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The Domain Specificity and Generality of Disjunctive Reasoning: Searching for a Generalizable Critical Thinking Skill

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The domain specificity and generality of an important critical thinking skill was examined by administering 9 reasoning and decision-making tasks to 125 adults. Optimal performance on all of the tasks required that disjunctive processing strategies—strategies requiring the exhaustive consideration of all of the possible states of the world—be adopted. Performance across these disjunctive reasoning tasks displayed considerable domain specificity, but 5 of the tasks displayed moderate convergence. Cognitive ability was associated with performance on only 3 of 9 tasks. Six of the 9 tasks displayed associations with 1 of 2 cognitive styles that were examined in the multivariate task battery (need for cognition and reflectivity). Performance on the 5 tasks that displayed some domain generality was also more associated with thinking styles than with cognitive ability in several regression analyses.

In an important article on the cognitive processes that underlie performance on many thinking and reasoning tasks, Shafir (1994) emphasized the importance of a fully disjunctive approach to decision-making and problem-solving situations. Shafir defined this *disjunctive reasoning skill* as the tendency to consider all possible states of the world when deciding among options or when choosing a problem solution in a reasoning task. Most decision-making situations can be thought of as disjunctions of possible states of the world. Thus, choosing optimally entails combining the probabilities of the states with the desirabilities of the outcomes under each of the decision options (Jeffrey, 1983; Savage, 1954). Many problem-solving situations can likewise be optimally evaluated by constructing all of the mental models that are consistent with the premises as presented (Johnson-Laird, 1983, 1999; Johnson-Laird & Byrne, 1991).

Despite the seeming obviousness of disjunctive reasoning as a general thinking strategy, Shafir (1994) demonstrated how, if one looks across the wide domain of reasoning tasks used in cognitive science, it is easy to find tasks in which people perform suboptimally because they do not use the strategy. Consider one of the simplest applications of the disjunctive reasoning strategy—that embodied in the sure-thing principle in Savage's (1954) seminal derivation of the axioms of expected utility theory. Imagine you are choosing between two possible outcomes, A and B, and event X is an event that may or may not occur in the future. If you prefer prospect A to prospect B if X happens and you also prefer prospect A to prospect B if X does not happen, then you definitely prefer A to B. A disjunctive consideration of the alternative states of the world (either X will occur or not) should lead to the conclusion that uncertainty about whether X will occur or not should have no bearing on your preference. Because your preference is in no way changed by knowledge of event X, you should prefer A to B whether you know anything about event X or not.

Shafir (1994) called the sure-thing principle "one of simplest and least controversial principles of rational behavior" (p. 404). Indeed, it is so simple and obvious that it hardly seems worth stating. Yet Shafir, in his article, reviewed a host of studies that have demonstrated that people do indeed violate the sure-thing principle because they do not reason disjunctively. For example, Tversky and Shafir (1992) created a scenario where individuals were asked to imagine that they were at the end of the term, tired and run down, and awaiting the grade in a course that they might fail and be forced to retake. They were to imagine that they had just been given the opportunity to purchase an extremely attractive vacation package to Hawaii at a very low price. More than half of a group of students who were informed that they had passed the exam chose to buy the vacation package. An even larger proportion of a group who had been told that they had failed the exam chose to buy the vacation package. However, only one third of a group who did not know whether they passed or failed the exam chose to purchase the vacation. What these results collectively mean is that, by inference, at least some individuals were saying, "I'll go if I pass and I'll go if I fail, but I won't go if I don't know whether I passed or failed."

Shafir (1994) described a host of decision situations where this outcome obtains. Individuals prefer A to B when event X obtains, prefer A to B when X does not obtain, but say they are undecided about A or B (or sometimes prefer B to A!) when uncertain about the outcome X—a clear violation of the sure-thing principle. These violations are not limited to toy problems or laboratory situations. Shafir provided some real-life examples, one involving the stock market just prior to the Bush–Dukakis election of 1988. Market analysts were near unanimous in their opinion that Wall Street

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preferred Bush to Dukakis. Yet subsequent to Bush's election, stock and bond prices declined, and the dollar plunged to its lowest level in 10 months. Analysts agreed that the outcome would have been worse had Dukakis been elected. Yet if the market was going to go down subsequent to the election of Bush, and if it was going to go down even further subsequent to the election of Dukakis, then why did it not go down before the election because of the absolute certainty that whatever happened (Bush or Dukakis) the outcome was bad for the market! The market seems to have violated the sure-thing principle.

Shafir (1994) described many other problems that are famous in cognitive science because people reason poorly on them, and he showed how the poor reasoning is due to the failure to reason disjunctively. These problems include prisoner's dilemmas (Rapoport & Chammah, 1965; Shafir & Tversky, 1992); framing problems (Tversky & Kahneman, 1981); Newcomb's quasi-magical thinking problem (Nozick, 1969; Shafir & Tversky, 1992); probabilistic judgment (Tversky & Kahneman, 1974); Wason's (1966) famous four-card selection task; "knights and knaves" puzzles (Rips, 1989; Smullyan, 1978); and so-called double disjunction problems (Johnson-Laird, Byrne, & Schaeken, 1992). These problems cut across many domains of cognitive science. For example, the first four come from the literature of decision theory, and the latter three come from the problem-solving and reasoning literature. Nevertheless, Shafir (1994) argued that all of the paradigms shared a common property in that they were problems in which the failure to think disjunctively spawned poor overall performance.

Shafir (1994) felt that the poor performance across these problem domains was not due to the sheer complexity of the tasks, a complexity that might strain the computational capacity of people. To counter this argument, he pointed out that

> the disjunctive scenarios reviewed in this paper were quite simple, most involving just a couple of possible disjuncts . . . . Typically, shortcomings in reasoning are attributed to quantitative limitations of human beings as processors of information . . . . Such limitations are not sufficient to account for all that is difficult about thinking. In contrast to the "frame problem" (Hayes, 1973; McCarthy & Hayes, 1969), for example, which is trivial for people but exceedingly difficult for artificial intelligence (AI), the task of thinking through disjunctions is trivial for AI (which routinely implements "tree search" and "path finding" algorithms) but is apparently quite unnatural for people. (pp. 425–426)

In the study to be reported here, we examined whether capacity limitations can explain some of the variance in the ability to think disjunctively by correlating individual differences in cognitive ability with performance across a variety of these problems (see Stanovich & West, 2000). We also explore the counterargument—more consistent with Shafir's position—that we are dealing here with something more accurately characterized as a cognitive style or thinking disposition (a "relatively stable psychological mechanism that tends to generate characteristic behavioral tendencies and tactics," Stanovich, 1999, p. 157). We examined two well-known thinking dispositions, need for cognition and reflectivity, in an attempt to see whether they could account for variance in performance on problems involving disjunctive reasoning (and specifically variance nonoverlapping with that explained by cognitive ability).

Shafir (1994) pointed out that the heart of the difficulty with disjunctive reasoning might be that it "requires people to assume momentarily as true something that may in fact be false" (p. 426). This is a theme that has been played out in the work of many different theorists, most notably Johnson-Laird (1999; Johnson-Laird & Byrne, 1991) and Evans and Over (1999). For example, in explaining how mental models work, Johnson-Laird (1999) made use of a fundamental assumption, what he termed the *principle of truth*, that "individuals minimize the load on working memory by tending to construct mental models that represent explicitly only what is true, and not what is false" (p. 116). Like Shafir, (1994), Legrenzi, Girotto, and Johnson-Laird (1993) considered the commonalities in the processing errors that occur across reasoning and decision-making tasks (in fact, they reviewed some of the same tasks as Shafir). Legrenzi et al. argued that the performance suboptimalities displayed on such tasks are due to what they term *focusing*—the fact that people restrict their reasoning to what is represented in their models. This feature of thinking, acting in concert with the principle of truth, ensures that people perform suboptimally in tasks that require a full disjunctive exploration of the alternative states of the world.

Despite these sound theoretical reasons for considering disjunctive reasoning as a global cognitive style, Shafir (1994) presented no data on individual differences to support the claim that this is the way we should view the concept. In fact, there are influential but competing traditions within which disjunctive reasoning can be conceptualized—the critical thinking literature, the contextualist tradition, and the domain-knowledge tradition—and these different theoretical traditions make different default assumptions about what an individual differences analysis reveals. For example, in the critical thinking literature, domain generality is assumed for the various thinking styles that are listed as the defining features of reflective thought. Indeed, Baron (1985b) made some degree of domain generality a defining feature of his notion of a thinking style: "Cognitive styles ought to be general. By ought I mean that evidence against the generality of a style is taken to make the style less interesting" (pp. 379–380). This view leads to an obvious individual difference prediction, that "we should expect some correlation across individuals between style in one situation and style in another, regardless of how discrepant the situations are" (Baron, 1985b, p. 380). However, whether disjunctive reasoning skills display any degree of domain generality or whether they are domain specific (and thus, under Baron's criterion, do not warrant treatment as a thinking style in the critical thinking literature) is almost completely unknown because no multivariate studies of disjunctive reasoning skill are available.

In contrast to the assumption of domain generality in the critical thinking literature, in developmental and cognitive psychology, the reigning assumption for a considerable time has been one of domain specificity. For example, the contextualist tradition within developmental psychology emphasizes the point that the exercise of cognitive skills is often quite situation specific (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Rogoff & Lave, 1984). Likewise, theorists who have emphasized the importance of domain knowledge (e.g., Alexander, Kulikowich, & Schulze, 1994; Ceci, 1993, 1996) have argued that many so-called basic cognitive processes are so dependent on familiarity with the specific stimulus domain and its context that it seems almost a misnomer to call them *basic* (see Ceci, 1996). Indeed, even within the reasoning literature, Thompson (2000) argued that "much of the variability in reasoning performance is tied to the interpretive stage, and is determined by the nature of the initial representation that is constructed" (p. 256), a representation critically determined by task–situation factors.

Thus, theorists in both the domain-knowledge tradition and the contextualist tradition of developmental–educational psychology emphasize the domain specificity of the exercise of a cognitive skill or style (for a critique of this view, see J. R. Anderson, Reder, & Simon, 1996). Such theorists question the existence of thinking styles having the generality ascribed by Baron (1985b). For example, under a contextualist conceptualization, the application of disjunctive reasoning strategies would be expected to display extreme domain specificity.

These competing theoretical traditions for conceptualizing the idea of disjunctive reasoning highlight the importance of producing empirical data that can at least partially adjudicate among the differing perspectives. In the current study we present the only attempt we know of to examine the domain generality of disjunctive reasoning as a cognitive style cutting across tasks differing widely in cognitive and response requirements. As did Shafir's (1994) review of failures in disjunctive reasoning, the tasks we examined ranged across the decision-making and problem-solving literatures—literatures that have remained separate for many years until recent attempts at theoretical integration (Evans, Over, & Manktelow, 1993; Johnson-Laird et al., 1999; Legrenzi et al., 1993; Manktelow, Sutherland, & Over, 1995; Oaksford & Chater, 1994; Reyna, 1996). The broadness of the task sampling ensured a true test of domain generality in the application of disjunctive reasoning strategies. As an aside, we point out that the notion of what constitutes a domain is a difficult one conceptually. For example, whereas Alexander et al. (1994) defined *domain* as analogous to a discipline such as science or mathematics, we use it here somewhat differently. In this article, domain becomes more similar to a problem type—specifically, the problem types associated with two different domains of reasoning (decision making and problem solving). Our use of the term *domain* is more procedural, whereas those discussed in Alexander et al. are more declarative.

We also assessed cognitive ability to determine the accuracy of Shafir's (1994) conjecture that computational limitations are a minor factor in the failure to activate the disjunctive strategy. We expected to interpret the lack of strong correlations between cognitive ability and disjunctive task performance, if they were obtained, as consistent with Shafir's conjecture. In contrast, moderate to strong correlations would be viewed as falsifying his model of task performance, which essentially discounts the effect of computational limitations in these tasks. Furthermore, we examined the relationships between two cognitive styles—need for cognition (Cacioppo, Petty, Feinstein, & Jarvis, 1996) and reflectivity (Kagan, Rosman, Day, Albert, & Phillips, 1964)—and the tendency to activate disjunctive reasoning strategies. The presence of such relationships becomes particularly interesting if disjunctive reasoning displays domain generality that is not explained by cognitive ability differences. We were able to ascertain whether the tendency to activate disjunctive reasoning strategies is best conceptualized as Baron (1985b) outlined in the passage quoted above, as a cognitive style akin to tendencies to completely engage with cognitive problems and to withhold responses until analytic processing (see Stanovich, 1999) is complete.

Method

Participants

The participants were 125 students (47 men and 78 women) recruited through poster advertisement on the campus of a large Canadian university. The average age of the participants was 22.6 years (SD = 5.5), and the modal age was 20 years. Each participant was paid $20. Two participants did not complete the prisoner's dilemma task and the disease framing task.

Design

We examined nine different disjunctive reasoning tasks. Four of the tasks were decision-making tasks, and five of the tasks were problem-solving tasks. A composite measure of cognitive ability, composed of four different tasks (two Wechsler Adult Intelligence Scale—Revised [WAIS–R; Wechsler, 1974a, 1974b] subtests, a vocabulary measure, and Raven's Matrices), was used. Two cognitive styles, need for cognition, and reflectivity, were assessed, the latter using the Matching Familiar Figures Test (MFFT; Kagan et al., 1964).

Measures

Decision-Making Tasks

Prisoner's dilemma. In the classic version of the prisoner's dilemma (e.g., Hargreaves Heap & Varoufakis, 1995; Rapoport & Chammah, 1965; Rasmusen, 1989), two players must choose to either cooperate or compete with the other player while being blind to the other's choice. The version used in our study was modeled on Shafir and Tversky (1992). The text of the problem was accompanied by a graphic that illustrated the payoff matrix for each player. The text of the problem was presented to participants as follows:

Intercollegiate Computer Game

> This game was originally designed to be played by pairs of students who were sitting in front of different computers on the same computer system. Since we are not using computers today, *please use your imagination,* and pretend that you are sitting in front of a computer and playing the Intercollegiate Computer Game with another student.
>
> In this game you will be presented with a situation involving you and one other player who is sitting at a computer in another room. You cannot communicate with each other. The situation requires that you make a strategic decision: to cooperate or to compete with the other player. The other player will have to make the same decision.
>
> The situation is represented by a payoff matrix that will determine how much money each of you earns depending on whether you compete or cooperate. [The matrix was presented here.]
>
> According to this matrix, if you both cooperate you will both earn $20 each. If you cooperate and the other person competes, the other will earn $25 and you will earn only $5. Similarly, if you compete and the other person cooperates, you will earn $25 and the other person will earn only $5. Finally, if you both choose to compete, you will each earn $10. Not knowing what the other person will choose to do, what would you choose?
>
> (a) I would choose to compete
> (b) I would choose to cooperate

Competing is the dominant action for each player in this situation because whatever the other player does, each person is better off competing than cooperating. The fact that this individually rational (dominant) action leads to an outcome that is suboptimal for both ($10, when each could have had $20 by cooperating) is what has piqued the interest of social scientists and philosophers in this problem. As Nozick (1993) put it: "The combination of (what appears to be) their individual rationalities leads them to forgo an attainable better situation and thus is Pareto-suboptimal" (p. 50). However, in the one-shot game (with no communication between players or repeated play) the compete strategy is usually championed as rational. Disjunctive consideration of each possible outcome helps the player realize that the optimal strategy is to compete in order to achieve maximal gain.

Newcomb's problem. Originally discussed by Nozick (1969), Newcomb's problem has been the subject of intense philosophical interest (Gibbard & Harper, 1978; Hurley, 1991; Nozick, 1993; see Campbell & Sowden, 1985, for a collection of useful readings). Shafir (1994) described the failure to reason disjunctively on Newcomb's problem as an instance of "quasi-magical thinking" (p. 414).

The problem we used was modeled on that used by Shafir and Tversky (1992). Participants were presented with a visual diagram of two boxes, Box A containing $20 and Box B containing $250 or no money at all. The text of the problem was presented to participants as follows:

> Here is a problem that asks you to make use of your imagination. Consider the two boxes above. Imagine Box A contains $20 for sure. Imagine that Box B may contain either $250 or nothing. Pretend your options will be to:
>
> 1. Choose both Boxes A and B (and collect the money that is in both boxes).
>
> 2. Choose Box B only (and collect only the money that is in Box B).
>
> Imagine now that we have a computer program called the "Predictor" that has analyzed the pattern of the responses you have already made to all of the earlier questions. Based on this analysis, the program has already predicted your preference for this problem and has already loaded the boxes accordingly. If, based on this analysis of your previous preferences, the program has predicted that you will take both boxes, then it has left Box B empty. On the other hand, if it has predicted that you will take only Box B, then it has already put $250 in that box. So far, the program has been very successful: Most of the participants who chose Box B received $250; in contrast, few of those who chose both boxes found $250 in Box B. Which of the above options would you choose?
>
> a) Choose both Box A and Box B.
>
> b) Choose Box B only.

The two-box consequentialist choice (see Gibbard & Harper, 1978; Hurley, 1991; Nozick, 1993) is clearly viewed as normative by most psychologists who have examined the problem (Shafir, 1994; Shafir & Tversky, 1992). This is especially true of this version, which was specifically designed by Shafir and Tversky to emphasize that the predictor's choice had already been made and to remove some seemingly supernatural elements from the original formulation of the problem (Nozick, 1969).

Disease framing problem. Failures of disjunctive reasoning are exhibited when people violate a fundamental assumption of decision theory, that of descriptive invariance: "that the preference order between prospects should not depend on the manner in which they are described" (Kahneman & Tversky, 1984, p. 343). The disease problem of Tversky and Kahneman (1981) is a classic problem in which participants sometimes do not display descriptive invariance. Instead, they display a framing effect. This problem was presented to the participants in this study. The version used was as follows:

> Problem 1. Imagine that the U.S. is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows: If Program A is adopted, 200 people will be saved. If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved. Which of the two programs would you favor, Program A or Program B?
>
> Problem 2. Imagine that the U.S. is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows: If Program C is adopted, 400 people will die. If Program D is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die. Which of the two programs would you favor, Program C or Program D?

Participants completed Problem 1 and several interposed tasks before completing Problem 2. The failure of disjunctive reasoning is exhibited when participants select alternatives A and D. This is because the two problems are redescriptions of each other, and Program A maps to Program C rather than D. This response pattern—termed in the literature a *framing effect*—thus violates descriptive invariance. Tversky and Kahneman (1981) discussed how their prospect theory can account for this violation, but their theory is beyond our scope here. We use this task only to demonstrate another type of disjunctive reasoning failure. The theory describes why participants are risk averse for gains and risk seeking for losses and are thus prone to certain types of framing effects.

Probabilistic choice task. The problem of probabilistic judgment was first studied by Shafir (1994) as an example of the failure of disjunctive reasoning in the probability domain. In the probabilistic choice task, participants were presented with a visual diagram of two boxes, Box A and Box B. The text of the problem was presented to participants as follows:

> Imagine that in front of you are two boxes. Inside each of the boxes is a ball that is equally likely to be either white, blue, or purple.
>
> You are now offered to play one of the following two games of chance:
>
> *Game 1*: You guess the color of the ball in the the left-hand box. You win 50 dollars if you were right, and nothing if you were wrong.
>
> *Game 2*: You choose to open both boxes. You win 50 dollars if the balls in the boxes are the same color, and nothing if they are different colors.
>
> Which would you prefer to play?
>
> a) Game 1
>
> b) Game 2
>
> c) no preference

In this problem, if one disjunctively considers the outcome of each game, it becomes evident that there is a 33% chance of winning either game. As Shafir (1994) noted, "to see that, one need only realize that the first box is bound to be either white, blue, or purple and that, in either case, the chances that the other will be the same color are 1/3. Notice that this reasoning incorporates the disjunctive logic of the sure-thing principle" (pp. 415–416). Therefore, participants should be indifferent about which game they choose to play, and this should lead them to select the "no preference" option.

Problem-Solving Tasks

Selection task. Originally used by Wason (1966), the abstract version of the selection task has been studied extensively in the deductive reasoning literature (e.g., Evans, Newstead, & Byrne, 1993; Evans & Over, 1996; Newstead & Evans, 1995). This problem has been studied as an instance of hypothesis testing and deductive reasoning on the basis of the logic of conditionals, but it also necessitates disjunctive strategies because one has to consider the consequences of turning each card for successful performance (Evans, Newstead, & Byrne, 1993; Johnson-Laird, 1999).

An abstract version of the problem was used in this investigation. Participants were presented with four cards and were given the following instructions:

> Each of the boxes below represents a card lying on a table. Each one of the cards has a letter on one side and a number on the other side. Here is the rule: *If a card has a vowel on its letter side, then it has an even number on its number side.* As you can see, two of the

> cards are letter-side up, and two of the cards are number-side up. Your task is to decide which card or cards must be turned over in order to find out whether or not the rule is being violated. Indicate which card or cards must be turned over by placing check marks in the appropriate places.

The cards visible to the participant were, from left to right, K, A, 8, and 5. Underneath each card was a query with two possible responses: Turn over? yes____ no____ The participant had to tick one of these choices for each of the four cards.

Because the rule is in the form of an if P, then Q rule, the participant must turn over the two cards that could potentially falsify the rule—the P and not-Q card (in this case, the A and 5 cards)—to see whether a falsifying case is present. If there is, the rule is false. If there is not, the rule is true. Typically, less than 10% of individuals make the correct selections of the P card (A) and not-Q card (5). The most common incorrect choices are the P card and the Q card (A and 8) or the selection of the P card only (A).

Knights and knaves problem. Originally from Smullyan (1978), the knights and knaves problem has been studied in the deductive reasoning literature (Johnson-Laird & Byrne, 1990; Rips, 1989). We used a slightly adapted version of the knights and knaves problem discussed by Shafir (1994):

> Imagine that there are three inhabitants of a fictitious country, A, B, and C, each of whom is a either a knight or a knave. Knights always tell the truth. Knaves always lie. Two people are said to be of the same type if they are both knights or both knaves. A and B make the following statements:
> A: B is a knave
> B: A and C are of the same type
> What is C?

A solution tree can be formulated for this problem, and such a tree leads systematically to the correct conclusion (person C can only be a knave). Nevertheless, the solution rate is low. As Shafir (1994) argued, "it is not the simple logical steps that seem to create the difficulties in this case, but rather the general, conceptual 'solution path' required to reason through a disjunction" (p. 425).

Double disjunction problem. The double disjunction problem is also taken from the deductive logic literature (Johnson-Laird et al., 1992) and has been discussed in some detail by Baron (1994) and Shafir (1994). The problem is as follows:

> Consider the following two facts:
> June is in Wales or Charles is in Scotland, but not both.
> Charles is in Scotland or Kate is in Ireland, but not both.
> What, if anything, follows from these two facts?

Participants responded by writing the conclusion that follows on a line below the problem. As Shafir (1994) noted, in order to solve this problem, one must work through both disjuncts. When the separate disjuncts are entertained, certain conclusions follow, specifically that either Charles is in Scotland or June is in Wales and Kate is in Ireland, but not both. The correct solution can be derived only by elaborating the full model (Johnson-Laird et al., 1992), that is, by considering both premises and the possible locations of each person.

Disjunctive insight Problem 1—the married problem. The married problem was borrowed from Levesque (1986, 1989) and reads as follows:

> Jack is looking at Ann but Ann is looking at George. Jack is married but George is not. Is a married person looking at an unmarried person?
> A) Yes B) No C) Cannot be determined

What Levesque defined as implicit information in this problem is analogous to what we, following Shafir (1994), have earlier discussed as fully disjunctive processing of problem components. That is, one must consider the disjuncts of Ann's marital status, which is the implicit information, in order to derive the correct conclusion. If Ann is married, then the answer is "Yes" because she would be looking at George who is unmarried. If Ann is not married, then the answer is still "Yes" because Jack, who is married, would be looking at Ann. The correct solution to this problem can be derived only by using a disjunctive strategy.

Disjunctive insight Problem 2—green blocks problem. The green blocks problem was borrowed from Levesque (1986, 1989). The text of the problem was accompanied by a graphic that displayed the five boxes and labeled the green and not green boxes as described in the text. The text of the problem was as follows:

> There are 5 blocks in a stack, where the second one from the top is green, and the fourth is not green. Is there a green block directly on top of a non-green block?
> A) Yes B) No C) Cannot be determined

As in the married problem, one must disjunctively consider the color of the third block in the stack. If the third block is green, then the answer is "Yes" because it sits directly over the fourth block which is not green. If the third block is not green, then the answer is still "Yes" because it sits directly under the second block, which is green.

Cognitive Ability Measures

Participants completed a short form of the WAIS–R (Wechsler, 1974a, 1974b). The short form consisted of the Vocabulary (verbal measure) and Block Design (nonverbal measure) subtests. Sattler (1992) reported that the combination of the Block Design and the Vocabulary subtests provides the most reliable two-subtest estimate of Full-scale IQ (with reliability of .90).

In addition to the WAIS–R subtests, one other verbal and one other nonverbal measure of cognitive ability were also formed. The verbal measure was a brief vocabulary measure using the checklist-with-foils format that has been shown to be a reliable and valid way of assessing individual differences in vocabulary knowledge (R. C. Anderson & Freebody, 1983; Cooksey & Freebody, 1987; Zimmerman, Broder, Shaughnessy, & Underwood, 1977). The stimuli for the task were 40 words and 20 pronounceable nonwords taken largely from the stimulus list of Zimmerman et al. (1977). The words and nonwords were intermixed through alphabetization. The participants were told that some of the letter strings were actual words and that others were not and that their task was to read through the list of items and to put a check mark next to those that they knew were words. Scoring on the task was determined by taking the proportion of the target items that were checked and subtracting the proportion of foils checked.

The nonverbal measure consisted of 18 items from Raven's Advanced Progressive Matrices (Set II, Raven, 1962), a task tapping analytic intelligence that is commonly viewed as a good measure of g (Carpenter, Just, & Shell, 1990). The students were given 15 min to complete the 18 items. The 12 easiest items were eliminated because performance in a college sample has been found to be near ceiling, and 6 of the most difficult problems were eliminated because performance is nearly floored (Carpenter et al., 1990; Raven, Court, & Raven, 1977). The remaining 18 items were used to achieve a cut-time version so that the Advanced Matrices would still have adequate reliability and discriminating power. A previous investigation used a 16-item version of the Standard Progressive Matrices for cut-time administration and achieved reliabilities above .75 in samples of children (Cahan & Cohen, 1989).

We formed a general cognitive ability measure. This measure was formed by summing the standardized scores of the WAIS–R Vocabulary Subtest, the WAIS–R Block Design Subtest, the Vocabulary Checklist, and the Raven's Progressive Matrices scores and then summing the standardized scores.

Need for Cognition Scale

Some research has already suggested that need for cognition is a thinking disposition that may relate to disjunctive reasoning tendencies. Specifically, Smith and Levin (1996) found that individuals who had a higher score on the 18-item Need for Cognition Scale (Cacioppo et al., 1996) were less likely to display a framing effect on problems similar to the disease framing problem described above. Sample items include "The notion of thinking abstractly is appealing to me," and "I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought."

Participants in this study completed a questionnaire consisting of a number of self-report subscales. Only the Need for Cognition Scale was analyzed in the present investigation. The items from the different subscales were randomly intermixed in the questionnaire, and the response format for each item in the questionnaire was as follows: *Strongly Agree* (6), *Moderately Agree* (5), *Slightly Agree* (4), *Slightly Disagree* (3), *Moderately Disagree* (2), and *Strongly Disagree* (1). The split-half reliability of the Need for Cognition Scale (Spearman-Brown corrected) was .79.

Reflectivity–Impulsivity: The Matching Familiar Figures Test (MFFT)

The MFFT developed by Kagan et al. (1964) was used to measure the dimension of reflectivity and impulsivity. In this task, participants were presented with a target picture of an object, and their task was to find the correct match from an array of six other pictures. Participants' latency and number of errors were measured for each choice and for each item. When participants made an incorrect selection, they were asked to select again. This was repeated until the participant found the correct match (up to a maximum of six possible responses).

The mean time to the first response for all items and the number of items on which the participant made at least one error were standardized for each participant. The standardized error metric was called $MFFT_{Errors}$ and the standardized metric for reaction time (RT) was called $MFFT_{RT}$. Then the difference between these standard scores was taken to create a variable that took into account both RT and number of errors. This variable was called $MFFT_{RT\text{-}Errors}$. However, analyses involving this composite variable indicated that $MFFT_{Errors}$ (as opposed to $MFFT_{RT}$) was doing all the work. That is, $MFFT_{RT\text{-}Errors}$ did not correlate with any variable higher than $MFFT_{Errors}$, and the correlations involving $MFFT_{RT}$ were negligible. Therefore, the $MFFT_{Errors}$ variable was used in the analyses that follow.

Procedure

Participants completed the tasks during a single 3–4 hr session in which they also completed some other tasks that were not part of the present investigation. All were individually tested by the same experimenter. The order of tasks completed was as follows: selection task, probabilistic choice problem, disjunctive insight problem 1, disease framing problem (Part 1), prisoner's dilemma, thinking dispositions questionnaire (Need for Cognition Scale), WAIS–R subtests, double disjunction problem, disease framing problem (Part 2), disjunctive insight problem 2, knights and knaves problem, Newcomb's problem, vocabulary checklist, MFFT, and Raven's Progressive Matrices.

Results

Overall Level of Disjunctive Responding Across Tasks

Our study largely replicated Shafir (1994) in finding that participants had substantial difficulty thinking disjunctively on many of these problems. However, the problems differed greatly in this respect. Table 1 displays the proportion of disjunctive responses for each of the tasks. The level of disjunctive reasoning performance varied quite widely across the different tasks (from 9% to 76%).

Table 1
Disjunctive Responses Given (in Percentages) on Each of the Tasks

Task	Responses
Decision-making task	
Prisoner's dilemma	54
Newcomb's problem	37
Framing problem	76
Probabilistic choice	24
Problem-solving task	
Selection task	46
Knights and knaves	42
Double disjunction	37
Disjunctive insight 1	13
Disjunctive insight 2	9

In cases where there was a previous literature on a problem, our results, in terms of the overall level of disjunctive responding, replicated the findings in the literature. For example, in using a prisoner's dilemma problem similar to ours, Shafir and Tversky (1992) found a substantial cooperation rate (37% of their sample). Consistent with these previous findings and with Shafir's (1994) argument that failures of disjunctive reasoning are not rare, we found that 46% of our sample (57 participants) chose the "cooperate" response. Likewise, in Newcomb's problem, 65% of Shafir and Tversky's (1992) participants preferred to take only one box (a finding replicated by Stanovich & West, 1999). Like the outcome in the Shafir and Tversky study, 63% (79 participants) of our sample made the nondisjunctive choice.

From the standpoint of disjunctive reasoning, the disease framing problem was the easiest task in our battery. The violation of descriptive invariance that defines the failure to reason disjunctively in this problem was displayed by only 21% (26 participants) of our sample. In contrast, 76% (93 participants) of the sample displayed no framing effect (they chose either A and C or B and D). A lack of a framing effect was our operational definition of disjunctive reasoning for this problem. Only 3% (4 participants) displayed a reverse framing effect (they chose B and C), and because the number making this theoretically inexplicable choice was small, they were dropped from the analyses that follow.

On the final decision-making task, the probabilistic choice problem, the participants displayed a low level of disjunctive reasoning. Only 24% ($n = 30$) of participants selected the "no preference" option—the disjunctive choice for this problem. In contrast, most participants (67%; i.e., 84 participants) selected the Game 1 option presumably because, as Shafir (1994) argued, "a certain lack of clarity about the disjunctive case may have led them to prefer the unambiguous first game" (p. 416). Only 9% (11 participants) of the sample chose the Game 2 option, and these participants were dropped from the analyses that follow.

Disjunctive responding was below 50% on all five of the problem-solving tasks. Classification of responses as disjunctive on the four-card selection task is complex. Overall, 7% of our sample answered correctly (P, not-Q). Consistent with previous research, the most common response (40% of the sample) was the so-called matching response (Evans & Lynch, 1973) of P and Q. The P-only selection was made by 17% of the sample, and 22% selected all four cards. An additional 14% of participants selected some other combination (most involving combinations including the not-P card). This distribution of responses mirrors that obtained in earlier work (Evans et al., 1993; Oaksford & Chater, 1994; Stanovich & West, 1998a). For statistical parsimony and on the basis of a theoretical rationale, we collapsed some response classes for the later statistical analyses. Specifically, we wanted to obtain a dichotomous classification (as in all the other tasks) of disjunctive and nondisjunctive responding. The selection task is complex in that numerous incorrect selections (answers other than P and not-Q) have been defended as reflecting fully analytic disjunctive processing. All of the major classes of responses that have been defended as reflecting analytic processing (see Stanovich, 1999) were included in our disjunctive category along with the correct response.

Specifically, participants who chose all four cards and participants who chose P-only were combined with the correct responders to form the disjunctive response category. (All other responses were classified as nondisjunctive.) Turning over all four cards is the correct response if the rule is read as a biconditional. Additionally, Margolis (1987) has shown that turning the P card only is an appropriate response if the participant has adopted a so-called "open" reading of the rule—one where the cards represent *classes* rather than individual exemplars. Consistent with the joint classification of the P and not-Q, P-only, and all cards responses as reflecting analytic processing, participants giving one of these three responses were higher in cognitive ability than participants giving one of the other responses (including the modal P and Q response).

In the knights and knaves problem, 42% of the sample (52 participants) gave the correct (disjunctive) response of "knave." In contrast, 49% of the sample (61 participants) selected the "cannot be determined" option, presumably an indicator that they did not reason disjunctively on the problem. This group was combined with the 10% of the sample (12 participants) who gave "knight" as a response to form the nondisjunctive response category.

As in the four-card selection task, classification of responses as disjunctive in the double disjunction problem required some theoretical presuppositions. In our sample, only 16 participants (13% of the sample) provided the fully disjunctive correct response. In the analyses that follow, which dichotomize participants into disjunctive and nondisjunctive responders, two other categories were collapsed with the correct responders to form the disjunctive reasoning group. These two categories of response required the building of mental models that, although not quite elaborate enough to generate the correct response, were more elaborated (and hence more disjunctive) than the models underlying the other responses.

The first of these two categories we termed the *partial contingency* category. It occurs when the participant works out the implications of one of the disjunctive paths but not the other—for example, when the participant draws the conclusion "If June is in Wales and Kate is in Ireland, Charles is not in Scotland" but does not explicitly state the implications when the other state of affairs is true (what follows when June is not in Wales and Kate is not in Ireland). This response required the truth values to be temporarily assigned to each disjunct in each premise, but it lacked an integration of conclusions from all states of affairs in the logical tree.

The partial contingency response is seen as a somewhat sophisticated one because as Shafir (1994) argued, it contains one of the critical steps that is often ignored in these problems: "presented with a disjunction of simple alternatives most subjects refrain from assuming the respective disjuncts and arrive at no valid conclusions" (p. 423). This response was made by 12% (15 participants) of the sample. It was collapsed into the disjunctive reasoning metacategory, as was one final response, the so-called June–Kate response: "If June is in Wales, then Kate is in Ireland." This response, although less high level than the other two, reflects some amalgamation across the two mental models (Johnson-Laird et al., 1992). That is, "June is in Wales" and "Kate is in Ireland" are separate premises, and this solution reflects some consideration of the two possible models and assignment of the same truth value to each of these premises. The June–Kate response was made by 12% (15 participants) of the sample.

All the remaining responses were collapsed into the nondisjunctive category. These included the 22% (27 participants) of the sample who responded "Charles is in Scotland," 9% (11 participants) of the sample who responded "Nothing," 9% (11 participants) who left the question blank, and 24% (30 participants) of the sample who provided another incorrect response.

Performance on the disjunctive insight problems was surprisingly poor. On disjunctive insight problem 1 (the "married" problem), only 13% of the sample (16 participants) selected the "yes" response that results from disjunctive reasoning. In contrast, 86% (107 participants) of the sample selected the "cannot be determined" response, indicating that they did not approach the problem in a disjunctive manner. (Two participants, or 2% of the sample, selected the "no" response, and these two participants were excluded from subsequent analyses.) Performance was no better on disjunctive insight problem 2 (the "green blocks" problem). Only 9% of the sample (11 participants) selected the "yes" response that results from disjunctive reasoning. In contrast, 84% (105 participants) of the sample selected the "cannot be determined" response, indicating that they did not approach the problem in a disjunctive manner; 7% of the sample, $n = 9$, selected the "no" response and these nine participants were excluded from subsequent analyses.

In summary, fully disjunctive reasoning was apparent in less than half of the sample on most of the tasks. The overall level of performance is consistent with Shafir's (1994) argument that nondisjunctive reasoning styles are not uncommon.

Relationships Among Disjunctive Reasoning Tasks

Does performance across these disjunctive reasoning tasks display indications of domain generality? The phi coefficients displayed in Table 2 are relevant to this question. (Phi coefficients are a special case of the product–moment correlation for dichotomous variables, and they can be interpreted as correlations; see Rosenthal & Rosnow, 1991.) In Table 2, all the bivariate associations among all of the tasks are displayed. Performance on each task was classified as disjunctive or nondisjunctive on the basis of the classification criteria discussed in the Method section. (The Note to the table serves as a reminder of these criteria.)

The domain generality in Table 2 is quite modest. Performance on many of the tasks is completely dissociated, although some tasks do display some modest associations. For example, within the set of four tasks taken from the decision-making literature, only two of the six phi coefficients were statistically significant—the associations between performance on Newcomb's problem and

Table 2
Phi Coefficients for Associations Between the Disjunctive Reasoning Tasks

Task	1	2	3	4	5	6	7	8	9
Decision-making task									
1. Prisoner's dilemma	—								
2. Newcomb's problem	.02	—							
3. Framing problem	.05	.17*	—						
4. Probabilistic choice	.10	.16*	.10	—					
Problem-solving task									
5. Selection task	.08	.02	.16*	.05	—				
6. Knights and knaves	.03	.13	.10	.02	.03	—			
7. Double disjunction	.06	.00	.15*	.25**	.19*	.20*	—		
8. Disjunctive insight 1	.11	.04	.09	.09	.02	.31***	.05	—	
9. Disjunctive insight 2	.00	.06	.03	.10	.01	.20*	.12	.31***	—

Note. The following comparisons were made, and the disjunctive response is italicized. Prisoner's dilemma: *compete* versus cooperate; Newcomb's problem: *both boxes* versus Box B only; framing problem: *no framing effect* versus framing effect; probabilistic choice: *no preference* versus Game 1; selection task: *correct* + *P* + *All* versus PQ + other incorrect; knights and knaves: *knave* versus CBD + knight; double disjunction: *correct* + *partial* + *June–Kate* versus Charles in Scotland + nothing + blank other incorrect; disjunctive insight problems: *yes* versus cannot be determined. CBD = cannot be determined.
* $p < .05$. ** $p < .01$. *** $p < .001$.

performance on the framing problem and probabilistic reasoning problem. Within the five tasks taken from the problem-solving literature, 5 of the 10 associations were statistically significant. Three of these five involved the knights and knaves problem. Finally, looking across the decision-making and problem-solving tasks, only 3 of 20 associations (2 involving the double disjunction problem) were statistically significant.

Predictors of Disjunctive Reasoning

Although assumptions about the domain generality of disjunctive reasoning were not strongly supported, Shafir's (1994) conjecture that nondisjunctive processing on these problems was not the result of computational limitations was warranted. We assessed this by examining the relationships between task performance and our measure of general cognitive ability. The lack of domain generality displayed in Table 2 might lead us to suspect that there is not a common capacity limitation hindering performance on all of these tasks, because such a common capacity limitation would be expected to yield more of an association among them than was apparent. This conjecture is supported by the data presented in Table 3, which presents the mean cognitive ability composite scores for the disjunctive and nondisjunctive reasoners in each task.

Cognitive ability differences were apparent; in seven of nine tasks, the disjunctive reasoners were higher in cognitive ability. However, not all of these differences were statistically significant. The disjunctive reasoners had significantly higher cognitive ability on three of the tasks: probabilistic reasoning, the selection task, and the double disjunction task. (The effect in the knights and knaves task was marginal.) The effect size (Cohen's *d*) of the difference was .48 on the probabilistic reasoning task, .52 on the selection task, and .69 on the double disjunction task. These effects sizes are classified by Rosenthal and Rosnow (1991, p. 446) as "medium." Thus, Shafir's (1994) conjecture that nondisjunctive reasoning on these tasks is not due to their inherent computational difficulty is somewhat supported by these results. Some tasks displayed no effect of cognitive ability; the participants giving the nondisjunctive response were almost as high in cognitive ability as those giving the disjunctive response. On three tasks, however, there were effects of cognitive ability of modest size, indicating that the failure to give the disjunctive response on at least some tasks is related to computational limitations.

Given that associations with cognitive ability were modest on most of the tasks, this naturally leads to the question of whether the tendency toward disjunctive processing is not better analyzed as a cognitive style than as a cognitive capacity. Data relevant to this conjecture are displayed in Table 4, which presents the mean reflectivity score ($MFFT_{Errors}$) and mean Need for Cognition Scale scores for the disjunctive and nondisjunctive reasoners in each task. For the former, the disjunctive reasoners obtained lower error *z* scores (indicating more reflectivity) in six of nine tasks—two of these differences attaining statistical significance (the selection task and the knights and knaves task) and two tasks were marginal.

Table 3
Mean Cognitive Ability Composite Scores of Disjunctive and Nondisjunctive Responders on Each of the Reasoning Tasks

Task	Disjunctive responders *M*	Disjunctive responders *SD*	Nondisjunctive responders *M*	Nondisjunctive responders *SD*	*t*
Decision-making task					
Prisoner's dilemma	0.31	2.55	−0.30	3.03	1.21
Newcomb's problem	−0.16	2.57	0.12	2.88	−0.53
Framing problem	0.20	2.97	−0.56	2.08	1.22
Probabilistic choice	1.06	3.30	−0.22	2.50	2.23*
Problem-solving task					
Selection task	0.75	2.69	−0.63	2.69	2.87**
Knights and knaves	0.57	2.78	−0.38	2.70	1.92†
Double disjunction	1.15	2.54	−0.65	2.69	3.66***
Disjunctive insight 1	−0.61	2.89	0.14	2.70	−1.02
Disjunctive insight 2	1.03	2.93	0.13	2.69	1.05

Note. Degrees of freedom range from 111 to 123.
† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$, all two-tailed.

Table 4
Mean $MFFT_{Errors}$ and Need for Cognition Scores of Disjunctive and Nondisjunctive Responders on Each of the Reasoning Tasks

	Disjunctive responders		Nondisjunctive responders		
Variable	*M*	*SD*	*M*	*SD*	*t*
			$MFFT_{Errors}$		
Prisoner's dilemma	0.07	0.97	−0.10	1.01	0.94
Newcomb's problem	0.08	1.06	−0.05	0.97	0.68
Framing problem	0.00	0.98	0.03	1.03	−0.16
Probabilistic choice	−0.24	0.86	−0.02	1.00	−1.11
Selection task	−0.33	0.84	0.28	1.05	−3.53***
Knights and knaves	−0.31	0.88	0.22	1.03	−3.04**
Double disjunction	−0.20	0.87	0.12	1.06	−1.71†
Disjunctive insight 1	0.05	1.13	0.01	0.98	0.12
Disjunctive insight 2	−0.49	0.78	0.04	1.00	−1.71†
		Need for Cognition Scale total raw score			
Prisoner's dilemma	77.5	10.8	79.5	10.3	−1.05
Newcomb's problem	77.4	11.9	78.7	10.9	−0.62
Framing problem	80.0	10.3	74.3	10.0	2.52**
Probabilistic choice	78.6	9.8	76.8	10.7	0.82
Selection task	79.8	11.0	76.9	10.4	1.52
Knights and knaves	81.3	11.3	76.0	9.9	2.75**
Double disjunction	81.2	11.2	76.4	10.2	2.44**
Disjunctive insight 1	81.2	10.1	77.9	10.9	1.15
Disjunctive insight 2	84.0	11.1	77.7	10.7	1.84†

Note. Degrees of freedom range from 111 to 123. MFFT = Matching Familiar Figures Test (Kagan et al., 1964).
† $p < .10$. ** $p < .01$. *** $p < .001$, all two-tailed.

Similarly, the disjunctive reasoners had higher Need for Cognition Scale scores on seven of the nine tasks—three of these attaining statistical significance (framing problem, knights and knaves, and double disjunction), and a fourth was marginal (disjunctive insight 2).

In subsequent analyses, we attempted to explore whether cognitive ability and the thinking dispositions measures ($MFFT_{Errors}$ and need for cognition) were independent predictors of disjunctive reasoning using a more potent overall measure of disjunctive reasoning. In these analyses, we used five of the nine tasks that we felt most purely captured the notion of disjunctive reasoning and that, in addition, had adequate statistical properties. Regarding the latter, we removed the two disjunctive insight problems from further consideration because performance on each of them was extremely low (13% and 9% disjunctive responses, respectively), low enough to cause floor effects in any statistical analysis. We also eliminated from our composite index of disjunctive reasoning performance on the prisoner's dilemma problem and Newcomb's problem. In retrospect, we feel that it may have been wrong to include these tasks in a category of tasks. In the other tasks, it is almost certain that the normatively incorrect response is arrived at by a failure to disjunctively consider all of the alternative states of the world. In contrast, there has been considerable discussion of the prisoner's dilemma problem and Newcomb's problem in the philosophical and decision theory literature, much of it concerning arguments that question the normative appropriateness of the so-called dominant response (noncooperation in the prisoner's dilemma and the two-box selection in Newcomb's problem) in both tasks (see Campbell & Sowden, 1985; Gibbard & Harper, 1978; Hurley, 1991; Nozick, 1993). For example, Nozick (1993) has discussed how making the nondominant response on both prisoner's dilemma problem and Newcomb's problem might not actually reflect a failure in disjunctive reasoning but instead be the result of the individual integrating symbolic factors into their decision (e.g., the desire to present oneself as a cooperator in the prisoner's dilemma problem). In summary, the argument is that any coding of symbolic utility (Nozick, 1993) or expressive rationality (Hargreaves Heap, 1992) in the representation of the problem might lead an individual to choose the nondominant response despite having considered all the alternatives and despite having recognized that from a purely instrumental sense the cooperative and two-box choices are dominated.

After eliminating the two disjunctive insight problems and both the prisoner's dilemma and Newcomb's problem, we were left with five clearly disjunctive tasks that produced no floor effects. We scored each of the disjunctive responses as 1 and each of the nondisjunctive responses as 0 and formed a five-item composite score of performance on the five clearly disjunctive tasks.

Table 5 presents several hierarchical regression analyses that were conducted in an examination of the predictors of this composite score. The first hierarchical regression shows that after the cognitive ability composite is entered (accounting for 15.5% of the variance), $MFFT_{Errors}$ accounted for a significant proportion (4.7%) of the variance. Additionally, when entered third, need for cognition accounted for 7.1% additional unique variance ($p < .001$).

The second analysis indicates that $MFFT_{Errors}$ was a significant unique predictor after the other two variables were entered (unique variance explained = .059, $p < .01$), and the third analysis indicates that cognitive ability also explained significant unique

Table 5
Hierarchical Regression Analyses Predicting Five-Item Composite Disjunctive Reasoning Score

Step and variable	R	R^2 change	F change
1. Cognitive ability composite	.393	.155	22.51***
2. $\mathrm{MFFT}_{\mathrm{Errors}}$	.449	.047	7.17**
3. Need for Cognition Scale	.523	.071	11.94***
1. Cognitive ability composite	.393	.155	22.51***
2. Need for Cognition Scale	.463	.059	9.21**
3. $\mathrm{MFFT}_{\mathrm{Errors}}$	.523	.059	9.87**
1. Need for Cognition Scale	.332	.110	15.22***
2. $\mathrm{MFFT}_{\mathrm{Errors}}$	.470	.111	17.32***
3. Cognitive ability composite	.523	.052	8.76**

Note. MFFT = Matching Familiar Figures Test (Kagan et al., 1964).
** $p < .01$. *** $p < .001$.

variance (unique variance explained = .052, $p < .01$). Considering the two thinking dispositions variables as a set, from the second and third analysis in Table 5 it is apparent that $\mathrm{MFFT}_{\mathrm{Errors}}$ and need for cognition together accounted for 11.8% unique variance after cognitive ability was entered, whereas cognitive ability accounted for 5.2% of the variance after the two thinking dispositions measures were entered.

An additional analysis indicated that this result was not due to allowing two thinking disposition variables to capitalize on chance as opposed to one cognitive ability variable. A verbal (vocabulary checklist and WAIS–R Vocabulary) and a nonverbal (Raven Matrices and WAIS–R Block Design) cognitive ability measure were constructed and entered into the equation in a hierarchical analysis by sets (Cohen & Cohen, 1983). In this analysis, the thinking dispositions set accounted for 11.9% unique variance compared with 6.7% for the cognitive ability set.

Discussion

Our participants, like those in the Shafir (1994) study, had problems thinking disjunctively. Consistent with his findings, on all but two of our tasks, the majority of participants did not reason disjunctively. Nevertheless, considering all of the nine disjunctive reasoning tasks together, performance across these tasks displayed a very limited amount of domain generality, probably not enough to justify considering them to comprise a domain of disjunctive reasoning. Instead, across most of the tasks, domain specificity seemed to be more the rule. Performance on any one of the tasks would have been difficult to predict from knowledge of performance on the others.

The domain specificity in these results is somewhat in contrast to the consistent but mild support for a domain general approach in previous research (Sá, West, & Stanovich, 1999; Stanovich & West, 1997, 1998b). The reason for this difference might be that the previous work overrepresented the epistemic domain and underrepresented the disjunctive domain. Specifically, the earlier work focused more on inductive and probabilistic reasoning and the calibration of belief to evidence, whereas the present tasks were designed to tap the exhaustive exploration of a finite problem space.

On the other hand, aspects of our analyses (particularly the full correlation matrix displayed in Table 2) may have given misleading impressions of domain specificity. First, performance on both of the disjunctive insight tasks was so low as to implicate floor effects. Second, there are theoretical reasons to question the classification of the prisoner's dilemma and Newcomb's problem as disjunctive reasoning tasks. Note that any misspecification in the classification of the tasks would result in a misleading conclusion of domain specificity. These considerations led us to look more closely at the five tasks that indisputably signal the tendency toward disjunctive reasoning. Five of the 10 correlations among these tasks were statistically significant (four of the five involving problem-solving tasks). Thus, among these more conceptually secure tasks, there were modest indications of domain generality exhibited alongside the considerable domain specificity still present.

With respect to the issue of which variables predicted the tendency to reason disjunctively, Shafir (1994) seems to have been largely correct in arguing that lack of disjunctive reasoning is not due to computational limitations. Our regression analyses of composite performance on the five indisputably disjunctive tasks indicated that thinking dispositions were, if anything, more potent predictors of performance than was cognitive ability. The two thinking dispositions ($\mathrm{MFFT}_{\mathrm{Errors}}$ and need for cognition) predicted twice the unique variance (11.8%) than did the composite cognitive ability measure (5.2%).

The regression results showing the relative potency of the thinking dispositions measures (at least compared with the cognitive ability index) and their ability to predict independent variance are consistent with frameworks in the critical thinking literature that distinguish between cognitive capacities and thinking dispositions (e.g., Baron, 1985a, 1994; Ennis, 1987; Moshman, 1994; Norris, 1992; Perkins, Jay & Tishman, 1993; Schrag, 1988). For example, in Baron's (1985a, 1994) conceptualization, *capacities* refer to the types of cognitive processes studied by information processing researchers seeking the underlying cognitive basis of performance on IQ tests. Perceptual speed, discrimination accuracy, working memory capacity, and the efficiency of the retrieval of information stored in long-term memory are examples of cognitive capacities that underlie traditional psychometric intelligence and that have been extensively investigated (Ackerman, Kyllonen, & Richards, 1999; Deary & Stough, 1996; Engle, Tuholski, Laughlin, & Conway, 1999; Fry & Hale, 1996; Hunt, 1987; Sternberg, 1982). According to Baron's (1985a) conception, cognitive capacities cannot be improved in the short-term by admonition or instruction. They are, nevertheless, affected by long-term practice.

Thinking dispositions, in contrast, are better viewed as cognitive styles, which are more malleable in Baron's (1985a) view: "Although you cannot improve working memory by instruction, you can tell someone to spend more time on problems before she gives up, and if she is so inclined, she can do what you say" (p. 15). Rational thinking dispositions concern the adequacy of belief formation, the adequacy of taking action consistent with one's goals, and the regulation of cognitive effort. These three categories of thinking dispositions have been called *epistemic regulation*, *response regulation*, and *cognitive regulation*, respectively (Sá et al., 1999; Stanovich, 1999), and the latter two were measured here by the $\mathrm{MFFT}_{\mathrm{Errors}}$ variable and Need for Cognition Scale scores, respectively.

We acknowledge that there is at present little empirical evidence for Baron's (1985a) view that thinking dispositions are more malleable than cognitive capacities (although some suggestive evidence is reported by Baron, Badgio, & Gaskins, 1986; see also Overton, Byrnes, & O'Brien, 1985). However, we feel that his conjecture is consistent with a fairly broad and common view of how certain types of constructs operate in cognitive science. The relative separability of the associations between disjunctive reasoning and the thinking dispositions and disjunctive reasoning and cognitive ability is consistent with a framework in which thinking dispositions and cognitive capacities represent individual difference constructs at different levels of analysis in cognitive theory and do separate explanatory work (Stanovich, 1999; Stanovich & West, 2000).

At least three levels of analysis are distinguished in cognitive theory (see J. R. Anderson, 1990; Dennett, 1987; Marr, 1982; Oaksford & Chater, 1995; Stanovich, 1999): a biological level that is inaccessible to cognitive theorizing, an algorithmic level concerned with the computational processes necessary to carry out a task, and the intentional (or rational) level. The latter level provides a specification of the goals of the system's computations (what the system is attempting to compute and why) and can be used to suggest constraints on the operation of the algorithmic level. It is concerned with the goals of the system, beliefs relevant to those goals, and the choice of action that is rational given the system's goals and beliefs (Bratman, Israel, & Pollack, 1991; Pollock, 1995). For example, in his model of mind as a control system, Sloman (1993) viewed desires as control states that can produce behavior either directly or through a complex control hierarchy by changing intermediate desire states. He viewed dispositions (high-level attitudes, ideals, and personality traits) as long-term desire states that "work through a control hierarchy, for instance, by changing other desire-like states rather than triggering behaviour" (p. 85). We simply add to this view the well-accepted notion that higher level control states are more infected by language-based representations (Clark, 1997; Dennett, 1991). We then have a commonplace cognitive model whereby thinking dispositions would be more responsive to language-based instructions (see Clark, 1997) than algorithmic level constructs.

Using the tripartite taxonomy above (biological level, algorithmic level, intentional level), we propose here that omnibus measures of cognitive ability such as intelligence tests are best understood as indexing individual differences in the efficiency of processing at the algorithmic level. In contrast, thinking dispositions as traditionally studied in psychology (e.g., Kardash & Scholes, 1996; Klaczynski, 2000; Klaczynski, Gordon, & Fauth, 1997; Kruglanski & Webster, 1996; Schommer, 1994; Stanovich & West, 1997; Sternberg, 1997) index individual differences at the intentional level of analysis. They are telling us about the individual's goals and epistemic values (Dole & Sinatra, 1998; Kuhn, 2001; Sá et al., 1999), and they are indexing broad tendencies of pragmatic and epistemic self-regulation.

Thus, thinking dispositions are reflective of intentional-level psychological structure, and the present results indicate that the tendency to reason disjunctively is associated with variation in intentional-level psychological structure. As Shafir (1994) argued, failures in disjunctive reasoning are not simply due to task complexity that stresses computational limitations. If this were so, the thinking dispositions examined here would not have been able to explain unique variance after differences in cognitive ability were partialed. These disjunctive reasoning problems, although they obviously stress algorithmic-level cognitive capacity to varying degrees, also differentially engage styles of response regulation (MFFT) and styles of cognitive regulation (need for cognition) that display some independence from algorithmic-level cognitive capacity. That independence suggests the possibility that failures of disjunctive reasoning are sometimes due to systematically suboptimal systems of regulation at the intentional level of analysis, systems that may be more malleable than cognitive ability itself.

References

Ackerman, P., Kyllonen, P., & Richards, R. (Eds.). (1999). *Learning and individual differences: Process, trait, and content determinants.* Washington, DC: American Psychological Association.

Alexander, P. A., Kulikowich, J. M., & Schulze, S. K. (1994). How subject-matter knowledge affects recall and interest. *American Educational Research Journal, 31,* 313–337.

Anderson, J. R. (1990). *The adaptive character of thought.* Hillsdale, NJ: Erlbaum.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25*(4), 5–11.

Anderson, R. C., & Freebody, P. (1983). Reading comprehension and the assessment and acquisition of word knowledge. In B. Huston (Ed.), *Advances in reading/language research* (Vol. 2, pp. 231–256). Greenwich, CT: JAI Press.

Baron, J. (1985a). *Rationality and intelligence.* Cambridge, England: Cambridge University Press.

Baron, J. (1985b). What kinds of intelligence components are fundamental? In S. Chipman & J. Segal (Eds.), *Thinking and learning skills,* (Vol. 2, pp. 365–390). Hillsdale, NJ: Erlbaum.

Baron, J. (1994). Nonconsequentialist decisions. *Behavioral and Brain Sciences, 17,* 1–42.

Baron, J., Badgio, P. C., & Gaskins, I. W. (1986). Cognitive style and its improvement: A normative approach. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 3, pp. 173–220). Hillsdale, NJ: Erlbaum.

Bratman, M. E., Israel, D. J., & Pollack, M. E. (1991). Plans and resource-bounded practical reasoning. In J. Cummins & J. Pollock (Eds.), *Philosophy and AI: Essays at the interface* (pp. 7–22). Cambridge, MA: MIT Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Cacioppo, J. T., Petty, R. E., Feinstein, J., & Jarvis, W. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition. *Psychological Bulletin, 119,* 197–253.

Cahan, S., & Cohen, N. (1989). Age versus schooling effects on intelligence development. *Child Development, 60,* 1239–1249.

Campbell, R., & Sowden, L. (Eds.). (1985). *Paradoxes of rationality and cooperation: Prisoner's dilemma and Newcomb's problem.* Vancouver, British Columbia, Canada: University of British Columbia Press.

Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the Raven Progressive Matrices Test. *Psychological Review, 97,* 404–431.

Ceci, S. J. (1993). Contextual trends in intellectual development. *Developmental Review, 13,* 403–435.

Ceci, S. J. (1996). *On intelligence: A bioecological treatise on intellectual development* (Expanded ed.). Cambridge, MA: Harvard University Press.

Clark, A. (1997). *Being there: Putting brain, body, and world together again.* Cambridge, MA: MIT Press.

Cohen, J., & Cohen, P. (1983). *Applied multiple regressional correlation analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
Cooksey, R. W., & Freebody, P. (1987). Aspects of a computer-managed test of children's reading vocabulary: Reliability, validity, and characterization of knowledge. *Reading Psychology, 8,* 103–118.
Deary, I. J., & Stough, C. (1996). Intelligence and inspection time. *American Psychologist, 51,* 599–608.
Dennett, D. C. (1987). *The intentional stance.* Cambridge, MA: MIT Press.
Dennett, D. C. (1991). *Consciousness explained.* Boston: Little, Brown.
Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist, 33,* 109–128.
Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128,* 309–331.
Ennis, R. H. (1987). A taxonomy of critical thinking dispositions and abilities. In J. Baron & R. Sternberg (Eds.), *Teaching thinking skills: Theory and practice* (pp. 9–26). New York: Freeman.
Evans, J. St. B. T., & Lynch, J. S. (1973). Matching bias in the selection task. *British Journal of Psychology, 64,* 391–397.
Evans, J. St. B. T., Newstead, S. E., & Byrne, R. M. J. (1993). *Human reasoning: The psychology of deduction.* Hove, England: Erlbaum.
Evans, J. St. B. T., & Over, D. E. (1996). *Rationality and reasoning.* Hove, England: Psychology Press.
Evans, J. St. B. T., & Over, D. E. (1999). Explicit representations in hypothetical thinking. *Behavioral and Brain Sciences, 22,* 763–764.
Evans, J. St. B. T., Over, D. E., & Manktelow, K. (1993). Reasoning, decision making and rationality. *Cognition, 49,* 165–187.
Fry, A. F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence. *Psychological Science, 7,* 237–241.
Gibbard, A., & Harper, W. L. (1978). Counterfactuals and two kinds of expected utility. In C. Hooker, J. Leach, & E. McClennen (Eds.), *Foundations and applications of decision theory* (Vol. 1, pp. 125–162). Dordrecht, The Netherlands: Reidel.
Hargreaves Heap, S. P. (1992). Rationality. In S. P. Hargreaves Heap, M. Hollis, B. Lyons, R. Sugden, & A. Weale (Eds.), *The theory of choice: A critical guide* (pp. 3–25). Oxford, England: Blackwell.
Hargreaves Heap, S. P., & Varoufakis, Y. (1995). *Game theory: A critical introduction.* London: Routledge.
Hayes, P. (1973). The frame problem and related problems in artificial intelligence. In A. Elithorn & D. Jones (Eds.), *Artificial and human thinking* (pp. 150–173). San Francisco: Jossey-Bass.
Hunt, E. (1987). The next word on verbal ability. In P. A. Vernon (Ed.), *Speed of information-processing and intelligence* (pp. 347–392). Norwood, NJ: Ablex.
Hurley, S. L. (1991). Newcomb's problem, prisoner's dilemma, and collective action. *Synthese, 86,* 173–196.
Jeffrey, R. C. (1983). *The logic of decision* (2nd ed.). Chicago: University of Chicago Press.
Johnson-Laird, P. N. (1983). *Mental models.* Cambridge, MA: Harvard University Press.
Johnson-Laird, P. N. (1999). Deductive reasoning. *Annual Review of Psychology, 50,* 109–135.
Johnson-Laird, P. N., & Byrne, R. M. J. (1990). Meta-logical problems: Knights, knaves, and Rips. *Cognition, 36,* 69–84.
Johnson-Laird, P. N., & Byrne, R. M. J. (1991). *Deduction.* Hillsdale, NJ: Erlbaum.
Johnson-Laird, P. N., Byrne, R. M. J., & Schaeken, W. (1992). Propositional reasoning by model. *Psychological Review, 99,* 418–439.
Johnson-Laird, P. N., Legrenzi, P., Girotto, V., Legrenzi, M. S., Caverni, J., & Savary, F. (1999). Naive probability: A mental model theory of extensional reasoning. *Psychological Review, 106,* 62–88.
Kagan, J., Rosman, B. L., Day, D., Albert, J., & Phillips, W. (1964). Information processing in the child: Significance of analytic and reflective attitudes. *Psychological Monographs, 78* (1, Whole No. 578).
Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist, 39,* 341–350.
Kardash, C. M., & Scholes, R. J. (1996). Effects of preexisting beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology, 88,* 260–271.
Klaczynski, P. A. (2000). Motivated scientific reasoning biases, epistemological beliefs, and theory polarization: A two-process approach to adolescent cognition. *Child Development, 71,* 1347–1366.
Klaczynski, P. A., Gordon, D. H., & Fauth, J. (1997). Goal-oriented critical reasoning and individual differences in critical reasoning biases. *Journal of Educational Psychology, 89,* 470–485.
Kruglanski, A. W., & Webster, D. M. (1996). Motivated closing the mind: "Seizing" and "freezing." *Psychological Review, 103,* 263–283.
Kuhn, D. (2001). How do people know? *Psychological Science, 12,* 1–8.
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge, England: Cambridge University Press.
Legrenzi, P., Girotto, V., & Johnson-Laird, P. N. (1993). Focussing in reasoning and decision making. *Cognition, 49,* 37–66.
Levesque, H. J. (1986). Making believers out of computers. *Artificial Intelligence, 30,* 81–108.
Levesque, H. J. (1989). Logic and the complexity of reasoning. In R. H. Thomason (Ed.), *Philosophical logic and artificial intelligence* (pp. 73–107). Dordrecht, The Netherlands: Kluwer Academic Publishers.
Manktelow, K. I., Sutherland, E., & Over, D. E. (1995). Probabilistic factors in deontic reasoning. *Thinking and Reasoning, 1,* 201–219.
Margolis, H. (1987). *Patterns, thinking, and cognition.* Chicago: University of Chicago Press.
Marr, D. (1982). *Vision.* San Francisco: Freeman.
McCarthy, J., & Hayes, P. (1969). Some philosophical problems from the standpoint of artificial intelligence. In B. Meltzer & D. Michie (Eds.), *Machine intelligence* (pp. 80–95). New York: Elsevier.
Moshman, D. (1994). Reasoning, metareasoning, and the promotion of rationality. In A. Demetriou & A. Efklides (Eds.), *Intelligence, mind, and reasoning: Structure and development* (pp. 135–150). Amsterdam: Elsevier.
Newstead, S. E., & Evans, J. St. B. T. (Eds.). (1995). *Perspectives on thinking and reasoning.* Hove, England: Erlbaum.
Norris, S. P. (1992). Testing for the disposition to think critically. *Informal Logic, 14*(2 & 3), 157–164.
Nozick, R. (1969). Newcomb's problem and two principles of choice. In N. Rescher (Ed.), *Essays in honor of Carl G. Hempel* (pp. 114–146). Dordrecht, The Netherlands: Reidel.
Nozick, R. (1993). *The nature of rationality.* Princeton, NJ: Princeton University Press.
Oaksford, M., & Chater, N. (1994). A rational analysis of the selection task as optimal data selection. *Psychological Review, 101,* 608–631.
Oaksford, M., & Chater, N. (1995). Theories of reasoning and the computational explanation of everyday inference. *Thinking and Reasoning, 1,* 121–152.
Overton, W. F., Byrnes, J. P., & O'Brien, D. P. (1985). Developmental and individual differences in conditional reasoning: The role of contradiction training and cognitive style. *Developmental Psychology, 21,* 692–701.
Perkins, D. N., Jay, E., & Tishman, S. (1993). Beyond abilities: A dispositional theory of thinking. *Merrill-Palmer Quarterly, 39,* 1–21.
Pollock, J. L. (1995). *Cognitive carpentry: A blueprint for how to build a person.* Cambridge, MA: MIT Press.
Rapoport, A., & Chammah, A. (1965). *Prisoner's dilemma.* Ann Arbor: University of Michigan Press.
Rasmusen, E. (1989). *Games and information: An introduction to game theory.* Oxford, England: Blackwell.
Raven, J. C. (1962). *Advanced progressive matrices* (Set II). London: Lewis.

Raven, J. C., Court, J. H., & Raven, J. (1977). *Manual for advanced progressive matrices* (Sets I & II). London: Lewis.

Reyna, V. F. (1996). Conceptions of memory development with implications for reasoning and decision making. *Annals of Child Development, 12,* 87–118.

Rips, L. J. (1989). The psychology of knights and knaves. *Cognition, 31,* 85–116.

Rogoff, B., & Lave, J. (Eds.). (1984). *Everyday cognition.* Cambridge, MA: Harvard University Press.

Rosenthal, R., & Rosnow, R. L. (1991). *Essentials of behavioral research: Methods and data analysis* (2nd ed.). New York: McGraw-Hill.

Sá, W., West, R. F., & Stanovich, K. E. (1999). The domain specificity and generality of belief bias: Searching for a generalizable critical thinking skill. *Journal of Educational Psychology, 91,* 497–510.

Sattler, J. M. (1992). *The assessment of children* (3rd ed.). San Diego, CA: Jerome Sattler.

Savage, L. J. (1954). *The foundations of statistics.* New York: Wiley.

Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review, 6,* 293–319.

Schrag, F. (1988). *Thinking in school and society.* New York: Routledge.

Shafir, E. (1994). Uncertainty and the difficulty of thinking through disjunctions. *Cognition, 50,* 403–430.

Shafir, E., & Tversky, A. (1992). Thinking through uncertainty: Nonconsequential reasoning and choice. *Cognitive Psychology, 24,* 449–474.

Sloman, A. (1993). The mind as a control system. In C. Hookway & D. Peterson (Eds.), *Philosophy and cognitive science* (pp. 69–110). Cambridge, England: Cambridge University Press.

Smith, S. M., & Levin, I. P. (1996). Need for cognition and choice framing effects. *Journal of Behavioral Decision Making, 9,* 283–290.

Smullyan, R. M. (1978). *What is the name of this book? The riddle of Dracula and other logical puzzles.* Englewood Cliffs, NJ: Prentice Hall.

Stanovich, K. E. (1999). *Who is rational? Studies of individual differences in reasoning.* Mahwah, NJ: Erlbaum.

Stanovich, K. E., & West, R. F. (1997). Reasoning independently of prior belief and individual differences in actively open-minded thinking. *Journal of Educational Psychology, 89,* 342–357.

Stanovich, K. E., & West, R. F. (1998a). Cognitive ability and variation in selection task performance. *Thinking and Reasoning, 4,* 193–230.

Stanovich, K. E., & West, R. F. (1998b). Individual differences in rational thought. *Journal of Experimental Psychology: General, 127,* 161–188.

Stanovich, K. E., & West, R. F. (1999). Discrepancies between normative and descriptive models of decision making and the understanding/acceptance principle. *Cognitive Psychology, 38,* 349–385.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioural and Brain Sciences, 23,* 645–726.

Sternberg, R. J. (Ed.). (1982). *Handbook of human intelligence.* Cambridge, England: Cambridge University Press.

Sternberg, R. J. (1997). The concept of intelligence and its role in lifelong learning and success. *American Psychologist, 52,* 1030–1037.

Thompson, V. A. (2000). The task-specific nature of domain-general reasoning. *Cognition, 76,* 209–268.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185,* 1124–1131.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, 211,* 453–458.

Tversky, A., & Shafir, E. (1992). The disjunction effect in choice under uncertainty. *Psychological Science, 3,* 305–309.

Wason, P. C. (1966). Reasoning. In B. Foss (Ed.), *New horizons in psychology* (pp. 135–151). Harmonsworth, England: Penguin.

Wechsler, D. (1974a). *Manual for the Wechsler Adult Intelligence Scale—Revised.* San Antonio, TX: Psychological Corporation.

Wechsler, D. (1974b). *Wechsler Adult Intelligence Scale—Revised.* San Antonio, TX: Psychological Corporation.

Zimmerman, J., Broder, P. K., Shaughnessy, J. J., & Underwood, B. J. (1977). A recognition test of vocabulary using signal-detection measures, and some correlates of word and nonword recognition. *Intelligence, 1,* 5–31.

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