontic. In other words, the difference between factual and deontic tasks should be flattened in such a context. A further aim of our experiment was to validate this prediction.

We tested our predictions in an experiment where children were randomly assigned to two experimental conditions. In the standard condition, they dealt with *Standard protocol*, i.e. a factual and a deontic version of the standard RAST. The protocol is identical to the one devised by Cummins (1996: experiment 2). In the mental state condition, they dealt with *Mental State protocol*, i.e. a factual and a deontic version of the RAST within the context provided by the possibility of a false belief.

For explorative purposes we investigate the ability to deal with the RAST in three different age groups of children. Indeed, it is possible that contexts facilitating young children performance lose such a facilitatory effect as the child grows up. With the age, the child might become more sensible to the false instances falsifying a rule. In other words, she could become competent enough, so to be less affected by the context within which the RAST is provided. Our youngest children are three years old. Indeed, theory of mind, defined as the ability to attribute mental states such as false beliefs to others, begins to emerge at around the age of 3 years, when children begin to talk and reason about epistemic states, and is firmly in place by 4 years (Wimmer & Perner, 1983). We can therefore predict that children of this age should be likely to consider counterexamples in selection tasks that invite to consider the others' mental states.

EXPERIMENT

We tested our prediction using two sorts of content, one factual and the other deontic. We use "complying" to refer to instances that would show that a factual assertion is true or instances that would comply with deontic obligation, and we use "non complying" to refer to instances that would show that the factual assertion is false and instances that would violate the deontic obligation. The correct answer given an assertion of the form:

All the A are/must be in B

and the choice between selecting B or not-B is to select not-B whether one is in a complying or non-complying task.

The experimental procedure was based on Cummins's (1996) version of the reduced array selection task for children, which she in turn adapted from Girotto et al. (1988). In this task, the children are told a story in which at a critical juncture there is either a factual assertion, such as:

All the noisy little dogs are in the house.

or an assertion that in the context is clearly deontic, i.e. a rule that a figure of authority in the story has made:

All the noisy little dogs must stay in the house.

One group of the children listened to 'standard' versions of the stories in which their task was to select either a potentially complying case (the dogs in the house) or a potentially violating case (the dogs in the backyard) in either a factual or a deontic context. Another group of children listen to 'mental state' versions of the two stories in which their task was to select either the potentially complying case or the potentially violating case in order to find out whether a character in the story is right or wrong in making the factual claim, and to find out whether a character in the story is right or wrong in thinking that no-one is disobeying her deontic rule. We note that in the mental state version of the deontic task, the participants are not checking whether or not the relevant animals are obeying the rule, but whether or not a character in the story has a true belief about deontic compliance. In other words, there is a less of a difference in the deontic and factual task in the mental state conditions.

Design

We tested three groups of Italian children: a group of three-year olds, a group of four-year olds, and a group of five-year olds. Each child was assigned at random to one of two experimental conditions: a mental-state condition and a standard condition. The experiment was in a single session, except for 3-year-old children who got tired in keeping their attention on the tasks for more than 20 minutes. Thus, they dealt with the two experimental conditions in two experimental sessions on separate days. For the other groups of children, the experiment was in a single session. Half of the participants carried out first a reduced array selection task with the factual story, then with the deontic story; half of the participants carried out the task with the deontic story first, then with the factual story. One story concerned dogs and the other story concerned cans of food, and these two contents were counterbalanced. Likewise, the order of the two tasks was coun-

terbalanced, so that in effect there were four subgroups within each age group to control for the order of the factual and deontic tasks, and the allocation of the content to the stories.

Materials

There were two versions of each story, one factual and the other deontic. Here is an English translation of the story about the dogs:

<Name of the child>, I'd like you to play a pretend game with me. I'd like you to pretend that this is a house, and these little dogs [*pointing to dogs*] live there. That's their house. Some of the little dogs are out in the backyard to play, see? They're having a good time. They play with the ball, they play hide-and-peek. So these little dogs are in the house [*pointing*] and these little dogs are in the backyard playing [*pointing*]. At night everybody goes in the house, and they close the door [*door is affixed*] so that they're nice and safe and nothing can get them. [*Door removed.*]

Now <name of child>, would you do me a quick favor? Would you point to the little dogs that are in the house? And would you point to the little dogs that are in the backyard? I have something else very interesting to tell you about these little dogs. See how they all look exactly alike? But they're really different. In fact, some of them are noisy [*demo noisy dog squeezed*] and some of them are quiet [*demo quiet dog squeezed*]. This is a noisy dog [*squeezed*] and this is a quiet dog [*squeezed*]. Squeeze this dog and you'll see it makes a lot of noise [*child is allowed to squeeze noisy dog*]. Now squeeze this one [*child is allowed to squeeze quiet dog*]. See? It's really quiet. It doesn't make any noise at all [*remove the demo dogs.*].

I have something else interesting to tell you. Sometimes in the evening, the dogs like to go out in the backyard to play. But when the noisy dogs play, they get really excited and they start to make noise, like this [*squeezing dog repeatedly*]. And then you know what happens? The neighborhood thief hears that noise, and he comes running, and catches them and puts them in his sack. [*The toy thief appears, chasing the dog.*] So it's not safe for the noisy dogs outside. It's only safe for the quiet dogs. [*Ask the child to repeat.*]

At this point, there are four alternative versions of the story depending on whether it concerns the mental state of a character in the story or is in the standard condition, and whether the general assertion is indicative or deontic.

1. The indicative version of the standard problem continues:

Now, I would like you to meet somebody. This is Minnie [Minnie is introduced] Minnie likes to tell stories to children. Let's listen carefully what she says, because then we must discover whether what she says is right or wrong.

Minnie: "Hi, <name of the child>! I've something to tell you about the little dogs. Uh, Uh! I know that it is not safe outside for the noisy little dogs because of the thief. So:

All the noisy little dogs are in the house!

Yes, all the noisy little dogs are in the house!"

Minnie said that all the noisy little dogs are in the house. Now, I wonder if it is true. Let's find out. Which dogs should we squeeze to find out if it is true, the dogs that are inside the house, or the dogs that are in the backyard playing ?

2. The deontic version of the standard problem continues:

Now, I would like you to know somebody. This is the queen of the little dogs [*The queen is introduced*] The queen of the little dogs is their mother and she makes very important rules, that everybody must follow. Let's listen carefully what she says, because she is making a rule and we must be sure that nobody disobeys the rule.

Queen: "Hi, <name of the child>! I've something to tell you about the little dogs. Uh, Uh! I know that it is not safe outside for the noisy little dogs because of the thief. Therefore, I'm making a rule, and the rule is:

All the noisy little dogs must stay in the house! Yes:

All the noisy little dogs must stay in the house!"

The queen said that all the noisy little dogs must stay in the house. Let's make sure that nobody is disobeying the rule, ok? Let's try to be sure that nobody is disobeying the queen. Which dogs should we check, the dogs that are inside the house, or the dogs that are in the backyard playing ?

The versions of the story that depend on a character's mental state introduce *two* new characters into the story at this point.

3. The indicative problem about a mental state continues:

Now, I would like you to meet some people. This is Minnie and this is Mickey Mouse [*Minnie and Mickey Mouse are introduced*]

Minnie: "Who knows what the noisy little dogs are doing?"

Mickey: "It is not safe outside for the noisy little dogs because of the thief. Do you think that the noisy little dogs are in the house or in the backyard?"

Minnie: "I think that all the noisy little dogs are in the house! Yes:

I think that all the noisy little dogs are in the house!"

Minnie thinks that all the noisy little dogs are in the house. Now, Mickey Mouse wonders if Minnie is wrong. Let's try to be sure that Minnie is not wrong in thinking that. Which dogs should we squeeze to find out if Minnie is wrong, the dogs that are inside the house, or the dogs that are in the backyard playing ?

4. The deontic problem about a mental state continues:

Now, I would like you to meet some people. This is the queen of the little dogs and this is the grandmother [*the queen and the grandmother are introduced*] The queen of the little dogs is their mother and she makes very important rules, that everybody must follow. Let's listen carefully what does she say, because she is doing a rule and we must be sure that nobody disobey the rule.

Queen: "It is not safe outside for the noisy little dogs because of the thief. Therefore, I have made a rule, and the rule is:

All the noisy little dogs must stay in the house! Yes:

All the noisy little dogs must stay in the house!"

Grandmother: "Do you think that somebody is disobeying your rule?"

Queen: "I think that nobody is disobeying my rule, and I think that all the noisy little dogs are in the house".

The queen thinks that all the noisy little dogs are in the house. Now, the grandmother wonders if the queen is wrong. Let's try to be sure that the queen is not wrong in thinking that. Which dogs should we check to find out if the queen is wrong, the dogs that are inside the house, or the dogs that are in the backyard playing ?

There were four analogous versions of the story about a set of cans that are kept by giraffes. A witch steals cans that are noisy because they contain chips, but not cans that are quiet because they contain vegetables. The cans are kept on an upper shelf or a lower shelf, and the factual generalization is:

All the cans of chips are on the upper shelf.

The children have to decide which cans they should check to find out whether the generalization is true — those on the upper shelf, or those on

the bottom shelf. The other versions of the story run in parallel to the variants on the story about the dogs.

Procedure

For several days before the experiment, the experimenter went to the nursery schools and got to know and to play with the children. When she invited the children to participate in the experiment, she told them that they were going to play a game with the experimenter. The children were tested individually in a quiet room. Each of the two sessions of 3-year-old children lasted about 20 minutes. The experimental session for the other groups of children lasted about 30 minutes. The experimenter acted out each story with the requisite props and puppets, e.g. a house, a set of dogs, and Minnie and Mickey Mouse, and each session was videotaped using a camera that was above the children so that it did not distract them.

Participants

We tested 144 children in the experiment. There were 48 in each of the following age groups (24 in each of the two conditions): 3-3;11 (mean age: 3;8 in Mental State condition and 3;7 in Standard condition), 4-4;11 (mean age: 4;4 in Mental State condition and 4;5 in Standard condition), and 5-5;11 (mean age: 5;5 in Mental State condition and 5;5 in Standard condition). They attended 5 nursery-schools in Turin, Italy.

RESULTS

The overall results show that there was no significant effect of the content of the stories (the mean of correct responses for dogs is 0.56, and for cans is 0.49, Wilcoxon test: $z = -1.054$, $p = .29$.) or of session (the mean of correct responses in the first session is 0.51, in the second session is 0.53; Wilcoxon test: $z = -0.21$, $p = .83$), and so we have pooled the results (see Table 1).

Table 1.

The overall percentages of correct responses – selection of not-*q* – for the four sorts of stories, pooling the results from the three age groups.

Type of story	Experimental conditions		
	Standard	Mental State	Overall
Indicative	40	54	47
Deontic	60	54	57
Overall	50	54	52

There was no significant difference in accuracy in the answers to the questions about Standard problems (50% correct) and about Mental State problems (54% correct; Wilcoxon test, tied z value = -0.89, tied p value .38); and there was no significant difference in accuracy in the answers to the questions about factual generalizations (47% correct) and to the questions about deontic problems (57% correct; Wilcoxon test: tied z value = -1.7, tied p value .09). The interaction was not significant (Mann-Witney test: z = -1.56, p = .117).

The analyses detailed for age groups confirm these results, except for 3 year olds who performed better with the Mental State questions than with Standard questions (54% versus 31% of correct responses, respectively: Wilcoxon test, tied z value = -2.15, tied p value = .03) and with the questions about deontic problems than with the questions about factual problems (56 versus 29% of correct responses, respectively: Wilcoxon test, tied z value = -2.6, tied p value = .009).

The analyses detailed for sort of protocols reveal that, in the Standard protocol, children were much more likely to perform correctly in the deontic task (60% correct) than in the factual task (40% correct; Wilcoxon test: tied z value = -2.33, tied p value = .019). However, the results detailed for age groups show that 3 years olds perform significantly better in the deontic task than in the factual task (46% of correct responses versus 17%, respectively: Wilcoxon test: tied z value = -1.94, p = .052), but not 4 years olds (67% versus 54% correct responses, respectively: Wilcoxon test: tied z value -.09, tied p value .37) nor 5 years olds (67% versus 50 correct responses, respectively: Wilcoxon test: tied z value -1.15, tied p value .25).

The results concerning the Mental states protocol fully confirm our expectations. Children had no advantage in the deontic task with respect to the factual task (54% versus 54% correct responses, Wilcoxon test, $z = -.00$, $p > .99$). This result holds if we consider the single age groups separately (Wilcoxon test, z value ranging from -1.7 to -0.9 , p value ranging from $.08$ to $.37$).

An explorative comparison between the two sorts of protocol reveals no advantage of the Mental State condition on the Standard condition in the indicative task (Wilcoxon test: tied z value = -1.67 , tied p value = $.095$), nor in the deontic task (Wilcoxon test: $z = -.55$, $p = .58$). Both results hold also if we consider the single age groups separately.

The percentages of correct responses for each question that were made by the three age groups are in Table 2.

Table 2.

Percentages of correct responses for each question in each age group.

	Experimental conditions			
	Standard indicative	Standard Deontic	Mental State Indicative	Mental State Deontic
Age groups				
3 years	17	46	42	67
4 years	54	67	58	46
5 years	50	67	63	50

The trend over the number of correct Mental State responses was no significant when we compared the performance of three years olds with the performance of four years olds (Mann-Whitney test: $z = -0.155$, $p = .877$), nor the performance of the latter with the performance of five years olds (Mann-Whitney test: $z = -0.33$, $p = .74$). The same results hold if we consider the trend over the number of correct deontic responses. The performance of three years olds was comparable to the performance of four years olds (Mann-Whitney test: $z = -0.000$, $p > .99$), and the performance of the latter was comparable to the performance of five years olds (Mann-Whitney test: $z = -0.18$, $p = .86$).

Results for Standard and indicative responses are different in that there was a significant improvement in the performance of four years olds with respect to three years olds (Mann-Whitney test: $z = -2.57$, $p = .01$, and $z = -2.29$, $p = .022$, respectively). However, five years olds performed as four years olds with both Standard and indicative tasks (Mann-Whitney test: $z = -0.21$, $p = .84$, and $z = .00$, $p > .99$, respectively).

DISCUSSION AND CONCLUSIONS

The assumption underlying our experiment was that any context that make salient the others' mental states sorts a facilitatory effect in a reduced array selection in young children. Thus, we expected to find out a difference in difficulty between the factual and the deontic version of the task in the standard context, where only the deontic task invites reasoners to consider the others' mental states. On the contrary, we expected this difference to be flattened in the context provided by the possibility of a false belief, where both tasks invite to consider the others' mental states.

The results concerning the standard version of the tasks show that three years olds perform better in the deontic version than in the factual version of the task. This result is consistent with our expectation, as well as with the results obtained by three years olds in Cummins' study (62% of correct responses in the deontic version versus 37% of correct responses in the factual version), although the performances of our three years olds are poorer (46% of correct responses in the deontic version versus 17% of correct responses in the factual version). Also, the results concerning the standard version of the tasks show that four and five years olds perform in the deontic version of the task as in the factual version. These results are not consistent with those obtained by four years olds in Cummins' study, who performed better in the deontic version of the task than in the factual version. In particular, our four years olds performed better than Cummins' subjects in the factual task (54% versus 30% of correct responses), and worst in the deontic task (67% versus 80% of correct responses). As our results concern within subjects comparisons, we believe they are more trustable than the results obtained by Cummins' study.

The results concerning the Mental State protocol show no difference in the performance of the three groups of children in the factual and the deontic tasks. As expected, in this protocol the deontic version has no more advantage on the factual one, and this result holds even for the youngest group of participants. This result is consistent with the assumption that the necessity to take into account possible false beliefs of the others might induce to easily envisage the false instances of a rule. Also, this explanation is consistent with the facilitatory effect sorted by deontic materials in the standard RAST.

Are the results of the experiment interpretable in favour of an innate module for deontic reasoning? Only if we assume that from 4 years of age

onward the functioning of the deontic module is overshadowed by other factors that contribute to determine children's performance in the standard RAST. As a consequence, deontic contexts would be no more facilitatory with respect to factual contexts. However, a result that would remain to be explained is that 3 year olds perform in the factual version of the task as in the deontic version when they are invited to reason about the possibility of a false belief of a character. More in general, the results of the experiment are not easily interpretable in favour of the deontic module hypothesis because we failed to replicate the results in the literature on standard tasks. Within our explanation, a possible reason could be that, from 4 years of age onward, the RAST is solved in the factual version as well as in the deontic version thanks to the experience acquired by children with social contexts involving the attribution of mental states to others.

The results concerning the trend over the number of correct responses are in line with this explanation. In particular, the results reveal no improvement with the age of subjects' performance with Mental states and deontic responses: both context facilitate even three years olds' reasoning. On the contrary, as regards Standard and indicative responses, we detected a significant improvement in the performance of four years olds with respect to three years olds. This result is consistent with the hypothesis that four years olds, but not yet three years olds, had sufficient experience with social interaction so to become able to envisage counterexamples to a rule. As a result, they are no more sensible to the facilitatory effect of the contexts involving the attribution of mental states' to others.

Globally, the results of our experiment are consistent with the assumptions of mental model theory. Indeed, the theory predicts that factors that make salient the false instances of a rule enhance children's performance in the selection task. Consistent, our results show that three years old are facilitated in their selection by the mental state context as well as by the deontic context. In this paper we have argued that both contexts make salient the false instances of a rule in that they invite the reasoners to use their theory of mind.

Acknowledgements

Monica Bucciarelli was supported in this research by Ministero della Pubblica Istruzione (Ex-40% Project, 1999). The names of the authors are ordered alphabetically.

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