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In the beginning stages: Conditional reasoning with category based and causal premises in 8- to 10- year olds

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ABSTRACT

Understanding the development of conditional (if-then) reasoning is critical for theoretical and educational reasons. Previous results have shown that there is a clear qualitative transition between reasoning with true causal conditionals and reasoning with either with contrary-to-fact and fully abstract premises. We examine the further idea that there is a similar developmental transition between reasoning with category-based premises (If an animal is a dog, then it has a tail) and with familiar causal conditionals (If a rock is thrown at a window, then the window will break). A total of 585 students between 8 and 10 years of age received priming conditions designed to encourage use of an alternatives generation strategy and reasoning problems with category based premises and causal premises in a counterbalanced order (with many or few potential alternatives). Results show that reasoning with category based premises is less difficult than reasoning with causal premises, at all ages, and that reasoning first with causal premises causes a global decrease in logical reasoning compared to reasoning first with category based premises. However, no effect of priming was observed. 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 category based and with causal conditionals. However, this transition is less qualitatively extreme than that between reasoning with familiar premises and reasoning with premises that have no empirical basis.

1. Introduction

Conditional reasoning involves making deductive inferences based on an initial if-then premise. Conditionals serve many important functions both in terms of logical reasoning and in terms of the way that people convey different forms of hypothetical relations. Understanding the development of conditional reasoning is thus of critical importance in being able to trace the developmental trajectory underlying logical reasoning. In addition, given the importance of logical reasoning to advanced mathematical and scientific understanding, understanding how conditional reasoning develops has very important educational implications.

Different approaches to conditional reasoning have often led to very different conclusions, reflecting the wide variation in empirical results. On the one hand, some researchers have claimed that conditional reasoning is fully accessible to even very young children, after studies that have shown that in certain cases very young children can indeed give the logically correct responses to conditional inferences (Dias & Harris, 1988, 1990; Hawkins, Pea, Glick & Scribner, 1984). Others have emphasized the fact that even very well educated adults find it very difficult to give consistently correct responses to what

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appeared to be the same problems that young children appear to reason well with (Cummins, Lubart, Alksnis, & Rist, 1991; Evans, Barston & Pollard, 1983), leading them to assume that few people are able to reason logically. Underlying this wide divergence is one basic fact. The inferences that both children and adults make to what are seemingly identical forms of conditional inferences vary dramatically according to the content of the premises. The key to reconciling what appears to be such inconsistent results is understanding how content can affect the developmental processes required to make conditional inferences. The present study focusses on elementary school children's ability to reason with causal and with categorical premises.

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 the consequent. 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 following premises: "If P then Q, P is true" and leads 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. Q is false" and leads 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. Q is true". Take for 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 since 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. P is false". Similarly to the analysis of the AC inference, the possible conclusion that "Q is false" is not certain.

Empirical results that have examined children's and adults' ability to make logical inferences with conditional premises have shown a mixed pattern of results. Several studies have shown that even quite young children are able to make logically correct inferences (Dias & Harris, 1988, 1990; Hawkins, Pea, Glick & Scribner, 1984). Others have shown clear developmental patterns in children's and adolescents' ability to do so (Barrouillet & Lecas, 1999; Janveau-Brennan & Markovits, 1999; Markovits & Vachon, 1989; O'Brien & Overton, 1980; Overton, Byrnes, & O'Brien, 1985). Finally, many studies have shown that even educated adults have difficulties making logically correct inferences (Cummins, Lubart, Alksnis, & Rist, 1991, Cummins, 1995; Markovits, 1985; Thompson, 1994). Existing developmental theories tend to focus on one or the other of these patterns of results (see Ricco (in press) for a comprehensive review). For example, the competence performance model developed by Overton and colleagues (Overton & Ricco, 2011) focuses on developmental improvements in reasoning while paying some attention to the difficulties that adults may have due to various kinds of performance factors. This model has a Piagetian underpinning and shares with this latter the basic idea that truly logical reasoning does not develop before adolescence. Barrouillet and colleagues (e.g. Barrouillet & Lecas, 1999; Geoffroy & Barrouillet, 2000) have used a mental model analysis that uses the number of models required to instantiate a fully conditional interpretation and the resulting load on working memory to produce a developmental analysis. This model also claims that pre-adolescents are not able to generate a conditional interpretation of conditional statements, using truth-table like tasks (although see Markovits, Brisson & de Chantal, 2016). On the other hand, the metacognitive model proposed by Moshman (2004) focuses more specifically on early ability to make logical inferences, with development seen as due to a basically metacognitive component.

These theories focus on important large-scale variations in reasoning ability, and in many cases they highlight some important, although somewhat contradictory developmental factors. For example, Overton's neo-Piagetian model recognizes that even pre-adolescents are capable of some form of more concrete reasoning, but that this contrasts with the more formal reasoning that is found with more abstract propositional contexts (Byrnes & Overton, 1986). Barrouillet's theory focusses specifically on the working memory constraints required to maintain a conditional interpretation, but suggests that this is not possible before adolescence. However, there are some important factors that are not addressed by these larger-scale theories that are tied to the specific content of the premises used for reasoning. One of the most robust effects that have been observed in the reasoning literature concerns the effects of the relative accessibility of *alternative antecedents* on the ability of children and adults to correctly reject the implied conclusions on the AC and the DA inferences. These are cases of A and Q, where A is not P (e.g. for the premise If a rock is thrown at a window, the window will break, throwing a chair at a window is an alternative antecedent). Many studies have found that when people reason with premises for which they have ready access to more such alternatives, they tend to more often (correctly) deny these two inferences (Cummins et al., 1991; Cummins, 1995; Markovits & Vachon, 1990; Thompson, 1995).

The relative accessibility of alternative antecedents can account for a great deal of the variation in logical reasoning within a given type of premise. For example, this dimension has been used to explain differences in reasoning with causal conditional premises (Cummins et al., 1991; Cummins, 1995; Markovits & Vachon, 1990), with deontic conditionals (Thompson, 1994, 2000), and with category-based conditionals (Markovits, 2000). Importantly, such alternative antecedents must be generated by a reasoner, since they are not part of the information provided by problem premises (we refer to the process by which alternatives are generated as the AGP for brevity). In addition to this form of variation, there is clear evidence that major developmental differences are related to premise type. Developmental results suggest that we can distinguish a sequence of four classes of premise content for which there appears to be consistent age-related differences in logical reasoning. These are respectively, category based premises (if an animal is a dog then it has four legs), causal premises (the rock is thrown at a window, then the window will break), contrary to fact premises (if a feather is thrown at a window, then the window will break) and abstract premises (if X, then Y). There is in fact direct evidence that rates of logical reasoning are lower with contrary to fact premises than with causal premises (Markovits & Vachon, 1989) and that rates of logical reasoning are lower