What is Special about Children's Deontic Reasoning?

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Abstract

The assumption underlying the present investigation is that comprehension and reasoning from deontic premises, as well as comprehension and reasoning from factual premises, depend on mental models, and these models predict what conclusions individuals are likely to draw. Experiment 1 (48 children aged 9-11 years) confirmed the prediction that children's comprehension of deontic assertions, like their comprehension of factual assertions, relies on models. Experiment 2 (40 children aged 9-11 years) confirmed the prediction that on the basis of the models it is possible to predict developmental changes in the ability to reason from pairs of deontic assertions. The results of the investigation run against the existence of specialized mechanisms for comprehension and reasoning from deontic matters.

Keywords: deductive reasoning; deontics; mental models; development

Introduction

Deontic reasoning concerns what is obligatory, permissibile, and impermissible. Many theorists propose that it depends on special mechanisms (see, e.g., Chao & Cheng, 2000; Cosmides, 1989; Cummins, 1996). In this paper, we propose a contrasting theory, which is based on *mental models*, and which postulates that the mental processes underlying the comprehension of, and reasoning from, deontic propositions (e.g., *Children are obligated to go to school*) are the same as those for dealing with factual propositions (e.g. *Children go to school*). The only important difference concerns the content of the propositions: given a true factual proposition, certain states of affairs are impossible; given a true deontic proposition, certain actions or inactions are impermissible, or, we sometimes say, *deontically* impossible. Alas, what is deontically impossible is all too often factually possible: individuals do not always do the right thing, or refrain from doing the wrong thing. In other words, a counterexample to a factual proposition shows that it is false, whereas a counterexample to a deontic proposition shows that someone has violated the principle it embodies, not that the proposition itself is false. Likewise, the truth of a factual proposition depends on the state of the world, whereas the truth of a deontic proposition is a more complicated matter depending on mores, customs, conventions, and much more besides: one man's meat is another man's moral violation. The theory of mental models claims, however, that both factual and deontic propositions are represented in mental models, which have appropriate annotations representing the status of a model as factual or deontic, that the two domains parallel one another both in terms of what tends to be represented and what tends not to be represented, and that they share a common underlying mechanism for reasoning.

The Mental Model Theory of Deontics

The mental model theory (MMT) postulates that individuals use the meaning of assertions and general knowledge to construct mental models of the possibilities described by factual assertions (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). Each model represents a separate possibility. Hence, a disjunction such as:

[1] Either you receive a grade or else you receive a comment, but not both

refers to two alternative possibilities that are represented in two mental models. A conventional notation for models lays out each of them on a separate row of a diagram. The two models of the preceding disjunction are as follows:

You receive a grade	
	You receive a comment

Of course, real mental models are representations of the state of the world, not sentences, which we use here for convenience. MMT is based on a principle of *truth*, which stipulates that mental models represent only what is true, not what is false. Hence, the two models above represent the possibilities in which the disjunction is true, and each of them represents a clause from the disjunction only when it is true in a possibility. *Fully explicit* models violate the principle of truth by representing clauses both when they are true and when they are false. Hence, fully explicit models of the disjunction are as follows:

You receive a grade	¬You receive a comment
¬You receive grade	You receive a comment

The symbol '¬' denotes negation, and so models represent false propositions as true negations. MMT readily extends to deontic assertions (Bucciarelli & Johnson-Laird, 2005). There are four main deontic relations, because they exhaust the set of possible dyadic deontic relations: *A permits B*, *A obligates B*, *A prohibits B*, *Not A obligates B*, where the variables *A and B* take as their values phrases capturing such propositions as, 'you make a promise', and 'you do what you say'. For example, the assertion *Your making a promise obligates you to do what you say*, captures a relation between a possibility (you make a promise) and what it obligates (you do what you promise). MMT postulates that such assertions of the form, *A obligates B*, are consistent with three alternatives:

A	B
¬ A	B
¬ A	¬ B

where *A* and its negation refer to possibilities and *B* and its negation refer to what is permissible, and where there is a temporal constraint that *B* doesn't occur prior to *A*. Hence, when *A* occurs and, say, you make a promise, there is only one state of affairs that is subsequently permissible – you do what you say. But, you may do what you say even without having made a promise (¬ *A* and *B*), or you may not do what you say without having made a promise (¬ *A* and ¬ *B*). The four underlying dyadic propositions can be realized in many different sorts of sentence, e.g., if you make a promise then you should do what you say, you should do what you say because you promised, you promised and so it isn't permissible for you not to do what you say, and given that you promised you must do what you say. Table 1 summarizes the sets of possibilities consistent with the four basic deontic relations. As the table shows, an assertion of the form, *A permits B*, has a weak interpretation consistent with all four possibilities, but it usually carries an implicature that *B* is not permissible without *A*, and in this case, the assertion has a strong interpretation consistent with only three possibilities. How do individuals interpret these assertions? MMT assumes that individuals are likely to use mental models, because the limited processing capacity of working memory makes it hard to hold in mind the fully explicit models in Table 1. Mental models represent only salient states, and the analogue of the principle of truth for deontic assertions is:

> The principle of *deontic* mental models: The mental models of *A permits B* represent that given *A*, *B* is permissible; the mental models of *A obligates B* represent that given *A*, only *B* is permissible; and the mental model of *A prohibits B* represents that given *A*, *B* is not permissible, but not-B is permissible.

Table 1: The semantics of four basic deontic relations illustrating their permissible states for both weak interpretations (+) and strong interpretations (*).

	The permissible states given certain possibilities						
The four sorts of assertion	A B A ¬ B ¬A B ¬A¬ B	A B A ¬ B ¬A¬ B	A B A ¬ B ¬A B	A B ¬A B ¬A¬ B	A B ¬A¬B	A ¬B ¬A B ¬A¬ B	A ¬B ¬A B
A permits B	+	*					
Not-a obli. B			+				*
A obligates B				+	*		
A prohibits B						+	*

Hence, the mental models of *A permits B* are as follows:

A B
A
. . .

The first, and most accessible, model represents the state in which A and B occur, and the second model represents the state in which A occurs without B. In other words, a further principle of the theory is that the absence is treated as negation in those cases in which there is a contrasting model in which the missing element is represented. The second model, as we will see, distinguishes permission from obligation. The third model denoted by the ellipsis is an implicit model, i.e., it has no explicit content but represents that there are other permissible states. Likewise, the mental models of *A obligates B* are:

A B
. . .

where individuals make a mental footnote that the implicit model cannot represent possibilities in which *A* occurs. As a corollary, individuals can construct a model representing that given *A*, *not-B* is impermissible:

A ¬*B*

where the italicised proposition (i.e.,¬*B*) is that one which is impermissible The mental models of *Not-A obligates B* are equivalent to those for *A obligates B* apart from the presence of the negation of A. Finally, the mental models of *A prohibits B* make most accessible that given A, B is *not* permissible (cf. Evans & Twyman-Musgrove, 1998). If, say, you are prohibited from exiting the room, then what you must *not* do is to exit the room. One reason for this focus is likely to be that children derive the meaning of *prohibits* and its cognates from discovering that they are not allowed to carry out certain actions. Hence, *A prohibits B* accordingly has a single mental model in which *B* is not permissible:

A *B*

and these mental models of what *is* permissible:

A ¬ B
. . .

where individuals make a mental footnote that the implicit model cannot contain instances of *A*. The mental models of deontic premises predict very well the conclusions that adult reasoners draw from them (Bucciarelli & Johnson-Laird, 2005). Our aim, however, is to account for children's deontic reasoning, and so we propose a set of two principles governing children's reasoning in general:

1. The principle of *limited working memory*: Children should tend to construct just a single mental model of premises, and this tendency should be greater than the analogous tendency of adult reasoners (see Bara, Bucciarelli & Johnson-Laird, 1995; Bara, Bucciarelli & Lombardo, 2001; Bucciarelli & Johnson-Laird, 1999).
2. The principle of *multiple models*: As children develop, they are more likely to envisage alternative models of the premises, and accordingly to respond that nothing follows from them.

Experiment 1: Children's Interpretations of Deontic Assertions

The aim of Experiment 1 was to understand *what* children take deontic verbs to mean, so that we could then check the prediction that their understanding predicts their reasoning. Following the assumptions of MMT, we expected that children would find, for each deontic verb, an interpretation (i.e., mental model) more salient than others, and those models would guide them in reasoning from premises containing such deontic verbs. Also, we expected to find that children would focus on impermissible states of affairs when interpreting Prohibits as compared with the other deontic verbs. This prediction, which derives from considering that children deal with situations involving prohibition since very early in their interactions with adults, was yet confirmed by a former study on comprehension of deontic verbs in adults (Bucciarelli & Johnson-Laird, 2005).

Method We presented participants with four deontic assertions of the form: *A permits B*, *Not-A obligates B*, *A obligates B*, *A prohibits B*. There were eight different lexical contents, which were rotated over the four sentences, so that each participants encountered a particular content only once, but each content occurred equally often with the four sorts of assertions in the experiment as a whole.

Procedure The participants were tested individually. The instructions were as follows: 'I'll show you four assertions, all concerned with one of the following verbs: permits, obligates, prohibits. Your task is to consider each assertion to be true and for each assertion to consider four states of affairs, or situations. For each state of affairs judge whether it is permissible or not permissible given the truth of the assertion'. There was also a practice trial where the experimenter presented the assertion 'Bosses who are lazy force employees to work hard', and a sheet of paper laying out the four cases:

Bosses who are lazy	Employees work hard
Bosses who are lazy	Employees do not work hard
Bosses who are not lazy	Employees work hard
Bosses who are not lazy	Employees do not work hard.

The experimenter invited the participant to judge whether each of these descriptions referred to a situation that was permissible or not permissible granted that the assertion was true. The participants readily understood the task and usually carried it out in the order in which the assertions occurred, but they were allowed to complete the task in any order that they liked. They then proceeded to the experiment proper. They were presented one at a time with the four typewritten sentences. The participants had to write down the list of the four situations and to write next to each situation whether or not it was permissible. Consider the following example of a deontic assertion (translated from the Italian) used in the experiment: 'Those enrolled for swimming are obligated to bring a lifebuoy'. The Italian equivalent of 'obligated' is easy for children to understand. Granted the truth of the assertion, three situations are permissible: those enrolled for swimming bring a lifebuoy, those not enrolled do bring a lifebuoy, and those not enrolled do not bring a lifebuoy. What is not permissible is for those enrolled *not* to bring a lifebuoy. The correct answers are in Table 1. There was no constraint on the order in which the participants carried out the task. If, as rarely happened, the participants failed to list one of the four situations, then the experimenter pointed out the omission. With one exception in the 11 year old group, each participant yielded a complete classification of all the sentences. We scored each set of evaluations provided for the 4 contingencies of each description. If a child listed as permissible only the contingencies allowed by one of the two logically correct interpretations (see Table 1), the child got 'correct', otherwise the child got 'incorrect'.

Participants Pupils from primary and secondary schools in Piedmont, Italy. There were 24 children in each of the following age groups: 9-10 years (mean age: 9;7 years) and 11-12 years (mean age: 11;4).

Results Table 2 presents the percentages of the most frequent interpretations made by the two age groups. The children tended to make the predicted interpretations. Also, the two groups of children did not differ in accuracy in their global performance with the four verbs (Mann-Whitney test: $z=1.37$, $p=.17$).

Table 2: Percentages of most frequent interpretations made by children in Experiment 1 arranged vertically in each cell: 9 year olds at the top, 11 year olds at the bottom. [e] indicates erroneous responses; the balances of percentages in any row are responses made on fewer than 13% of trials.

The four sorts of assertion	A B A ¬B ¬A B ¬A¬B	A B A¬B ¬A¬B	A B A¬B ¬AB	A B ¬A B ¬A¬B	A B ¬A¬B	 A ¬B ¬A B ¬A¬B	 A¬B ¬A B	A B A¬B
A permits B	38 13	59 60						
Not-A oblig. B			37 26				50 48	
A oblig.B				30 17	59 56			
A proh. B						38 13	46 17	 [e]17

Table 3 presents the percentages of trials on which participants started each listing with the state corresponding to the mental model of the assertion in the permissible condition. Children in the two groups tended to list first a permissible situation (Binomial tests on the numbers of participants starting with a permissible situation on more than two of the four assertions were reliable for both age groups, p always <.001). The one obvious exception to this bias was the tendency for *A prohibits B* to elicit the impermissible situation in which A occurs with B.

Table 3: The four deontic relations and the percentages of states listed first by children in Experiment 1. The balance of the percentages are states listed first on fewer than 13% of trials. *B* or ¬*B* indicates that the state was listed as impermissible; the other states were listed as permissible.

Deontic relations	9 year old group (N=24)		11 year old group (N=23)	
A permits B	A B	83	A B A ¬B	74 13
Not-A obligates B	¬A B A *B* A B	46 25 13	¬A B A B	61 13
A obligates B	A B A¬*B*	67 17	A B	70
A prohibits B	A *B* A¬B	67 21	A *B* A B	35 39

Discussion Children tend to converge on the salience of a model when interpreting each of the four deontic verbs. As we assumed that models guide children's reasoning, on these bases we can predict the conclusions they will draw. As we expected, when dealing with the verb Prohibit children construct a model representing an impermissible state of affairs. The same result, to our surprise, did not hold for 11 year old children. But, as we'll see in Experiment 2, the predictions derived from these results lead us to predict effectively the reasoning performance of the oldest group of children with pairs of deontic premises involving Prohibits. We have only a tentative explanation for this unexpected result: models for deontic assertions represent what is permitted or not within possible states of affairs. Eleven year old children might be more likely to focus on possibilities rather than on what is either permitted or not within them. Thus, given an assertion in the form A prohibits B, the model would be

A B

which is the possible state of affairs, not yet annotated to represent the fact that B is not permitted. Also, as a general result, children tend to use the strong interpretation of each deontic verb; the adult participants in the study by Bucciarelli and Johnson-Laird (2005), instead, show the opposite tendency and prefer the weak interpretation. This difference between children and adults can be accounted for by the principle of limited working memory and the principle of multiple models.

Experiment 2: Children's Reasoning from Pairs of Deontic Assertions

The participants in Experiment 2 were invited to draw conclusions from pairs of deontic premises. We assumed that, given a pair of deontic premises, children construct the models detected through Experiment 1, and illustrated in Table 3, and draw their conclusions from such models. In particular, children construct integrated models of the premises following the principles illustrated above. Also, we know from Experiment 1 that Permits is the only verb for which children claim that all the four states of affairs are permissible (see Table 2). On the basis of this results we formulated a third principle:

3. The principle of *implicit models*: children add an implicit model to the model representation of A permits B.

Through this principle we aimed at inserting in children's model representations the implicit model (i.e., dots). Our predictions concerning the conclusions can be summarized as follows:

1. Children should tend to draw those conclusions corresponding to mental models.
2. Inferences depending on one mental model should be easier than those depending on multiple mental models.
3. The premises with multiple models should also elicit more 'no valid conclusion' responses than the latter premises, especially in 11 year old group.
4. Premises yielding more than one mental model with an explicit content would elicit a greater variety of responses than premises yielding only one mental model with an explicit content.

This last prediction should hold especially for the 11 year old group, who are capable, in principle, to construct more than one mental model of the premises. Consider, as an example of multiple model problem, the premises *A permits B, B prohibits C*. On the basis of the models identified in Experiment 1, we predict that children may construct the following integrated representation:

A B ¬C

which supports the logically incorrect conclusion 'A prohibits C'. Indeed, in order to draw the logically correct conclusion it is necessary to construct an enriched representation of the premises, namely:

A B ¬C
…

where the implicit model (i.e., dots) mean that there are other permissible states, not considered in the model. Only this representation supports the correct conclusion 'A permits not C'. On the basis of the very same enriched model, we also predict the logically incorrect conclusion 'No valid conclusion' ('Nvc').

Method The material consisted of the 16 pairs of premises, resulting from the combination of the four deontic relations investigated in Experiment 1 with the first and the second premise in the pair. We used 16 triplets of lexical content that we combined with the 16 problems in two different ways, so that we obtained two experimental protocols. The result of the assignments of the triplets to the problems are problems concerning everyday matters. For example, 'Those enrolled for swimming are obligated to bring the lifebuoy. Those who bring the lifebuoy are permitted to dive into the water'.

Procedures Participants were randomly assigned to one of the two experimental protocols. Half of them were tested with one protocol and half with the other one. The participants were told that the experiment was about reasoning. The key instruction was as follows: "Your task is to read carefully the premises, and to try to draw a conclusion. To draw a conclusion, you must relate the terms that are not directly related in the premises. There might not be any conclusion that has to be true given the premises, and in which case you should say so". Each participants dealt with the problems in a different random order. They were allowed to take as much time as they needed to make their responses. Mean time for children 45-50 minutes.

Participants Forty children participated in the experiment, with 20 in each of the following age groups: 9-10 years (mean age: 9;7 years) and 11-12 years (mean age: 11;5). In each age group, children were balanced by gender. They were pupils from two primary and two secondary schools in Piedmont, Italy.

Results Children in both age groups made more predicted responses than unpredicted responses. The percentages of responses predicted was 82% for 9 year olds and 93% for 11 year olds, and the mean number of predicted responses per problem was 16.4 out of 20 for 9 year olds and 18.7 out of 20 for 11 year olds. Likewise, every problem yielded more predicted responses than unpredicted responses. One model problems were easier to solve than multiple model problems for 9 year olds (a mean of 82% versus a mean of 38.9% of correct conclusions, respectively: Wilcoxon test: $z=3.65$, tied $p<.0001$), and the same result held for 11 year olds; one model problems were easier to solve than multiple model problems (a mean of 81% versus a mean of 26% of correct conclusions, respectively: Wilcoxon test: $z=3.87$, tied $p<.0001$). Further, a by-materials analysis shows that multiple model problems yield a greater diversity of responses than one-model problems in the 9 year olds group (a mean of 3 versus a mean of 1.4, respectively: Mann Whitney test: tied $z= 2.90$, tied $p<.002$), as well as in the 11 year olds group (a mean of 3 versus 2, respectively: Mann Whitney test: tied $z=2.70$, tied $p<.01$). A comparison between the performance of the two groups of children revealed no increase with age in accuracy overall. Rather, 9 year olds (a mean of 8.40 correct conclusions over the 16) performed better than 11 year olds (a mean of 6.95 correct conclusions over 16: Mann-Whitney test: $z=2.83$, $p<.003$). In particular, for 4 problems, the latter did better than the former, 1 problem yielded a tie, and in the remaining 11 problems 11 year old children did worse, with a significant deterioration with premises involving Prohibits. Such a difference in performance can be explained if we consider the results of Experiment 1; they showed that 11 year olds were poorer than 9 year olds in interpreting Prohibits. And indeed, in Experiment 2, the performance of the 11 year olds was poorer than the performance of 9 year olds for the 7 problems involving Prohibits (a mean of 0.36 and 0.51 correct conclusions, respectively: Mann-Whitney test: $z=3.04$; $p<.004$), but not for the other 9 problems: (a mean of 0.48 and 0.51 correct conclusions, respectively: Mann-Whitney test $z=1.36$, $p=.19$). Also, we found that children in the two age groups never draw 'nvc' responses to one model problems. However, as predicted for multiple model problems, 9 year olds drew few 'nvc' responses while 11 year olds drew several 'nvc' responses. Thus, children in the oldest group showed evidence of not limiting themselves to construct just one model of the premises.

Discussion The results of Experiment 2 globally confirmed our predictions. On the basis of the models detected for the four deontic relations in Experiment 1, and on the basis of three assumptions on children's reasoning, we were able to predict both correct and erroneous conclusions for pairs of deontic premises. The oldest group of children did not reach, anyway, the accuracy that adults can reach in reasoning from deontic premises. Adults in the study by Bucciarelli and Johnson-Laird (2005) performed better than the oldest group of children especially with multiple model problems: they tended to produce a greater number of correct responses rather than 'nvc' responses. With one model problems, however, children and adults have comparable performances. May we conclude that children develop in their ability to reason deontically as they grow older? The answer is no, at least if we consider the correctness of the conclusions that the oldest group of children draw as compared with the youngest groups of children. However, if we consider the type of erroneous conclusions produced, especially to multiple model problems, we can appreciate that they are based on more sophisticated model representations of the premises. What explains the nature of a reasoning development that can not be appreciated in terms of accuracy but in terms of type of erroneous conclusions? Our results suggest that the oldest children are able to hold more models in mind and they are able to consider more than the explicit mental model. Also, our results are in line with the literature concerning children's reasoning from factual premises (see, e.g., Bara et al., 2001; Barrouillet, Grosset & Lecas, 2000; Lecas & Barrouillet, 1999; Markovits & Barrouillet, 2002).

General Conclusions

Does there exist a special mechanism dedicated to comprehension and reasoning from deontic premises? Many theorists (Chao & Cheng, 2000; Cheng & Holyoak, 1985; Cosmides, 1989; Cummins, 1996) advance this idea in order to justify the fact that individuals' performance with the hypothesis testing tasks devised by Wason (1966; 1968) are facilitated by deontic contents (see, e.g., Cummins, 1996; Kroger, Cheng & Holyoak, 1993). MMT proposes a contrasting view according to which the beneficial effect of the deontic content on these hypothesis testing tasks is to make salient the false instances of a rule, namely what is impermissible (Johnson-Laird & Byrne, 1991). And indeed, the effect has been obtained also with factual (non-deontic) material (see, e.g., Bucciarelli & Johnson-Laird, 2001; Sperber, Cara & Girotto, 1995; Staller, Sloman & Ben-Zeev, 2000). In the perspective of MMT factual and deontic reasoning depend on a general inferential mechanism. The proposal of a unified mechanism for reasoning is advanced also by mental logic theorists. In contrast with MMT, they argue that individuals possess a mental logic made up from formal rules of inference (e.g., Braine & O'Brien, 1998; Osherson, 1974-6; Rips, 1994). The central idea is that individuals construct a formal proof that a conclusion follows from the premises. Each step in the proof depends on a formal rule of inference. Errors may occur because people fail to apply a formal rule correctly (Rips, 1994, p. 153). Errors should therefore be more likely with proofs that call for a greater number of steps, or for more complex and varied steps (ib., 1994, p. 386). Rips (1994, p. 322) argues that individuals can make deontic inferences that do not depend on familiarity with the domain, such as: *It is obligatory that P given Q. Therefore, it is permissible that P given Q.* He suggested that such inferences can be handled in his system by the addition of modal operators akin to those proposed by logicians (see also Osherson, 1974-6). However, as he pointed out, the extension of his system to account for deontic reasoning would entail more than just adding a few rules (Rips, 1994, p. 336). The main difficulty for mental logic theories is to explain systematic errors in reasoning without invoking rules of inference that are invalid (an assumption with disastrous consequences, see, e.g., Johnson-Laird & Savary, 2996). Alas, for such theories, individuals of different ages make consistent patterns of error, which can not be explained by assuming random factors like a misinterpretation of the premises and so on (see the results of Experiment 2). Within the perspective offered by MMT comprehension and reasoning from deontic premises rely on the same mental processes as comprehension and reasoning from factual premises. However, there is no need to postulate, as a unified mechanism for reasoning, a mental logic. We construct mental models of the possibilities described by deontic assertions like we construct mental models of the possibilities described by factual assertions. The mental models for the deontic assertions, however, also capture the relations between the possibilities and the states of affair permissible within such possibilities. Both in the factual and in the deontic domain we tend to represent only the models, namely what is possible and what is permissible, respectively. When we reason from both factual and deontic premises we manipulate their models in order to reach our conclusions. The models of a pair of premises may yield the construction of one or multiple models of the premises. The number of models does affect the difficulty of the problem, both in the factual and in the deontic domain. What is relevant within a developmental perspective is that children differ from adults in the way they represent the meaning of (factual and) deontic assertions, namely in the models that they tend to construct from them. Also, children, as compared with adults, have a poorer working memory capacity. Hence, children differ from adults in the conclusions they draw from (factual and) deontic premises, especially from premises yielding multiple models.

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References

Bara B., Bucciarelli M., & Johnson-Laird, P. N. (1995). The development of syllogistic reasoning. *The American Journal of Psychology, 108*, 157-193.

Bara, B. G., Bucciarelli, M., & Lombardo, V. (2001). Model theory of deduction: A unified computational approach. *Cognitive Science*, *25*, 839–901.

Barrouillet, P., Grosset, N., & Lecas, J-F. (2000). Conditional reasoning by mental models: Chronometric and developmental evidence. *Cognition*, *75*, 237-266.

Braine, M. D. S., & O'Brien, D. P. (Eds.). (1998). *Mental logic*. Mahwah, NJ: Erlbaum.

Bucciarelli M. & Johnson-Laird, P. N. (1999). Strategies in syllogistic reasoning. *Cognitive Science*, *23*, 247-303.

Bucciarelli, M., & Johnson-Laird, P. N. (2001) Falsification and the role of the theory of mind in the reduced array selection task. *Current Psychology Letters: Behavior, Brain & Cognition*, *4,* 7-22.

Bucciarelli, M., & Johnson-Laird, P.N. (2005). Naïve deontics: a theory of meaning, representation, and reasoning. *Cognitive Psychology*, *50*, 159-193.

Chao, S-J., & Cheng, P.W. (2000). The emergence of inferential rules. The use of pragmatic reasoning schemas by preschoolers. *Cognitive Development*, *15*, 39-62.

Cheng, P. N., & Holyoak, K. J. (1985). Pragmatic reasoning schemas. *Cognitive Psychology*, *17*, 391-416.

Cosmides, L. (1989). The logic of social exchange: has natural selection shaped how humans reason? Studies with the Wason selection task. *Cognition*, *31*, 187-276.

Cummins, D. D. (1996). Evidence of deontic reasoning in 3- and 4-year-old children. *Memory & Cognition, 24*, 823-829.

Evans, J. St. B. T., & Twyman-Musgrove, J. (1998). Conditional reasoning with inducements and advice. *Cognition*, *69,* 811-816.

Johnson-Laird, P.N. (1983). *Mental models: Towards a cognitive science of language, and consciousness.* Cambridge University Press, Cambridge, UK.

Johnson-Laird, P. N. (2006). *How we reason*. Oxford: Oxford University Press.

Johnson-Laird, P. N., & Byrne, R. (1991). *Deduction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Johnson-Laird, P.N., & Savary, F. (1996). Illusory Inferences about Probabilities. *Acta Psycholog.*, *93,* 69-90

Kroger, K., Cheng, P.W., & Holyoak, K.J. (1993). Evoking the permission schema: The impact of explicit negation and a violation-checking context. *Quarterly Journal of Experimental Psychology*, *46A*, 615-635.

Lecas, J-F., & Barrouillet, P. (1999). Understanding conditional rules in childhood and adolescence: A mental models approach. *Current Psychology of Cognition*, *Vol 18*(3), 363-396.

Markovits, H., & P. Barrouillet, P. (2002). The development of conditional reasoning: A mental model account. *Developmental Review, 22,* 5-36.

Osherson, D. N. (1974-6). *Logical abilities in children* (Vols. 1-4). Hillsdale, NJ: Lawrence Erlbaum Associates.

Rips, L. J. (1994). *The psychology of proof: Deductive reasoning in human thinking*. Cambridge, MA: MIT Press.

Sperber, D., Cara, F., & Girotto, V. (1995). Relevance theory explains the selection task. *Cognition*, *52*, 3-39.

Staller, A., Sloman, S. A., & Ben-Zeev, T. (2000). Perspective effects in nondeontic versions of the Wason selection task. *Memory & Cognition*, *28*, 396-405.

Wason, P. (1966). Reasoning. In B. M. Foss (Ed.), *New horizons in psychology* (pp. 135–151). Harmondsworth, UK: Penguin.

Wason, P. (1968). Reasoning about a rule. *Quarterly Journal of Experimental Psychology*, *20,* 273-281.