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Original Article

Rethinking relevance: Repetition priming reveals the psychological reality of adaptive specializations for reasoning

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ABSTRACT

Theories advanced to explain conditional reasoning range from those that invoke inference systems that evolved for specific domains (such as social exchange, precautions, or deontic regulations) to relevance theory, a relatively domain-general account that invokes conversational pragmatics. The present research utilized a novel extension of repetition priming, in conjunction with the Wason selection task (a widely known and used task to test people's conditional reasoning), to evaluate alternative theories of human reasoning. Across five experiments, testing over 600 participants, consistent priming across selection tasks was demonstrated. The pattern of priming effects supports models of human reasoning based on specific evolved reasoning abilities, and was inconsistent with general conditional reasoning models such as relevance theory. These results also converge with neurological and clinical evidence of divided psychological processes for reasoning about relatively specific domains, based on functionally distinct inference systems.

1. Introduction

Does the human mind include cognitive adaptations for reasoning about social exchange and precautionary rules? Evidence for this claim rests heavily on studies of conditional reasoning using the Wason selection task (see, e.g., Cosmides & Tooby, 2008, 2015; Fiddick 2004, and references therein). This evidence has been challenged by Sperber, Cara, and Girotto (1995), who argue that relevance theory provides an alternative explanation for all of these results. In their view, relevance theory "explains the selection task", with no need to invoke adaptive specializations. Is that true? We report studies with the Wason selection task that are inconsistent with relevance theory, but follow from the hypothesis that the mind has specializations for reasoning about social contracts and precautionary rules.

1.1. Theories of human reasoning and the method that produces them

One of the most widely known and commonly used research methodologies to study human reasoning today is the Wason selection task (Wason, 1968). Strictly speaking, this task tests whether people recognize that, by the rules of formal logic, a conditional rule of the form, *If P then Q*, is potentially violated by instances of *P* and *not-Q*. As part of the selection task, participants are given four cards (or, more usually, pictures of cards; see Supplemental Materials, available on the journal's website at www.ehbonline.org) with information about *P* on one side and *Q* on the other. The visible sides of the four cards contain the information *P*, *not-P*, *Q*, and *not-Q*. For example, if the conditional rule is *If the wind is blowing, it will be a cool night*, then the potential cards that could be selected would be *The wind was blowing, The wind was not blowing, It was a cool night,* and *It was not a cool night.* Participants are asked to indicate the cards, and only those cards, that are necessary to check for violations of the conditional rule. Typically, fewer than 25% of participants recognize that the *P* and *not-Q* cards, and only those cards, are potential violations of the conditional rule, even when the rules deal with familiar content drawn from everyday life (e.g., Manktelow & Evans, 1979; Wason, 1983).

Although originally designed to assay people's ability to test conditional rules more generally, the Wason selection task eventually became widely employed in studies focused on aspects of people's deontic reasoning (i.e., reasoning about what is socially permitted or obligated; what one *may* do or *must* do, respectively, as opposed to reasoning about material statements of fact or other contexts). This stems, in large part, from earlier "content effects" that had puzzled reasoning researchers. Whereas most participants routinely failed to solve the task correctly when given abstract conditional rules, the majority of participants typically solved it correctly when given certain versions of the

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task employing conditional obligations (e.g., Griggs & Cox, 1982). These content effects (and many novel ones) were drawn upon to support social contract theory (Cosmides, 1989) and a wide range of subsequent, evolutionary hypotheses about domain-specific, adaptive reasoning (e.g., Brown & Moore, 2000; Cummins, 1999; Fiddick, Cosmides, & Tooby, 2000; Hiraishi & Hasegawa, 2001). However, the observation that some nondeontic versions of the selection task also elicit enhanced (logical) performance led some researchers to question these proposals (Almor & Sloman, 1996; Love & Kessler, 1995; Sperber et al., 1995).

The finding that nondeontic versions of the selection task could also elicit enhanced logical performance was not actually a new finding. It had long been known, for example, that even abstract conditionals with negated consequents– *If P then NOT Q*– also tend to elicit enhanced logical performance on the selection task (Evans & Lynch, 1973). What lent weight to the newer findings of enhanced logical performance on nondeontic versions of the selection task that was relevance theory's (Sperber, Cara, & Girotto, 1995) credible, universally applicable account of high levels of logical performance on both nondeontic and deontic rules. But does relevance theory's proposed mechanism actually generalize? As it currently stands, there is actually little evidence that the proposed psychological processes operate on both deontic and nondeontic rules. Such evidence is possible to obtain using techniques such as priming methods, but those experiments have not been done to date. We undertake these studies herein. Finding that good nondeontic reasoning can prime deontic reasoning on selection tasks would be evidence supporting relevance theory's more domain-general reasoning process. On the other hand, finding that priming across selection tasks is differentially effective within narrow content types would be evidence supporting more domain-specific reasoning process.

1.2. Adaptive specializations for reasoning about evolutionarily significant domains

Toward the more domain-specific side are proposals that content effects in the selection task are due to specific abilities to reason about deontic conditionals: rules stating social regulations of what one may or must do, e.g., *If you drink alcohol, then you must be at least 21 years old* (Cheng & Holyoak, 1985; Cummins, 1996a, 1996b; Manktelow & Over, 1990, 1991). For example, Cummins (1996a, 1996b, 1999) provided an evolutionary account of such reasoning, qua deontic reasoning, that highlights the social status of interactants as an evolutionarily relevant variable. Others have proposed accounts of more narrowly specialized adaptations for reasoning about specific forms of social interaction (e.g., Brown & Moore, 2000; Cosmides, 1989; Hiraishi & Hasegawa, 2001; Thompson, Plowright, Atance, & Caza, 2015). For example, social contract theory (e.g., Cosmides, 1989; Cosmides & Tooby, 1992; Gigerenzer & Hug, 1992; Platt & Griggs, 1993) proposes that reasoning about if-then rules that have the form *If Benefit Accepted, then Requirement Satisfied* activates reasoning processes that lead people to investigate individuals who have *accepted the benefit* (to see if they failed to satisfy the requirement) and individuals who have *not satisfied the requirement* (to see if they illicitly took the benefit). In selecting the logically correct *P* and *not-Q* cards on social contract versions of the task, participants are actually choosing the adaptively correct *Benefit Accepted* and *Requirement-not-Satisfied* cards, respectively. A second, complementary proposal is that people have specific evolved abilities for reasoning about precautions (i.e., hazard management; Fiddick et al., 2000), distinct from social contract reasoning. For instance, the rule: *If you clean up spilt blood, then you must wear rubber gloves* is not plausibly interpreted as a social contract (Manktelow & Over, 1990), but in selecting the logically correct *P* and *not-Q* cards on this task, participants are focusing on adaptively significant situations of the *Hazard Exists* (spilt blood) and *not-Protected* (no gloves).

Both social contracts and precautions can be formulated as conditional permissions and obligations regulating people's behavior, stipulating what one *may* or *must* do, respectively. Hence, a common set of deontic reasoning mechanisms governing both sorts of rules has also been proposed on evolutionary grounds (Cummins, 1996a, 1996b, 1999).

Although these evolutionary proposals vary, the studies testing them with the Wason selection task have tended to follow the same methodological strategy: Construct at least two different versions of the selection task in which the formal structure of the task is held constant, while the content of a conditional rule and/or the scenario within which it is embedded is varied. The content is varied in a manner predicted to be relevant to the hypothesized psychological mechanisms. If this influences the pattern of cards that participants select, this is claimed as support for the existence of a psychological adaptation (e.g., Cosmides, 1989; Cummins, 1999).

1.3. The case for relevance theory and domain-general reasoning

A more domain-general approach claims that these content effects are better explained by factors such as conversational pragmatics (Girotto, Kemmelmeier, Sperber, & van der Henst, 2001; Love & Kessler, 1995; Sperber et al., 1995) or text processing (Almor & Sloman, 1996, 2000). Relevance theory, in particular, interprets performance on selection tasks as entirely driven by conversational pragmatics (Sperber et al., 1995). Whether or not people solve the task correctly, relevance theory argues, depends upon whether people interpret the rule employed, *If P then Q*, as precluding entities or events with the features *P and not-Q*. When the pragmatic context in which a conditional is employed induces people to represent a conditional as *There exists no [P & not-Q]* or *Instances of [P & not-Q] are forbidden*, logical performance on the selection task will increase because these forms of representation make the solution of the task (instances of *P* & *not-Q*) mentally explicit. Indeed, when *There exists no [P & not-Q]* is the most relevant interpretation of the conditional, the level of logically correct *P* & *not-Q* selections increases even when nondeontic conditionals are employed (Sperber et al., 1995).

According to relevance theory, the relevance of an interpretation is increased by the cognitive effects of a given interpretation and decreased by the cognitive effort required to derive the interpretation (Sperber & Wilson, 1986). In the case of deontic rules, the relevance of *P & not-Q* violations could be increased by reducing the cognitive effort required to explicitly represent violations; *P & not-Q* violations are already explicitly represented provided the rule is interpreted as a prohibition: *One is forbidden to P-and-(not-Q)*. The social consequences and, hence, cognitive effects, of *P & not-Q* violations are (supposedly) greater than the social consequences of rule compliance, *P & Q* (a common selection pattern on nondeontic versions of the selection task; see, however, Fiddick et al., 2000; Delton, Krasnow, Cosmides, & Tooby, 2011). However, a deeper account of the significance of rule violations compared with rule compliance is suggested by an evolutionary perspective. Monitoring and punishing violations provide negative feedback that is a more cost effective, incentive system than monitoring and rewarding compliance, which result in a less cost effective, positive feedback incentive system (Fiddick & Erlich, 2010). Hence, the main advantage of relevance theory over the evolutionary proposals is that the former potentially explains performance on both deontic and nondeontic versions of the selection task.

So far as we are aware, the only study conducted to provide positive evidence in support of the relevance theoretic account of the deontic selection task is a single experiment conducted by Girotto et al. (2001). The experiment employed a precautionary deontic rule: *If a person travels to any East African country, then that person must be immunized against cholera*. Besides the indirect evidence supplied by participants' card selections, no independent confirmation of participants' interpretations of the rule, let alone the cognitive effort and effects associated with different interpretations, was provided. Instead, Girotto et al. manipulated whether or not the rule was in effect and whether or not participants were instructed to look for violations– precisely the same sort

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of manipulation that should influence participants reasoning performance according to all the main domain-specific theories of deontic reasoning (see Gigerenzer & Hug, 1992).

1.4. Human reasoning and priming

Several people have noted that the field of human reasoning research has relied quite heavily – perhaps too heavily – on Wason selection task studies (e.g., Almor & Sloman, 1996; Sperber et al., 1995). However, these concerns have been addressed elsewhere, where the pattern of results provide further support for the more domain-specific evolutionary proposals (Fiddick, 2004; see also Farrelly & Turnbull, 2008; Fiddick et al., 2016). Certainly the use of the selection task should not be *de rigueur* to count as a study of human reasoning, yet new research should also be consistent and connect with prior work — including the selection task findings. For better or worse, the relevance theoretic challenge to evolutionary accounts of deontic reasoning has only been tested using the Wason selection task and so it is reasonable to employ the selection task yet again. However, the current set of studies adopts coordinated dual methodologies: Wason selection tasks and repetition priming across multiple versions of those tasks.

All the above theories of human reasoning and their accounts of the selection task assume that conditional rules are represented by structural forms that generalize from the specific content of the rule. For example, social contract theory proposes that the rule: *If you use the tennis court, then you must be a member of the country club*, is assigned the higher order representation: *If you accept the benefit, then must satisfy the requirement*. A deontic reasoning account would assign *If you take the action, then you must satisfy the precondition* as the higher order representation. Finally, relevance theory proposes that the rule is assigned the higher order representation: *It is forbidden to P & not-Q*. It is, therefore, conceivable to distinguish these proposals by attempting to prime the higher-order structural representations of rules and observing the pattern of performance elicited from subsequent rules.

Psycholinguistic studies have demonstrated structural priming — a "speakers' tendency to use current utterances that are similar in general form to sentences they have previously experienced" (Ferreira & Bock, 2006; Pickering & Ferreira, 2008). For example, many verb constructions are susceptible to alternation such as that between the prepositional dative: *Sam gave a present to Jane*, and the double-object dative: *Sam gave Jane a present* (Pinker, 2007). Bock and Griffin (2000) have demonstrated that this structural repetition priming can persist for upwards of a minute delay with a filler task. Hence, the potential exists to use structural repetition priming between an initial (priming) selection task and a subsequent (target) selection task. The primary difference between this phenomenon and the varying interpretations of the conditional rule in the selection task is that these alternate verb constructions are explicitly stated in the surface form of what is communicated, whereas in the selection task the alternate rule constructions are implicit.

It is precisely because the interpretations of the rule are implicit that the specific construction adopted by participants is so open to conjecture. As reviewed above, there are alternate possible interpretations of rules employed in the selection task. Relevance theory postulates that, when participants solve the task correctly, they represent the rule as precluding instances of *P & not-Q*. The various evolutionary psychological proposals suggest participants adopt an alternate, content-specific representation. Although these representations of the rule remain implicit, their existence can be inferred from the pattern of priming, or lack thereof, on selection task performance.

2. Experiment 1: is it possible to prime performance on the selection task?

An initial question is if priming across selection tasks possible. There are inconsistent indications on this matter. Cox and Griggs (1982) found that the level of logically correct performance on the apparel-color rule, *If a person is wearing blue, then the person must be over 19 years old*, increased when it followed the drinking-age rule: *If a person is drinking beer, then the person must be over 19*. The same apparel-color rule, however, elicited low levels of logically correct card selections when not preceded by the drinking-age rule. The drinking-age rule has routinely elicited high levels of logically correct performance on the selection task, and can be interpreted as a deontic rule– consistent with multiple reasoning theories. However, this result is not an unambiguously clear case of *structural* priming, because the effect may be due to surface similarities between the rules (i.e., both include "*then the person must be over 19*"). In fact, Smith, Langston, and Nisbett (1992) failed to experimentally produce priming on the selection task when surface similarities among rules are removed.

The purpose of this first experiment was therefore to determine if structural priming is possible with Cox and Griggs' apparel color problem once surface similarities are accounted for, and to determine which patterns occur in the event of any priming. Two rival hypotheses were posited:

H_1. No priming effects will occur (as in Smith et al., 1992) because the reasoning process involves the application of abstract rules that apply regardless of contents.

H_2. Priming effects will occur, such that deontic selection tasks will prime performance on further tasks that can be interpreted similarly.

Results supporting the second hypothesis would be consistent with several theoretical positions; our intent here is merely to demonstrate that bona fide *structural* priming is possible on the Wason selection task.

2.1. Participants

The participants were 88 undergraduates in a personality psychology class at a large public research university. The participants were recruited and participated during class time. An additional two undergraduates were recruited outside of the class to complete the descriptive control condition. The participants were randomly assigned in equal numbers to one of three priming conditions, which are described below.

2.2. Materials and procedure

Participants received one of three problem booklets, each consisting of three pages. The first page explained the nature of the task they would perform using a nondeontic rule as an illustrative example. The second page presented one of three possible priming problems. All three priming problems were given an anthropological framing in which participants were asked to imagine that they were an anthropologist studying the Kalama tribe. The social contract problems further highlighted the fact that the Kalama teenagers to whom the rule applied "like to go out at night, to party and visit with their friends", lending a social contract interpretation to the rules (see Supplemental Materials, available on the journal's website at www.ehbonline.org). The three possible priming problems had the following properties:

a) a social contract obligation, employing the rule: If you go out at night, then you must first milk the cow;
b) a social contract permission (also sometimes called a "switched" social contract), employing the rule: If you first milk the cow, then you can go out at night; or
c) a nondeontic descriptive, employing the rule: If a man eats cassava root, then he must have a tattoo on his face, modeled after Cosmides' (1989) non-social contract version of the cassava root problem.

The third page (target problem; see Supplemental Materials, available on the journal's website at www.ehbonline.org) contained a

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variant of the apparel color problem (Cox & Griggs, 1982), employing the rule: *If one wears a gray shirt, then one is at least 19 years old.* The target problem was not given a deontic framing. The conditional was described as a statement, as opposed to a rule, and no explanation for the statement was provided.

Numerous studies have demonstrated that permission rules, unlike obligations, elicit a logically different pattern of card selections, *not-P & Q*. By employing both an obligation and a permission prime this study can test whether participants engage in a form of simple logical/linguistic pattern matching — indicated by participants making *P & not-Q* selections on the target following the obligation and *not-P & Q* selections on the target following the permission. However, if priming is sensitive to the deontic structure of the rules, and in particular its benefit-requirement structure, then both primes should lead to enhanced levels of *P & not-Q* selections on the target problem given that *wearing a gray shirt* is more readily interpreted as a rationed benefit than *being at least 19 years old*, which is not something that can be regulated.

Although the rule employed in the descriptive scenario featured the modal verb, *must*, the scenario in which the rule was embedded gave the rule a nondeontic interpretation as an empirically based hypothesis. The same sort of scenario, employed by Cosmides (1989), has been found to elicit low levels of logically correct performance compared with scenarios in which the same rule is given a social contract interpretation (i.e., regulates access to a rationed benefit).

Participants were instructed to read the problem booklet carefully, do the problems in the order they appeared, and not review or revise their answers. Participants were allowed to complete the booklet at their own pace. Participants received no training other than initial printed instructions, no feedback about their performance, and were not told that the tasks might be related.

2.3. Results and discussion

Table 1 displays the proportion of *P & not-Q* and *not-P & Q* selections for each problem. As anticipated, participants made significantly more *P & not-Q* selections on the social contract obligation than on the descriptive problem: 47% versus 20% (X^2 (1) = 4.80, N = 60, p = .028). They also made significantly more *not-P & Q* selections on the social contract permission than on the descriptive problem: 57% versus 7% (X^2 (1) = 17.33, N = 60, $p < .0001$).

There was successful priming, as indicated by enhanced levels of logically correct performance on the target problems following the social contract problems. Moreover, the priming followed the benefit-requirement structure of the rules, as indicated by the fact that participants selected the *P* and *not-Q* cards regardless of whether they were primed by the social contract obligation or the social contract permission: 47% versus 43% of selections, X^2 (1) = 0.07, N = 60, p = .791. By contrast, only 20% of participants selected *P & not-Q* on the target problem when it followed the descriptive task. This is significantly lower than when the target followed the social contract obligation or permission (X^2 (1) = 4.80, N = 60, p = .028; X2 (1) = 3.77, N = 60, p =.052).

Of course, simply working on the initial prime problem does not ensure that the hypothesized mechanisms have been activated. Such activation is more likely to have been the case if the initial prime was solved correctly. If one analyzes the data of just those participants who correctly solved the initial prime [these proportions are reported in the rightmost columns of Table 1, *Target Problem (Corrected)*], the levels of *P & not-Q* selections on the target problems increase: moderately in the case of the social contract permission (by 10 percentage points), somewhat more for the social contract obligation (24 percentage points), and quite substantially for the descriptive problem (63 percentage points). At first glance these corrected results would appear to suggest that there is little difference between the social contracts and the descriptive problem; if either type of rule is solved correctly, the target problem likewise tends to be solved correctly, suggesting a simple logical/linguistic pattern matching. But closer consideration of the performance on the target following the social contract permission prime suggests otherwise. Instead, the wider pattern of results suggests that the minority of participants (n = 6) that solved the descriptive task correctly understood the abstract logic of the task and consequently solved the target problem as well — not because of transfer from the one task to the other, but because they understood the abstract logic of the selection task, regardless of the problem's content. This possibility will be discussed further after considering the results of the next experiment.

Table 1
Experiment 1: Proportion of P & not-Q and not-P & Q selections on both the prime and target selection tasks. (SC = social contract).

Condition	*Prime (n = 30)*	*Target Problem (n = 30)*	*Target Problem (Corrected*)*
P & Not-Q Selections			
SC obligation	.47	.47	.71 (n = 14)
SC permission	.07	.43	.53 (n = 17)
Descriptive	.20	.20	.83 (n = 6)
Not-P & Q Selections			
SC obligation	.03	.07	.00 (n = 14)
SC permission	.57	.00	.00 (n = 17)
Descriptive	.07	.03	.00 (n = 2#)

* Calculated based only on the participants that selected *P & not-Q* (*not-P & Q* for the social contract permission) on the prime problem.
\# Calculated based only on the participants that selected *not-P & Q* for the descriptive prime.

3. Experiment 2: is it possible to prime performance with the scenarios of Sperber et al.?

Having demonstrated priming of *P & not-Q* selections on the selection task when a social contract scenario is employed, can the effect be replicated with a nondeontic version of the task that nevertheless has a demonstrated potential for eliciting enhanced levels of performance? To answer this, Experiment 2 employs the Virgin-Mothers problem, which has elicited logically correct performance by 78% of participants (Sperber et al., 1995). Additionally, this experiment sought to replicate the priming effect with a precautionary scenario in order to establish whether other deontic domains can also prime performance.

Relevance theory predicts that any observed priming should be domain-general. That is, priming, should it occur, will be observed following both the Virgin-Mothers problem prime and the precautionary scenario prime, assuming that these priming problems elicit logically correct performance. The domain-specific account of precautionary reasoning advanced by Fiddick et al. (2000) predicts that priming should only occur following the precaution prime.

3.1. Participants

The participants in this study consisted of 103 undergraduates in introductory psychology courses at a large public research university, who received course credit for their participation in the study.

3.2. Materials and procedure

The procedure was the same as for Experiment 1, but with a different set of selection tasks to solve. There were two priming conditions: a relevance condition (N = 51) and a precaution condition (N = 52). Participants in both conditions worked on the same target problem, an abstract precaution.

Participants in the relevance prime condition first worked on the Virgin Mothers problem of Sperber et al. (1995). The scenario of this problem (see Supplemental Materials, available on the journal's website at www.ehbonline.org) described a secretive cult that has been accused of artificially inseminating young girls in order to create an elite of "virgin mothers". The cult leader rejects these rumors and claims that, for

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women of his sect, *if a woman has a child, she has had sex*. In the context of this scenario, that claim is most likely to be interpreted as the denial: *There exist no women who HAVE HAD A CHILD and HAVE NOT HAD SEX*. The current version of the scenario varied only slightly from Sperber et al. (1995, p. 63) in that it used the more standard 'card turning' instructions consistent with other selection tasks (the original scenario had participants imagine four cards that were all partially obscured).

Participants in the precaution prime condition first worked on a precaution problem devised by Stone, Cosmides, Tooby, Kroll, and Knight (2002), the TB problem. The scenario explained that tuberculosis (TB) is an airborne infectious disease, and doctors and nurses are therefore advised, 'If you work with patients with TB, then you have to wear a surgical mask'" (see Supplemental Materials, available on the journal's website at www.ehbonline.org). Hence the rule was precautionary in nature.

Besides the differences in their content, the Virgin-Mothers problem and the TB problem also differed in some minor, though potentially significant ways. Paralleling Sperber et al., the Virgin-Mothers conditional was never described as a rule, and participants were instructed to evaluate the truth of the cult leader's statement rather than look for violations. By contrast, the TB problem conditional was described as a rule and the instructions were to look for rule violations (see Supplemental Materials, available on the journal's website at www.ehbonline.org). Therefore, in order to not bias priming against the Virgin-Mothers problem, the framing and the instructions for the target problem more closely matched the Virgin-Mothers problem.

In both conditions, the target problem was an abstract precaution problem modeled after the abstract precaution problem of Cheng and Holyoak (1989), "If one takes dangerous action D, then one must take protective measure P"; (see Supplemental Materials, available on the journal's website at www.ehbonline.org). Unlike other precaution problems typically employed in the selection task literature, but parallel to the Virgin-Mothers problem, the conditional was described as a 'claim', not a rule, and participants were instructed to test the truth of the claim rather than look for violations. Hence, in terms of similarity in surface structure, the abstract precaution target more closely matched the Virgin-Mothers problem.

3.3. Results and discussion

Both of the priming problems produced elevated levels of correct *P & not-Q* selections, compared to those typically observed for nondeontic versions of the selection task: 47% for the relevance prime condition and 83% for the precautionary prime condition. Performance on the relevance problem was statistically lower, however, X^2 (1) = 14.36, N = 103, $p = .0001$. Therefore it will be important to control for these differences in assessing differences in the levels of priming exhibited on the target problems.

Without taking into account differences in performance on the initial prime problems, *P & not-Q* selections on the target problems were significantly lower in the relevance condition than the precaution condition: 24% versus 65% correct (X^2 (1) = 18.26, N = 103, $p < .0001$). Considering only the performance of those participants that solved the initial prime correctly (n = 24 in the relevance condition and n = 43 in the precaution condition) to correct for differences in performance on the initial prime, *P & not-Q* selections on the target problem were still lower in the relevance condition than in the precautionary condition: 29% versus 79% correct (X^2 (1) = 16.17, N = 67, $p < .0001$). That the precautionary TB scenario primed correct logical performance on the target problem substantially more than the relevant Virgin-Mothers scenario suggests that the abstract precaution target is much more similar structurally to the TB rule than the Virgin-Mothers conditional (despite the apparently greater surface similarities of these two problems).

The contrast been the raw versus corrected logical performance levels on the targets following the Virgin-Mothers prime problem in this experiment and the descriptive prime problem in Experiment 1 is striking. Eliminating the participants that failed to solve the Virgin-Mothers problem correctly only increased performance on the target problem by five percentage-points, whereas it increased performance by 63 percentage-points on the descriptive cassava root problem. One way of interpreting these differences is that, as Sperber et al. (1995) argue, participants do not truly reason their way through the Virgin-Mothers problem. They are led to the correct solution by the conversational pragmatics of the scenario and, therefore, there is no underlying psychological process that constructs a representation of the abstract structure of the rule. However, contrary to the contention of Sperber et al., this is not the case with all versions of the selection task (it doesn't seem to apply to social contract and precaution versions), nor does it apply to all participants (it doesn't seem to apply to the minority of participants who grasp the formal logic of the selection task, e.g. those who solved the descriptive problem correctly in Experiment 1). Regardless, the results clearly demonstrate that structural priming is domain-specific as predicted by Fiddick et al. (2000), but not by relevance theory.

4. Experiment 3: is it possible to prime performance with the scenarios of Girotto et al.?

One could argue that contrasting the Virgin-Mothers scenario with a precautionary scenario is not a fair comparison because the TB scenario and the abstract precaution are both deontic scenarios, whereas the Virgin-Mothers scenario is not. By this argument, logical differences between deontic and nondeontic conditionals could have made it unlikely that the structural representation assigned to the conditional in the Virgin-Mothers problem successfully generalized to the abstract precaution. This objection, however, neglects to consider that the abstract precaution target: a) was not framed as a deontic rule (c.f., true and false descriptive scenarios of Girotto et al., 2001), b) was simply described as a "claim," in parallel with the format of the conditional in the Virgin-Mothers problem, and c) was presented with instructions to test whether it was true, also in parallel with the format of the Virgin-Mothers problem. Thus, there is an equally compelling argument that the test was biased against priming in the precautionary condition.

A more specific objection could be made that the test was biased against the Virgin-Mothers problem because the content of the Virgin-Mothers scenario was not precautionary, whereas both the TB problem and the abstract precaution were. This objection, though, runs contrary to the fundamental premise of the relevance theory account. Relevance theory's basic position is that conversational pragmatics are what drive performance on the selection task, not higher order content effects. Therefore it would be contradictory to invoke higher order content effects to account for poor logical performance in the relevance condition.

Nevertheless, these concerns can be addressed by using the same deontic rule across conditions. Experiment 3 did this by employing the cholera scenarios of Girotto et al. (2001) that featured the same precautionary rule throughout: *If a person travels to any East African country, then that person must be immunized against cholera*. Despite the fact that the same rule was employed in four different scenarios, only one scenario, the true deontic condition of Girotto et al., is hypothesized by the evolutionary perspective to activate content-specialized reasoning processes. In contrast, Girotto et al. (2001) hypothesized and found that their false descriptive condition (also employing precautionary content), for which violations were highly relevant, also produced high levels of correct logical performance. Contrasting these scenarios, therefore, should be a fair test of the two accounts.

This experiment also provides the first attempted independent replication of the findings of Girotto et al. (2001). Although deontic content effects in support of the evolutionary proposals have been replicated many times, even by impartial researchers (e.g., Platt & Griggs, 1993), there have been no published replications of the findings of Girotto et al.

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4.1. Participants

The participants in this study consisted of 195 undergraduates in introductory psychology courses at a large public research university, who received course credit for their participation in the study.

4.2. Materials and procedure

The procedure was the same as that for previous experiments: participants received an initial prime problem followed by a target problem. There were four conditions: true descriptive (N = 49), true deontic (N = 49), false descriptive (N = 49), and false deontic (N = 48), which were distinguished by the type of priming problem employed. Participants in all conditions worked on the same target problem; the abstract precaution employed in Experiment 2.

Although Girotto et al. (2001) did not reprint the full scenarios used in that study, the descriptions of the scenarios were sufficient to reconstruct the four prime problems (our scenarios are given in full in the Supplemental Materials, available on the journal's website at www.ehbonline.org). Each scenario featured the same precautionary rule, *If a person travels to any East African country, then that person must be immunized against cholera* and cued participants into the perspective of a travel agent, but the framing of the rule differed across scenarios. The true descriptive scenario involves trying to convince a client that the rule is in effect and selecting cards to determine whether the statement is true. In the true deontic condition a boss confirms that the rule is in effect and card selection is to check whether or not any clients have broken the rule. The false descriptive condition involves considering travel to East Africa and suspecting that cholera immunizations are no longer required, but the boss asserts otherwise (claiming the above rule and implicitly denying that one can travel to East Africa without immunization). The card selection therefore is to determine whether or not the boss's claim is true. Finally, in the false deontic condition, the rule is discovered to be no longer in effect and so card selection is to check that none of the agency's clients are obeying the rule because they have been misinformed. Girotto et al. (2001) found elevated levels of logical performance on both the true deontic *and* false descriptive versions of the scenario.

4.3. Results and discussion

Consistent with the evolutionary perspective, only the true deontic prime displayed substantially elevated levels of *P & not-Q* selections, 59% (see Table 2). *P & not-Q* selections on the true deontic prime were significantly higher than in any other condition [vs. true descriptive, X^2 (1) = 37.66, N = 98, $p < .0001$; vs. false descriptive, X^2 (1) = 23.50, N = 98, $p < .0001$; vs. false deontic, X^2 (1) = 16.62, N = 97, $p < .0001$]. Although *P & not-Q* selections on the false descriptive prime were low– 12% correct–this was significantly higher than 2% correct found for the true descriptive prime, X^2 (1) = 3.85, N = 98, $p = .0497$.

Using correct logical performance on the target problem in the true descriptive prime condition as the benchmark, priming was only observed in the true deontic condition. In the true deontic condition, 51% of participants selected *P & not-Q* on the target problem, which was significantly greater than the 27-31% found in all other conditions [vs. true descriptive, X^2 (1) = 6.19, N = 98, $p = .013$; vs. false descriptive, X^2 (1) = 4.22, N = 98, $p = .040$; vs. false deontic, X^2 (1) = 5.83, N = 97, $p = .016$]. Performance on the target in the false descriptive condition was not significantly different than that observed in the true descriptive condition, X^2 (1) = 0.20, N = 98, $p = .655$. Even excluding participants that failed to solve the initial priming problem correctly, performance on the target in the true deontic condition, 62% *P & not-Q* selections, was substantially greater than performance in the false descriptive condition, 33% correct; however, small sample sizes in the false descriptive condition (n = 6) suggest against performing inferential analyses on the contrast.

Table 2
Experiment 3: Proportion of P & not-Q Selections.

Condition	*Prime*	*Target Problem*	*Target Problem (Corrected*)*
True Descriptive (n = 49)	.02[a]	.27[A]	1.00 (n = 1)
True Deontic (n = 49)	.59[b]	.51[B]	.62 (n = 29)
False Descriptive (n = 49)	.12[c]	.31[A]	.33 (n = 6)
False Deontic (n = 48)	.19[c]	.27[A]	.22 (n = 9)

[a b c] Proportions with different letters are significantly different from each other based on X^2 analyses.
[A B] Proportions with different letters are significantly different from each other based on X^2 analyses.
* Calculated based only on the participants that selected *P & not-Q* on the prime.

As in Experiment 2, a high-relevance selection task failed to prime *P & not-Q* selections on a subsequent target problem. Indeed, this false descriptive task–a high-relevance prime with precautionary content–itself failed to elicit elevated levels of logically correct performance. Girotto et al. (2001) reported that 47% of participants selected *P & not-Q* for the false descriptive problem in that study (compared with 62% correct on the true deontic problem). The present results offer a possible explanation for this discrepancy: The true deontic condition preceded the false descriptive problem in the study of Girotto et al., and may have primed performance on the latter. Experiment 4 was conducted to better assess the feasibility of this explanation.

5. Experiment 4: is it possible to prime performance on the false descriptive problem?

In Experiment 4, participants sequentially completed two versions of the selection task: the true deontic prime and the false descriptive prime from Experiment 3. Half worked on the true deontic problem first, and half worked on the false descriptive problem first. If the true deontic problem primes logical performance on the false descriptive problem then there should be a significant scenario × position interaction, with logical performance on the false descriptive problem increasing when it follows the true deontic problem.

5.1. Participants

The participants in this study consisted of an additional 82 undergraduates in introductory psychology courses at a large public research university, who received course credit for their participation in the study.

5.2. Materials and procedure

The procedure was the same as the preceding experiments. Each participant received two problems: the true deontic problem and the false descriptive problem (both as described earlier). Exactly half of the participants worked on the true deontic problem first and half worked on the false descriptive task first.

5.3. Results and discussion

As before, *P & not-Q* selections were significantly greater on the initial true deontic problem than the initial false descriptive problem, 51% versus 12% correct, X^2 (1) = 14.42, N = 82, $p < .001$. More importantly, answering the true deontic problem first primed performance on the false descriptive problem. Compared with the 12% of participants who selected *P & not-Q* for the false descriptive task when it appeared first, substantially more participants, 29%, selected *P & not-Q* when it followed the true deontic task, X^2 (1) = 3.64, N = 82, $p = .056$.

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The simple contrast of performance on the false descriptive task in the two conditions fails to factor in order effects. For example, logical performance on the true deontic problem actually decreased when it appeared second (39% second vs. 51% first). A better test of priming is the scenario × position interaction [i.e., (true deontic$_{first}$ − true deontic$_{second}$) − (false descriptive$_{first}$ − false descriptive$_{second}$)], which was tested with a difference of difference of proportions test (Blalock, 1972, pp. 228–230). This revealed a statistically significant interaction, $Z = 2.09$, $p = .018$.

The elevated levels of logical performance observed by Girotto et al. (2001) for the false descriptive scenario failed to replicate in both this and the previous experiment. These failures call into question the robustness of the relevance effect they propose. The present results furthermore establish that the Girotto et al. (2001) results can be explained as being due to a priming effect, produced because the false descriptive scenario followed the true deontic scenario in that study. Girotto et al. (2001) noted such a possibility and, therefore, replicated their study with a completely between-subjects design. That study reported that 77% of participants solved the true deontic problem correctly, compared with only 40% for the false descriptive task. Although Girotto et al. did not report any analysis, we will presume that this was a statistically significant difference.

The much larger differences in logical performance on the true deontic versus false descriptive problems suggest that the relevance theory account leaves the bulk of the variance in performance unexplained. However, Girotto et al. (2001) also found significantly greater levels of *P & not-Q* selections on the false *descriptive* task compared with their true *descriptive* task, which suggested that relevance theory may be a viable account of performance on *descriptive* versions of the selection task, even though it does not explain the much larger differences in performance between descriptive and deontic tasks. By contrast, the current priming results suggest that relevance theory might not have a viable account of enhanced levels of *P & not-Q* selections on even descriptive tasks. The enhanced levels of performance they observed on the false descriptive task were likely due to priming in their within-subjects study, with some participants spontaneously analogizing the problem to a true deontic scenario in the later between-subjects replication.

6. Experiment 5: can one dissociate priming by social contracts from priming by precautions?

Experiments 2–4 assumed that relevance theory predicts that participants form a representation of the conditional rule that precludes instances of *P & not-Q,* without making any distinction between whether these instances are forbidden (deontic cases) or simply denied as a factual matter (nondeontic cases). A revised version of relevance theory might argue that this is an important distinction that could result in psychologically distinct interpretations of the rules in the virgin mother problem and the abstract precaution problem in Experiment 2–especially given that the rule in the TB problem employed the modal verb, *must*, and the rule in the target problem employed the construction "have to", both of which provide lexical cues that the rules in question are to be interpreted deontically, whereas the rule in the virgin mothers problem lacked any such cues. Rather than debate the merits of this revised theory's explanation for the failure of the virgin mothers problem to prime performance on the abstract precaution prime, we report one last study addressing this possible counterargument.

This experiment uses two deontic primes, but drawn from different deontic subdomains – social exchange and hazard management – that that have been found to be neurologically dissociable (Ermer, Guerin, Cosmides, Tooby, & Miller, 2006; Fiddick, Spaminato, & Grafman, 2005; Reis, Brackett, Shamosh, Kiehl, Salovey, & Gray, 2007; Stone et al., 2002). Because social contracts and precautions, respectively, fall into the domains of different cognitive adaptations, it is predicted that social contracts will differentially prime social contracts and precautions will differentially prime precautions. However, because both social contracts and precautions are deontic rules, relevance theorists can not argue that differences in performance can be explained by the deontic/nondeontic distinction.

6.1. Participants

The participants in this study were 199 undergraduate students at Harvard University, who were either enrolled in an undergraduate anthropology class or recruited in a dining hall. The students in the anthropology class participated as part of an in-class demonstration, whereas the dining hall participants were paid a fee for their participation.

6.2. Materials and procedure

The basic procedure was the same as in the preceding experiments. Participants received one of six problem booklets containing an initial page of instructions, followed by one priming problem and ending with one target problem. The initial priming problem featured either a social contract obligation: *If a man uses cassava root, then he must have a tattoo on his face*, a social contract permission: *If a man has a tattoo on his face, then he can use cassava root* (modeled after one of Cosmides', 1989, standard and switched social contract problems, respectively), or a precautionary obligation, *If you make poison darts, then you must wear rubber gloves* (an anthropological variant of Manktelow & Over's, 1990, glove rule). The final target problem featured either an ambiguous social contract, *If one attends the festival then one is a villager*, or an ambiguous precaution, *If one empties garbage cans, then one first eats red clay* (see Supplemental Materials, available on the journal's website at www.ehbonline.org). The ambiguous target rules were designed to exclude the rival interpretation — i.e., the festival rule was designed to be difficult to interpret as a precaution (i.e., attending a festival is difficult to construe as a hazard) and the garbage rule was designed be difficult to interpret as a social contract (i.e., emptying garbage cans is difficult to construe as a benefit). At the same time, it is conceivable that attending a festival could be a rationed benefit and emptying garbage could be hazardous, but ideally these interpretations should not spontaneously come to mind; otherwise the rules would be expected to trigger the cheater-detection and hazard management mechanisms without the aid of priming. As intended, pretesting on a separate group of Harvard students showed that logical performance on the ambiguous target problems, presented alone, was low by Harvard standards (ambiguous social contract, 42% correct, N = 33; ambiguous precaution, 45% correct, N = 33; see Cosmides, 1989, for comparable performance by Harvard students on nondeontic selection tasks; see Brase, Fiddick, & Harries, 2006 on performance differences across institutions).

6.3. Results

The prime problems generally produced high levels of performance in the patterns previously found. The percent of participants selecting *P & not-Q* was 87% for the social contract obligation problem, 82% for the social contract permission problem, and 80% for the precautionary obligation problem (see Table 3 for details).

As predicted by the hypothesis that social exchange and precautions activate distinct cognitive adaptations, priming on the target problems was domain-specific. The ambiguous social contract target elicited *P & not-Q* selections from 82% of participants who first worked on the social contract obligation (SC_{obl}) and 76% of participants who first worked on the social contract permission (SC_{perm}). By contrast *P & not-Q* selections were produced by only 58% of participants who first worked on the precautionary obligation (PRE_{obl}). Conversely, the ambiguous precaution target elicited *P & not-Q* selections from 64% of participants who first worked on the precautionary obligation, compared to 48% of participants who first worked on the social contract obligation and 61% of

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participants who first worked on the social contract permission. As in Experiment 4, the target results were analyzed with two difference of difference of proportions tests [($SC_{afterSC} - SC_{afterPRE}$) − ($PRE_{afterSC} - PRE_{afterPRE}$)], one test for the social contract obligation prime and the other for the social contract permission prime. Both interactions were significant: SC obligation, $Z = 2.46$, $p = .007$; SC permission, $Z = 1.83$, $p = .034$.

Table 3 shows that the levels of *P & not-Q* selections on the priming problems were not equivalent. In order to eliminate any bias introduced by unequal performance on the initial prime, the analyses were rerun using only those participants who correctly solved the priming problem (see the columns labeled *Target Problem (Corrected)* in Table 3). This revealed two significant interactions: SC obligation, $Z = 3.14$, $p = .0008$; SC permission, $Z = 2.51$, $p = .006$. Social contracts differentially prime social contracts, and precautions differentially prime precautions.

These differential patterns of priming are consistent with neurological evidence suggesting that different regions of the brain are engaged when people reason about social contracts and precautions (Ermer et al., 2006; Fiddick, Spampinato, & Grafman, 2005; Reis et al., 2007; Stone et al., 2002), and with functional dissociations between them (Fiddick, 2004). They are difficult to reconcile with analyses of the selection task that invoke domain-general processes to account for logical performance on deontic selection tasks (Almor & Sloman, 1996; Love & Kessler, 1995; Sperber et al., 1995).

7. General discussion

The present studies have succeeded in priming reasoning about social contracts (Experiment 1) and precautions (Experiment 2). These priming effects did not correspond to patterns compatible with relevance theory (Experiments 2, 3, and 5). Moreover, in what is the first independent attempt to replicate the findings of Girotto et al. (2001) we failed to replicate enhanced performance on their false descriptive task (Experiment 3), and provided an alternative explanation for those prior results (Experiment 4), namely, repetition priming.

Could one object that we did not faithfully recreate the false descriptive task of Girotto et al. (2001) in our failure to replicate? Perhaps, but the findings with respect to the true deontic task did replicate, documenting the robustness of a deontic content effect for precautionary rules, at least when the rule is clearly in effect (a situation that was in question in the false deontic task). It has also been found that stripping out all but a bare skeleton of social contract problems leaves the deontic content effect intact (Noveck, Mercier, & Van der Henst, 2007). Thus, if the deontic content effect is robust to such heavy-handed contextual manipulations, why isn't the same true of the Girotto et al. (2001) false descriptive task? A simple explanation is that there is no dedicated inference mechanism for the situation it describes.

Table 3
Experiment 5: Proportion of Correct Selections (P & not-Q selections for obligation frames and not-P & Q selections for permission frames) on both the prime and target selection tasks (SC_{obl} = Social Contract obligation, SC_{perm} = Social Contract permission, PRE_{obl} = Precaution obligation).

Condition	*Prime*	*Target Problem*	*Target Problem (Corrected*)*
$SC_{obl\ prime} \rightarrow SC_{target}$ (n = 33)	.91	.82	.90 (n = 31)
$SC_{perm\ prime} \rightarrow SC_{target}$ (n = 33)	.79#	.76	.88 (n = 26)
$SC_{obl\ prime} \rightarrow PRE_{target}$ (n = 33)	.82	.48	.59 (n = 27)
$SC_{perm\ prime} \rightarrow PRE_{target}$ (n = 33)	.85#	.61	.68 (n = 28)
$PRE_{obl\ prime} \rightarrow SC_{target}$ (n = 33)	.88	.58	.58 (n = 29)
$PRE_{obl\ prime} \rightarrow PRE_{target}$ (n = 33)	.73	.64	.79 (n = 24)

* Calculated based only on the participants that selected *P & not-Q* on the obligation primes or *not-P & Q* on the permission primes.
\# *not-P & Q* selections.

7.1. The emerging psychology of precautions

Just as the very first selection tasks using social contract contexts were initially discovered by research that did not recognize them as such (Griggs & Cox, 1982 see also Johnson-Laird, Legrenzi, & Legrenzi, 1972), some of the first contexts that involved reasoning about precautions and hazards were highlighted by deontic reasoning theorists with no recognition of them as a separate domain (e.g., Cheng & Holyoak, 1989; Girotto et al., 1989; Manktelow & Over, 1990). Precautions and social contracts were classified as instances of a more general category, deontic rules, operated on by an unitary reasoning system. What this view fails to consider, however, is that looking for cheaters in social exchange requires different computations than looking for people in danger by virtue of not having taken precautions. Different adaptive problems, with different demands, require different evolved mechanisms to implement effective solutions. When two domains activate distinct adaptations, it should be possible create situations in which success does not generalize across problems. Producing failures to generalize requires problems that activate mutually inconsistent representations (as in Experiment 5–benefits that are not hazards, hazards that are not benefits) or inconsistent task demands (look for cheaters vs. look for those in danger; Fiddick et al, 2000; Fiddick, 2004; Cosmides, Barrett, & Tooby, 2010).

Beyond the selection task literature, the idea that domain-specific subdivisions exist within the class of deontic rules is widely accepted (Fiddick, 2004), but even in fields such as moral development (where domain-specificity is widely accepted) the study of precautions and precautionary psychology has lagged. It is in the field of abnormal psychology where several theorists have proposed a link between a domain-specific, precautionary psychology and obsessive compulsive disorder and other ritualized behavior (e.g., Abed & de Pauw, 1998; Boyer & Liénard, 2006; Cosmides & Tooby, 1999; Leckman & Mayes, 1998, 1999; Szechtman & Woody, 2004). These theories propose that obsessive compulsive disorder occurs when precautionary psychology malfunctions. The reasoning results presented here, along with converging neurological (Ermer et al., 2006; Fiddick et al., 2005; Reis et al., 2007; Stone et al., 2002) and other evidence (Fiddick, 2004), suggest that the postulation of a distinct precautionary psychology is warranted (see Fiddick, 2011, for a review).

More broadly, these results feed into a more general debate about the functional architecture of the human mind at an information processing level of description and, in particular, the issue of how domain-specific psychological mechanisms are. Even highly "domain-general" models assume some specificity: logical reasoning is distinct from statistical judgments (and from vision, language, motor movement, and so on). The present research informs a relatively discrete part of this debate: the granularity of domains within just the field of human reasoning, just using the selection task, and contrasting a handful of specifically tractable theories. It should be noted, though, that there exist other fields, other tasks, and other theories. For instance, Oaksford and Chater (1994) have applied expected utility ideas to explain some selection task results, and Gigerenzer and Gaissmaier (2011) have a different model of more domain-specific processes. These different theories can implicate different norms about what constitutes a "correct" response, and more research that systematically evaluates theory-based rival hypotheses against each other is needed.

7.2. Structural priming or inference priming?

The priming produced in the present experiments has been described as *structural* priming, comparing the deontic rules to verb constructions. But what is being primed: the structure of the conditional or a inferential procedure that operates on it? Prior evidence shows that activating the structure of a social contract does not elicit violation detection unless violations would reveal cheaters–individuals with a disposition to cheat (Cosmides et al., 2010; Gigerenzer & Hug, 1992).

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The results of Experiment 4 could be interpreted similarly: activating the structural representation of a precautionary rule does not elicit violation detection unless the search for violations would reveal people in danger. The rule in the false deontic condition in Experiment 4 (and, perhaps, the descriptive conditions) likely shared the same structural representation as that assigned to the rule in the true deontic condition. Yet the levels of *P & not-Q* selections on both the prime and the target in the false deontic condition were low. This has a natural explanation if the function of the hazard management system is to identify people in danger. In these conditions, looking for violations will not reveal people in danger because the rule is either inoperative (the hazard no longer exists) or ineffective (the vaccine no longer protects; the scenario does not specify which is the case). Indeed, the explicit instructions were to look for rule-following, not rule-breaking. Regardless, it is quite possible that something beyond the precautionary structure of the rule is required to trigger people's hazard management mechanisms in such a way that they lead to the selection of the *P & not-Q* cards; therefore, the observed priming might be better described more generally as *inference* priming.

Whether the observed priming is truly an instance of structural priming or is better described as inference priming (or as something else) is an interesting theoretical and empirical question, but it is a question for a different metatheoretical framework. If one adopts Fodor's (1983) distinction between horizontal and vertical faculty psychology, then the question of whether structural or inference priming has occurred is a question for horizontal faculty psychologists. The theory that two different adaptive specializations govern reasoning about social exchange and precautions embraces a modular view of the mind. If these vertical faculties exist, then the question of whether a rule's structure or the processes it enters into get primed is less important than the content of the rule and the specificity of the processes that it activates (i.e., is the priming domain-specific?). Simply put, vertical faculty psychology carves the mind in such a way that the question of whether structural or inference priming is implicated is not so important. Interesting as this question may be, it is left to others and future studies to resolve.

Supplementary Materials

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.evolhumbehav.2016.11.008.

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