A Model Theory of Deontic Reasoning About Social Norms

Sieghard Beller (beller@psychologie.uni-freiburg.de)
Department of Psychology, University of Freiburg
D-79085 Freiburg, Germany

Abstract

This paper outlines a model theory of deontic reasoning. It proposes that social norms form the basic concept on which deontic inferences operate. The theory unifies and extends current deontic approaches. Empirical findings from the deontic selection task will be presented which support the theory.

Introduction

Deontic reasoning is thinking about which action a person *may* or *must* perform with respect to a social rule. Imagine an officer who has to administer the admission to an event. The promoter has given him the rule "If a person has a ticket, then this person *may* enter." Lisa has *no* ticket. *May* she enter? The officer answers: "No, Lisa *must not* enter. She does not fulfill the entry condition." Although intuitively plausible, this answer is in conflict with standard conditional logic. The antecedent of a conditional '*If* P *then* Q' denotes a sufficient but not necessary condition. If 'P' does not hold then one can *not* decide whether 'Q' holds. Thus, the officer should rather ask his promoter what to do with Lisa instead of refusing the entry. Why is it, that his answer nevertheless seems right? The goal of this paper is to introduce a new theory of deontic reasoning which explains such phenomena. It will be compared to alternative approaches and backed up with findings from the deontic "micro-laboratory" of the selection task (Wason, 1966).

The Deontic Mental Models Theory (DMM)

The model theory assumes that reasoning requires the construction of mental models which represent the meaning of, for example, verbal premises or a person's background knowledge (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). Their structure and content capture semantic relations of the situations they refer to. To make an inference, reasoners first extract a putative conclusion from an initial model and then validate it or, if necessary, revise it by fleshing out alternative models. Of which structure and content are the models that underlie deontic reasoning? In this article, it is proposed that the underlying models represent social norms.

Normative Models and Deontic Inferences

Social norms constitute constraints on actions but they do not really restrict a person's freedom of action. A person may follow a norm or violate it. Consequently, two types of models must be distinguished: factual models and normative models.

Factual models describe which conditions hold or which actions are taken. A condition (`C`) is viewed as a state of affairs that can be fulfilled or not (symbolized as `C` vs. ¬`C`). Actions are taken by a person on a certain occasion; not performing an action is notated by negation (`Action` vs. ¬`Action`); a more detailed analysis is given by von Wright (1963). The fact, for example, that a person with a ticket is entering an event can be represented by the following factual model:

(1) Normative	Factual
	[entering] [ticket]

Normative models cannot describe which actions persons really take. They describe constraints on actions, that is, under which conditions actions are forbidden or obligatory. In a consistent system of norms an action cannot be forbidden and obligatory at the same time, otherwise the person is trapped in a dilemma. In the following, 'bans' are taken as the basic normative concept and represented as `forbidden(Action)`. In accordance with the axiom of definitional equivalence in modal logics '*must* X ≡ *must-not* ¬X' (e.g., Chellas, 1980), an obligation can also be represented as a ban: the obligation to take an action means that the omission of the action is forbidden (`forbidden(`¬`Action)`).

With regard to the relation between a ban and its conditions, two assumptions are made: First, people represent *each* ban together with *all* conditions that put the ban into force (*closed world assumption*). Second, people treat the relation between a banned action and the conditions as an *equivalence* (which is justified under the closed world assumption): If the conditions are met, then the action is forbidden, otherwise it is allowed. Taking both assumptions together, the basic schema of a norm (concerning one action) takes the following explicit standard form:

(2) Normative		Factual
[forbidden(Action)]	[Conditions]	
[¬forbidden(Action)]	[¬Conditions]	

Each line denotes a separate model. Since all conditions concerning this action are considered (closed world assumption), the representation is exhaustive (indicated by square brackets). In the simplest case, there is one norm with one condition. Having a ticket, e.g., is often the only condition to be admitted to an event:

(3) Normative		Factual
[forbidden(entering)]	[¬ticket]	
[¬forbidden(entering)]	[ticket]	

Sometimes, however, several conditions have to be considered in combination. Necessary conditions may be treated by a conjunctive model, alternative conditions by a disjunction of models. Spectators of German soccer matches, for example, are often examined not only for their tickets but additionally for weapons. The normative models then contain two disjunctive conditions: A person is not allowed to enter, if (and only if) he or she has no ticket *or* has a weapon:

(4) Normative		
[forbidden(entering)]	[¬ticket]	[weapon]
[forbidden(entering)]	[¬ticket]	[¬weapon]
[forbidden(entering)]	[ticket]	[weapon]
[¬forbidden(entering)]	[ticket]	[¬weapon]

Of course, there may be additional norms concerning other actions as well. Their representation, however, follows the same schema. *Deontic inferences* connect normative and factual models. If a person fulfills the conditions (Cs) associated with a forbidden action then one can assert "the action *must not* be taken" and – according to the axiom of definitional equivalence – "the action *must* be omitted". Thus, two inferences can be drawn from the corresponding set of models[1]:

(5) Normative		Factual
[forbidden(Action)]	Cs	[Cs]
...		∴ must-not Action
		∴ must ¬Action

If an action is taken which is potentially forbidden, then it follows that the conditions Cs *must not* be fulfilled or else the norm would be violated. Equivalently, it *must* be the case that the conditions are *not* fulfilled:

(6) Normative		Factual
[forbidden(Action)]	[Cs]	[Action]
		∴ must-not Cs
		∴ must ¬Cs

While the modals *must not* and *must* correspond to the notions of *ban* and *obligation*, the modals *may* and *need not* are related to the concepts of *permission* and *release* from obligation. Both pairs, ban and permission as well as obligation and release, are *contradictories*. In a consistent system of norms, exactly one of each pair is true: an action is either forbidden or allowed; it is either obligatory or not. One can infer that something *may* be the case if it is not forbidden, and that something *need not* be the case if it is not obligatory. Finally, a norm is *violated* if a person takes an action while fulfilling at least one condition under which the action is banned:

(7) Normative		Factual	
[forbidden(Action)]	[Cs]	[Action]	[Cs]
		∴ violation	

To illustrate the application of the theory, let's reconsider the introductory example. An officer was given the rule: If a person has a ticket, then this person *may* enter. It mentions one condition for the action of entering. Since norms constitute constraints on actions, the officer can map the rule to norm (3) which expresses that entering is not forbidden with a ticket, but it is forbidden without one. For Lisa who has no ticket, model (5) applies which allows the officer to answer: "She *must not* enter".

"Why a New Theory of Deontic Reasoning?"

... one may ask since a number of well-established proposals already exist. While each of the current approaches emphasizes a different aspect, the proposed DMM theory tries to unify their main characteristics.

DMM theory takes up two previous ideas: (1) Modal terms gain their deontic meaning by referring to deontic norms (Johnson-Laird, 1978) which represent (2) permissible and impermissible situations (Johnson-Laird & Byrne, 1992). DMM theory goes beyond these ideas by proposing a concrete representation of norms and relating deontic modals to it. Manktelow and Over (1991; 1995) claimed that social roles and utilities need to be incorporated. These factors are indeed important since social roles distinguish between the parties affected by a social rule and utilities influence its negotiation. They seem not necessary, however, for deontic inferences (Johnson-Laird & Byrne, 1992). Once a social rule has been established, it defines the normative constraints on each parties' actions, and the corresponding normative models determine the possible deontic inferences.

Thompson (2000) argued that a theory of reasoning should not only specify the inferential procedures that operate on a given representation; it must also specify the interpretative processes that set up this representation. As her experiments show, the interpretation of conditional reasoning tasks is affected by two factors: by the perceived necessity and sufficiency relations and by the pragmatic relation (deontic vs. factual). DMM theory integrates necessity and sufficiency relations on the condition-side of norms and it considers the characteristics of the deontic domain she condensed from her studies: the normative character of the models which gives relevance (Sperber, Cara & Girotto, 1995) to the notion of norm-violation. In addition, DMM theory may be used to analyze the interpretation of normative statements by exploring how they are related to norms.

The theory of *pragmatic reasoning schemas* (PRS;

[1] For reasons of simplicity, the action side of the norm is represented exhaustively: all banning conditions are subsumed under Cs. The condition side in model (5) is not represented exhaustively because there may be other bans under the same conditions.

Cheng & Holyoak, 1985; Holyoak & Cheng, 1995) proposed two deontic inference schemas – one for permission and one for obligation – each consisting of four rules which are applicable when their appropriate content is present. The rules of the permission schema are:

P1: If the action is to be taken,
then the precondition *must* be satisfied.
P2: If the action is not to be taken,
then the precondition *need not* be satisfied.
P3: If the precondition is satisfied,
then the action *may* be taken.
P4: If the precondition is not satisfied,
then the action *must not* be taken.

The two deontic schemas are sufficient to explain many findings with deontic reasoning tasks (see, e.g., Holyoak & Cheng, 1995). As a theory of deontic reasoning, however, the PRS approach is faced with two problems. First, with regard to terminology the two schemas are not clearly distinguishable – both include a permission rule (e.g., P3) and an obligation rule (e.g., P1) – and the modal terms defining the schemas are themselves undefined (Manktelow & Over, 1995). The idea of a domain-specific representation of norms is adopted by DMM theory but it uses a single normative concept (bans) instead of different schemas and defines the modals by reference to norms, actions, and conditions. This approach encompasses both PRS schemas (Beller, 1997). Second, the scope of PRS theory is quite restricted: It does not cover some deontic inferences that people easily draw. For example, from the entry-rule "If a man has no ticket, then he *must not* enter" people easily infer that without a ticket "he *must* stay out". A corresponding inference rule is available in neither schema; the inference is supported, however, by DMM theory (model 5 applied to norm 3). By considering relations of modal logics the range of covered deontic inferences is extended beyond the PRS schemas.

"What is the *origin* of domain-specificity in reasoning?" is the question posed by evolutionary approaches. Are domain-specific concepts learned as assumed, for example, by PRS theory or do they reflect innate evolutionary adaptations (e.g., Cosmides, 1989; Cummins, 1996)? DMM theory stresses which information persons represent in their models and how these affect reasoning. It is open with respect to the origin question.

Having justified the theoretical relevance of the new theory, it is now applied to Wason's (1966) selection task. Since the discovery of content effects in the 1970s, this prominent paradigm has developed into a micro-laboratory of deontic reasoning with findings that each deontic theory must be able to explain.

Touchstone "Deontic Selection Task"

How does DMM theory fit the basic findings with deontic task versions? For reviews of the vast selection task literature see, for example, Beller (1997), Evans, Newstead and Byrne (1993), or Newstead and Evans (1995).

The Deontic Task: In the original, non-deontic task (Wason, 1966) persons are shown four cards with a letter on one side and a number on the other side. One side is visible: "A", "K", "5", and "8". A rule is given: "If there is an 'A' on one side, then there is a '5' on the other." The task is to select all cards which need to be turned over to find out whether the rule is true or false. Since a conditional '*If* P, *then* Q' is false only if the antecedent 'P' holds and the consequence 'Q' is false, exactly two cards can prove the rule: the 'P'-card ("A") and the '*not* Q'-card ("8"). This answer is usually given by less than 10 % of the participants (e.g., Evans, Newstead & Byrne, 1993). Now, consider the following deontic version (adapted from Griggs & Cox, 1982):

> *Imagine that you are a police officer on duty. It is your job to ensure that people conform with certain rules. The cards in front of you have information about four people. On one side of a card is a person's age and on the other side is what the person is drinking. Here is a rule: If a person is drinking beer, then he or she must be over 19. Select the card(s) that you need to turn over to determine whether people are violating the rule.*

The cards show: "drinking beer", "drinking Coke", "22 years", and "16 years" ('P', '*not* P', 'Q', and '*not* Q' with respect to the rule '*If* P, *then must* Q'). As in the abstract task, 'P'/'*not* Q' should be selected because these cards indicate a rule violation: a person under 19 drinking beer. Deontic tasks often yield solution rates of about 70-90 % (Dominowski, 1995). Different from the abstract task, people need not to evaluate the truth of the conditional. According to DMM theory they can construct normative models that tell them which persons (cards) they have to check. With the closed world assumption and the equivalence assumption, the drinking age rule can be mapped to norm (8):

(8) Normative

[forbidden(drinking_beer)]	[¬over_19]
[¬forbidden(drinking_beer)]	[over_19]

The norm is violated (model 7 applied to 8) by a person under 19 ('*not* Q') who is drinking beer ('P') which can be checked for by selecting the cards 'P'/'*not* Q'.

It was this "facilitation effect" that necessitated a deontic theory. Subsequent experiments revealed several factors that are of particular relevance for the deontic solution. Besides the use of the deontic term *must* (e.g., Platt & Griggs, 1993) and a "detective" scenario (van Duyne, 1974) – both strengthening the deontic interpretation – three factors received particular attention: the instruction, the type of negation used, and the rule form.

Instruction: While the abstract version asks for testing the truth of the conditional, the deontic task requires to detect cases of rule violation thereby making clear that each card has to be examined independently from the others (Stenning & van Lambalgen, in press). The high rate of 'P'/'*not* Q' in deontic tasks decreases when the testing instruction is used (e.g., Noveck & O'Brien, 1996; Yachanin, 1986). This is exactly what one would expect from the perspective of a deontic theory, because the testing instruction is not applicable in the deontic

case. Different from indicative conditionals, the truth of a deontic rule is independent from individuals who may conform to the rule or not. Its truth cannot be determined by simply observing persons' behavior – little astonishing that the solution rate decreases.

Negation: The use of explicit negation turned out to be crucial for the solution of tasks with abstract deontic rules like "If one is to take action 'A', then one must first satisfy precondition 'P' " (e.g., Cheng & Holyoak, 1985). An explicit negation of the fact that a person "has taken action 'A' " would be "has not taken action 'A' " while the statement "has taken action 'B' " can be regarded as an implicit negation. Typically, the proportion of 'P'/'*not* Q' decreases when implicit negation is used on the cards (e.g., Jackson & Griggs, 1990; Noveck & O'Brien, 1996). But again, this is consistent with a deontic theory as Holyoak and Cheng (1995) pointed out. Two actions need not exclude each other; they can take place at the same time. If a reasoner does not know whether taking action 'B' and action 'A' are mutually exclusive there is no basis to interpret the two "implicitly negated" cards '*not* P' and '*not* Q' as really negated.

Rule Form: Persons' apparent insensitivity to syntactic modifications of the conditional rule used in the tasks has been taken as an argument against a purely "syntactic" view of reasoning. Cosmides (1989), for example, reversed conditionals from '*If* P *then must* Q' in the 'standard' form to '*If* Q *then* (*may*) P'. From a syntactic point of view, one may expect that the cards to be selected should switch correspondingly from 'P'/'*not* Q' to '*not* P'/'Q'. From a deontic point of view, the reversed rule cannot be violated at all (in the sense of doing something forbidden) because the consequence (by using the modal *may*) does not express a behavioral constraint a person could offend. Consequently, none of the cards should be selected. In either case the predominant selection should change. Empirically, the opposite has been found: 60-70 % keep choosing 'P'/'*not* Q' (e.g., Cosmides, 1989). What is the reason for that? Consider two drinking-age rules: The standard form "If a person is drinking beer (P), then he or she *must* be over 19 (Q)" and the reversed one "If a person is over 19 (Q), then he or she *may* drink beer (P)". According to DMM theory, both rules can be mapped to the same norm (8) although they describe different aspects. The norm is violated by a person drinking beer who is not over 19 ('P *and not* Q'). By assuming that people derive their answer from this norm and not from the conditionals, DMM theory accounts for the insensitivity to their form. The related effect of perspective change (e.g., Gigerenzer & Hug, 1992; Manktelow & Over, 1991) can be explained in a similar way (Beller & Spada, 2000).

Deontic Tasks Without Deontic Solution? The previous results can all be brought in line with DMM theory. Cosmides (1989), however, reported findings that seem to rule out a deontic explanation categorically. She demonstrated that non social contract (non-SC) versions of deontic standard rules produce significantly less facilitation than equivalent social contract (SC) versions although both are said to trigger the same deontic solution. One of her examples is the 'school problem' about assigning students to either Grover High or Hanover High. Both versions mention the deontic conditional: "If a student is to be assigned to Grover High School, then that student *must* live in Grover City". However, while the SC problem (task 9) specifies that the cards should be checked for *cheating*, the non-SC version (task 10) leaves the subjects with an incomplete deontic interpretation. In this latter task it is said that "There are *rules* to determine which school a student is to be assigned to, the most important of these rules is …". Rule violations are attributed to an "… old lady … who often made mistakes when categorizing student documents" (p. 270). The first quotation implies that several normative rules have to be applied in the categorization process but not all of them are known (the closed world assumption is violated). The term "mistakes" leaves open whether the old lady incorrectly assigned students to Grover High *or* Hanover High. – Experimental manipulations that weaken the deontic interpretation or end up with an inconsistent or incomplete interpretation may result in a decrease of the deontic solution but they cannot be taken as an argument against a deontic explanation.

Rule-Change Revisited

The DMM explanation of the deontic selection task assumes that persons do not rely on the conditional rule itself but on normative models that tell them which cards to check. The finding with switched rules corroborates this hypothesis. Nevertheless, persons could also have derived their solution from the conditional rule since there is a rule available in both the standard and the switched version. A stronger argument in favour of the "normative-models hypothesis" would be, if (1) people kept choosing the same cards in a "rule-free" selection task – like those that have been used recently to back up the effect of knowledge about causal relationships (Beller & Spada, 2000) and about promises (Beller & Spada, 2000; Fiddick, Cosmides & Tooby, 2000). The rule-change effect seems to show subjects' insensitivity to the form of deontic conditionals. Although both the standard and the switched form are consistent with one and the same norm, the switched rule cannot be violated deontically as argued above. Thus, if (2) a task does not allow persons to construct a normative model but requires to evaluate the conditional itself, then they should state correctly which conditional can be violated. Both hypotheses are examined in the following experiment (Beller, 1997).

Materials: The materials comprised six tasks: five versions of selection tasks and one rule evaluation task. Four deontic conditionals were used:

R1: If a child is drinking Coke,
then he or she *must* be over 12 years of age.

R2: If a child is over 12 years of age,
then he or she *may* drink Coke.

R3: If a child is over 12 years of age,
then he or she *need not* drink juice.

R4: If a child is drinking Coke,
then he or she *must not* be under 12 years of age.

R1 denotes a standard rule ('*If* P *then must* Q' with "drinking Coke" symbolized as 'P' and "over 12 years" as 'Q') while R2 is reversed ('*If* Q *then may* P'). R3 and R4 are corresponding rules using the other two deontic operators. All rules are derived from norm (9) that forbids drinking Coke if a child is younger than 12 years:

(9) Normative	
[forbidden(drinking_coke)]	[¬over_12]
[¬forbidden(drinking_coke)]	[over_12]

The *selection tasks* started with an introductory part:

In a particular country there are two beverages popular with children: Coke containing caffeine and a particular sort of juice. A scientific study has shown that the circulatory system of children younger than 12 years is often affected by drinking Coke. Therefore, the government passed a rule permitting to drink Coke dependent on age. A dispenser offers both beverages, the juice and Coke. The children of a school class are standing in front of the dispenser together with their teacher. Some of the children are already over 12 years of age, some are under 12 years. The teacher reminds her pupils of the correct behavior. [She mentions the following beverage rule].

The five versions differed in the rule following right after this part: Four tasks mentioned one of R1-R4; the fifth task comprised no conditional (and omitted the sentence in square brackets). The instruction continued:

The cards below represent four children who took a beverage from the dispenser. On one side of each card it is written whether the child is drinking Coke or juice, the other side shows whether he or she is over 12 years. Your task: Please indicate all the cards that you would have to turn over (i.e., all of which you need to know the information on the back) in order to find out whether the child has violated the beverage rule.

The cards read: "is drinking Coke", "is drinking juice", "is over 12", and "is under 12" ('P', '*not* P', 'Q', and '*not* Q'). Since all tasks can be mapped to one and the same norm (9), the model theory predicts that people choose the same cards 'P'/'*not* Q' that may indicate a violation of this norm (model 7 applied to 9) by children under 12 ('*not* Q') who are drinking Coke ('P').

The instruction of the *rule evaluation task* required to evaluate the deontic conditionals (R1-R4) without reference to an underlying norm:

Please read carefully through the following if-then-statements. Check for each statement whether it expresses a behavioral rule that can be violated by a child.

Only the obligation and the ban (R1 and R4) can be violated by doing something forbidden: drinking Coke under 12 years of age. R2 and R3 do not express a behavioral restriction and hence cannot be violated.

Participants: 168 students from various disciplines (excluding psychology, mathematics, and philosophy) of the University of Freiburg volunteered for the study and were paid for participating. They were untrained in logic and had no prior experience with selection tasks.

Table 1: (a) *Selection tasks*: Frequency of 'P'/'*not*-Q' responses depending on rule version (n each 28). (b) *Rule evaluation tasks*: Frequency of selecting a rule as one that can be violated (n = 28, multiple selections possible).

Rule	(a)	(b)
R1 '*If* P, *then must* Q.'	27	24
R2 '*If* Q, *then may* P.'	27	9
R3 '*If* Q, *then need-not not*-P.'	22	3
R4 '*If* P, *then must-not not*-Q.'	26	25
R5 None	26	

Design and Procedure: The participants were randomly assigned to one of six groups (n = 28). Each received one of the six tasks together with other tasks analyzed elsewhere (Beller & Spada, 2000). The treatment was administered in small groups. Each participant received a booklet with a general instruction on the first page and the various tasks each on a new page. Each booklet presented the tasks in a new random order. The order of the conditionals in the rule evaluation task and of the "cards" in the selection tasks was also determined randomly for each participant.

Results: The results of the *selection tasks* are shown in Table 1(a). As predicted, changing the conditional had only a marginal effect ($\chi^2_{(4,\, n\,=\,140)} = 7.84$; $p = 0.10$). Most participants (m = 91.4 %) selected the predicted cards 'P'/'*not* Q', even in the task without an explicit conditional. Table 1(b) shows the frequency of selecting each conditional as a rule that can be violated (*rule evaluation task*). Summed up over individual combinations, the predicted conditionals R1 and R4 were selected 49 times while R2 and R3 were selected 12 times (80.3 % vs. 19.7 %; $p < 0.01$, based on the binomial distribution with n = 61 and r = 1/2). The combination of R1 and R4 was selected by 16 participants.

Summary and Discussion

The experimental results show how violation checking is affected task-specifically by the possibility of constructing normative models. (1) Given the possibility to construct a norm, as in the selection tasks, persons rely on this *norm* and appear to be insensitive to the *form* of the conditional rule describing the norm. This replicates the effect of changing the rule from 'standard' to 'switched' and extends it to other rules. The rule-free version demonstrates that an enriched deontic context (as it is used in many other deontic selection tasks as well) is sufficient to elicit this effect. Since the participants do not regard the conditional rules as relevant premises, their insensitivity to the syntactic form of the rules should not be attributed to illogical reasoning. In fact, persons' answers are in accordance with the logic of social norms. (2) If a task does not allow persons to construct normative models but requires to evaluate deontic conditionals directly, then their answers are indeed quite sensitive to the deontic form. Together,

these findings strongly support the dual source argument (Beller, 1997; Beller & Spada, 2000): in order to understand human deductive reasoning it is necessary to integrate inferences from two sources, namely from the syntactic form of an argument and from conceptual knowledge associated with its content or context.

A mental models notation was used to describe the representation and inferential use of norms (although it is assumed that the deontic principles may be adapted to a mental logic framework as well). The course overview of selection task findings demonstrated how a fine-grained analysis of the domain can guide the interpretation of experimental results. The next step will be to apply DMM theory to findings from other tasks, for example, reformulation tasks or conditional syllogism tasks (e.g., Thompson, 1995), in order to assess its full potential. Two assumptions characterize the proposed representation of norms: the closed world assumption (all norms are known to the reasoner) and the equivalence assumption (concerning the relation between a ban and its conditions). The selection task data are consistent with both. However, they only provide indirect evidence. Reformulation tasks or sufficiency and necessity ratings could prove both assumptions more directly.

Acknowledgements I am grateful to Keith Stenning (University of Edinburgh) as well as to Andrea Bender, Gregory Kuhnmünch, Nikol Rummel, and Hans Spada (Freiburg) for encouraging discussions and helpful comments. This work was supported by a grant from the German Research Foundation (DFG) within the graduate program GK MMI at the University of Freiburg.

References

Beller, S. (1997). *Inhaltseffekte beim logischen Denken*. Lengerich: Pabst.

Beller, S., & Spada, H. (2000). The logic of content effects in propositional reasoning: The case of conditional reasoning with a point of view. Under review.

Chellas, B. F. (1980). *Modal logic: An introduction*. Cambridge: Cambridge University Press.

Cheng, P. W., & 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 for the innateness of deontic reasoning. *Mind & Language, 11*, 160-190.

Dominowski, R. L. (1995). Content effects in Wason's selection task. In S. Newstead, & J. St. B. T. Evans (Eds.), *Perspectives on thinking and reasoning*. Hove: Erlbaum.

Evans, J. St. B. T., Newstead, S. E., & Byrne, R. M. J. (1993). *Human reasoning*. Hove: Erlbaum.

Fiddick, L., Cosmides, L., & Tooby, J. (2000). No interpretation without representation: The role of domain-specific representations and inferences in the Wason selection task. *Cognition, 77*, 1-79.

Gigerenzer, G., & Hug, K. (1992). Domain-specific reasoning: Social contracts, cheating, and perspective change. *Cognition, 43*, 127-171.

Griggs, R. A., & Cox, J. R. (1982). The elusive thematic-materials effect in Wason's selection task. *British Journal of Psychology, 73*, 407-420.

Holyoak, K. J., & Cheng, P. W. (1995). Pragmatic reasoning about human voluntary action: Evidence from Wason's selection task. In S. Newstead, & J. St. B. T. Evans (Eds.), *Perspectives on thinking and reasoning*. Hove: Erlbaum.

Jackson, S. L., & Griggs, R. A. (1990). The elusive pragmatic reasoning schemas effect. *Quarterly Journal of Experimental Psychology, 42A*, 353-373.

Johnson-Laird, P. N. (1978). The meaning of modality. *Cognitive Science, 2*, 17-26.

Johnson-Laird, P. N. (1983). *Mental models*. Cambridge: Cambridge University Press.

Johnson-Laird, P. N., & Byrne, R. M. J. (1991). *Deduction*. Hove: Erlbaum.

Johnson-Laird, P. N., & Byrne, R. M. J. (1992). Modal reasoning, models, and Manktelow and Over. *Cognition, 43*, 173-182.

Manktelow, K. I., & Over, D. E. (1991). Social roles and utilities in reasoning with deontic conditionals. *Cognition, 39*, 85-105.

Manktelow, K. I., & Over, D. E. (1995). Deontic reasoning. In S. Newstead, & J. St. B. T. Evans (Eds.), *Perspectives on thinking and reasoning*. Hove: Erlbaum.

Noveck, I. A., & O'Brien, D. P. (1996). To what extent do pragmatic reasoning schemas affect performance on Wason's selection task? *The Quarterly Journal of Experimental Psychology, 49A*, 463-489.

Newstead, S., & Evans, J. St. B. T. (Eds.) (1995). *Perspectives on thinking and reasoning*. Hove: Erlbaum.

Platt, R. D., & Griggs, R. A. (1993). Darwinian algorithms and the Wason selection task: A factorial analysis of social contract selection task problems. *Cognition, 48*, 163-192.

Sperber, D., Cara, F., & Girotto, V. (1995). Relevance theory explains the selection task. *Cognition, 57*, 31-95.

Stenning, K., & van Lambalgen, M. (in press). Semantics as a foundation for psychology: A case study of Wason's selection task. *Journal of Logic, Language and Information*.

Thompson, V. A. (1995). Conditional reasoning: The necessary and sufficient conditions. *Canadian Journal of Experimental Psychology, 49*, 1-58.

Thompson, V. A. (2000). The task-specific nature of domain-general reasoning. *Cognition, 76*, 209-268.

van Duyne, P. C. (1974). Realism and linguistic complexity in reasoning. *British Journal of Psychology, 65*, 59-67.

von Wright, G. H. (1963). *Norm and action: A logical enquiry.* London: Routledge & Kegan Paul.

Wason, P. C. (1966). Reasoning. In B. M. Foss (Ed.), *New horizons in psychology.* Harmondsworth: Penguin.

Yachanin, S. A. (1986). Facilitation in Wason's selection task: Content and instructions. *Current Psychological Research and Reviews, 5*, 20-29.