Reasoning With Premises That Are Not Empirically True: Evidence for the Role of Inhibition and Retrieval

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Two studies examined conditional reasoning with false premises. In Study 1, 12- and 16-year-old adolescents made "if-then" inferences after producing an alternative antecedent for the major premise. Older participants made more errors on the simple modus ponens inference than did younger ones. Reasoning with a false premise reduced this effect. Study 2 examined the relation between performance on a negative priming task (S. P. Tipper, 1985) and reasoning with contrary-to-fact premises in 9- and 11-year-olds. Overall, there was a correlation between the relative effect of negative priming on reaction times and the number of knowledge-based responses to the reasoning problems. The results of these studies are consistent with the idea that reasoning with premises that are not true requires an interaction between information retrieval and inhibition.

Logical reasoning involves making deductions on the basis of some given premises that are considered to be true. Although there have been a great many studies of how both children and adults reason, one of the most important characteristics of such reasoning has been relatively neglected. Specifically, the ability to reason "logically" with premises that are not necessarily true (Inhelder & Piaget, 1958) is a vital component of advanced reasoning. This basic ability underlies much of modern science, in which disregarding what is believable in order to follow a train of thinking to a logical (and often startlingly unbelievable) conclusion is a key element. Such reasoning also appears in children's early fantasy play when children pretend and follow this pretense through an often long and complex chain of reasoning (e.g., Lillard, 2001). A specific form of reasoning with false premises, counterfactual ("what if") reasoning, has been shown to have effects in a variety of contexts, including understanding of causality and individual belief (e.g., Spellman & Mandel, 1999).

These examples show the pervasiveness and the importance of reasoning with false premises. However, the diversity of contexts in which this form of reasoning is used has led to very different conclusions about how difficult such reasoning is and, associated with this variety of conclusions, to very different ideas about what might be involved in such reasoning. For example, very young children can in limited circumstances reason with false premises in a "logical" way (e.g., Dias & Harris, 1988; Leevers & Harris, 1999). Some theorists who have focused on these kinds of results have supposed that the ability to reason with false premises can be described by a single, unitary ability (e.g., analytical or hypothet-
that very young children reliably conclude that “If P, then Q: P is true” implies that “Q is true” (Ennis, 1976) with simple, empirically true premises before they can respond consistently to any of the other conditional inferences, such as modus tollens (MT), and (b) that adults generally tend to endorse the MP inference at a high rate when the premises are empirically true (Evans, 1993). Thus, failure to accept the MP inference (particularly among older reasoners) cannot be due to the difficulty of actually making the inference once an appropriate representation of the major premise has been established. Examining performance on the MP inference allows focusing on the representational process, that is, what the reasoner must do “to suppose that the major premise is true.” Although much of the focus of the present analysis is on the MP inference, performance on the other logical forms must also be considered. The MT inference involves reasoning with the premises “P implies Q; Q is false.” As for the MP inference, there is a logically valid conclusion in this case, that is, ‘P is false.” Affirmation of the consequent (AC) involves reasoning with the premises “P implies Q; Q is true.” Denial of the antecedent (DA) involves reasoning with the premises “P implies Q; P is false.” In these latter two cases, there is no logically necessary conclusion.

Many studies have generally found that even very young children show a high rate of endorsement of the MP inference with empirically believable premises (e.g., Ennis, 1976). However, several studies have shown that this is not the case when prior knowledge puts into doubt the empirical truth of the major premise. Both children (Dias & Harris, 1988, 1990; Hawkins, Pea, Glick, & Scribner, 1984) and young adolescents (Markovits & Vachon, 1989) tend to deny the MP inference when given premises that are considered to be false. For example, children who are given a premise such as “If it rains, then the street will be dry” will often infer that “The street is wet” when given the minor premise “It has rained.” Similarly, adults who reason with major premises that they consider to be relatively unbelievable often tend to refuse the MP inference (George, 1995, 1997). These studies indicate that understanding how reasoning with premises that are believed to be false is done requires an understanding of how stored real-world knowledge (that might contradict the truth of these premises) is processed by the reasoner.

There is increasingly clear evidence that conditional reasoning in general is strongly affected by the nature of stored knowledge about premises (e.g., Cummins, 1995; Cummins, Lubart, Alksnis, & Rist, 1991; Janveau-Brennan & Markovits, 1999; Johnson-Laird & Steedman, 1978; Marcus & Rips, 1979; Markovits, Fleury, Quinn, & Venet, 1998; Markovits & Vachon, 1990; O’Brien, Costa, & Overton, 1986; Quinn & Markovits, 1998; Thompson, 1994). More specifically, there are two important kinds of information that have been shown to have clear effects on how children and adults reason with conditionals. For a given “If P, then Q” premise, these are (a) alternative antecedents, which refer to examples of “A then Q,” where A is different from P, and (b) disabling conditions (Cummins et al., 1991), which are conditions, C, such that if P and C are true, then Q will not necessarily follow. For example, take the premise “If a rock is thrown at a window, then the window will break.” “Throwing a chair at a window” is an example of an alternative antecedent, whereas “The window is made of Plexiglas” is an example of a disabling condition. Greater availability of potential alternative antecedents in reasoners’ long-term memory increases the probability of producing an uncertainty response to both the AC and DA inferences, both in children and adults (e.g., Cummins et al., 1991; Markovits & Vachon, 1990). Greater availability of disabling conditions is associated with decreased acceptance of the MP and MT inferences (Cummins, 1995; Cummins et al., 1991; De Neys, Schaeken, & d’Ydewalle, 2002; Janveau-Brennan & Markovits, 1999; Vadeboncoeur & Markovits, 1999).

Studies that have looked at the relation between access to disabling conditions and reasoning have shown that even in the absence of “logical” instructions, both children (Janveau-Brennan & Markovits, 1999) and adults (Cummins, 1995; Cummins et al., 1991) will accept the MP inference if they have limited access to real-world knowledge that denies the truth of the major premise. However, when such knowledge is readily available, then reasoners will spontaneously tend to deny the MP inference. These results are also consistent with results from studies that have looked at reasoners’ performance with premises that are abstract in nature. In these cases, there is no empirical knowledge available to suggest that a given if-then premise might not be true, and both children and adults tend to make the MP inference at a high rate (Hawkins et al., 1984; Markovits & Vachon, 1990; Venet & Markovits, 2001). It is clear that the presence of empirical knowledge that might put into doubt the truth of a given if-then premise is one factor in understanding what determines the nature of the MP inferences made to different premises. In fact, the many studies that have looked at reasoning with concrete premises allow the clear general conclusion that when children and adults make conditional inferences, they attempt to access whatever information they have in long-term memory that is relevant to the premises (Markovits & Barrouillet, 2002). This conclusion is supported by recent empirical evidence that individual differences in the efficiency of retrieval of information correlate with the nature of the inferences that are made, both by children (Janveau-Brennan & Markovits, 1999) and adults (De Neys et al., 2002; Markovits & Quinn, 2002). Thus, the kinds of inferences that are made with concrete premises will depend on the nature of the information about the premises that is retrieved by the reasoner (see Venet & Markovits, 2001, for an account of the kinds of processes that might explain more abstract reasoning).

This approach suggests that one factor in understanding how reasoners make inferences with premises that are not (always) true depends on the relative ease with which they can retrieve information that allows them to deny that P will always lead to Q. However, there is evidence that this is not the only factor involved. For example, the nature of task instructions can strongly modulate the kinds of MP inferences that are made to premises for which there is empirical information that the premise is not always true. Vadeboncoeur and Markovits (1999) found that instructions that emphasize the logical nature of the inference required of reasoners can strongly decrease the tendency to deny the MP inference with causal conditionals for which there are many potential disabling conditions. This is consistent with the results of developmental studies showing (a) that when preadolescent children are given contrary-to-fact premises and asked to “suppose that these are true,” they tend to refuse the MP inference but (b) that this pattern of spontaneous responding decreases with age, with 15-year-olds making the MP inference quite consistently with these same premises (Markovits & Vachon, 1989). In fact, Leevers and Harris
(1999) found that even simple instructions to focus on premises allowed very young children to reliably make the MP inference with empirically false premises.

Thus, although it appears clear that one component of understanding reasoning with unbelievable premises concerns the potential retrieval of information that puts these premises into doubt, another component involves understanding how task instructions can modulate the effects of this information. Specifically, these issues raise the question of what kinds of processes are engaged by the instructions to “suppose that the premises are true.”

The basic model that we propose is derived from some general analyses of developmental trends in how stored information is used. There is clear evidence that as children age, they become increasingly more efficient at retrieving information from memory (e.g., Kail, 1992). This greater efficiency allows them to access greater amounts of information from long-term memory more quickly. However, given the relatively automatic nature of much memory retrieval, this evidence also implies that older children will tend to access larger amounts of information that are irrelevant to the specific task. It has been proposed that an increasing capacity to inhibit activation of inappropriate information is an important component of cognitive development, one that mirrors the increased efficiency of information retrieval (e.g., Bjorklund & Harnishfeger, 1990, 1995; Demetriou, Christou, Spanoudis, & Platsidou, 2002). Inhibition is considered to be a necessary component in managing the increased information load implied by increasing efficiency of retrieval. The specific analysis of reasoning that we present here fits very clearly into this general framework, because one of the key developmental components of reasoning is presumed to be increased efficiency of retrieval of information from memory. In the specific case of “logical” reasoning with false premises, this increased efficiency implies the potential activation of information that puts these premises into doubt, information that contradicts task instructions.

In line with this general model, it has recently been proposed that the effect of logical instructions to accept that “If P, then Q” is indeed true is to inhibit activation of any information that might exist in long-term memory that puts into doubt the truth of the major premise (Markovits & Barrouillet, 2002; Vadeboncoeur & Markovits, 1999). Thus, the way that children and adults respond to the MP inference with premises that are not empirically true when given “logical” instructions can be seen to be the result of two complementary, but somewhat contradictory, processes. On the one hand, there is a clear general tendency to retrieve information about concrete premises during reasoning, including information that puts into doubt that P always leads to Q. On the other hand, there is an attempt to inhibit activation of information that is not appropriate to the specific, logical task, which specifically includes the latter form of information.

There is some evidence that retrieval and inhibition processes may well underlie “logical” reasoning with premises that are not always true. First, there are results that suggest that the effect of logical instructions or context is not necessarily well focused and can interfere with retrieval of information that is not explicitly targeted. Markovits and Vachon (1989) examined the inferences that were made with contrary-to-fact premises by reasoners 10 to 18 years old who were explicitly asked to suppose that these premises were true. They found that there was a clear developmental increase in the tendency to accept the MP inference with these premises and that the tendency to give responses that used real-world knowledge that the if–then premise was not true disappeared by 15 years of age. However, among reasoners who were able to stop real-world knowledge from influencing their inferences, there was also a relative decrease in the production of uncertainty responses to the AC and DA forms with contrary-to-fact premises compared with equivalent true premises. Because the tendency to produce uncertainty responses to the AC and DA forms is related to retrieval of potential alternative antecedents (e.g., Cummins et al., 1991; Markovits & Vachon, 1990), this result indicates that instructions to suppose that contrary-to-fact premises are true not only decrease retrieval of empirical knowledge suggesting that these premises are not true but also decrease retrieval of empirical knowledge concerning alternative antecedents, information that is not specifically targeted by the “logical” instructions. Similar results are found when the effects of context on contrary-to-fact reasoning are examined. Insertion of contrary-to-fact premises into fantasy contexts increases the frequency of acceptance of contrary-to-fact premises on the MP form (Dias & Harris, 1988, 1990; Markovits & Vachon, 1989) but also results in decreases in the production of uncertainty responses to empirically true premises (Markovits, 1995; Markovits et al., 1996). Similarly, Janveau-Brennan and Markovits (1999) found that individual differences in retrieval efficiency correlated with both an increase in uncertainty responses to the AC and DA forms (which indicates increased retrieval of alternative antecedents) and an increase in the tendency to deny the MP inference (which indicates increased retrieval of disabling conditions).

Second, there is evidence that the effect of logical instructions can be negated by subsequent retrieval demands. Vadeboncoeur and Markovits (1999) examined MP inferences made with causal conditionals (“If cause P, then effect Q”). They found that when strong “logical” instructions were preceded by explicit presentation of potential disabling conditions, the effect of the instructions on the rate of acceptance of the MP inference was significantly diminished. Markovits and Potvin (2001) found that when adult reasoners were asked to generate an alternative antecedent with causal conditionals, they showed strong rates of rejection of the MP inferences despite explicit instructions to suppose that the premises were true. In both cases, the effects were interpreted as consistent with the idea that information retrieval demands could interfere with the process of inhibition that allows reasoners to accept an MP inference that is contrary to their empirical knowledge.

In this article, we present two studies in which we attempted to further explore the interaction between retrieval and inhibitory processes in reasoning with premises that are not empirically true.

Study 1

In Study 1, we used the interaction between retrieval of alternative antecedents and the inferences made to the MP form that was discovered by Markovits and Potvin (2001) to examine two predictions derived from our basic analysis. Specifically, Markovits and Potvin asked reasoners to produce a potential alternative to the antecedent term following explicit instructions to suppose that the major premise was true. Markovits and Potvin gave reasoners premises such as “If a rock is thrown at a window, the window will break” and asked them to produce another possible
reason for a window breaking. When reasoners did so, they subsequently tended to deny the MP (and the associated MT) inference, an effect that was not attributable to either the specific information that was produced or to the request itself. Because there is generally little relation between alternative antecedents and responding to the MP form, this result was interpreted as indicating that the request to produce an alternative also resulted in simultaneous activation of the other forms of knowledge available to the reasoner, which included potential disabling conditions. Consistent with this interpretation, the results also indicated that the extent to which reasoners refused the MP inference depended on the nature of stored knowledge about the premises; that is, the effect was greater when there were more disabling conditions available.

An example might be useful to illustrate what this phenomenon entails. If reasoners are given a premise such as “If a stone is thrown at a window, the window will break” and told to suppose that this premise is true (which, of course, is not always the case empirically), then if asked what conclusion can be formulated to empirically, then if asked what conclusion can be formulated to that this premise is true (which, of course, is not always the case uniformly conclude that it is certain that “The window will break.” If, however, after being given the premise, they are asked to produce an example of something else that can break a window (e.g., “throwing a chair at a window”), then they will show a clear tendency to conclude that it is not certain that “The window will break” when told that “A stone is thrown at a window.”

Now, in this case, there is what appears to be a clear inverse relation between retrieval efficiency and the tendency to accept the MP (and MT) inference. Specifically, if reasoners deny the MP inference when asked to produce an alternative because they tend to also activate and retrieve potential disabling conditions, then one would predict that the more efficient a reasoner’s retrieval processes are, the greater will be his or her tendency to deny the logical inferences in this case. This leads to the clear prediction that older reasoners should be more susceptible to the effects of generating alternative antecedents than should younger reasoners. Specifically, it can be predicted that when asked to generate alternative antecedents, older reasoners will tend to deny the MP inference despite explicit instructions to suppose that the major premise is true to a greater extent than will younger reasoners. Examining this prediction was one of our goals in Study 1.

Our second aim in Study 1 was to examine another hypothesis related to the notion of inhibition. Specifically, it is assumed that reasoners will tend to deny the MP inference after producing an alternative antecedent because they find it difficult to re inhibit information invalidating the sufficiency of the major premise after this latter information is reactivated. If this is the case, it should be possible to “prime” the inhibition process by requiring reasoners to perform a reasoning task that also requires a similar process of inhibition. One such example is given by reasoning with empirically false premises, for example, “If an object is put into boiling water, it will become cold.” It should be noted that with these kinds of premises, we consider the “true” version to be equivalent to a strongly associated disabling condition (De Neys et al., 2002). Specifically, when given “An object is put into boiling water,” there is a strong tendency for reasoners to spontaneously retrieve “hot,” which clearly puts into doubt the major premise. In fact, young children show a spontaneous tendency to conclude that “If an object is put into boiling water, then it will become hot” (Dias & Harris, 1988; Hawkins et al., 1984). However, this tendency disappears at the beginning of adolescence (Markovits & Vachon, 1989). If, in fact, inhibition is key to responding correctly to premises that are not necessarily true “as if they were true,” then it would certainly be key when reasoning with empirically false premises. Available data allow the conclusion that both young and older adolescents are able to inhibit use of inappropriate information with these kinds of premises. Thus, presenting reasoners with a reasoning task that involves the latter kind of premise could naturally prime the inhibition process and reduce the subsequent effects of producing alternatives. Our second aim in Study 2 was thus to examine this possibility.

Finally, although the emphasis here was on performance with the MP inference, participants were also asked to respond to the other inferential forms: MT (“P implies Q; Q is false”), AC (“P implies Q; Q is true”), and DA (“P implies Q; P is false”). The general model that we are using allows some further predictions concerning these forms. First, the MT form has been found to be affected by access to disabling conditions in the same way as the MP form (e.g., Cummins et al., 1991), although the pattern of such variation is less clear (e.g., Vadeboncoeur & Markovits, 1999). Responding to the MT inference is also affected by alternative antecedents (Markovits, 1984; O’Brien & Overton, 1980). One would generally predict that the MT inference should show the same general pattern of variation as the MP inference, but given that refusal of the MT inference can be generated by both disabling information and alternative antecedents, this prediction remains less clear-cut than that for the MP inference. Second, because performance on the AC and DA forms has been shown to vary with the degree of access to alternative antecedents (and not to be affected by disabling conditions), one would predict that the proportion of uncertainty responses to these forms should increase when reasoners are asked to produce an alternative antecedent.

Method

Participants

A total of 219 participants were examined. Of those who were in the production condition, 65 were in Secondary 1 (average age = 12 years 7 months; 65 boys) and 51 were in Secondary 5 (average age = 16 years 7 months; 11 girls and 40 boys). Of the participants in the nonproduction condition, 46 were in Secondary 1 (average age = 12 years 7 months; 46 boys) and 57 were in Secondary 5 (average age = 16 years 7 months; 13 girls and 44 boys). All children were native French speakers at the same private secondary school. They were from upper-middle-class families and of ethnic European descent.

Materials

Two separate sets of materials were constructed that used the same basic reasoning problems. In the production condition, two versions of a basic test booklet were constructed. Each booklet contained a total of three sets of problems. All problems were presented in French, and the following examples are translations of the original versions.

The front page of each booklet included a request for basic demographic data (date of birth and sex) that was followed by these instructions: “For each of the following three pages, suppose that the sentence at the top of the page is true and reply to the multiple choice questions.” The first version of the test booklet presented two sets of problems using causal conditionals for which participants were asked to produce an alter-
native antecedent. On the first page, the instruction to “Suppose that it is true that” was followed by the major premise “If a window pane is struck with a stone, then the window pane will break.” Below the major premise were the following instructions, which were followed by a line on which participants were to write their response: “Other than being struck by a stone, there are other reasons that could lead to a window pane being broken. On the line below, write one of these reasons.” Following these instructions were four questions corresponding to the four logical forms, MP, AC, DA, and MT. For each question, subjects were given a choice of two possible responses. An example question follows:

If a window pane is struck with a stone, then one can say:
(a) that it is certain that the window pane will break.
(b) that one cannot be certain if the window pane will break or not.

On the second page, the instruction to “Suppose that it is true that” was followed by the major premise “If there is a snow storm, then Jean will be late for his meeting.” Below the major premise were the following instructions, followed by a line on which participants were to write their response: “Other than a snow storm, there are other reasons that could lead to Jean being late. On the line below, write one of these reasons.” Following these instructions were four questions corresponding to the four logical forms, AC, MT, MP, and DA. Note that the causal conditionals used in these two problem sets were taken from a previous study (Markovits & Potvin, 2001), where they had been shown to produce a large effect with adult reasoners.

On the third page, the instruction to “Suppose that it is true that” was followed by the contrary-to-fact major premise “If an object is placed in boiling water, then it will become cold.” Directly following this premise were four questions corresponding to the four logical forms, MP, DA, AC, and MT.

A second version of the production condition booklet was constructed in which the contrary-to-fact premise was presented first, followed by the two causal conditionals. Finally, the booklets in the nonproduction condition were constructed so that they were identical to the two in the production condition with the sole exception that participants were not asked to produce an alternative antecedent following presentation of the causal conditional premises.

Procedure

Booklets were given to entire classes, and participants were instructed to take as much time as required to answer the questions. The two versions of the production condition booklet were distributed at random within two classes of Secondary 1 students and two classes of Secondary 5 students. The two versions of the nonproduction condition booklet were distributed at random within two other classes of Secondary 1 students and two other classes of Secondary 5 students at the same school.

Results

We first examined performance in the production condition. Booklets were first examined to determine whether participants had actually responded to the request to produce an alternative antecedent to the two causal conditionals. Only those in which participants produced alternatives to both problems were retained for further analysis (9 booklets were rejected on this basis). For each of the four logical forms, the percentage of responses in which reasoners refused the invited inference was calculated. Table 1 indicates this percentage for the four logical forms for the causal conditionals and for the contrary-to-fact problem as a function of grade level and position of the contrary-to-fact problem (before or after the causal conditionals) in both the production and nonproduction conditions. Initially, performance on the causal conditionals was analyzed.

Following Conover (1980), we reperformed all analyses of variance (ANOVAs) using rank order instead of cumulative scores as dependent variables. Results were similar in all cases, so we report only the analyses using cumulative scores. For each of the four logical forms, an ANOVA was performed with number of

Table 1: Percentage of Responses to the Four Logical Forms in Which Reasoners Refused the Inference for the Causal Conditionals and the Contrary-to-Fact (CF) Problem in the Production and Nonproduction Conditions as a Function of Grade Level and Position of the CF Problem

<table>
<thead>
<tr>
<th>Grade level and position of CF problem</th>
<th>Causal conditionals</th>
<th>Contrary-to-fact</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>MP</td>
<td>MT</td>
</tr>
<tr>
<td>Production condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before (n = 32)</td>
<td>25.0</td>
<td>32.8</td>
</tr>
<tr>
<td>After (n = 31)</td>
<td>32.3</td>
<td>54.8</td>
</tr>
<tr>
<td>Secondary 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before (n = 22)</td>
<td>36.4</td>
<td>45.5</td>
</tr>
<tr>
<td>After (n = 22)</td>
<td>70.5</td>
<td>72.7</td>
</tr>
<tr>
<td>Nonproduction condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before (n = 23)</td>
<td>4.3</td>
<td>15.2</td>
</tr>
<tr>
<td>After (n = 23)</td>
<td>28.3</td>
<td>37.0</td>
</tr>
<tr>
<td>Secondary 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before (n = 30)</td>
<td>11.7</td>
<td>23.3</td>
</tr>
<tr>
<td>After (n = 27)</td>
<td>9.3</td>
<td>22.2</td>
</tr>
</tbody>
</table>

Note. MP = modus ponens; MT = modus tollens; AC = affirmation of the consequent; DA = denial of the antecedent.
refusals as the dependent variable and condition (production or nonproduction), grade level (Secondary 1 or 5) and position of the contrary-to-fact problem (before or after the causal conditional problems) as independent variables. Post hoc tests were performed using the Tukey key test with $p < .05$.

For the MP inference, the analysis indicated significant main effects of condition, $F(1, 209) = 9.69, p < .01$, and condition, $F(1, 209) = 29.96, p < .01$, and significant Condition $\times$ Grade Level, $F(1, 209) = 9.20, p < .01$, and Position $\times$ Grade Level $\times$ Condition, $F(1, 209) = 6.93, p < .01$, interactions. Overall, as expected, the MP inference was refused more often in the production condition (38.8%) than in the nonproduction condition (13.1%). As predicted, the MP inference was refused less often when the contrary-to-fact problem was presented first (19.2%) than when it was presented last (33.5%). There was no difference between the two grade levels in the rate at which the MP inference was refused in the nonproduction condition, but in the production condition, as predicted, older reasoners refused the MP inference more often (53.4%) than did younger reasoners (28.6%). Analysis of the three-way interaction indicated the following effects. In the nonproduction condition, the Secondary 1 reasoners refused the MP inference more often when the contrary-to-fact problem was presented last (28.3%) than when it was presented first (4.3%). When the contrary-to-fact problem was presented first, there was no difference. In the production condition, the older reasoners refused the MP inference more often (70.5%) than did the younger ones (32.3%) when the contrary-to-fact problem was presented last, whereas there was no difference when this latter problem was presented first.

For the MT inference, this analysis indicated significant main effects of condition, $F(1, 209) = 23.19, p < .01$, and position, $F(1, 209) = 9.70, p = .01$. There was a marginally significant Condition $\times$ Grade interaction, $F(1, 209) = 2.74, p < .10$. There were more refusals of the MT inference in the production condition (50.0%) than in the nonproduction condition (24.3%). There were fewer refusals of the MT inference when the contrary-to-fact problem preceded the causal conditionals (29.0%) than when it was given after (46.1%). The marginal interaction was consistent with older participants tending to refuse the MT inference more often than younger ones only in the production condition.

For the AC inference, there was a significant effect of condition, $F(1, 209) = 6.86, p < .01$. The AC inference was refused more often in the production condition (93.4%) than in the nonproduction condition (84.0%).

For the DA inference, there was a significant effect of condition, $F(1, 209) = 113.59, p < .01$. The DA inference was refused more often in the production condition (89.7%) than in the nonproduction condition (47.6%).

Performance on the contrary-to-fact problem was examined next. For each of the four logical forms, an ANOVA was performed with the number of correct responses as the dependent variable and condition (production or nonproduction), grade level (Secondary 1 or 5) and position of the contrary-to-fact problem (before or after) as independent variables. There were no significant effects for the MP, AC, and DA inferences. For the MT inference, there was a significant effect of condition, $F(1, 209) = 10.65, p < .01$, and a significant Condition $\times$ Grade interaction, $F(1, 209) = 10.63, p < .01$. Older reasoners refused the MT inference more often in the production condition (75.0%) than in the nonproduction condition (41.3%). No differences were observed with the younger reasoners.

**Discussion**

Overall, the results of Study 2 support the two hypotheses. First, and most strikingly, older adolescents rejected the MP inference at a much higher rate than younger adolescents when asked to produce an alternative antecedent, and this was despite specific instructions to suppose that the major premise was true (a similar, although less clear, pattern was observed in the case of the MT inference). Specifically, participants were given instructions to “suppose that it is true that” and were then presented with a causal conditional premise. Following this presentation, they were requested to produce one alternative antecedent (cause) before answering questions corresponding to the four logical forms. It is worth repeating that the type of information that was produced by the reasoners in this study (alternative antecedents) has not been shown to have any effect on the nature of the MP inferences made by reasoners (e.g., Cummins, 1995; Markovits & Vachon, 1990) but has been shown to affect only the AC and DA forms. Despite this fact, older adolescents showed a strong tendency to reject the MP inference after producing an alternative antecedent (with 70% doing so when the causal conditionals were not preceded by the contrary-to-fact problem). In contrast, younger adolescents rejected the MP inference in the same conditions at a lower rate (with about 32% doing so when the causal conditionals were not preceded by the contrary-to-fact problem). Examination of the performance of students who were given the same causal conditionals without being asked to produce an alternative antecedent shows that the MP inference was uniformly made at a high rate, with 90% of Secondary 5 students doing so.

Our first hypothesis was that older adolescents would reject the MP inferences more frequently than would younger ones in this particular situation, because the older reasoners would have more efficient retrieval processes than the younger reasoners. Thus, the probability that a reasoner would activate a potential disabling condition when retrieving an alternative antecedent, one that would lead him or her to put into doubt the major premise, should be lower for younger adolescents than for older ones. These results are indeed consistent with this idea.

The second hypothesis examined here was that presenting a contrary-to-fact problem before the causal conditionals (when an alternative antecedent was asked for) would increase reasoners’ tendency to inhibit use of information that would put into doubt the major premise. Indeed, as hypothesized, responding to a contrary-to-fact problem initially greatly decreased the tendency to reject the MP inference with causal conditionals when also generating an alternative antecedent (this was also the case for the MT inference).

One potential alternative explanation for these results is that asking reasoners to produce an alternative antecedent simply primed them to put into doubt the specific task instructions for a variety of reasons and that older reasoners might be more susceptible to such pragmatic effects. The effects of the contrary-to-fact task can be seen in a similar light, because it might be claimed that they act to undo whatever pragmatic effect was induced by the production condition. However, in judging the potential of any such explanation, the specific results found by Markovits and
Potvin (2001) must be considered. These results showed that asking reasoners to produce information other than alternative antecedents had no effect on acceptance of the MP premise. In addition, presenting an explicit alternative antecedent had little effect on MP responding (see also Rumain, Connell, & Braine, 1983), whereas having reasoners produce the same alternative generated a strong effect on MP responding. Finally, and most convincingly, the extent of the effect depends on the relative numbers of available disabling conditions (the items used here were chosen from those having the greatest effect). Thus, in the case of premises for which it is difficult to think of conditions in which the major premise is not true, producing an alternative antecedent has little effect on MP acceptance rates. The sum of these results makes it difficult to imagine that the effect of the production condition on MP inferences can be explained by any mechanism that does not involve retrieval of information that might falsify the premise.

One final effect is worth noting in this context. Presenting a contrary-to-fact problem before reasoning problems with causal conditionals decreased the effects of producing alternate antecedents, as predicted. However, it also decreased the tendency for younger reasoners to reject the MP inference with causal conditionals in the nonproduction condition (older reasoners accepted the MP inference at a high rate in this condition). Given that the tendency to reject the MP inference when reasoning with causal conditionals with standard instructions appears to be clearly related to the retrieval of potential disabling conditions, this finding provides more evidence of the implication of inhibition in the effect of contrary-to-fact reasoning.

Thus, although there is no way to completely eliminate alternative hypotheses about the mechanism in play in this basic effect, both existing evidence and the current results are consistent with the idea that reasoning with premises for which there is evidence that puts into doubt the sufficiency of the antecedent to cause the consequent involves an interaction between retrieval and inhibition of information.

Study 2

The results of Study 1, along with those of others that have been previously discussed, provide evidence that is consistent with the idea that reasoning with concrete premises that are not empirically true requires an interaction between inhibition and retrieval of a reasoner’s knowledge about the premises. In this second study, we examined this idea by looking at the relation between individual differences in inhibition and reasoning with empirically false premises in primary school children. We chose this age level because previous studies indicated that children at this age spontaneously tend to make inferences to contrary-to-fact premises that clearly indicate use of empirical knowledge even when given explicit instructions to suppose that these premises are true (Markovits & Vachon, 1989). To examine individual differences in speed of retrieval and inhibition processes, we used an adaptation of the negative priming task designed by Tipper and colleagues (Tipper, 1985; Tipper & Cranston, 1985; Tipper & McLaren, 1990; Tipper, Weaver, & Kirkpatrick, 1991). In this task, two letters of different colors are presented simultaneously on a screen, and the participants are asked to name the letter of one color as fast as possible. In some trials, the letter that was ignored on the previous trial is used as the target. This task can be used to provide two separate indices of individual differences. The first is the mean reaction time required to name a new letter; the second is the mean reaction time to name a previously ignored letter. The first reaction time can be used to provide an estimate of average processing speed in this task. The ratio of the two reaction times provides an estimate of the relative impact of inhibition on processing speed, with a higher ratio indicating a greater relative effect of previously inhibited information on current processing.

Our overall premise is that there is a trade-off between inhibition and retrieval processes in reasoning with premises that are false. Our basic hypothesis is that reasoners who are asked to suppose that false premises are true will attempt to inhibit real-world knowledge that contradicts this supposition. One of the criteria for successfully doing so during reasoning requires the ability not to be affected by previously inhibited real-world knowledge when making a specific inference. Thus, reasoners whose current processing is relatively more affected by previously inhibited information would be expected to be more prone to use their real-world knowledge that the major premise is false when making inferences with false premises. Specifically, we predicted that there should be a positive correlation between (a) the ratio of reaction times to ignored and new letters and (b) the number of inferences that reasoners gave that indicated use of this real-world knowledge despite task instructions. We can, in fact, make a somewhat larger prediction. The evidence that was previously cited suggests that, at least for children, the effects of inhibition are not well targeted. This evidence suggests that younger reasoners who are more able to successfully inhibit the use of information about the premises will tend not to access either (a) information that suggests that the major premise is not (always) true or (b) information that suggests alternative antecedents when making inferences. Inhibition of these two classes of information should thus produce a strong tendency to accept all four of the conditional inferences. This leads to the prediction that there should be a negative correlation between the ratio of reaction times to ignored and new letters and the overall number of responses that are consistent with a biconditional response (which are inferences that would be made if the premise took the form “If, and only if, P, then Q”).

Method

Participants

A total of 82 participants were examined. Of these, 45 were in Grade 4 (average age = 9 years 11 months; 22 boys and 23 girls) and 37 were in Grade 6 (average age = 11 years 8 months; 22 boys and 15 girls). All children were native French speakers at an elementary school outside of Montreal. Children were from middle-class families and of ethnic European descent.

Materials

Conditional reasoning questionnaire. A test booklet was constructed containing a total of four problem sets. All problems were presented in French, and the following examples are translations of the original versions.

The front page of each booklet included a request for basic demographic data (date of birth and sex) followed by these instructions: “For each of the
following four pages, suppose that the sentence at the top of the page is true and reply to the multiple choice questions.

On the first page, the instruction to “Suppose that it is true that” was followed by the contrary-to-fact major premise “If a car has lots of gas, then the car will not run.” Following this premise were four questions corresponding to the four logical forms, MP, AC, DA, and MT. For each question, participants were given a choice of three possible responses. An example question follows:

If a car has lots of gas, then one can say:
(a) that it is certain that the car will run.
(b) that it is certain that the car will not run.
(c) that one cannot be certain if the car will run or not.

On the second page, the instruction to “Suppose that it is true that” was followed by the contrary-to-fact major premise “If it rains, then the street will be dry.” Following this premise were four questions corresponding to the four logical forms, AC, MT, MP, and DA.

On the third page, the instruction to “Suppose that it is true that” was followed by the contrary-to-fact major premise “If an object is placed in boiling water, then it will become cold.” Directly following this premise were four questions corresponding to the four logical forms, MP, DA, AC, and MT.

Finally, on the fourth page, the instruction to “Suppose that it is true that” was followed by the contrary-to-fact major premise “If a window is hit with a feather, then the window will break.” Directly following this premise were four questions corresponding to the four logical forms, DA, MP, AC, and MT.

Negative priming task. Participants faced a computer screen. On the screen were presented a series of trials. On each trial, two capital letters were presented in the center of the screen; there were 3 cm between the two letters, and the letter on the right was placed 2 cm higher than the letter on the left. One of the letters was red, and the other was green. Between trials, a series of asterisks was presented in place of the letters. The letters were presented on screen for 2 s, and the intertrial interval was 1 s. An audible beep was played at the beginning of the trial period. Task instructions asked participants to verbally name the red letter on each trial as rapidly as possible. Thus the red letters were targets, and the green letters were always distractors.

A total of 10 letters, divided into two subgroups, were used as stimuli: A, X, Y, H, E and B, G, F, O, U. There were a total of 150 trials. Each trial presented one letter from each of the two subgroups. Each individual letter was presented as the target (red) letter 15 times and as the distractor (green) letter 15 times. Each letter was paired six times with each of the five letters of the other subgroup. The position of the target (red) letter was varied randomly across the 150 trials. Over the 150 trials, 25 trials used a target letter that had been presented as a distractor in the previous trial. These trials were randomly distributed across the total trials.

The trials were presented in blocks of 10. After each block of 10 trials, participants were given a short rest period of approximately 10 s before starting on the next block. A tape recording was made of each trial. The recordings were transferred onto a computer and analyzed by a sound manipulation program. Using this program, we calculated the time between the beep that was used to mark the beginning of a trial and the beginning of the wave-form that corresponded to the verbal response. This method allowed judgments accurate to about 50 ms.

Procedure

Half of the participants received the reasoning questionnaire first followed by the negative priming task; for the other half, the order of the two tasks was reversed. The reasoning questionnaire was given out to entire classes. Participants were instructed to read the questions carefully. No time limit was imposed. For the priming task, participants were taken individually by an experimenter to a small room close by, where the experimenter explained the task requirements. Each session took about 10 min to complete.

Results

For the negative priming task, the response latencies for all the items were determined. We calculated three indices for this task. The first was the mean reaction time for the 125 target letters that had not been presented in the previous trial as either targets or distractors. This index provided a measure of the mean reaction speed of a given participant. The second was the mean reaction time for the 25 target letters that had been used as distractors in the previous trials. This index provided a measure of the mean speed with which a participant could recognize a previously inhibited letter. The third index was the ratio between these two reaction times, that is, the mean reaction time for a previously inhibited target divided by the mean reaction time for a new target. This index provided a measure of the relative effect of inhibition for a given participant. These indices are shown in Table 2 as a function of grade level and task order.

Preliminary analyses of the data suggested the existence of a strong order effect. We then examined performance on the negative priming task as a function of task order and grade level. An ANOVA with grade and task order (priming first or reasoning first) as independent variables and mean reaction time for new letters as the dependent variable was performed. This analysis indicated significant effects of task order, F(1, 81) = 12.76, p < .01, and grade, F(1, 81) = 13.20, p < .01, and a significant Task Order × Grade interaction, F(1, 81) = 5.27, p < .03. Post hoc analyses were performed using the Tukey test with p = .05. These indicated that overall reaction time was significantly faster for older than for younger children. Overall reaction time was also significantly faster when the reasoning task was given first. Finally, the age difference in reaction times was significant only when the priming task was given first. As can be seen from Table 3, the pattern of results for mean reaction times for previously ignored letters was quite similar to that for the overall means. Finally, analysis of the ratio of mean reaction times for ignored

<table>
<thead>
<tr>
<th>Task order</th>
<th>Reaction time (in ms)</th>
<th>Ratio of RTs (ignored/new)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New letters</td>
<td>Ignored letters</td>
<td></td>
</tr>
<tr>
<td>Priming first (n = 23)</td>
<td>752</td>
<td>758</td>
</tr>
<tr>
<td>Reasoning first (n = 22)</td>
<td>664</td>
<td>676</td>
</tr>
</tbody>
</table>

Table 2 Mean Reaction Times (RTs) for New Letters and Previously Ignored Letters and the Ratio Between These Two in the Priming Task by Grade and Task Order
letters to mean reaction times for new letters showed no influence of either grade or task order.

A second analysis was then performed that looked at the reasoning task as a function of grade and task order. In order to simplify this analysis, we calculated three overall indices. First, we calculated the number of inferences that clearly indicated use of real-world knowledge that P did not lead to Q (referred to as inversion responses, Markovits & Vachon, 1989). Reasoning such as “Suppose that if a rock is thrown at a window, the window will not break. A rock is thrown at a window. It can be concluded that the window will break.” is an example of an inversion response. We then calculated the mean number of such responses across all of the four logical forms (out of a total of 16 total responses). In addition, we also calculated the mean number of uncertainty responses given to the AC and DA forms. These correspond to reasoning of the following kind: “Suppose that if a rock is thrown at a window, the window will not break. A window is not broken. It can be concluded that it is not certain whether or not a rock was thrown.” We then calculated the mean number of such responses across the AC and DA logical forms (out of a total of 8 total responses). Finally, we calculated the mean number of times (out of a total of 16) that reasoners accepted the implied inference combined across all of the four logical forms (referred to as biconditional responses). These correspond to reasoning of the following kind: “Suppose that if a rock is thrown at a window, the window will not break. A window is not broken. It can be concluded that a rock was thrown at a window.” These means are shown in Table 3. Note that uncertainty responses to the MP and MT forms are not included in any of these response types.

An initial analysis looked at the numbers of inversion responses. An ANOVA with the numbers of such responses as the dependent variable and grade and task order as independent variables was performed. This analysis indicated a significant effect of task order, $F(1, 81) = 3.99, p < .05$. No other effects were significant.

Post hoc analysis showed that more inversion responses were produced when the priming task was given first. The same pattern was found for uncertainty responses, whereas the opposite pattern (a decrease when priming was presented first) was found for biconditional responses.

Finally, we looked at the relation between individual differences on the priming task and performance on the reasoning task. Because the reasoning task was strongly affected by task order and there were no significant age differences in the reasoning task measures, we looked at correlations for the two task orders separately but combined across grades. Table 4 presents these correlations. As can be seen from this table, when the reasoning task was presented first, there was no relation between priming task performance and reasoning. However, when the priming task was presented first, then, as predicted, there were strong positive correlations between the ratio of old to new letters and the relative numbers of inversion responses, and there was a strong negative correlation between this ratio and the relative number of biconditional responses. To examine whether these correlations were driven by a limited subset of participants, we examined them for each of the two age levels separately. For younger and older participants receiving the inhibition task first, correlations between the ratio of old to new letters and both the relative numbers of biconditional responses, $r(21) = -.38, p = .07$ for Grade 4 and $r(12) = -.48, p = .08$ for Grade 6, and the relative numbers of inversion responses, $r(21) = -.40, p = .06$ for Grade 4 and $r(12) = -.34, ns$ for Grade 6, showed a similar pattern, although the significance levels were only marginal because of the comparatively few participants in each group. For younger and older participants receiving the inhibition task first, correlations between the ratio of old to new letters and both the relative numbers of biconditional responses, $r(20) = -.01, ns$ for Grade 4 and $r(21) = -.09, ns$ for Grade 6, and the relative numbers of inversion responses, $r(20) = -.05, p = .06$ for Grade 4 and $r(21) = .08, ns$ for Grade 6, also showed a very similar pattern.

To provide a more global analysis of this pattern, we used regression analyses to examine each variable. We first performed a stepwise regression analysis with the number of inversion responses as the dependent variable and including grade level, order, ratio of old to new letters, and the Order x Ratio interaction. We used a natural log transformation of the ratio score in order to adjust for lack of normality. The resulting model included order, ratio, and the Order x Ratio interaction and accounted for 10% of the variance. The best single predictor was order, which contributed 4% of explained variance, $F(1, 78) = 3.46, p < .07$. The ratio

Table 3

<table>
<thead>
<tr>
<th>Task order</th>
<th>Inversion (max = 16)</th>
<th>Uncertainty (max = 8)</th>
<th>Biconditional (max = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priming first</td>
<td>4.65</td>
<td>1.56</td>
<td>7.96</td>
</tr>
<tr>
<td>Reasoning first</td>
<td>3.45</td>
<td>1.32</td>
<td>10.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade 6</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Priming first</td>
<td>5.93</td>
<td>1.86</td>
<td>6.93</td>
</tr>
<tr>
<td>Reasoning first</td>
<td>3.30</td>
<td>0.74</td>
<td>11.43</td>
</tr>
</tbody>
</table>

Note. max = maximum.

Table 4

<table>
<thead>
<tr>
<th>Priming</th>
<th>Inversion</th>
<th>Uncertainty</th>
<th>Biconditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT, new letters</td>
<td>-.15</td>
<td>-.11</td>
<td>.11</td>
</tr>
<tr>
<td>RT, ignored letters</td>
<td>.20</td>
<td>.16</td>
<td>-.27</td>
</tr>
<tr>
<td>RT(ignored)/RT(new)</td>
<td>.37*</td>
<td>.28</td>
<td>-.41**</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reasoning</th>
<th>Inversion</th>
<th>Uncertainty</th>
<th>Biconditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT, new letters</td>
<td>-.02</td>
<td>-.01</td>
<td>.01</td>
</tr>
<tr>
<td>RT, ignored letters</td>
<td>-.02</td>
<td>.09</td>
<td>-.04</td>
</tr>
<tr>
<td>RT(ignored)/RT(new)</td>
<td>-.00</td>
<td>.12</td>
<td>-.06</td>
</tr>
</tbody>
</table>

Note. RT = reaction time.
*p < .05. **p < .01.
term accounted for a marginally significant proportion of the remaining variance, $F(1, 78) = 2.07, p = .15$, as did the Ratio × Order term, $F(1, 78) = 2.38, p = .13$. We then ran the same regression with the biconditional responses as the independent variable. The resulting model included order, ratio, and the Order × Ratio interaction and accounted for 16% of the variance. The best single predictor was order, which contributed 8% of explained variance, $F(1, 78) = 7.06, p < .01$. The ratio term also accounted for a significant proportion of the remaining variance, $F(1, 78) = 4.07, p < .05$, and there was a marginally significant contribution of the Ratio × Order term, $F(1, 78) = 2.17, p = .14$.

Discussion

The results of Study 2 present a complex and, in certain respects, surprising pattern. The most striking result is the strong effect of task order. When the reasoning task was presented first, the children examined here responded more rapidly to the priming task, they produced fewer inversion errors on the reasoning questions, they produced fewer uncertainty responses to the AC and DA forms, and conversely, they accepted the implied conclusion to the four logical forms much more often. When the priming task was presented first, children responded less rapidly to the priming task, they produced more inversion errors, they produced more uncertainty responses to the AC and DA forms, and they accepted the implied conclusion to the four logical forms less often. This interaction between the two tasks is particularly surprising because they appear to involve different kinds of processing. The priming task requires simple identification of a letter with a given color, whereas the reasoning task is usually acknowledged to require some fairly complex level of semantic processing.

Despite this surface difference, there is in fact an important similarity in the ways that participants performed on the two tasks. When participants were given the contrary-to-fact reasoning task first, with its attendant instructions, they produced fewer inversion and uncertainty responses and, concomitantly, more biconditional responses. In other words, they generally accessed their available information about the premises less often, whether this concerned potential alternatives to the antecedent (which would produce uncertainty responses) or the empirically believable relationship between the antecedent and consequent terms (which would produce inversion responses) in these problems. One straightforward way of characterizing participants’ responses to the reasoning problems in this condition is to say that they tended to process task information in a surface way, which implies a fairly rapid form of processing that reduces access to associated semantic information. This is in turn consistent with order effects on the priming task. The results show clearly that when the priming task follows the contrary-to-fact reasoning task, participants take less time to correctly identify both the new and the previously ignored letters (whereas the ratio between these times is not affected by task order). In other words, they perform the identification task in a more rapid way, which would again suppose a more surface form of processing of task stimuli than that used in the opposite order. Thus one way of understanding the interaction effect is to suppose that the effect of receiving the contrary-to-fact task first is to generally limit processing of task stimuli to a more surface level, thus reducing access to associated information. This is of course consistent with our basic hypothesis that task instructions to “sup-
information at a more surface level with reduced access to associated semantic information. Thus, participants who received the logical task first would be using surface-level processing to a relatively great extent, thus reducing the effects of individual differences. However, in the other condition, processing occurs at a deeper level, thus allowing generally greater access to associated information. It is in this condition that there is a correlation between reactions to inhibited stimuli in the priming task and reasoning. Furthermore, what the observed correlations show is that when semantic processing becomes more generalized, it is those participants who can process previously inhibited stimuli at a relatively faster rate who produce the fewest inversion responses and the most biconditional responses. Thus, the patterns of individual correlations found mirror the patterns observed in the order effects.

Conclusion

One of the most clear-cut results of many recent studies that have examined conditional reasoning in both children and adults is that inferential reasoning is subject to very large content-related effects (Cummins, 1995; Cummins et al., 1991; Janveau-Brennan & Markovits, 1999; Markovits et al., 1998; Markovits & Vachon, 1990; O’Brien et al., 1986; Quinn & Markovits, 1998; Thompson, 1994). Some recent accounts of the cognitive processes that are involved in such reasoning have placed a corresponding emphasis on the way that information about premises is retrieved during reasoning (Markovits & Barrouillet, 2002; Oakford et al., 2000). However, whereas it does seem clear that reasoning is affected by access to knowledge that is related to premises, it is also true that reasoners can often reason “logically” with premises that are not believable when given specific instructions to do so, although even educated adults find this difficult to do at least in some circumstances (Markovits & Potvin, 2001). In these two studies, we have presented evidence that is consistent with the idea that inhibition of potentially activated information is a complementary process that can explain what underlies the ability to “suppose that the premises are true” when these premises are known by the reasoner to be not necessarily true.

This analysis also points out one of the major cognitive difficulties inherent in such contrary-to-fact reasoning. This is the fact that inhibition and retrieval processes are partially antagonistic. Thus, one of the difficulties in reasoning with premises that are not empirically true consists of selectively inhibiting access to empirical knowledge that puts into doubt the sufficiency of the major premise while allowing access to other forms of information such as potential alternative antecedents. The results of Study 2 are particularly eloquent with respect to this difficulty, showing the clear interaction between global inhibitory processes and retrieval processes, as are related results concerning the effects of context on reasoning (e.g., Markovits et al., 1996). The interaction between these processes can in turn explain what appear to be paradoxical developmental results. Very young children can, with some help, reason with contrary-to-fact premises as if these were true (Dias & Harris, 1988; Leevers & Harris, 1999; Markovits & Vachon, 1989). The evidence from the present studies, and others, strongly suggests that this is done by global inhibition of access to information about the premises, which allows children to make appropriate direct inferences but also restricts their ability to make more complex inferences that depend on other kinds of information. Older reasoners are able to more easily retrieve greater amounts of information, which in turn requires the ability to selectively coordinate inhibition and retrieval processes so as to inhibit use of inappropriate information while enabling access to useful information. This coordination is clearly difficult and is both at the heart of the development of the ability to reason “logically” with premises that are not always true “as if they were true” and the source of the problems that adults sometimes have in reasoning this way.

The measure of inhibition used in the second study involved fairly low-level processing that did not involve explicit instructions. In fact, there is no reason that the participants would even have been aware of the nature of the conflict raised by the negative priming task. This fact, combined with the fairly undifferentiated nature of the inhibitory process at this age, in turn suggests that individual differences in inhibition are due to some basic characteristics of the cognitive system. However, it is also the case that older reasoners are more focused when asked to reason with false premises and are more aware of the exact nature of their reasoning. This would imply some role for explicit learning in acquiring an ability to inhibit only irrelevant information while retaining access to information that is required by the reasoning task. An interesting task for future research would be to examine the interaction between basic differences in inhibition that reflect the cognitive system and the subsequent effects of education on reasoning abilities.

In a more general sense, the model of conditional reasoning that we present both fits with and complements recent views of reasoning in general. There is increasing evidence for the usefulness of distinguishing between two modes of reasoning, one that is associative in nature and relies on rapid access to stored processes and information and a second one that is more explicit and relies on more rule-based, and conscious, processing (e.g., Evans & Over, 1996; Sloman, 1996). Although the details of these dual process models may vary, they share the idea that in a variety of forms of reasoning, there are processes that are primed to use fairly automatic retrieval mechanisms in order to provide rapid access to stored information, whereas other processes require some form of explicit computation. There is a basic antagonism between the two systems, because the associative system generates responses fairly automatically, and often these responses are incompatible with the more normative responses generated by the explicit system. There is in fact a great deal of empirical data from a variety of sources (see Sloman, 1996, for a summary) showing that people will often reason in ways that clearly reflect the way that information is accessed by the retrieval system (e.g., by similarity, by relative frequency). The results of both of the two studies presented here and of the many others previously mentioned are clearly consistent with the view that conditional reasoning with concrete premises is subject to precisely the kinds of retrieval processes that are assumed to underlie associative processing in general. However, what the present model suggests is that increasingly selective inhibitory processes may underlie the development of any associative system and that these could allow increasingly complex (and more normative) processing without recourse to any explicit rules or abstract concepts.
References


Received October 22, 2002
Revision received May 8, 2003
Accepted May 15, 2003

RETRIEVAL, INHIBITION, AND REASONING 975