Rethinking Logical Reasoning Skills from a Strategy Perspective

Bradley J. Morris*

Grand Valley State University and LRDC, University of Pittsburgh, USA

Christian D. Schunn

LRDC, University of Pittsburgh, USA

Running Head: Logical Reasoning Skills

* Correspondence to: Department of Psychology, Grand Valley State University, 2117 AuSable Hall, One Campus Drive, Allendale, MI 49401, USA. E-mail: morrisb@gvsu.edu, Fax: 1-616-331-2480.

Rethinking Logical Reasoning Skills from a Strategy Perspective

Overview

The study of logical reasoning has typically proceeded as follows: Researchers (1) discover a response pattern that is either unexplained or provides evidence against an established theory, (2) create a model that explains this response pattern, then (3) expand this model to include a larger range of situations. Researchers tend to investigate a specific type of reasoning (e.g., conditional implication) using a particular variant of an experimental task (e.g., the Wason selection task). The experiments uncover a specific reasoning pattern, for example, that people tend to select options that match the terms in the premises, rather than derive valid responses (Evans, 1972). Once a reasonable explanation is provided for this, researchers typically attempt to expand it to encompass related phenomena, such as the role of 'bias' in other situations like weather forecasting (Evans, 1989). Eventually, this explanation may be used to account for all performance on an entire class of reasoning phenomena (e.g. deduction) regardless of task, experience, or age. We term this a unified theory.

Some unified theory theorists have suggested that all logical reasoning can be characterized by a single theory, such as one that is rule-based (which involves the application of transformation rules that draw valid conclusions once fired; Rips, 1994). Other theorists believe that all logical reasoning can be described as model-based (creating veridical representations of premises, and searching them for possible conclusions; Johnson-Laird, 1999). Others still have suggested yet additional approaches (e.g., matching rules, pragmatic schemas) that may unify all aspects of performance. It seems possible, however, given the range of problem types, task demands, and experience and cognitive resources of reasoners, that there may be more than one way for solving an entire class of reasoning problem.

Consider the case of deduction. This involves a wide variety of tasks, from simple statement evaluation (e.g., “Is my cat black?”) to more complex tasks such as evaluating predicate syllogisms (e.g., Some A are not B, Some B are C, therefore Some A are not C; TRUE or FALSE) (Roberts, 2000; Johnson-Laird, 1999). There is no evidence that deduction occupies a particular region of the brain (Goel, Buchel, Frith, & Dolan, 2000; Osherson, Perani, Cappa, Schnur, Grassi, & Fazio, 1998). This suggests that deduction is not a special process separate from the rest of cognition, and hence it is not likely to be unified across tasks or situations. Likewise, there is no behavioral evidence that deduction is a coherent distinct process (Johnson-Laird, 1999). Moreover, cognitive psychology has identified a variety of general processes (e.g., analogy, retrieval, guessing) that could, in theory, be used. Thus, it should not be controversial to suggest that several types of process might be used to solve reasoning problems in at least some situations.

In contrast to unified theories, we propose an alternative, in which many possible strategies may be used to solve a deductive problem, rather than always the same single type of reasoning process. Thus, this is a new framework for explaining reasoning performance, incorporating simplified versions of existing theories as possible strategies (see also Roberts, 2000). We list a variety of such strategies that seem likely to be used in at least some situations. It is not crucial to the argument that all of these are actually used. However, we will propose conditions under which various strategies are particularly likely to manifest themselves, thereby developing a framework through which these can be distinguished theoretically and empirically.

It should be noted that recent research from mental models theorists (Van der Henst, Yang, & Johnson-Laird, 2002) suggests that there are individual differences in the application of mental models, for example when solving syllogisms. Although this work suggests that reasoners use various approaches (classified as strategies), all of these are derived from the same inferential mechanism: mental models. While we agree that we should investigate individual differences in approaches to reasoning, we suggest not only that there are differences in how people apply the same inferential mechanism, but also that several different mechanisms are used.

Strategy Use in Logical Reasoning

What does it mean, as a cognitive researcher, to think in terms of strategies? A glance at the literature suggests that unified theories have difficulty accounting for differences in performance, both between individuals, and across tasks/situations (for a review see Rips, 1994; Johnson-Laird, 1999). We suggest that these differences are due to the selection of different strategies, and that this is a function of (1) the history of success with each strategy, and (2) the match between the processing demands of the strategy and the task demands. Together, these form the situational niche.

As stated earlier, unified theories posit a single account for the range of human performance, although there are disagreements as to which single theory is correct. We suggest a strategy selection theory to explain the same phenomena, proposing a series of specified strategies, each relegated to explaining a subset of the total range of human deductive performance. This is closely related to other models that focus on individual differences (Roberts, 2000, 1993). For example, Roberts (2000) suggests that deductive performance can be better accounted for by three strategies (spatial, verbal, task-specific) than any single theory (e.g., mental models; Johnson-Laird, 1999).

What do we gain from this logical strategy model? It allows for a wide range of findings -- patterns of variability across problems, tasks, individuals, and different points of development -- to move from theoretical embarrassment to core, theoretically relevant phenomena, that not only can be explained, but also are crucial to understanding the cognition of logical reasoning. It also allows a variety of established theories to be incorporated into a single framework, in which all form strategies that are possible explanations of behavior, differing only in the extent to which each particular strategy has been used in similar situations, and their matches to current task demands.

The match between a particular strategy and its situational niche may not be rational, but may help to explain individual and situational differences. For example, it is well established that familiar content tends to improve performance on the Wason selection task (Wason & Johnson-Laird, 1972). Hundreds of experiments have been used to investigate this phenomenon, and these have led to a variety of explanations (e.g., pragmatic reasoning schemas). These differ widely in their range of applicability: Some are specific to a particular set of materials, while others seek to explain a broader range of behavior. What has rarely been investigated is the influence of the situational niche on performance, or, more specifically how is the task itself contributing to the response pattern? For example, take two contrasting theories: in one, specific knowledge is required to solve a problem, and in the other, abstract rules (excluding the influence of knowledge) are needed. Problem A is given in which a substantial amount of relevant content knowledge is provided. In this case, we would expect the knowledge-based strategies to be best suited. If however, Problem B were given in which no background information is supplied, then we would predict that a different solution strategy is more likely to be used. Hence the logical strategy model permits flexibility in explanation by allowing for an individual to display a range of possible solution strategies.

The logical strategy model is in stark contrast to unified theories, in which explanations of processing logical statements are confined to one type of strategy. A possible criticism at this point is that a unified theory is more parsimonious: Why suggest that individuals possess a collection of competing strategies when a single type would suffice? We provide two responses.

First, current unified theories have been unable to account for a range of performance without many ad hoc additions. For example, mental logic theory posits that logical inferences are derived by the application of a set of near-automatic content-free inference rules (Rips, 1994; Braine & O'Brien, 1998). In order to explain the effect of familiar content, this theory has incorporated an additional step in the reasoning process, a “pragmatic filter”, which determines whether a statement is to be considered logical or conversational. In the former, logical inference rules are applied, while in the latter case, less formal conversational rules are applied. The result is that the theory postulates an approach to reasoning that undermines its own primary thesis. As another example, mental models theory suggests that logical inference is achieved by the creation and search of models of a problem’s premises (Johnson-Laird, Byrne, & Schaeken, 1992). This theory does not specify how models of ambiguous or metaphorical premises can be constructed without exceeding working memory capacity (Braine & O’Brien, 1998). Similar problems can be found with the universal application of all unified theories.

Second, the logical strategy model does not require a set of resources specific to logical reasoning, which is an ad hoc component of some theories. Instead, it assumes a variety of general-purpose cognitive mechanisms. Within this framework, a series of strategies can be derived, with minimal effort on the part of the cognitive system, as a result of experience with the environment. Let us return to the example given earlier. To account for reasoning in situations in which either statements are presented (1) with familiar content, or (2) without familiar content, our framework can account for empirical findings in terms of two strategies. The first situation does not trigger the use of formal rules. Instead, specific content is used to derive a plausible conclusion. In the second situation, inference rules are used because the most salient property of the problem is the <u>relations</u> between elements, not the <u>content</u> of the elements. The use of each strategy is specific to the situation.

In the sections that follow we will outline eight types of strategy, examining each on eight dimensions: general processing demands, task demands, influence of context, efficacy/solution time (accuracy and cost), possibility of transfer (i.e., will a solution be usable in a different context?), type of memory activated (e.g., declarative), representational form (e.g., propositional), and change in strategy as a function of experience. The results are also summarized in Table 1.

These eight strategies do not reflect prescriptive norms, but represent the range that naïve or untrained subjects may use when they are given deduction tasks. Note that this is not yet an exhaustive list, and we are merely suggesting the most plausible core set. After describing the strategies, we will examine the influence of task demands on strategy selection and use. Space limitations preclude a description of the full range of possible applications. However, our model is reasonably articulated for the purposes of this paper.

1. Token-Based (Mental Models)

Overview. The token-based reasoning strategy has the following characteristics: (1) information is represented as tokens derived from natural language. These correspond to perceptual or verbal instantiations of possible states, and (2) reasoning is achieved not through the application of formal rules but by the creation, inspection, and manipulation of tokens (Johnson-Laird, 1983; Johnson-Laird, Byrne, & Schaeken, 1992). This strategy is similar to Roberts' (2000) spatial strategy[1].

Processing Demands. There are three steps in applying token-based processes: (1) propositional analysis refers to language processing, and is largely analogous to representing the surface structure of a statement, requiring sufficient verbal/spatial working memory to encode and parse language; (2) model generation refers to the creation of tokens derived from the propositional analysis, and any other relevant information in the existing knowledge base and the environment. This requires sufficient verbal/spatial working memory to create and hold tokens; (3) model use is the process of searching and evaluating the set of models created, and requires sufficient processing capacity to maintain these while searching for counterexamples, and evaluating truth-values. The primary limitation on processing is the working memory required to create and search models for a solution. One particular difficulty is that ambiguous premises may require multiple mental models, thus leading to a dramatic increase in the use of working memory capacity and processing time.

The token-based strategy seems particularly useful in the solution of problems in which there are spatial relations because token-based representations can encode these more easily than can proposition-based ones (Johnson-Laird, 1983, 1999). For example, in the transitive problem “Bill is to the right of Fred, Fred is to the right of Sam, Is Sam to the right of Bill?” the relevant dimension is easily encoded as follows:

[Sam] [Fred] [Bill]

<u>Summary</u>. The token-based strategy is content/context dependent, in that the type of semantic information influences the tokens created. However, there should be consistency in the treatment of logical connectives based on their meaning (requiring the activation of procedural memory). There should be transfer between problem isomorphs, though success will vary by the degree of similar semantic content (and hence the activation of declarative elements in memory). This is an algorithmic strategy, in that under optimal conditions, processing should result in a valid/correct conclusion. Processing costs (defined as solution time) should be high because of the procedures involved in creating and searching models.

<u>2</u>. <u>Verbal</u> (<u>Mental</u> <u>Logic</u>)

<u>Overview</u>. Verbal theories explain logical reasoning as the result of content-free, logical transformation rules applied to linguistically derived mental structures (Rips, 1994; Braine & O’Brien, 1998).

<u>Processing</u> <u>Demands</u>. The core elements of verbal theories share basic characteristics. Input is represented and processed in a verbal form (e.g., predicate-argument structures; Braine & Rumain, 1981, 1983). Sufficient verbal working memory is required to hold formal elements and represent them. The action of transformation rules is content-free, and these are implemented as either condition-action pairs (Rips, 1994) or as inferential schemas (Braine & O’Brien, 1998). The output of a rule is either in the form of a conclusion, a statement that will be operated upon by additional rules, or a statement that does not trigger additional rules. Errors

may be explained either by (1) a failure in the activation, or failure in the output of one (or several) rules or (2) the failure to apply an inferential rule, instead applying a pragmatic rule. As problem complexity increases, there will be an increase in the number of rules to fire, thus increasing the possibility of overall error, and hence problem difficulty.

The verbal strategy is most useful in solving abstract problems in which the focus is on relationships between elements (e.g., <u>If A is tweeky, then B is zop)</u>. For example, the original version of the Wason selection task (Wason, 1961) is specified only by formal structure, not by content.

<u>Summary</u>. The verbal strategy is context-independent, algorithmic, and should transfer between isomorphic problem types. Processing costs should be low, because inference takes place via compiled rules that fire automatically as a result of a match to syntactic relationships. Thus the action of rules is dependent on the activation of procedural rather than declarative memory.

<u>3</u>. <u>Knowledge-Based Heuristics</u>

<u>Overview</u>. Heuristics are rules that do not utilize logically valid algorithms. Such a strategy need not generate a valid conclusion but may result in “logic-like” performance (Cheng & Holyoak, 1985; Cosmides, 1989). Knowledge-based heuristics are easily implemented processing rules that use content as the basis for deriving a conclusion. Unlike algorithmic procedures (e.g. a verbal strategy), these conclusions are not necessarily valid (often violating logical inference rules), yet are often pragmatically supported. An example is the <u>pragmatic reasoning schema</u> (Cheng & Holyoak, 1985) in which social (permission rules) and physical (causality) regularities form the basis of inference schemata.

<u>Processing Demands</u>. There are three steps in the use of knowledge-based heuristics: <u>sentence parsing</u>, <u>detection of relations</u>, and <u>solution output</u>. Sentence parsing refers to comprehension and utilises implicit and explicit information. The

detection of relations occurs when the present content is similar to content for which there are available rules. For example, in permission relations, there are established rules (typically phrased as conditionals) that suggest appropriate responses. Activating content allows these rules to be accessed. Cues such as temporal sequence may suggest obligatory or causal relations between elements. For example, in the statement "Mow the lawn and I will give you five dollars" the condition is set in the first clause while the consequent is set in the second clause. Once the rules are accessed, they are applied to the specific situation of the content and a solution is produced. Previous knowledge of other exchanges (e.g., in which transactions are made on the basis of obligations) form the basis of these heuristics.

Summary. Use of a knowledge-based heuristic does not necessarily lead to a valid response. This is a context-dependent strategy that requires activation of declarative memory, through which conclusions are drawn. Thus there should be little transfer away from the domain of applicability. Processing cost should be low because little is required other than activating and applying appropriate rules.

4. Superficial Heuristics

Overview. Superficial heuristics are selective processing strategies in which solutions are derived from surface details, such as terms or common elements, rather than on content (as in knowledge-based heuristics). Two well-known examples lead to matching biases (Evans, 1989) and atmosphere effects (Woodworth & Sells, 1935).

Processing Demands. Superficial heuristics lead to selective processing, but differ from all previous strategies in that the focus is on the presence of surface elements; no specific content is accessed. They operates as follows: (1) surface structure is encoded, (2) key elements are identified, and (3) rules applied to them. For example, in the Wason selection task, subjects prefer to choose cards named in the rules rather than cards that are not named (Evans, 1972). Given "If there is an odd number on one side, then there is a vowel on the other side" the subject may focus on "odd number" and "vowel" as key elements. Then, when searching possible solutions, the subject will attend to those states that contain the key elements. Hence, a card with an odd number and a card with a vowel are selected because these match the elements in the rule. A similar processing model applies to the heuristics that lead to atmosphere effects.

Summary. Superficial heuristics are context-independent strategies that do not necessarily produce valid conclusions. Their use depends upon the activation of procedural memory. We should see transfer between tasks, but with low solution accuracy, due to focusing on surface elements. Processing cost should be low because little is required beyond matching surface content, thus solution times should be fast.

5. Analogy

Overview. Analogical reasoning utilises knowledge of existing situations to derive solutions to novel problems (Holyoak & Thagard, 1989). This is typically distinguished as a separate process from deduction, however we suggest that analogical mapping may provide resources for solving such problems. Analogies enable solution by mapping meaningful links between one already in memory (source) and the new problem (target). As an illustration, we recount the results for a 10-year-old girl enrolled in a gifted program. On a version of the Wason task framed with abstract materials (e.g., thogs, merds), she produced the correct responses, which is surprising given that few adults do so. When we asked her to explain her reasoning, she said that the question was like a chemistry experiment she had recently completed in her class. She outlined the procedure -- including allusions to confirming and disconfirming evidence -- and explained how each 'card' in the Wason task was like one of these options. She proceeded to explain the need for both correct options.

Processing Demands. Analogical mapping takes place in three steps (1) accessing a suitable source from memory, or current perception, that is meaningfully related to the new problem (target), (2) adapt this analog to the demands of the target, and (3) induce useful commonalities between the source and the target (Gentner, 1983; Holyoak & Thagard, 1995). The first step may entail a range of possible information including solutions to previously solved problems, identification of similar problem elements, or partial solutions for the problem at hand. Once a suitable source is found, equivalences between this and the target must be identified, which form the basis of the solution.

Summary. Unlike superficial heuristics, in which there is a focus on common terms (low cost), or knowledge-based heuristics, in which there is a focus on semantic or thematic relations between elements (low cost), the analogy strategy focuses on relations between structural elements, such as similarities in the problem space (or in regions of the total problem space). Analogy is a heuristic, context-independent strategy that should have a high processing cost due to processing high-level similarities (e.g., the Waitresses and Oranges problem versus the Tower of Hanoi; Zhang & Norman, 1994). Analogies should transfer, and depend upon the activation of either declarative or procedural memory, or both.

6. Task-Specific Procedures

Overview. Like superficial heuristics, task-specific procedures are non-logical, but can achieve correct solutions without the need for long sequences of formal inference rules, or the consideration of multiple mental models. They are reasoning "short-cuts" that produce solutions without the need for a declarative understanding, although some insight may be required to induce them. By necessity, the solution cannot represent the total problem space, and must result from an incomplete or partial search, otherwise these would be of no benefit compared with algorithmic strategies (i.e. token-based or verbal). One limitation of task-specific procedures is that they do not generalize beyond the specific type of task in which they were induced. Logical training may include instruction in the use of such procedures, but this will lead to an "understanding" analogous to that attributed to the occupant of the Chinese Room (Searle, 1984, 1990).

Processing Demands. Once a task-specific procedure has been induced and added to memory, processing demands are due to three steps: (1) encoding relevant, but necessarily incomplete, problem features, (2) activating an appropriate procedure, and (3) implementing this. For example, in a syllogism evaluation task, some subjects concluded that any syllogism with two "somes" in the premises was invalid (Gallotti, Baron, & Sabini, 1986). Implementing a solution requires only sufficient working memory to hold the encoded premises and to fire the appropriate procedure.

Summary. Task-specific procedures are context-dependent, do not necessarily yield a valid conclusion, and do not transfer. The processing cost should be relatively low once a procedure has been induced, due to this being relatively short and/or compiled. Once stored, use depends upon activation of procedural memory by familiar problem elements.

7. Pragmatic Acquiescence

Overview. The preceding six strategies are all traditional cognitive problem solving methods through which responses are produced. However, another possibility is that social elements may influence solutions. Consider the following scenario: A student is asked by his professor to draw a conclusion from two written premises. The student hastily draws a conclusion. The professor begins to talk about other possible interpretations and begins to build a case for another conclusion. When she asks the student if he agrees with her reasoning, the student replies "yes". Pragmatic acquiescence refers to response patterns that are attempts to match the expectations of the questioner. In a situation in which someone has little prior knowledge, he or she may be inclined to seek social cues from the questioner as to how to respond. Rather than using the surface features of the problem, as in superficial heuristics, these solutions are derived from the pragmatics of the problem/testing situation. This type of strategy is used when (1) the pragmatic cues are most salient, (2) subjects lack motivation, or (3) other strategies fail to produce an acceptable solution.

Processing Demands. Pragmatic acquiescence is likely to require at least two steps: encoding relevant cues, and selecting a solution from these. We suggest at least four types of cue: speaker status, language, intonation, and gesture. These cues should demonstrate developmental and cultural effects. For example, children tend to be deferential to adults. Similarly, people in 'collective' cultures tend to defer to authority more than those in 'individual' cultures (Akimoto & Sanbonmatsu, 1999).

Speaker status should be directly related to the probability of acquiescence. That is, the likelihood of matching the expectations of the questioner should increase as the authority of the speaker increases. One implication is that we would expect that suggestions from experts would be more likely to influence behavior than non-experts. This also suggests an informal metric for calculating the status of self and speaker. Language cues may be the most obvious for suggesting the type of response that is expected (e.g., "don't you agree?"). Intonation and gesture cues may trigger the use of pragmatic knowledge, and together may suggest the type of responses expected. For example, increasing pitch at the end of a sentence, or holding an outstretched hand, are both pragmatic cues. Once the reasoner has encoded and interpreted relevant cues, these can determine a response.

Pragmatic acquiescence can occur under a variety of conditions: (1) if no other strategy is identified, (2) if a strategy produces a solution that is in conflict with the pragmatically cued response and fails to override this solution, or (3) if the cued response is so highly activated that it overrides all other strategies. In all cases, this suggests that the reasoner lacks the knowledge or motivation (e.g., being uninterested, polite, political) necessary to solve the problem at hand.

Summary. Pragmatic acquiescence is a heuristic strategy that is context-independent and should transfer across tasks. The cost is relatively low in that it may completely circumvent processing and is, by itself, relatively inaccurate.

8. Retrieval

Overview. Retrieval involves accessing a previous solution from long-term memory. Because there is no processing, this should be the lowest cost strategy with the highest accuracy. The solution in this case is a declarative element (the answer), rather than procedural (a method for finding an answer). No processing is required, but the solution could be the result of previous processing on the part of the reasoner, or by other means (e.g., observing the processing of someone else). In contrast, the retrieval of procedural elements (e.g., context-sensitive schemas in knowledge-based heuristics) requires additional processing to derive a solution.

Retrieval differs from all other proposed strategies in that it is the only one that does not create a solution on-line, instead a solution is accessed directly from memory. For example, we suspect that many cognitive psychology students (and faculty) solve the Wason 4-card task by retrieving the textbook-presented solution. While this may seem an atypical case, logical reasoning problems in the real world often do repeat themselves, and solutions are often socially transmitted.

The tendency to access solutions will vary as a function of the time interval between discovery and access (recency), the number of times the solution is accessed (frequency), and the degree to which the current problem state is similar to the problem state associated with the solution (fit). Guessing could be a loosely constrained form of retrieval in which a response is produced on the basis of inaccurate or irrelevant information[2].

Processing Demands. Retrieval of previous solutions depends on a variety of factors. The most crucial is the number of possible matches to the current problem. If there is only one match, then retrieval is simple. Because there are often several possible solutions to a particular problem, in order to retrieve one, there must be a mechanism to determine which of these will be accessed at any given time, or to perform conflict resolution. We suggest the three common memory mechanisms (recency, frequency, and fit) described above (see Anderson & Lebiere, 1998).

Summary. Retrieval is a context dependent strategy that requires simply the activation of declarative memory. Because there is no processing, this should be the lowest cost strategy with the highest accuracy.

******* INSERT TABLE 1 ABOUT HERE *******

Task Characteristics and Situational Niches

The previous section outlined the key processing stages for each of eight types of strategy. The probability that each will be used is a function of its processing demands and its situational niche. The following section will outline how these factors may be related so as to influence the likelihood of application of specific strategies.

The situational niche is similar to Todd & Gigerenzer’s (1999) notion of ecological rationality. Both notions are derived from Simon’s (1957) concept of bounded rationality, in which reasoning proceeds on the basis of limited processing capacity, and both notions are content/context-sensitive, in that the type of process is a function of the task demands. However, while a system with ecological rationality seeks the most adaptive decision/judgment within an open system (i.e., one in which the most appropriate decision need not result in a favourable outcome), a situational niche represents the current context in which reasoning is occurring, and within this there is a need to match the processing demands of the strategy with the current task demands, but within a closed reasoning system.

The degree to which a problem is familiar will influence the use of a particular strategy. This is expressed on two dimensions: (1) the familiarity of the content and context, and (2) the degree of experience with a particular problem type. Increased familiarity in the first sense should raise the probability of knowledge-based heuristic, analogy, and retrieval strategies. For example, it is a well-documented finding that an invalid syllogism with a believable conclusion is more likely to be accepted than an invalid syllogism with an unbelievable conclusion (Evans, Barston, & Pollard, 1983). In this case, the familiarity of the conclusion may be the most salient element, and thus most likely to elicit a strategy choice (e.g., retrieval, or a knowledge-based heuristic). In the case of less familiar content, for example a syllogism with two “somes” in the premises, a reasoner may recognise that a task-specific procedure can be used to derive a conclusion (Gallotti, Baron, & Sabini, 1986). When given a series of unfamiliar, abstract materials, a reasoner may rely strictly on the formal elements of inference, applying a mental models or a mental logic strategy. In each of these cases the familiarity of content changes the problem’s situational niche, resulting in different probabilities of triggering a given strategy.

In the second sense of familiarity, strategy selection may also depend on the degree of experience a reasoner has with a specific problem type. If a reasoner has a great deal of experience, he or she is more likely to use analogies, or use the same strategy as used on previous trials. Strategy selection will be influenced by previous experiences and outcomes, and these will be associated with the further use of prior strategies. As experience decreases, strategy selection is more likely to be a function of other factors in the situational niche. For example, presentation can be an important influence: Formats may be verbal, written, or visual, and may illustrate or obscure problem characteristics crucial to a correct solution (Larkin & Simon, 1987).

In order to illustrate the possible links between strategy selection and situational niche, we present the following example. Imagine a transitivity problem in which the basic instructions are given as follows:

<u>Five people are waiting in line at a movie theater with a new seating policy. This states that in order to allow everyone to see the screen, all patrons have to be seated by height. That is, shorter patrons are seated near the front while taller patrons are seated near the back. The five people are Homer, Marge, Bart, Lisa, and Maggie. Based on their relative height (including hair), place them in proximity to the screen.</u>

Knowledge of the source material may influence the type of strategy used. A reasoner with a great deal of knowledge of The Simpsons® may simply retrieve a solution due to the high content familiarity. Those with no knowledge of the television show will need to solve the problem using a different strategy, and its selection may depend on the format of additionally presented information. If presented pictorially, the format directly mimics a token-based representation and allows a solution to be derived from scanning the relative heights from the visual array. If presented in writing, task format can influence both difficulty and strategy usage. For example, with an ordered list (as in Example 1), a simple scan of relations may allow a partial solution to be derived. In this case, a task-specific procedure can be used in which the tallest person appears only on the left side of the text, and the shortest person only on the right. From here, the remaining relations must be inferred by using a different strategy.

Example 1:

Homer is taller than Lisa.

Marge is taller than Bart.

Homer is taller than Bart.

Bart is taller than Lisa.

Lisa is taller than Maggie.

Marge is taller than Homer

When terms are randomly distributed in text (i.e., ordering is not aligned with task demands), each element must be encoded and compared to all other components, requiring greater working memory resources (see Example 2). Such a format may best match a token-based strategy, in which the entities are represented spatially as a series of tokens.

Example 2: <u>Homer</u> <u>is</u> <u>taller</u> <u>than</u> <u>Lisa</u>. <u>Bart</u> <u>is</u> <u>taller</u> <u>than</u> <u>Lisa</u>. <u>Marge</u> <u>is</u> <u>taller</u> <u>than</u> <u>Bart</u>. <u>Homer</u> <u>is</u> <u>taller</u> <u>than</u> <u>Bart</u>. <u>Lisa</u> <u>is</u> <u>taller</u> <u>than</u> <u>Maggie</u>. <u>Marge</u> <u>is</u> <u>taller</u> <u>than</u> <u>Homer</u>

These examples suggest a link between task demands, task presentation, strategy processing demands, and individual's processing resources. In particular, differences in task demands and formatting will lead to differences in the salience of problem elements. In addition, previous strategy use will influence the probability that a given strategy will be used in the future. Using this framework, we may be able to explain both inter- and intra-individual differences.

To illustrate further the competition between strategies, consider performance differences due to conclusion believability (belief bias effects). For verbal strategies, errors in processing are attributed to a failure in applying an appropriate rule. There are at least two conditions under which a rule is unavailable: (1) Failure to retrieve[3] a rule may occur temporarily even though it is present in long-term memory. (2) Failure to apply a rule can occur because of content effects (Braine & O'Brien, 1998). That is, when the content is either familiar, or supports an inference beyond that of the statement's form, then the application of a rule is either suppressed or an incorrect rule may be triggered (Rips, 1994). Although this suppression has been cited as a condition under which abstract rules fail to apply, it is plausible that instead knowledge-based heuristics are more likely to be applied. Conversely, knowledge-based heuristics often fail to fire when given abstract elements (e.g., If A then B) and their use is restricted to situations where relations such as obligation and permission can be readily identified (Cheng & Holyoak, 1985; Rips, 1994).

Experiment

We tested three general predictions (detailed below) of the logical strategy model using a web-based experiment in which subjects were given a series of deduction problems (1) to evaluate conclusions as valid or invalid, or (2) to produce correct responses. After producing a response to each problem, subjects were asked to report how they solved each by selecting one from five strategy descriptions. To keep the set of alternatives manageable we focused on those that were most likely to be used for the chosen tasks: token-based; verbal; superficial heuristics; knowledge-based heuristics, and analogy.

The experiment examines three general predictions of the logical strategy model: (1) individuals should use a variety of strategies across a range of logic problems. We predict that no individual will use only one strategy across the entire problem set. (2) Strategy use should be related to problem type such that each strategy's processing demands, in conjunction with a problem's task demands, lead to particular patterns of strategy selection. We particularly predict that (a) problems with familiar content should be associated with knowledge-based heuristics, unfamiliar problems with token-based strategy use; difficult problems with token-based strategies and superficial heuristics, and abstract problems with verbal strategies (because this form is the closest match to the inferential schemas and should be less likely to activate pragmatic schemas; Braine & O'Brien, 1998). We also predict that (b) each strategy has a cost, operationalized as reaction time, and in particular that superficial heuristics and knowledge-based heuristics have a lower cost than analogies, token-based, and verbal strategies. (3) Strategy use should be related to performance: Algorithmic strategies (e.g., token-based, verbal) should be associated with more correct responses than heuristic strategies (e.g., superficial and knowledge-based heuristics).

Method

Subjects

The subjects were 45 University students (mean age 20.8) enrolled in an upper level psychology course. Subjects were given extra credit for participating.

Materials

Twenty-four deductive problems were selected from well-known studies of reasoning (> 100 citations). There were two problem types: syllogisms and conditionals. The syllogisms and most conditionals each consisted of a series of premises (or antecedents) and a conclusion, and subjects were asked to evaluate the conclusion as valid or invalid. In a small subset of the conditionals (Wason-type problems), subjects were presented with a rule in the form of a conditional, and given a series of possible evidence states. Subjects were asked to select those that were necessary to test the validity of the rule.

For each problem type, there were different subtypes in which one element of the problem content was manipulated: abstract versus concrete, familiar versus unfamiliar, and simple versus difficult. Abstract problems used letters only, while concrete items used elements that were related either causally or by permission/ obligation. Familiar elements were well-known (e.g., dogs, cats) while unfamiliar items had nonsensical terms (e.g., thogs, merds). Simple and difficult problems were taken from Braine & O'Brien (1998, Chapter 7) based on subject difficulty ratings of conditional and syllogism problems[4]. Examples of problems are provided in the Appendix.

Subjects were also asked to reflect on how they solved each problem. They were presented with five strategy descriptions, each corresponding to the processing operations in one of the aforementioned strategies. For example, with superficial heuristics, subjects are expected to focus on the surface structure and try to maintain consistency between the terms in the premises and conclusions. The verbal strategy was presented as shown in Table 2 because the implementation of verbal rules is described as being automatic and not requiring conscious processing (Braine & O'Brien, 1998). Each strategy description was tailored to match the content in the problem. Examples are presented in Table 2.

******* INSERT TABLE 2 ABOUT HERE *******

<u>Procedure</u>

Subjects were given a web-link in class and asked to log on and complete the experiment at some point during a one-week period. When subjects logged on they were asked to select their birth date from a range of eight periods. These links took subjects to one of four orders (syllogism first/forward, syllogism first/backward, conditional first/forward, conditional first/backward). The next page gave a brief description of the study. Two further pages asked subjects to give demographic information including major, GPA, SAT scores (verbal, math), and the number of logic, math, and science classes they had taken. The remainder of the experiment consisted of the logic problems and strategy self-reports. The final pre-experimental page presented a brief description of the procedure.

The subjects were asked to solve a series of logic problems for which they (1) evaluated the given conclusion as either valid or invalid, or (2) (for half of the conditionals) selected the correct cases that would test a given rule in Wason tasks (Wason, 1961; Wason & Johnson-Laird, 1972, Cheng & Holyoak, 1985, Cosmides, 1989). The web pages were constructed so that only one response was possible for the former, while up to four responses were acceptable for the latter problems. After selecting their response(s), subjects clicked on the “Continue” button that took them to the strategy self-selection page. On this page, they were asked to think about how they had solved the immediately previous problem. They were asked to select one description from five (see Table 2) -- only one response was possible. After completing all 24 problems, subjects were directed to a final page with a short debriefing, thanking them for their participation.

Results

We conducted this experiment to test three predictions of the logical strategy model: (1) subjects should report using a variety of strategies across the problem set, (2) strategies have costs and that strategy use should be related to the demands of the problem type, (3) strategy use should be closely associated with performance. Unless otherwise mentioned, alpha levels are $p < .01$.

(1) Variation in strategy use.

As predicted, the subjects used a variety of strategies—all five were endorsed by at least some subjects (see Table 3). Subjects differed in which strategies they preferred. The most common modal strategy was superficial heuristics (23), followed by knowledge-based heuristics (11), token-based (9), verbal (2), and analogy (0). The great majority of subjects used several strategies. None of the subjects used only one strategy. Only 2 subjects used a single strategy for more than 75% of the problems. Two thirds of the subjects used all five strategies at least occasionally, endorsing each for at least 10% of trials.

******* INSERT TABLE 3 ABOUT HERE *******

(2) The relationship between strategy use and problem type

(a) Is strategy use associated with a particular type of problem? To investigate this possibility, we calculated strategy frequencies for each problem type. For each problem there was one strategy that was used most frequently. Superficial heuristics were the most frequently selected strategy for 13 problems (3 conditionals, 10 syllogisms), knowledge-based heuristics were most frequently selected for 8 problems (6 conditionals, 2 syllogisms), while token-based were most frequently selected for 3 conditionals, verbal for 1 conditional, and analogy was never the most frequently selected. Table 2 displays strategy choices by problem type (conditional vs. syllogism), by type of conditional (Wason-type vs. non-Wason-type), and by problem content (e.g., familiar).

We predicted specific relationships between problem types and strategy use: That familiar problems would be particularly associated with knowledge-based heuristics, unfamiliar problems with token-based strategies, difficult problems with token-based strategies and superficial heuristics, and abstract problems with verbal strategies.

Knowledge-based heuristics were most commonly used on three of four familiar problems. By contrast, superficial heuristics and token-based strategies were the most frequently selected for all four unfamiliar problems. Superficial heuristics were most frequently selected for all four difficult problems. However, contrary to our predictions, verbal strategies were not selected the most frequently for abstract problems, where there was no clear preference. These results generally confirm our predictions that problem types should be associated with particular strategies, because each strategy's processing demands should be associated with particular task demands/features.

(b) Cost: Strategy use and solution time. We next examined whether strategies had different processing costs as measured by solution times[5]. There were significant differences in solution times related to the type of strategy chosen in the self-report question. The differences in the overall mean solution times were compared in a 2 (item type: conditional vs. syllogism) x 5 (strategy) ANOVA. The results are displayed in Figure 1. There was a main effect of item type, $F(1, 44) = 10.7$, as syllogism solution times (mean = 11 seconds) were significantly longer than conditional solution times (mean = 8.8 seconds).

There was a main effect for strategy, $F(4, 44) = 19.3$. Tukey HSD tests indicated that knowledge-based heuristics (ST = 4.8 sec) and verbal strategies (ST = 6.8 sec) had significantly shorter solution times than token-based (ST = 14.2 sec) and superficial heuristics (ST = 13.2 sec). The solution times for superficial heuristics were much longer than we had predicted and may have interesting implications for our model of strategy choice. In particular, we suspect that subjects, in the course of trying to solve a difficult problem, tried a more accurate strategy first, failed, and then switched to superficial heuristics. This multi-strategy process would hence yield surprisingly long times for the superficial heuristics.

There were no interactions for solution times between item type and strategy, despite some necessary differences in the wording of the strategy questions across tasks types, indicating a stability of these processing differences between strategies.

******* INSERT FIGURE 1 ABOUT HERE *******

(3) The relationship between strategy use and performance

Is strategy choice related to performance? As suggested earlier, algorithmic strategies (e.g., verbal, token-based) should be associated with more correct responses while heuristic strategies (e.g., knowledge-based, superficial) should be associated with more errors. A correlational analysis between the number of correct responses on syllogisms, standard conditionals, Wason-type conditionals, and strategy choices found several significant values. There was a significant positive relationship between the use of algorithmic strategies and correct responses on syllogisms (r = .47), while there was a significant negative relationship between the use of heuristic strategies and the number of correct responses on syllogisms (r = –.29). A similar relationship was found for Wason-type conditionals: The overall number of correct responses was significantly, positively correlated with the use of algorithmic strategies (r = .51) and significantly, negatively correlated with heuristic strategies (–.31)

Conclusions

The Logical Strategy Model suggests that deductive performance is not the result of a specialized system, but results from the application of numerous general strategies. These compete, and ultimately selection is made on the basis of the fit between the unique costs and benefits of the strategy (processing demands) and the salient properties of the problem (task demands). This situational niche (processing and task demands) specifies a task-sensitive strategy selection mechanism on the basis of the ‘best fit’ between available strategies and problem type.

Similar multi-strategy models have been suggested for judgment and decision-making (see Bettman, Johnson, Luce, & Payne, 1993; Todd & Gigerenzer, 1999). Like the logical strategy model, these suggest competition between various strategies in which selection is accomplished, in part, from an evaluation of effort-accuracy trade-offs. However, the logical strategy model (LSM) differs from these models in its function and goals: (1) the function of the LSM is the creation and evaluation of knowledge (inference) rather than selection and evaluation of which knowledge is needed for decision making; (2) the goal of LSM is to explain reasoning performance within a closed system (i.e., definable correct/incorrect responses) while the goal of other, related models is to explain how the most adaptive decision is taken in an open system (i.e., no definable correct/incorrect responses; Todd & Gigerenzer, 1999); and (3) the details of the particular strategies proposed also vary between these accounts.

The results of the experiment provide evidence to support three predictions of the logical strategy model: (1) Individuals used multiple strategies over the problem set. Most subjects reported using multiple strategies and no individual reported using one strategy on more than 75% of trials. (2a) Strategy use was related to problem type. Subjects reported using knowledge-based heuristics when familiar content was present, used superficial heuristics for more difficult and less familiar problems, and reported using token-based strategies for Wason-type tasks. (2b) Strategies had different costs as measured by processing time. Token-based and superficial heuristics were associated with the longest processing times, while knowledge-based heuristics and verbal strategies were associated with the shortest processing times. We had predicted that the use of superficial heuristics would be relatively low-cost, and the higher than expected cost may suggest that either each processing step is costly or that superficial heuristics may be used after unsuccessful attempts with other strategies (e.g., knowledge-based heuristics). (3) Strategy use was associated with accuracy. As predicted, the use of heuristic strategies was associated with a larger number of incorrect responses, while the use of algorithmic strategies was associated with a larger number of correct responses.

As stated earlier, the LSM may allow for explanation of previous findings. Recent research such as Stanovich and West (1998, 2000) has also focused on individual differences. They have shown that individual variability in logical reasoning performance correlates with intelligence for certain types of task but not others. Our model would predict how strategy choice could vary with intelligence (higher capacity strategies for higher capacity individuals), and also that choice could vary independently of intelligence (given the large variety of applicable strategies and relevant background experiences that influence strategy choice).

Our work with the LSM is just in the beginning stages, and there are several obvious next steps to strengthen the empirical basis for our model. (1) We will examine the effect of strategy descriptions on self-report to show that subjects are not confused by the definitions (thereby producing variability) or simply selecting based on social desirability of options (thereby selecting strategies they in fact do not use); (2) we will do more work to triangulate other indicators of strategy use with self-reports of strategy use; (3) we will investigate the possibility of multiple strategies being used on a single problem (as a possible explanation for why superficial heuristic solution times were so long); and (4) we will more closely examine the dimensions on which processing and task demands may influence strategy selection.

Footnotes

[1] It is important to note that the “tokens” need not be represented via a visual or spatial image (see Johnson-Laird, 1999).

[2] Guessing might also resemble other strategies. For example, a guess may be based on surface elements (superficial heuristics), social pressure (pragmatic acquiescence), or the activation of related information (knowledge-based heuristics).

[3] Note that this use of (rule) retrieval is different than our proposed (answer) retrieval strategy.

[4] No information was given on actual difficulty ratings, thus there is no comparison between subject and actual difficulty ratings for these problems.

[5] The solution time was measured as the difference in the time stamp on the designated problem and the strategy selection page that preceded it. Once each solution time was calculated, it was labeled by the strategy self report that followed. For example, a subject responds to the familiar conditional in 3.4 seconds. After responding to this question, the subject then chooses superficial heuristics for the self-report. The datum is entered as “superficial heuristics 3.4 seconds”.

Acknowledgements

The authors would like to thank Corinne Zimmerman, Max Roberts, Elizabeth Newton and Walter Sá for their comments on a previous draft.

References

Akimoto, S. A., & Sanbonmatsu. (1999). Differences in self-effacing behaviors between European and Japanese Americans: Effect on competence evaluations. Journal of Cross-Cultural Psychology, 30, 159-177.

Anderson, J. R., & Lebiere, C. (1998). The atomic components of thought. Mahwah, NJ: Erlbaum.

Bettman, J. R., Johnson, E. J., Luce, M. F., & Payne, J. W. (1993). Correlation, conflict, and choice. Journal of Experimental Psychology: Learning, Memory and Cognition, 19, 931-951.

Braine, M. & O'Brien, D. (Eds.). (1998). Mental Logic. Mahwah, NJ: Erlbaum.

Braine, M., & Rumain, B. (1981). Development of comprehension of "Or": Evidence for a sequence of competencies. Journal of Experimental Child Psychology, 31, 46-70.

Braine, M. & Rumain, B. (1983). Logical Reasoning. In J. H. Flavell & E. Markman (Eds.), Handbook of Child Psychology: Vol. 3. Cognitive Development (pp. 263-339). New York: Wiley.

Cheng, P. W., & Holyoak, K. J. (1985). Pragmatic Reasoning Schemas. Cognitive Psychology, 17, 391-416.

Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans reason? Studies with the Wason selection task. Cognition, 31, 187-276

Evans, J. St. B. T. (1972). On the problems of interpreting reasoning data: Logical and psychological approaches. Cognition, 1, 373-384.

Evans, J. St. B. T. (1989). The psychology of deductive reasoning. London: Routledge.

Evans, J. St. B. T., Barston, J. L., & Pollard, P. (1983). On the conflict between logical and belief in syllogistic reasoning. Memory and Cognition, 11, 295-306.

Galotti, K. M., Baron, J., Sabini, J. P. (1986). Individual differences in syllogistic reasoning: Deduction rules or mental rules? Journal of Experimental Psychology: General, 115, 16-25.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. Cognitive Science, 7, 155-170.

Goel, V., Buchel, C., Frith, C., & Dolan, R. J. (2000). Dissociation of mechanisms underlying syllogistic reasoning. Neuroimage, 12, 504-514.

Holyoak, K. J. & Thagard, P. R. (1989). A computational model of analogical problem solving. In S. Vosniado & A. Ortony (Eds.), Similarity and analogical reasoning. Cambridge, England: Cambridge University Press.

Holyoak, K. J. & Thagard, P. R. (1995). Mental leaps: analogy in creative thought. Cambridge, MA: MIT Press.

Johnson-Laird, P. N. (1983). Mental models. Cambridge, MA: Harvard University Press.

Johnson-Laird, P. N. (1999). Deductive Reasoning. In J. Spence (Ed.), Annual Review of Psychology, Vol. 50 (pp. 109-135). Palo Alto, CA: Annual Reviews.

Johnson-Laird, P. N., Byrne, R. M. J., & Schaeken, W. (1992). Propositional reasoning by model. Psychological Review, 99, 418-439.

Larkin, J. H., & Simon, H. A., (1987). Why a diagram is (sometimes) worth ten thousand words. Cognitive Science, 11, 65-100.

Osherson, D., Perani, D., Cappa, S., Schnur, T., Grassi, F., & Fazio, F. (1998). Distinct brain loci in deductive versus probabilistic reasoning. Neuropsychologica, 36, 369-376.

Rips, L. J. (1994). The Psychology of Proof. Cambridge, MA: MIT Press.

Roberts, M. J. (1993). Human reasoning: deduction rules or mental models, or both? Quarterly Journal of Experimental Psychology, 46A, 569-589.

Roberts, M. J. (2000). Individual differences I reasoning strategies. In Schaeken, W., DeVooght, G., Vandierendock, A., & d'Ydewalle, G. (Eds.), Deductive reasoning and strategies (pp. 23-48). Mahwah, NJ: Erlbaum.

Searle, J. R. (1984). Minds, brains, and science. Cambridge, MA: Harvard.

Searle, J. R. (1990). Consciousness, explanatory inversion, and cognitive science. Behavioral & Brain Sciences, 13(4), 585-642.

Simon, H. A. (1957). Models of man: social and rational; mathematical essays on rational human behavior in society setting. New York: Wiley.

Stanovich, K. E., & West, R. F. (1998). Individual differences in rational thought. Journal of Experimental Psychology: General, 127(2), 161-188.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? Behavioral & Brain Sciences, 23(5), 645-726.

Todd, P.M. & Gigerenzer, G. (1999). Precis of simple heuristics that make us smart. Behavioral and Brain Sciences, 23, 727-780.

Van der Henst, J., Yang, Y, & Johnson-Laird, P.N. (2002). Strategies in sentential reasoning. Cognitive Science, 26, 425-468.

Wason, P.C. (1961). Response to affirmative and negative binary statements. British Journal of Psychology, 52, 133-142.

Wason, P.C., & Johnson-Laird, P.N. (1972). The psychology of reasoning: Structure and content. London: Batsford.

Woodworth, R. S., & Sells, S. B. (1935). An atmosphere effect in syllogistic reasoning. Journal of Experimental Psychology, 18, 451-460.

Zhang, J., & Norman, D. A. (1994). Representation in distributed cognitive tasks. Cognitive Science, 18, 87-122.

Table 1. Summary of predicted strategy properties.

Strategy	Processing demands	Task properties match	Context dependent?	Efficacy/ Solution time	Transfer?	Memory activation	Form of representation	Change with experience
Token-based	High: Verbal and spatial memory	Spatial; Contextual relevance	Yes	Algorithmic Slow	Yes	Procedural Declarative	Linguistic Spatial	Increase
Verbal	Low: Verbal memory	Abstract materials	No	Algorithmic Medium	Yes	Procedural	Schemas; Match to syntax	Increase
Knowledge-based heuristic	Low: Semantic or thematic relations	Semantic and thematic relations	Yes	Heuristic Fast	No	Declarative	Schemas; Match to context	Decrease
Superficial heuristics	Low: Superficial features	Surface structure relations	No	Heuristic Fast	No	Procedural	Surface	Decrease
Analogy	High: Deep structure relations	Structural relations; Isomorphic areas in problem space	No	Heuristic Slow	Yes	Procedural Declarative	Propositional or spatial	No change
Task-specific	Low: Inducing regularities	Previous experience	Yes	Heuristic Fast	No	Procedural	Schemas; Match to task	Increase
Pragmatic acquiescence	Low: Social cues	Social situation	No	Heuristic Fast	Yes	???	???	Decrease
Retrieval	Low: Match to solution	Previous experience	No	Algorithmic Fast	No	Declarative	Propositional	Increase

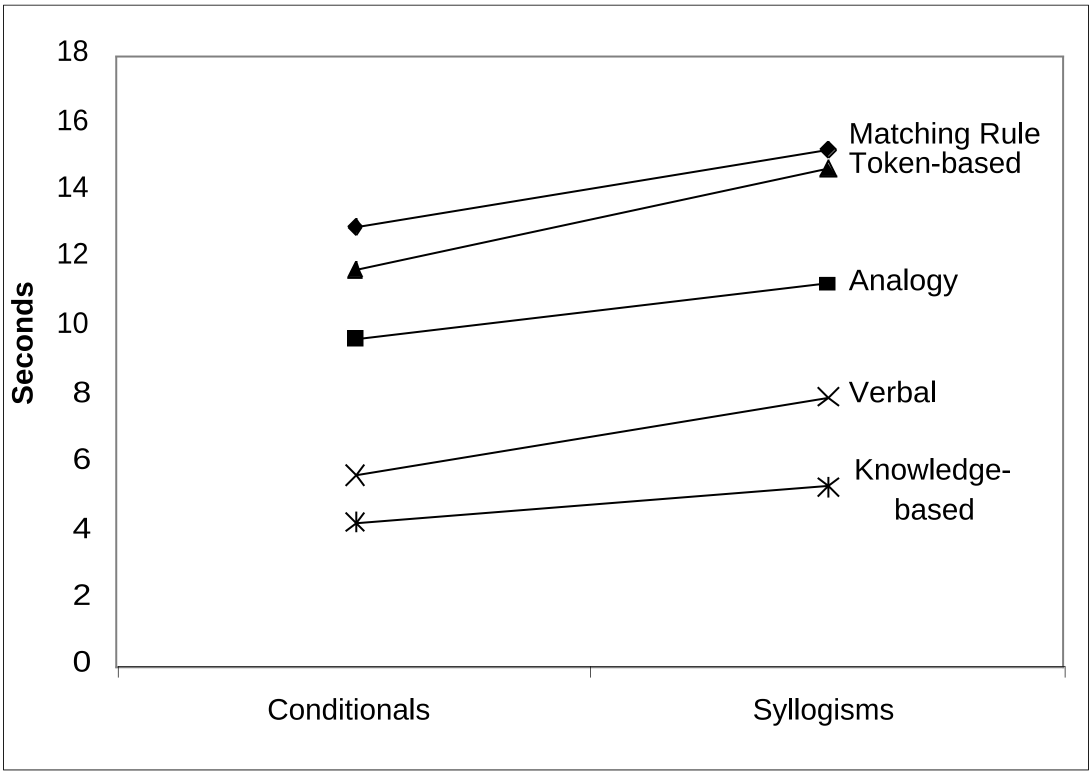
Table 2. Examples of strategy descriptions for the web-experiment.

Tell us how you solved that last problem. Select the description below that best describes how you solved that last problem	
Verbal	I didn’t really have to think it through. My choice just seemed right.
Token-based	I imagined a variety of situations with various letters and looked to see if the conclusion matched what I was imagining.
Superficial heuristic	I looked to see if the key words in the argument (e.g., some, A) were also in the conclusion.
Knowledge-based heuristic	This is the kind of situation in which these items have to be related and I just looked to see if the situation was true.
Analogy	This reminded me of another situation. I thought through the other situation and that allowed me to answer this problem.

Table 3. Strategy selection by problem type.

	Verbal	Token-based	Knowledge-based	Superficial heuristic	Analogy
All items	13%	21%	27%	**31%**	8%
Familiar	13%	21%	**38%**	22%	7%
Unfamiliar	14%	23%	17%	**37%**	8%
Simple	13%	24%	25%	**30%**	8%
Difficult	12%	24%	25%	**33%**	6%
Abstract	10%	29%	18%	**33%**	11%
Concrete	12%	20%	26%	**32%**	10%
Syllogisms	10%	25%	24%	**31%**	11%
Conditionals	14%	24%	23%	**33%**	6%
Wason	14%	**36%**	21%	20%	8%
Non-Wason	12%	22%	22%	**36%**	8%

Figure 1. Solution times associated with self-reported strategies for conditional and syllogistic reasoning problems.



Appendix: Example Problems

(1) Syllogism (abstract)

You are given the following argument:

No A are B

Some C are B

Conclusion: Some C are not A

Is the conclusion valid or invalid?

(2) Wason-type conditional (abstract)

You are given the following rule:

If a card has a vowel on one side, then it has an even number on the other side

Four cards are placed on a table as follows: (A, D, 6, 7).

Which card or cards would be turned over to determine whether the rule is true or false?

Select all that you would need to turn over

A D 6 7

(3) Conditional (familiar)

You are given the following argument:

If Bill is here, then Sam is here

If Sara is here, then Jessica is here

Bill is here or Sara is here

Conclusion: Sam or Jessica is here

Is this conclusion valid or invalid?