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Reasoning with conditionals: A test of formal models of four theories ☆

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Abstract

The four dominant theories of reasoning from conditionals are translated into formal models: The theory of mental models (Johnson-Laird, P. N., & Byrne, R. M. J. (2002). Conditionals: a theory of meaning, pragmatics, and inference. *Psychological Review*, *109*, 646–678), the suppositional theory (Evans, J. S. B. T., & Over, D. E. (2004). *If*. Oxford: Oxford University Press), a dual-process variant of the model theory (Verschueren, N., Schaeken, W., & d'Ydewalle, G. (2005). A dual-process specification of causal conditional reasoning. *Thinking & Reasoning*, *11*, 278–293), and the probabilistic theory (Oaksford, M., Chater, N., & Larkin, J. (2000). Probabilities and polarity biases in conditional inference. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 883–899). The first three theories are formalized as multinomial models. The models are applied to the frequencies of patterns of acceptance or rejection across the four basic inferences modus ponens, acceptance of the consequent, denial of the antecedent, and modus tollens. Model fits are assessed for two large data sets, one representing reasoning with abstract, basic conditionals, the other reflecting reasoning with pseudo-realistic causal and non-causal conditionals. The best account of the data was provided by a modified

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version of the mental-model theory, augmented by directionality, and by the dual-process model.

Keywords: Conditionals; Reasoning; Multinomial models

1. Introduction

Conditionals, that is statements of the form "If *p* then *q*," are pervasive in everyday reasoning—for example, from the rule, "If the suspect has an alibi, then he cannot have committed the crime," and the information that a suspect has an alibi, police officers and crime fiction readers readily infer that this suspect most likely is innocent. Conditionals are also a backbone to scientific reasoning. For example, from the premise "If my theory is right, then the training group should surpass the control group," and the finding that the training group did not do better than the control group, an investigator should infer at least some serious doubt about the validity of her theory.

Inferences such as these have been a topic of psychological investigation for many decades (Evans, Newstead, & Byrne, 1993). Most of this research has focused on four simple inference forms, summarized in Table 1. Two of them, MP and MT, are licensed by formal logic, whereas the other two, AC and DA, are not valid according to formal logic, unless the conditional that forms the major premise is understood as a biconditional, that is, a statement of the form "If and only if *p* then *q*." The basic pattern of findings across numerous experiments with these four inference schemas is that MP is endorsed by nearly all participants, MT is endorsed with considerably lower frequency, and both AC and DA are endorsed quite frequently, AC having a slightly higher acceptance rate than DA (Evans, 1993; Schroyens, Schaeken, & d'Ydewalle, 2001).

Several theories have been proposed to account for reasoning with conditional premises. Mental rule theories (Braine & O'Brien, 1991; Rips, 1994) assume that our mind is equipped with inference rules, among them a rule for MP inferences, which apply to propositional representations of premises and generate propositional representations of appropriate conclusions. The theory of mental models (Johnson-Laird & Byrne, 2002; Johnson-Laird, Byrne, & Schaeken, 1992) assumes that reasoning proceeds on a representation of the meaning of premises, cast as a set of models of their truth conditions. The probabilistic inference theory (Oaksford, Chater, & Larkin, 2000) and the suppositional theory (Evans & Over, 2004) share the assumption that conditionals are represented as expressing a high conditional probability of the consequent, given the antecedent. The theories diverge, however, in their assumptions about inferences. Oaksford and colleagues

Table 1
The four basic inference forms

Inference form	Major premise	Minor premise	Conclusion
Modus ponens (MP)	If *p* then *q*	*p*	*q*
Acceptance of the consequent (AC)	If *p* then *q*	*q*	*p*
Denial of the antecedent (DA)	If *p* then *q*	Not *p*	Not *q*
Modus tollens (MT)	If *p* then *q*	Not *q*	Not *p*

Note: The variables *p* and *q* stand for propositions; *p* is called the antecedent and *q* is called the consequent.