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# On the road toward formal reasoning: Reasoning with factual causal and contrary-to-fact causal premises during early adolescence

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ABSTRACT

Understanding the development of conditional (if–then) reasoning is critical for theoretical and educational reasons. Here we examined the hypothesis that there is a developmental transition between reasoning with true and contrary-to-fact (CF) causal conditionals. A total of 535 students between 11 and 14 years of age received priming conditions designed to encourage use of either a true or CF alternatives generation strategy and reasoning problems with true causal and CF causal premises (with counterbalanced order). Results show that priming had no effect on reasoning with true causal premises. By contrast, priming with CF alternatives significantly improved logical reasoning with CF premises. Analysis of the effect of order showed that reasoning with CF premises reduced logical responding among younger students but had no effect among older students. Results support the idea that there is a transition in the reasoning processes in this age range associated with the nature of the alternatives generation process required for logical reasoning with true and CF causal conditionals.



## Introduction

Conditional (if–then) reasoning is one of the most important and widely studied forms of logical reasoning. One of the most important uses of conditionals, and conditional inferences, is the creation of a hypothetical link between two propositions (categories, actions, events, etc.). Such a conditional

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allows mathematicians and scientists to create a theoretical world in which the hypothesized relation is true in order to examine the potential consequences and then compare these with empirical data. This is one of the key components of formal thinking (Inhelder & Piaget, 1958). Understanding whether an inference is logically necessary must be done without using knowledge or belief. However, developmental studies of the ability to make logical inferences with conditional relations clearly show a complex pattern of dependence on empirical knowledge. For example, children find it much easier to make logical inferences with very concrete premises ("If an animal is a dog, then it has four legs") than with causal premises ("If a rock is thrown at a window, then the window will break"). This suggests that there is an equally complex developmental progression preceding the ability to reason abstractly. In the current study, we specifically focused on the transition between reasoning logically with factual causal conditions and the ability to reason logically with contrary-to-fact (CF) conditionals during early adolescence.

Conditional reasoning involves reasoning on the basis of a given "if P then Q" premise (where P is the antecedent term and Q is the consequent term). There are four basic inferences that can be made from a given if–then premise by affirming or denying the antecedent or consequent term. Two of these lead to logically certain conclusions. The most direct of the four inferences is called *modus ponens* (MP), from the Latin term meaning "affirms by affirming," and involves the premises "If P then Q" and "P is true," leading to the logical conclusion that "Q is true." The *modus tollens* (MT) inference, from the Latin term meaning "denies by denying," involves the premises "If P then Q" and "Q is false," leading to the logical conclusion that "P is false." The two remaining inferences do not allow any certain conclusion. The first of these is the *affirmation of the consequent* (AC), which involves the premises "If P then Q" and "Q is true." Take the following example: "If a rock is thrown at a window, then the window will break. Suppose that a window is broken." In this case, the conclusion that "a rock was thrown at the window" is not logically certain because something else might have broken the window. The second of these is the *denial of the antecedent* (DA), which involves the premises "If P then Q" and "P is false." Similar to the analysis of the AC inference, the possible conclusion that "Q is false" is not certain.

A major problem in understanding the development of conditional reasoning is the very strong variation in the kinds of inferences made by children and adults when premise content is varied. Children as young as 6 or 7 years can reason logically on the AC and DA inferences with some category-based premises; for example, "If an animal is a dog, then it has legs" (Markovits, 2000; Markovits & Thompson, 2008). By contrast, even adults do not consistently give the logical response to these same inferences when reasoning with true causal conditionals; for example, "If a rock is thrown at a window, then the window will break" (Cummins, Lubart, Alksnis, & Rist, 1991). Individual and developmental differences in reasoning with concrete premises up to middle adolescence are related to working memory, retrieval efficiency, and inhibitory capacity (De Neys & Everaerts, 2008; Janveau-Brennan & Markovits, 1999; Klaczynski & Narasimham, 1998; Markovits & Barrouillet, 2002; Simoneau & Markovits, 2003). These suggest that a key component of the development of reasoning abilities in this age range involves the way that information about premises is used during reasoning.

Premises used in inferential problems explicitly present the relation between antecedent and consequent terms and the potential truth value of one of these (e.g., "P implies Q" and "Q is true"). However, there are other implicit forms of information that are relevant to reasoning. The first refers to potential alternatives to the antecedent term. For example, take the premise "If a rock is thrown at a window, then the window will break." In this case, "throwing a chair at a window" is an example of an alternative antecedent because it is a concrete example of another way to break a window. Having more potential alternative antecedents in long-term memory increases the probability of producing the logically correct response to both the AC and DA inferences in children as well as adults (e.g., Cummins, 1995; Cummins et al., 1991; Daniel & Klaczynski, 2006; Janveau-Brennan & Markovits, 1999; Klaczynski & Narasimham, 1998; Markovits & Vachon, 1990; Thompson, 1994). Using our previous example, being able to easily retrieve information such as "throwing a chair" allows people to readily conclude that "If a window is broken, it is not necessarily true that a rock was thrown at the window."

A second type of information refers to what Cummins (1995; see also Cummins et al., 1991) called disabling conditions. These are conditions that potentially disable the connection between the