ACQUISITION OF COVARIATION INFORMATION IN ELEMENTARY SCHOOL CHILDREN

JILL NOSEWORTHY

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by

©Jill Noseworthy

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Department of Psychology

Memorial University of Newfoundland

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Abstract

The study was designed to determine how children learn covariation information and whether increasing the number of irrelevant dimensions would facilitate implicit learning. Ninety-six fourth and fifth graders were trained on sets of three stimuli varying in size (large and small) and shape (curved and straight). Of the three stimuli, one represented the covariation between shape and size (e.g., large and curved). Half of the participants were trained on sets with one irrelevant dimension (position of the stimulus on the computer screen) and half were trained on sets with two irrelevant dimensions (position and the stimulus pattern; open, filled, or striped). Following training, participants were exposed to a transfer task with novel stimuli, but the same covariation employed in training. Finally, participants were given a verbal awareness test requiring them to tell the experimenter how they solved the problem. This test resulted in three classifications: verbally aware (explicit learners), partially aware, and not verbally aware (implicit learners).

All participants included in the analyses reached criterion during training, indicating that children can

learn covariation information either explicitly or implicitly. As the complexity of the task increased, the learning rate for all participants decreased, particularly for the explicit learners who presumably relied on hypothesis testing. On transfer, explicit learners performed better than implicit learners. The implicit system was not particularly smart, perhaps due to a reliance on contextual cues acquired in associative learning. Partial learners performed like implicit learners on transfer when trained on one irrelevant dimension, and like explicit learners when trained on two irrelevant dimensions.

From these results several assumptions were made about cognitive processes. First, both implicit and explicit pathways are activated in a learning task, with explicit learning rate falling off more steeply than the implicit learning rate as a function of increasing task difficulty. Second, an intersection occurs where both implicit and explicit learning are occurring at approximately the same rate; task difficulty at the point of intersection will vary between individuals. Therefore, an individual who usually learns implicitly has an intercept at a low level of task difficulty and learns difficult problems implicitly. An individual who usually learns explicitly has an intercept at a high level of task difficulty and learns easier problems explicitly. The third assumption was that partial learners acquire information at approximately the same rate implicitly and explicitly; in other words, each partial learner is at the point of intersection. When an individual is a partial learner on an easy task, their implicit and explicit learning curves are presumed to resemble those of individuals who usually learn implicitly. When an individual is a partial learner on a difficult task, their implicit and explicit learning curves are presumed to resemble those of individuals who usually learn explicitly. The final assumption was that learners will show a preference for accessing either implicit or explicit information based on how they usually solve similar problems.

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Introduction

A recent debate in the cognitive literature has focussed around how "smart" or "dumb" the unconscious is. One of the main questions that has been researched involves the level (or levels) of analysis at which the cognitive unconscious functions as it processes information that can later influence thoughts, perceptions, and behaviours. Research and reviews to date uncover mixed evidence for simple versus sophisticated unconscious processes. Consequently, a renewed interest in, and greater scrutiny of, the cognitive unconscious has ensued.

The cognitive literature is rich with evidence for unconscious acquisition of information, particularly within priming studies and learning paradigms. However, other tasks have yielded information that is inconsistent regarding the sophistication of unconscious processes (see Greenwald, 1992; Shanks & St. John, 1994 for reviews). Priming studies demonstrate facilitation of the perception of previously seen single words and figures, even when those words and figures are degraded to the point of not being consciously detectable (Tulving & Schacter, 1991; Loftus & Klinger, 1992). However, facilitation has not been obtained with more complex sequences of words. Thus, priming seems to occur with simple but not complex stimuli.

Similarly, subliminal activation research has yielded inconsistent results which consequently challenge the sophistication of unconscious processes. In subliminal activation studies target stimuli (visual or auditory) are below the threshold for conscious detection. Kunst-Wilson and Zajonc (1980) reported that participants exposed to shapes at intervals too brief to allow for later recognition, gave more favourable ratings to those stimuli to which they had been previously exposed. Mandler, Nakamuri, and Van Zandt (1987) found that prior exposure in the absence of recognition facilitates any relevant judgement about the stimulus. Clearly, information that can facilitate later performance has been processed at an unconscious level.

Greenwald (1992) argued that despite the evidence for unconscious processing in priming studies, the processes themselves are not particularly sophisticated. Therefore, such evidence lends no credence to the unconscious as a complex entity. Similarly, with respect to the subliminal activation research, Greenwald proposes that the memory traces for shapes or words presented during the exposure phases are quite simplistic and should not be used as evidence for a highly sophisticated unconscious. Greenwald (1992) does not attempt to discount evidence for unconscious processes. However, he does caution readers that the levels of analysis upon which the unconscious is operating in these studies are so fundamental that arguments for a complex unconscious are premature.

Despite the scepticism, much research exists in support of the activation of the unconscious, particularly within learning paradigms. Such unconscious acquisition of information, or so-called "implicit learning", has been demonstrated in the cognitive literature and will be the focus of this study (see Reber, 1989; Lewicki, Hill & Czyzewska, 1992 for reviews).

In the following sections, issues related to the implicit acquisition of information will be addressed. Distinctions will be made between the conscious and unconscious learning pathways, whether the unconscious pathway is capable of acquiring information, how the implicit system may be more efficient than the explicit system, the relative sophistication of the implicit system, and whether or not the processes engaged in by the implicit system may be regarded as "smart". Criticisms of implicit learning research also will be discussed. Specific to the present study, unconscious learning will be addressed from a developmental perspective and reasons will be presented regarding why children may be better participants than adults in implicit learning studies.

Defining The Conscious - Unconscious Dichotomy

Although at the most basic level "unconscious" merely means "unaware of", Greenwald (1992) poses two senses of the conscious-unconscious dichotomy. The first sense of "unconscious" is that which is "outside of attention". From this point of view, the conscious end of the dichotomy is viewed as a selective aspect of attention. Therefore, one is unconscious or unaware of a stimulus when it falls outside the focus of selective attention but still impinges on receptors. An illustration of this sense of "unconscious" would be the dichotic listening task. In this selective attention task, two different messages are delivered to the two ears, but only one message, that which is delivered to the primary channel, usually is attended to. Some evidence exists for the low level analysis of physical features and intermediate level analysis of word meaning from information delivered in the secondary channel, providing support for the unconscious processing of unattended stimuli (see Greenwald, 1992, for review).

The second sense of "unconscious" described by Greenwald (1992) is "lack or failure of introspection". Here, if consciousness is presumed to be an individual's ability to validly report experience, then unconsciousness is described as an individual's inability to verbally report the stimuli to which they have attended. Such dissociation between performance and awareness has been demonstrated in most implicit learning research (Reber, 1967; Reber, 1976; Reber & Lewis, 1977; Lewicki, 1986; Lewicki, Czyzewska, & Hoffman, 1987; Lewicki, Hill, & Bizot, 1988). It is this sort of "verbally unreportable" acquisition of information that is the focus of the present study.

Unconscious Acquisition of Information

The next point of contention is whether it is possible for humans to acquire information unconsciously; that is, without the information being verbally reportable. Despite the current debates surrounding the sophistication of implicit processes, the answer would appear to be "yes".

Such "implicit learning", according to Reber (1967), occurs without concurrent awareness of what is being learned and can be viewed as distinct from "explicit learning". But what exactly is implicit learning? Seger (1994) offers three criteria that characterize the nature of implicit learning. The first criterion states that the knowledge that is acquired as a function of implicit learning is not available to consciousness. This would appear to be the case by virtue of the fact that individuals participating in implicit learning studies are rarely capable of providing a verbal account of what they have learned (Lewicki, 1986; Lewicki et al., 1987; Lewicki et al., 1988; Reber, 1967; Reber & Lewis, 1977).

The second criterion states that the information acquired during implicit learning is more complex and sophisticated than the learning of simple associations or frequencies (Seger, 1994). Seger (1994) contends that implicit learning reflects the acquisition of information that is rather abstract and presumably too sophisticated to be handled efficiently by the conscious. Both of these criterion echo the descriptions already put forth by Reber (1989) and supported by Lewicki et al. (1992). However, the existing literature fails to specify the processes that may be involved in implicit learning. Despite the conjectures of Seger (1994), participants may indeed be learning simple associations or automatically tallying frequency counts. For example, in the rule-based implicit learning paradigm, such as the artificial grammar studies of Reber (1967; 1976), some bigrams or larger stimulus string segments are generated that have a higher frequency count than others. The participants in these studies may become sensitive to the frequency of certain segments. Similarly, in the pattern learning paradigm employed by Lewicki and colleauges (1986; 1987; 1988) the participants may acquire associations between segments of the stimulus patterns that precede the key trial and the key trial itself.

The third criterion put forth by Seger (1994) is that implicit learning is an "incidental consequence of the type and amount of processing performed on the stimuli" (p.164), and does not involve the processes used during conscious hypothesis testing. Seger (1994) proposes that such an interpretation can defend against those arguments suggesting that the participants have gained fragmentary knowledge of the rules that govern the experimental task (Dulany, Carlson, & Dewey, 1984; Perruchet, Gallego & Savy, 1990; Shanks & St. John, 1994). Because the participants have not acquired their information through hypothesis testing (conscious pathways), one might conclude that an independent and unconscious pathway was used.

Evidence for unconscious or implicit learning can be best illustrated with the work of Reber (1967, 1976) and Reber and Lewis (1977). In one of his earliest studies, Reber (1967) showed participants exemplary strings of a rule-governed artificial grammar. The participants, however, were not informed that the grammar was founded on a set of rules. Instead, they were instructed to use rote rehearsal tactics to memorize the strings they were shown. Results demonstrated that those participants required to memorize the rule-governed strings improved across trials. Control participants, who were given strings of random letters with no underlying set of rules, showed no marked improvement in memorizing the letter strings. Despite the neutrality of the instructions, the experimental participants appeared to become sensitive to the rules that governed the artificial grammar. Reber (1967) concluded that participants learn to use the structural relationships that exist in a complex stimulus environment, and use that information to direct their choices. This finding has been supported by others providing evidence that at some level the unconscious is capable of acquiring new information (Morgan & Newport, 1981; Dulany et al., 1984).

Similarly, Broadbent and colleagues have demonstrated that participants can implicitly learn the complex rules governing an economic/production simulation. In a series of studies, participants were given a hypothetical manufacturing dilemma whereby they were required to manipulate variables like wages and worker output in order to yield a satisfactory production standard. Unknown to the participants, the simulation operated on a set of sophisticated rules that related variables to each other. Consequently, these rules would have to be known in order to achieve the required production standard. Results showed that the participants acquired the complex rules. The acquisition appeared to be implicit as they had no conscious knowledge of those rules (Broadbent & Aston, 1978; Berry & Broadbent, 1984; Broadbent, Fitzgerald, & Broadbent, 1986).

Implicit Learning Versus Explicit Learning

The studies mentioned above involved the withholding of specific instructions and information to the participants. The instructions were sufficiently vague to insure the participants would not be motivated to look for existing patterns and regularities. Given the evidence for unconscious or implicit learning under these conditions, Reber and Millward (1968) set out to determine what effect explicit instructions, and consequently, explicit learning, would have on the performance of individuals. More specifically, would participants given explicit instructions, as compared to those given vague instructions, be at an advantage? Or, put differently, would participants learning explicitly outperform those learning implicitly?

Reber and Millward (1968) used a probability learning paradigm. Participants were required to indicate which of a number of lights would dominate in brightness over a series of trials. One group was given explicit instructions with respect to the frequency and probability rules that governed the task; the other group was not given any specific information. Contrary to expectations, the group which received specific instructions regarding the rules did not perform any better than the group that received only vague instructions. More importantly, the participants receiving specific instructions reported that although the instructions they were given were precise and reliable, they were not sufficient. Actual experience with the task was what participants reported relying on most heavily (Reber & Millward, 1968).

It would appear that in tasks that employ frequency and probability rules, conscious processes (explicit) are not as efficient as unconscious processes (implicit) at learning information. Actual experience with the task may be more beneficial to the participants than exposure to complex and potentially confusing rules. This proposition was eluded to by Reber (1976). In his study, two groups were required to memorize exemplars from an artificial grammar. However, one group was explicitly instructed to look for the structure that guided the grammar whereas the other group was given instructions that were vague. During the test phase, participants were asked to assess the grammatical correctness (within the constraints of the artificial grammar) of novel strings. Participants who were given explicit instructions performed more poorly than those given vague instructions. These participants took longer to learn the exemplars, performed more poorly on the grammatical correctness task, and induced rules that were not close to those being employed in the artificial grammar.

Sophistication of the Implicit Learning System

In the learning experiments described so far, participants demonstrated their knowledge through improved performance, but they were unable to verbalize those rules that were presumably accounting for their performance. What is the nature of the learning task that makes unconscious processing a more likely option than conscious processing? Seger (1994) notes that all of the stimulus structures employed for implicit learning studies are complex, in fact, so complex that participants cannot verbalize the patterns responsible for performance change. It is possible that implicit learning processes function ideally only with those patterns that are highly complex. This is not an unreasonable assumption given that simple patterns would be more likely to become known explicitly through noticing the pattern incidentally or engaging in conscious hypothesis testing (Seger, 1994). Whether the process is incidental or a function of conscious hypothesis testing, Seger (1994) believes that simple patterns and rules are obvious enough to be picked up by the conscious.

In addition, the cognitive unconscious appears to be more adept at processing complex information than the conscious. As was demonstrated by Reber and Millward (1968), who investigated the effects of explicit versus vague instructions, implicit processing held an advantage over explicit processing. The opinion that implicit processes are superior to explicit processes when stimuli are composed of complex contingencies is also held by Lewicki and colleagues. Lewicki et al. (1992) believe that the research to date indicates that unconscious acquisition processes are not only faster, but structurally more sophisticated than conscious processes. In addition, they contend that unconscious processes allow for "the development of procedural knowledge that is unknown to conscious awareness not merely because it has been encoded ... through channels that are independent from consciousness. This knowledge is fundamentally inaccessible to the conscious because it involves a more advanced and structurally more complex organization than could be handled by consciously controlled thinking" (Lewicki et al., 1992;

p. 796). This is precisely the position that is defended by Seger (1994).

Despite Lewicki (1992) and Seger's (1994) support for the sophistication of implicit processing, neither offer a mechanism explaining how or when implicit learning is likely to occur. Specification of such a mechanism might foster an understanding of implicit learning. As an initial attempt, it is proposed that both implicit and explicit learning occur in parallel, with the observed process being that which acquires the necessary information most quickly. Whether that process is explicit or implicit would most likely depend on the complexity level of the task.

Defining Unconscious Processes as "Smart"

From the evidence presented above, it appears that the unconscious is capable of processing information, and that humans are capable of using the information which has been acquired implicitly. In other words, the unconscious appears to be "smart". It is exactly this conclusion that has sparked the recent debates between those who support a smart unconscious and those who do not. It is necessary to note here what defines a "smart" process. According to Loftus and Klinger (1992), smart processes can be categorized in different ways. One factor described by Loftus and Klinger (1992) is certainly not new. Advocated by Greenwald (1992), a "smart" mental process can be defined as one that is complex. If we were to polarize, the analysis of basic stimuli like lines and angles would fall on the simplistic end of the continuum, and the more intricate analysis of multi-string words and their relations would fall on the complex end (Greenwald, 1992). Thus the processing of patterns into abstract and sophisticated information would constitute a smart process (Loftus & Klinger, 1992).

Another factor, described by Loftus and Klinger (1992), that may deem a process "smart", is the ability to deal with novel situations. Thus, a process that can functionally adapt to an atypical situation would be considered "smarter" than one that cannot make creative use of resources to solve a novel dilemma.

Implicit Processes in the Implicit Learning Paradigm

In the implicit learning paradigm, stimuli are above the threshold for detection (supraliminal). That is, participants are aware of the presence of the stimuli. However, they are unaware of the relationship(s) between those stimuli and the required responses. A clear example of supraliminal information and unconscious learning is the work of Reber (1967; 1989). In his artificial grammar and probability learning paradigms, the stimuli are never masked or hidden from the participants. However, the relationships between the stimuli in these paradigms are inconspicuous, and it is these relationships that the participants must learn, possibly at an unconscious level, in order to solve subsequent tasks.

Lewicki and colleagues (1987; 1988) have also used the probability learning paradigm to investigate implicit processes. In the pattern learning experiments, participants are seated in front of a computer screen which is divided into four quadrants. At set intervals, the target stimulus can appear in any one of the four quadrants. Their job is to indicate, as quickly as possible following target exposure, in which of the four quadrants the targets appeared. The target location is not random but governed by a set of complex rules. The position of the target in some of the preceding trials determines where the target should appear in the final key trial of a sequence.

Over trials the participants show improvement as their response rates to target position become quicker and their success rates higher; clearly they are becoming sensitive to the rules upon which the sequences are governed (Lewicki et al., 1987; Lewicki, Hill, & Bizot, 1988). Moreover, once the trials are completed and the participants are required to indicate to the experimenter what rules were used, they are unable to verbalize the actual set of rules upon which the pattern was based. This is to say that there is a dissociation between the actual performance and the awareness of the rules that guided performance. Alternatively, as Greenwald (1992) would put it, there is a lack or failure of introspection; this can be taken as evidence for unconscious learning (Lewicki et al., 1987; 1988).

Criticisms and Imposing Criteria

The data and conclusions reached by both Reber and Lewicki and colleagues, although impressive, are controversial. Some researchers claim that the results obtained by Reber (1967; 1977) and Lewicki et al. (1987; 1988) are the due to participants having acquired a partial conscious knowledge of the patterns that develop during the experimental procedures. In some studies, experimenters have found that participants could report fragments of the complex rules that governed the experimental patterns (Dulany et al., 1984; Perruchet et al., 1990; Brooks & Vokey, 1989). It could be the case that the rules governing those particular tasks were too obvious or simplistic and, thus, easily discerned by the conscious.

Shanks and St. John (1994) have recently proposed two criteria they argue must be met in order to conclude that unconscious learning has taken place. First, the Information Criterion requires the experimenter to establish that the information sought in the awareness test (that is, the test that will assess whether or not the subject is aware of the rules that underlie the task they have completed) is indeed the information that is responsible for the performance change in the participants. Second, the Sensitivity Criterion requires that the awareness test be sensitive, or able to pick up on all of the relevant conscious information possessed by the subject. It is possible that a performance test is quite sensitive to conscious information, whereas an awareness test is not sensitive to that same information (Shanks & St. John, 1994). The end result then, is apparent unconscious learning that should be attributed to conscious processes.

From the perspective of Shanks and St. John (1994), the research of Lewicki et al. (1987) does not satisfy the above mentioned criteria. In their pattern learning study, Lewicki et al. (1987) showed participants nonrandom sequences of targets on a computer screen divided into four quadrants. The participants were required to press the button that corresponded with the quadrant in which the target appeared as soon as they were aware of the target location. Participants were exposed to twelve hour-long sessions, divided into four segments by short breaks. Each segment consisted of 96 blocks, with each block composed of six simple trials followed by one complex matrix scanning trial. On a simple trial, the target appeared clearly in one of the four quadrants. On the complex trial, the target was shown against a back-drop of visual noise (the target was embedded in a 36 digit distracter display) making it more difficult for the subject to detect. Unknown to the participants, the position of the target on this "complex" trial was a function of the position of the targets on four of the six preceding "simple" trials (1, 3, 4, and 6). The positions of the target on the remaining two "simple" trials (2 and 5) were random and irrelevant in determining the position of the target on the complex trial.

This relation was rather complicated. Nonetheless, the participants appeared to become sensitive to the nonrandom nature of the target presentations as evidenced by decreased response latencies over trials. In addition, when assessed on the awareness test, the participants were unable to verbalize the complex relationship that determined the placement of the target on key (complex) trials - there was complete dissociation between performance and awareness.

Shanks and St. John (1994), however, argue that these conclusions are incorrect. The problem lies in what Shanks and St. John (1994) refer to as "micro-rules", that enabled the participants to acquire a fragmentary knowledge of the rules governing the sequences. In reviewing the four key simple trials, Shanks and St.John (1994) found that although thorough knowledge of the sequence guaranteed certainty about the target placement in the seventh trial, the sixth trial alone was informative enough to increase the probability of guessing correctly which quadrant the target would appear, thus, decreasing the reaction time. Such fragmentary rules, if consciously acquired and implemented, would increase the probability of responding correctly and quickly on the seventh key trial. Thus, the information that Lewicki et al. (1987) were looking for through the awareness test may not be the information that was responsible for the change in performance. That is, there would appear to be a violation of the Information Criterion.

With respect to the Sensitivity Criterion, Shanks and St. John (1994) question whether the performance and awareness tests employed by Lewicki et al. (1987) were matched with respect to the conscious information they were able to pick up. That is, it could be the case that the performance test was sensitive to the conscious information acquired through fragmentary rules, but the awareness test could not tap into this conscious information. As a result, the questions posed during the awareness test would not be relevant to the information employed by the participants, and that information would not be revealed by the participants during questioning. Thus, dissociation could have been erroneously attributed to unconscious acquisition of information.

Another study by Lewicki (1986) has also been subjected to the scrutiny of Shanks and St. John (1994). In order to determine whether information about covariations could be learned implicitly, Lewicki (1986) exposed participants to pictures of peoples' faces. The experimental manipulation consisted of the covariation between hair length and personality characteristics on the acquisition trials. All participants saw pictures of people with both short and long hair, as well as a brief personality description. The covariation with personality was manipulated in such a way that half the participants were exposed to long-haired people whose accompanying personality description eluded to a "kind" quality, and the other half were exposed to short-haired people whose accompanying description eluded to a "capable" quality.

During the test phase, participants were shown a new set of pictures and asked to agree or disagree with statements that categorized the people in those pictures as either "kind" or "capable". Results indicated that participants were more likely to confirm the categorization when it was consistent with the covariation upon which they had been exposed to during the acquisition phase. These results were taken as evidence that the participants had unconsciously acquired the relevant covariation between hair length and personality.

Finally, during the awareness test, participants were asked if they were aware of any co-occurrence between the psychological descriptors of the stimulus people and any of their physical features. The participants gave no indication that they were consciously aware of the existing relationship between hair and personality suggesting that the covariation had been acquired by the participants unconsciously. Shanks and St. John (1994), however, argue that there is no evidence that Lewicki (1986) has satisfied the Sensitivity Criteria. As was the criticism of Lewicki et al. (1987), it could be that the acquisition test was far more sensitive to the participants' conscious knowledge than was the awareness test.

In an attempt to replicate the work of Lewicki et al. (1986), Stadler (1989) conducted a similar study. According to Shanks and St. John (1994), the Sensitivity and Information Criteria were met. The study replicated the Lewicki et al. (1987) target location paradigm with one exception; instead of the standard "question and answer" style awareness test, Stadler (1989) employed a transfer test called a "prediction task".

In the prediction task, the participants were shown similar blocks of seven trials where the target location on the seventh complex trial could be determined by the sequence of four preceding simple trials. On the seventh trial, however, the participants were faced not with an embedded target, but four question marks placed in the four locations that could possibly house the target. The participants were then required to guess, without experimenter feedback, which of the four quadrants the target would appear.

Because this prediction task made it possible for the participants to use whatever conscious knowledge they had acquired (sequential or fragmentary), the Information Criteria was satisfied. The experimenter would not be restricting awareness questions to aspects that were not responsible for performance change. In addition, because the prediction task was very similar to the learning trials, Shanks and St. John (1994) contend that the Sensitivity Criteria was met, as both the acquisition and the awareness test would pick up on the same amount of conscious knowledge.

Stadler (1989) replicated the finding of Lewicki et al. (1986) that over trials reaction time on complex target trials significantly decreased. Performance on the prediction (awareness) task revealed the participants could correctly predict target location only 11 to 13 times out of 48. Thus, there was no evidence for the subject's awareness of the rules. Shanks and St. John (1994) suggest that the complexity of the prediction task may have caused the participants to forget what they had previously learned, due to interference. An alternative explanation could be that the participants acquired the relevant information implicitly during the acquisition phase, but were unable to transfer that information to the novel complex trial used in the prediction task.

The work of Reber (1967)and Reber and Lewis (1977) has not escaped the criticisms of Shanks and St. John (1994). In the typical grammar learning paradigm, participants are required to memorize a series of letter strings that are generated from a rule-driven artificial grammar. A control group is required to memorize similar, but random, letter strings. Participants are then tested on novel strings.

They are required to indicate to the experimenter whether or not the string is "correct" within the constraints of the artificial grammar or rules they have acquired. Participants in the rule-governed group perform well above chance and are unable to verbally report the rules used to solve the task. The conclusion drawn in these studies is that the participants have used an unconscious rule induction mechanism.

With respect to the Sensitivity Criteria, Shanks and St. John (1994) are not convinced that a retrospective verbal report is sensitive enough to test the conscious knowledge of rules. An alternative could be concurrent thinking aloud and recognition tests to increase the Sensitivity between acquisition and awareness (Shanks & St. John, 1994). With respect to the violation of the Information Criteria, Shanks and St. John (1994) suggest that within the artificial grammar paradigm, the participants may be learning something other than rules during the training trials. Thus, to ask the participants to reveal what they have learned about rules during the awareness test will inevitably result in false conclusions. Shanks and St. John (1994) suggest that the participants in these studies acquire the information about the task over trials via "...simple memory mechanisms that collect frequency statistics..." on occurring sequences.

Insuring Conformity to Information and Sensitivity Criteria

It would appear that the Information and Sensitivity Criteria are essential to researchers who wish to explore unconscious learning. To ensure that neither of these criteria are violated, Shanks and St. John (1994) suggest that either the test of awareness must be sensitive to all potentially relevant conscious information or be at least as sensitive as the performance test in detecting potentially relevant conscious information. The best solution is to make the awareness test as similar as possible to the performance test with respect to retrieval context. However, the tests should differ in terms of instructions (Shanks & St. John, 1994). The instructions for the awareness test should encourage the participants to retrieve as much information as possible. Given this format, it is unlikely that the participants would retrieve more conscious information on the performance test than the awareness test because the instructions on the awareness test are particularly motivating (Shanks & St. John, 1994).

A Developmental Perspective of Unconscious Learning

From a developmental perspective, it is unquestionable that pre-verbal children learn without verbal awareness. For example, at preschool age it is relatively easy to demonstrate that grammatical information is acquired intrinsically. In her classic "wug" study, Berko (1958) demonstrated that children as young as pre-school age clearly possess knowledge of morphological rules and can transfer that knowledge to novel artificial words. By preschool children have acquired and are capable of using complex grammar rules without actually being aware of the underlying structure of those rules, thus indicating implicit acquisition of this linguistic knowledge. Based on the artificial grammar studies of Reber (1967, 1977) and the pattern learning and covariation studies of Lewicki et al.(1986, 1987, 1988), the goal of the present study is to determine whether or not older children have the ability to learn covariation information implicitly or explicitly.

There is evidence for children understanding covariations at a very early age. Kuhn, Amsel, and O'Loughlan (1988) carried out a set of experiments to evaluate participants ability to understand the relationship between antecedent and outcome. In these experiments, it was demonstrated that children as young as eight years old were capable of understanding the covariation between antecedent (cause) and outcome (effect) when directed to the realtionship and asked to rate the extent to which the presence or absence of a variable (e.g. component of a stain removal mixture) will effect outcome (e.g. whether or not the stain is removed) (Kuhn et al., 1988).

The ability of children to understand covariations is also evidenced in a study by Sodian (1991) (cited in Ruffman, Perner, Olson, & Doherty, 1993). Children were told the story of a character trying to determine whether the size of a tennis racket or the materials it was made from would affect the manner in which the racket could be used to serve a ball. In the story, the character developed an experiment whereby different people made serves with rackets that varied on one dimension while the other was held constant. At the end of the character's experiment, the children were shown ratings of each of the rackets. The children were then required to explain to the experimenter how each rated racket either supported or refuted the hypothesis that it was size alone that had the greatest effect on serve. That is, the children were required to demonstrate an understanding of the covariation between a focal variable (size) and an optimum outcome (high quality serve) in order to provide supporting evidence for a hypothesis. Results indicated that by the age of eight, more than half of the children were proficient at verbalizing an understanding of the relationship.

In a similar study, Ruffman et al. (1993) set out to determine at what age children could understand covariations that supported a hypothesis in favour of a particular cause for an observed effect. Four and five year old children were first introduced to a character "Sally" who left to "go play" shortly before the task was to begin. The children were then shown pictures of boys "eating" either red or green food; actually, the food was represented by pieces of coloured paper laid next to the pictures. All of the boys who were eating red food had a full set of healthy teeth. However, those who were eating green food had several of their teeth missing. The children were first asked to assess the covariation evidence by telling the experimenter which food makes kids teeth fall out. All of the children answered correctly, associating the correct colour food with tooth loss.

In the second phase, the children were told that "Sally" would be returning. The experimenter then "faked" the evidence so that it now looked like the red food caused tooth loss and the green food resulted in healthy teeth. The children were then asked what "Sally's" conclusion would be given that the evidence was now faked. A control question followed in order to determine whether or not the children had changed their hypotheses in light of the faked evidence even though they were told by the experimenter what hypothesis was "true". The results indicated that the five year olds performed well above chance, successfully determining that changing the covariation evidence would alter the hypothesis for "Sally", but not for themselves.

The research of Kuhn et al. (1988), Sodian (1991) and Ruffman et al. (1993) are by no means indicative of children's ability to acquire covariation information implicitly. In fact, the tasks adopted in both studies were quite explicit, with the children clearly directed to the existence of a covariation (evidence) with an accompanying hypothesis. It does, however, demonstrate that very young children can appreciate the concept that two variables (size and serve quality or food colour and tooth loss) must always occur together in order to maintain a supported hypothesis.

To date, there is little published material investigating children's unconscious acquisition of covariation information. However, in an unpublished manuscript, Czyzewska, Hill and Lewicki (1991) found that four and five year old children were able to implicitly learn a covariation between the clothing colour of children presented on posters and general categories (physically active or physically passive) of their activities (cited in Lewicki et al., 1992). Based on these findings, Lewicki et al. (1992) concluded that very young children are capable of learning complex contingencies unconsciously.

More specific to the present study is the work of Rabinowitz and Howe (1994). In Experiment 2, they looked at the role of verbal awareness and implicit learning in the acquisition of the middle concept (that is, the conceptual middle as opposed to the positional middle). Participants ranging in age from 7 to 10 years old were shown stimulus sets of three items each, from which they were required to select the conceptual "middle" item. The pretraining sets consisted of two sets each representing area (masonite squares), number (number of dots on a card), and height (wooden dowels). Of these sets, participants were pretrained on either one or two sets within the same dimension, or two sets from different dimensions. Participants were instructed that they would be shown three items in a set, and from that set they were to select the "correct" thing. They were not told the rule that made one item "correct", but were told whether or not they had made the correct choice.

After criterion had been reached on pretraining, the children were exposed to 18 test sets (the transfer task) representing physical dimensions (colour, gap size in the arc of a circle, ellipse shape) and cognitive dimensions (age, body parts, story sequence). These dimensions were novel and differed from those they had been trained on, but still represented the middle rule. In transfer, the children were told that they would view some new items, and if they thought about what they had learned in the previous task they would be able to determine the correct response. They were not told whether they were right or wrong on the transfer tests. Once the transfer task was completed, the children were asked how they had solved the problem. Those children who indicated that the solution was "middle" or "second" were classified as "extrinsic learners", as they had verbally described the middle rule, while those who could give no indication were classified as "intrinsic learners".

Both children classified as "intrinsic" and "extrinsic" learners were able to reach criterion during pretraining. Such a finding provides further support for Lewicki et al. (1992) who purport that children are capable of learning complex contingencies intrinsically. However, Rabinowitz and Howe (1994) also found that intrinsic learners required more trials to reach criterion than those participants classified as extrinsic learners. Consequently, it is questionable whether or not the cognitive unconscious is capable of operating faster than the conscious, which is a contention of Lewicki et al. (1992).

With respect to verbal awareness for the middle rule, children who were pretrained on two training sets (either same or different dimensions) were more likely than children trained on only one training-set to extract the middle rule and demonstrate this knowledge with verbal awareness.

Moreover, only those participants who demonstrated verbal awareness of the middle rule (that is, the explicit learners) were able to transfer that rule on the test trials. If, as Loftus and Klinger (1992) contend, that a smart cognitive process is one that can deal flexibly with novel situations (in this case, the transfer task) then conscious learners, within the Rabinowitz and Howe (1994) paradigm, were smart. Unfortunately, the poor transfer performance of the implicit learners lends no such evidence for a smart unconscious. These results appear to favour Greenwald (1992) and a relatively unsophisticated unconscious.

Transfer Task as a Method for Increasing Sensitivity

The transfer task adopted by Rabinowitz and Howe (1994) has merit as a mechanism to address the Sensitivity Criterion. Shanks and St. John (1994) contend that the Sensitivity Criterion is violated when the awareness test cannot detect conscious information that may be responsible for the change in performance. By using a transfer task, an additional source of information becomes available which can be compared with that obtained from the awareness test. Since the transfer test employs the same methodology as the training task, a "sensitive" performance measure would also impact conclusions.

The introduction of the transfer task provides alternatives for interpreting the results. With a transfer task, a new set of stimuli are shown to the participants. Although the stimuli are new, the "rule" is still the same as that which was used to solve the pretraining task. Using this paradigm, there are several possible outcomes. First, participants could transfer and display verbal awareness, thus showing a smart conscious that can deal flexibly with novel situations. Second, participants may be able to transfer but be unable to demonstrate verbal awareness. Such a finding would provide evidence for a smart unconscious that can transfer information independent of conscious awareness. Third, participants may be unable to transfer but be able to demonstrate verbal awareness. This would be indicative of a rather dumb conscious. Finally, participants may be unable to transfer and unable to demonstrate verbal awareness, consequently showing a dumb unconscious.

Advantages Gained by Using Child Participants

Most studies of implicit learning have involved adult participants and highly complex tasks (Berry & Broadbent, 1984; Broadbent & Aston, 1978; Broadbent et al., 1986; Lewicki et al., 1986, 1987, 1988, Reber et al., 1967, 1977). Clearly with an adult population, the learning task employed will be more complex than those used in studies involving children. A highly complex task carries with it the opportunity for participants to solve the problem by means other than that intended by the experimenter. This problem results in violation of the Information Criterion put forth by Shanks and St. John (1994) and is precisely the basis upon which the studies of Lewicki et al. (1986, 1987) and Reber (1967; 1977) have been criticized. The Information Criterion requires the experimenter to establish that the information sought through the awareness test is indeed the information responsible for performance change in the participants (Shanks & St. John, 1994). By using adult participants, and the necessarily complex tasks, firm conclusions about implicit learning are less likely than when the task employed is less complex. The complexity of the task employed in adult studies may provide participants with conscious knowledge of alternative solutions that the experimenter did not intend and subsequently is not accessed through later awareness tests. With child participants, the tasks employed are less complex, relative to those employed with adult participants. For this reason, children are better participants in studies that look at the unconscious acquisition of information. By using child participants, and simpler learning tasks for which there are fewer solutions, improved performance can be attributed to the intended rule with greater confidence. In addition, because the majority of implicit learning studies have involved adult populations, it is interesting to look at children in order to determine what sort of developmental trends exist in implicit learning.

Overview

The present study was designed to determine how children in grades four and five learn covariations, and whether the number of irrelevant dimensions present in stimulus sets would facilitate implicit learning. Seger (1994), based on findings reported by Lewicki et al. (1987) and Kushner et al. (1991), conjectured that irrelevant aspects of stimuli may be dealt with more efficiently by the implicit system. Seger (1994) speculated that the reason for this could be that the explicit thought system has more difficulty determining which stimuli can be ignored. The implicit learning system, on the other hand, appears to be less affected by irrelevant information presumably because it can determine the dependencies between a larger number of variables than the explicit system (Seger, 1994). Alternatively, it may be that the explicit learning system is especially sensitive to irrelevant information because the explicit system engages in hypothesis testing. For example, it is possible to generate a large number of new hypotheses when an irrelevant dimension is added to a discrimination learning task (see Gholson, 1980).

The following predictions are based on the conjecture that the explicit system engages in conscious hypothesis testing through serial processing of stimulus characteristics. With each additional two-valued dimension present in stimulus items, if all possible hypotheses are tested, the number of hypotheses to test increases by a power of two, thus increasing the difficulty of the task and the amount of processing. The processing engaged in by the implicit system, on the other hand, is conjectured to be associative[1], perhaps automatic, and parallel. In other words, each additional two-valued dimensions present in stimulus items would be processed simultaneously, or in parallel. Hence, the amount of processing required by the implicit system would not increase to the same extent as that required by the explicit system engaging in serial processing. Therefore, the learning rate of the implicit system will decrease at a slower rate than that of the explicit system as task difficulty increases.

Predictions

Fourth- and fifth-graders were chosen in light of the research of Rabinowitz and Howe (1994) and the results of a pilot study[2], both of which demonstrated the difficulty that third grade children have reaching criterion, verbalizing rules, and transferring information. In their investigation of the role of verbalization in the acquisition of the middle concept, Rabinowitz and Howe (1994) found that the percentage of fourth and fifth graders who were verbally

[1]The crux of the argument does not depend on associative processing, but that the processes involved in implicit and explicit learning are different.

[2]The task used in the pilot study proved to be too complex for the grade three children with only 57% reaching criterion. It was determined the grade 3 sample would not be representative based on such a poor success rate. Therefore, grade 4 children were chosen instead.

aware (explicit learners) differed significantly from third graders, with more fourth- and fifth-graders than third-graders verbally stating the middle rule. Rabinowitz and Howe (1994) also showed that only those children who verbalized the rule were able to transfer the concept on test trials. It was predicted that only those children who demonstrated verbal awareness of the covariation rule would be successful in the transfer task.

Given the assumption that the implicit learning system engages in parallel processing and subsequently appears to be less affected by irrelevant information than the explicit system, it was also predicted that the percentage of participants learning implicitly (without verbal awareness), as compared to explicitly, would increase as a function of the number of irrelevant training dimensions. In addition, since the implicit learning system is assumed to be less affected by irrelevant information, implicit learners trained on two irrelevant dimensions would be expected to show smaller increases in the number of trials to criterion during training than explicit learners.

Method

Participants

The participants were 112 elementary school children. Parental and school board consent were required in order for children to participate. Children were chosen from two grade levels; those who did not reach criterion were replaced. Sixty-one fourth- and 52 fifth graders were needed to yield 48 children (24 male and 24 female) who reached criterion at each grade. At the grade four level, five children failed to reach criterion when trained on one irrelevant dimension; eight children failed to reach criterion on two irrelevant dimensions. At the grade five level, one child failed to reach criterion when trained on one irrelevant dimension; three children failed to reach criterion on two irrelevant dimensions. The mean age of grade four children was 114.54 months with a standard deviation of 4.90 months; the mean age of the grade five children was 129.48 months with a standard deviation of 19.83 months.

Design

The design was a grade (four and five) by gender by treatment (one and two irrelevant dimensions on training) factorial. Twelve participants were quasi-randomly assigned to each cell. The dependent variables were errors to criterion[3], the number of correct responses made on the transfer task, response latency on the criterion run, mean response latency during transfer, and verbal awareness.

Stimuli

Training. The treatment conditions differed in the training sets employed. In both conditions, children were trained on sets of three stimuli varying in size (large or small) and shape (curved or straight)(see Figure 1a). Of these three stimuli, only one represented the covariation between shape and size (e.g., curved and large). Of the four possible combinations of size and shape, only three were used in the stimulus sets presented to a particular subject. Those used possessed at least one of the cue values that defined the covariation (e.g., one that is curved and small, one that is large and straight, and one that is both curved and large - the covariation). The features which defined the covariation were counter-balanced over participants. Thus, for 25% of the participants in

[3]Analyses conducted on both errors to criterion and trials to criterion yielded similar results.

each cell, the covariation was small and straight, for 25% the covariation was small and curved, for 25% the covariation was large and straight, and for the remaining 25% the covariation was large and curved.

During training, both groups of participants were exposed to a variety of training sets in which the covariation rule was represented. This was accomplished by using three-sided figures during training which were varied randomly between trials in terms of length of sides, whether the curved side was convex or concave, and defining angle of the isosceles triangle (30, 60, 90, 120 degrees).

Participants in the one irrelevant dimension condition experienced the stimulus sets described above. Within trials, the stimuli differed in size (large or small), shape (curved or straight), and position on the computer screen (left, middle or right). Size and shape were the relevant dimensions determining the covariation, while position was an irrelevant dimension. For the two irrelevant dimensions participants, the stimulus dimensions (size, shape, and position) also varied within trials. In addition, the two irrelevant dimension groups were exposed to another irrelevant dimension, stimulus pattern, which varied within trials (see Figure 1b). Thus, these participants experienced two irrelevant dimensions - position of the stimulus on the screen and stimulus pattern. Stimulus pattern refers to the way in which the inside of the shape was patterned. The cue values used to represent the pattern dimension were solid-filled (the stimulus shape was coloured in completely), stripes (the stimulus shape had stripes running through it), and unfilled (the stimulus shape was left unpatterned).

Transfer. The covariation between shape and size was maintained on the transfer task. However, instead of the three-sided figures used in training, four-sided figures were used (see Figure 2). The participants were exposed to four stimulus sets, which consisted of either three squares, three parallelograms, three rhombuses, or three irregular quadrilaterals. Each of the sets was presented six times during transfer generating a total of 24 transfer trials. On eight randomly determined trials the irrelevant dimension of position was present; on another eight randomly determined trials the irrelevant dimension of position and the irrelevant pattern dimension was present; and on the final eight randomly determined trials the irrelevant dimension of position, the irrelevant pattern dimension, and an additional third irrelevant dimension was present. This third irrelevant dimension involved the number of lines (one, two, or three) projecting from the top of the stimuli. As in training, length of sides, whether the curved side was convex or concave, and the position of the correct stimulus was randomized for each subject.

Procedure

The participants were tested in their schools. The stimuli were presented via computer. A button box, with three buttons representing the three stimuli on the screen, was used for the participants to indicate their choices. During training, the children were told: "Each time you will see three things on the computer screen. One of them will always be correct. If you choose the correct thing you will see a "check" over your choice. If you choose the wrong thing you will see an "X" over your choice." The appropriate word, either "correct" or "incorrect" also appeared at the bottom of the screen. No additional feedback was given. The training criterion was nine correct responses in any successive ten trials.

Immediately after reaching criterion, the transfer test was presented. The children were told: "Now you will see some new things on the computer screen. If you think about what you just learned, then you will be able to choose the correct thing each time. This time though, the computer will not tell you whether you are right or wrong."

After completing the transfer task, the children were given a verbal awareness test, designed around a four-point scoring system (see Appendix A). Children were first asked: "How did you solve the problem?" If they correctly identified the covariation (e.g., "It was always the large curved one."), they were scored a three and questioning ceased. If they correctly identified only one member of the covariation, (e.g., "Yes. The large one":), they were asked, "How do you know this? There were two large ones." Following this question, if they correctly identified the second dimension they were scored a two, otherwise they received a one.

Children who incorrectly answered the first question (i.e. "How did you solve the problem?") were scored zero, while children who failed to give any answer to this question were prompted by the question "Did you notice that any particular type of object was correct?" If they then correctly identified the covariation they were scored a three. If they correctly defined only one member of the covariation, they were asked "How do you know this; there were two (dimensions)?". If they correctly answered that question, they were scored a two, otherwise they were scored a one. Participants who gave a wrong answer to the prompted question, or failed to answer the question at all were scored zero.

Results

The main focus of this study was to see how individual differences in awareness affect covariation learning and transfer. Preliminary analyses were conducted in order to determine which variables could be eliminated from subsequent analyses. It was expected that there would be an unequal distribution of participants' awareness scores across grade, and the number of irrelevant dimensions during training. Preliminary analyses are described first, in order to justify the elimination of the between-subjects variable gender and justify the reasoning behind the rescaling of the verbal awareness measure for subsequent analyses. Further references to preliminary analyses will be included only if it adds to the findings from subsequent analyses. A Chi Square analysis performed on the number of participants obtaining each of the rescaled awareness scores is then described. This is followed by a description of the unweighted means analyses which were designed to explore the effects of verbal awareness. All participants included in the analyses reached criterion, reflecting that children are capable of learning covariations either implicitly or explicitly.

Preliminary Analyses

Initial analyses of variance were performed on the dependent variables verbal awareness, criterion latency (average time, in seconds, of latencies on the last nine trials of the criterion run), errors to criterion (the number of errors made during training), transfer latency (average time, in seconds, of latencies over each of one, two, and three irrelevant test dimensions), and number of correct responses made during transfer (total number of correct responses for eight sets each of one, two, and three irrelevant test dimensions). The independent variables in these analyses were grade (four versus five), gender (male versus female), the number of irrelevant training dimensions one versus two), and, where appropriate, the number of irrelevant test dimensions (one versus two versus three). In no analysis was a contrast effect involving gender significant. Therefore, gender was not included as an independent variable in subsequent analyses of variance.

Verbal awareness. Upon completion of the transfer task, participants were asked the question "How did you solve the problem?". Participants who could not provide an answer to this question were assigned an awareness score of zero; those who could provide only one dimension of the covariation were scored one; those who could initially provide only one dimension, but were able to supply the second when prompted were scored two; and finally, those who responded initially with both dimensions of the covariation were scored three. This procedure resulted in a four-point awareness scale ranging from unaware (zero) to aware (three).

As was expected (see Table 1), an unequal distribution of awareness scores was apparent across grade and number of irrelevant training dimensions. There were only two grade five participants trained on one irrelevant dimension, and one grade five participant trained on two irrelevant dimensions who had awareness scores of zero. Moreover, there were very few fifth grade participants trained on one irrelevant dimension who had an awareness score of one (see Table 1). Because of the paucity of participants in the cells representing grade five participants trained on one irrelevant dimension who had awareness scores of zero and one, and grade five participants trained on two irrelevant dimensions who had an awareness score of zero, the awareness scoring system was rescaled. Participants who could not provide any dimension of the covariation (that is, scored zero on awareness) were combined with those who could supply one dimension of the covariation (that is, scored one on awareness); this group was given a score of one in subsequent analyses[4]. The rescaling resulted in three classifications of awareness; verbally unaware (one, implicit learners), partially aware (two), and verbally

[4]It may be argued that the participants included in the rescaled awareness level one are actually partial learners, as they acquired one dimension of the covariation. However, in the context of the task employed, knowledge of only one dimension would not have been enough for participants to solve the problem successfully. It was assumed that successful training performance of this combined group could not have been due to conscious knowledge of just one dimension alone. Indeed, preliminary analyses indicated no difference between the zero and one awareness level groups. On the errors to criterion measure, participants who had an awareness score of zero averaged 15.04 errors (standard error of the mean=3.67) and participants who had an awareness score of one averaged 16.92 errors (standard error of the mean=2.87). Similarly, there were no differences between these two groups on transfer. Participants who had an awareness score of zero averaged 4.68 correct responses on transfer (standard error of the mean=.62) and participants who had an awareness score of one averaged 4.81 correct responses on transfer (standard error of the mean=.46). Because the training and transfer performance of levels zero and one awareness did not differ, it was presumed that both groups were employing the same implicit learning processes.

aware (three, explicit learners).

Number of Participants Categorized at Each Level of Awareness as a Function of Number of Irrelevant Training Dimensions

A χ^2 test of independence was conducted to test the prediction that the percentage of participants learning implicitly would increase as a function of the number of irrelevant dimensions. Consistent with prediction, this increase was obtained, $\chi^2(1) = 4.48$, $p < .05$. The number of participants classified as implicit learners increased from 13 (27%) on one irrelevant dimension to 23 (48%) on two irrelevant dimensions supporting the proposition of Seger (1994) that the implicit system can deal better with increases in irrelevant information than the explicit system. Conversely, the number of explicit learners dropped from 23 (48%) on one irrelevant dimension to 17 (35%) on two irrelevant dimensions. Similarly, the number of partial learners dropped from 12 (25%) on one irrelevant dimension to 8 (17%) on two irrelevant dimensions.

Unweighted Means Analyses

Errors to Criterion. The interaction between the number of irrelevant training dimensions and awareness, $F(2,$

84) = 4.62, $p < .05$, was higher order to the main effect of number of irrelevant training dimensions, $F(2, 84) = 15.25$, $p < .001$. It was predicted that learning would be slower as the number of irrelevant dimensions increased. As this was the case for participants at all levels of awareness, the main effect of number of irrelevant training dimensions is interpretable (see Table 2). However, even though this difference was significant for implicit, S^2 (2, 60) = 6.44, $p < .05$, and explicit learners, S^2 (2, 60) = 28.07, $p < .001$, the difference was not significant for partial learners, S^2 (2, 60) = .01, $p > .10$.

The prediction that explicit learners would be more affected by the added irrelevant dimensions than implicit learners was partially supported (see Table 2). Explicit learners made fewer errors than the average of implicit and partial learners when trained with one irrelevant training dimension, S^2 (2, 60) = 18.67, $p < .001$, and made more errors than the average of implicit and partial learners when trained with two irrelevant training dimensions, S^2 (2, 60) = 3.60, $p < .10$. Although the difference between explicit learners and the mean of implicit and partial learners trained on two irrelevant dimensions was not significant, the difference between explicit and partial learners was significant, S^2 (2, 60) = 7.75, $p < .05$.

Criterion latency. No significant contrast effects were obtained in the unweighted means analysis of variance performed on the criterion latency measure. The weighted means analysis of variance, however, was a little more sensitive showing an effect for grade, F (1, 88) = 4.08, $p < .05$. Older children (grade five) responded faster during training than younger children (grade four), with respective criterion latency means of 2.99 and 3.66 seconds.

Transfer latency. The analyses performed on the transfer latency data yielded no significant contrast effects. Clearly, the time it took participants to respond during training and transfer was little affected by the number of irrelevant training dimensions, gender, or level of awareness, while grade had only a minor effect.

Number of correct responses on transfer. The interaction between awareness level and the number of irrelevant training dimensions, F (2, 84) = 3.62, $p < .05$, was higher order to the main effects of awareness level, F (2, 84) = 14.98, $p < .001$, and the number of irrelevant training dimensions F (1, 84) = 5.15, $p < .05$. When training involved one irrelevant dimension explicit learners made more correct responses on transfer than did the average of the implicit and partial learners, S^2 (2, 60) = 6.52, p < .05 (see Table 3). When two irrelevant dimensions were used in training, implicit learners made fewer correct responses on transfer than did the average of the partial and explicit learners S^2 (2, 60) = 8.66, p < .05. Note, however, the main effect of number of irrelevant training dimensions is interpretable as the number of correct responses made on transfer increased as a function of the number of irrelevant dimensions during training for all levels of awareness (see Table 3). This finding suggests that the presence of increased irrelevant dimensions during training facilitates transfer under a variety of conditions.

Interestingly, grade four participants made more correct responses on transfer when trained with one irrelevant dimension, than did grade five participants with mean correct responses of 5.85 and 5.22, respectively. The opposite pattern was obtained when training involved two irrelevant dimensions. Grade five participants made more correct responses on transfer when trained with two irrelevant dimensions than grade four participants with mean correct responses of 6.71 and 5.93, respectively. This cross-over pattern produced a significant grade by irrelevant training dimensions interaction, F (1, 84) = 4.13, $p < .05$. Although an explanation for this effect is not readily apparent, it could have something to do with experience in complex problem solving domains.

Finally, the grade by test interaction, F (2, 168) = 3.08, $p < .05$, was higher order to the main effect of test, F (2, 168) = 7.34, $p < .001$. In both grades performance was worse when 3 irrelevant dimensions appeared on test trials (see Table 4). Grade four participants performed better on transfer sets with one irrelevant test dimension than on the average of two and three irrelevant test dimensions, S^2 (2, 60) = 17.37, $p < .001$. Grade five participants, on the other hand, performed better on transfer over the average of one and two irrelevant test dimensions than on three irrelevant test dimensions; however, this difference was not significant, S^2 (2, 60) = 6.18, $p < .10$. It would seem that as children get older they get better at handling increasingly complex irrelevant information.

Discussion

The predictions made in the present study were, for the most part, supported. As the number of irrelevant dimensions increased, the percentage of children learning implicitly also increased. In addition, the number of irrelevant training dimensions did indeed slow down learning. Although this trend was apparent at all levels of awareness, the effect was particularly large for the explicit learners. Trabasso and Bower (1968) state that over-training can facilitate explicit knowledge of the rules governing a training task. Because an increase in the number of irrelevant dimensions resulted in the explicit learners being exposed to more trials before reaching criterion, it might be argued that this particular group may have acquired explicit knowledge through over-training. This argument can be readily discounted however, as explicit learners trained on one irrelevant dimension were exposed to the fewest training trials of all groups. Still, they acquired explicit knowledge of the covariation rule.

Participants at all levels of verbal awareness, not just explicit learners, were able to transfer to some extent. However, the best transfer performance was apparent in explicit learners when training involved one irrelevant dimension, and in partial and explicit learners when training involved two irrelevant dimensions.

Much of the implicit learning literature to date has been atheoretical. Most implicit researchers (Reber, 1967; 1976; Reber & Lewis, 1977; Lewicki, 1986; Lewicki et al., 1987; 1988) have drawn conclusions regarding whether implicit learning can occur, while reviewers of existing implicit studies (Seger, 1994; Shanks & St.John;1994) have dealt primarily with methodological flaws and criticisms. However, neither the researchers nor the reviewers have attempted to present a model which illustrates the processes through which implicit and explicit learning occur. In the following discussion, a working model of the way in which both implicit and explicit processes may function in the learning process will be offered and emphasized in an attempt to integrate the existing literature with the results of the present study. The principle assumption is that learning is not either implicit or explicit, but both, with the observed process being that which acquires the relevant information more quickly.

Methodological Issues

Much of the criticism surrounding the implicit learning studies, such as those undertaken by Reber (1967, 1977) and Lewicki et al. (1987, 1988), has centred around methodological issues. Specifically, Shanks and St. John (1994) claim previous research to be in violation of the Information and Sensitivity Criteria. Recall that the Information Criterion requires that the awareness test assess the information responsible for performance change. In the present study, an attempt to meet the Information Criterion was made by using child participants and a simple task for which there were only a few possible solutions. The more difficult tasks required for adult populations lend themselves to alternative solutions that the experimenter may not seek or find in verbal awareness. When difficult tasks are used and participants cannot verbalize the rule that the experimenter expects them to employ, the conclusion may be implicit learning when conscious learning actually occurred. With child participants and a simple task, it is more likely that the information sought in the verbal awareness test is indeed the information responsible for performance change.

An attempt was also made to meet the Sensitivity Criterion. According to Shanks and St. John (1994), the Sensitivity Criterion requires that the awareness test be able to pick up all relevant conscious information possessed by the participant. In the awareness test employed in the present study participants were encouraged to draw on all relevant conscious information they may have acquired during training. In addition, the transfer task, which used the same methodology as training, was presumed to supplement the awareness test with an additional measure of performance. The transfer task was designed to determine whether the information acquired during training could be transferred to a novel task, and whether successful transfer was a function of verbal awareness. The awareness test could only provide a verbal account of acquired knowledge, while the transfer task allowed this knowledge to be measured as a function of performance, in a context similar to that of training.

Acquisition of Covariation Information

Little research has been conducted investigating how children acquire covariation information. Kuhn et al. (1988), Sodian (1994) and Ruffman et al. (1993) have shown that children are capable of understanding covariations when they are explicitly directed to them. They did not, however, address the questions of whether children can learn covariations without specific direction, or whether they can learn covariations implicitly or explicitly. These were the questions the present study was designed to answer, with special attention paid to level of awareness and the presence or absence of irrelevant dimensions.

Implicit versus explicit learning. All children included in the analyses in the present study reached criterion during training, demonstrating that fourth and fifth grade children can learn covariations either implicitly or explicitly without specific direction to the covariation. This finding supports the conjecture of Lewicki et al. (1994) who proposed that children can learn complex contingencies implicitly. However, it should be noted that not all of the children initially employed in this study reached criterion. Of the grade four participants, four were replaced in the one irrelevant training dimension condition and nine were replaced in the two irrelevant training dimensions condition, whereas of the grade five participants, one was replaced in the one irrelevant training dimension condition and three were replaced in the two irrelevant training dimensions condition. Therefore children's ability to acquire information implicitly would appear to be influenced by their grade level as well as the relative difficulty of the task.

Under what conditions is implicit learning likely to be activated over explicit learning? From the point of view of Seger (1994), implicit learning reflects the acquisition of information that is too sophisticated to be handled efficiently by the conscious. This position is also held by Lewicki et al. (1992) and Reber (1989). Recall the proposal that the implicit system uses parallel processing in acquiring information via associations whereas the explicit system engages in conscious hypothesis testing through serial processing. Based on this presumption, the implicit system would become more efficient than the explicit system when dealing with increasingly complex information because the explicit system would incorporate the extra information into testable hypotheses, increasing the amount of processing as a power function of additional dimensions, thereby, decreasing the rate of learning.

In the present study, adding an irrelevant dimension during training was the means by which the complexity of the learning task was increased. The additional irrelevant information was presumed to result in an increase in the number of testable hypotheses for the conscious system to process, subsequently decreasing its efficiency in reaching a solution. The unconscious system, on the other hand, may rely more on associations than hypothesis testing and therefore may be less affected by extra information. For both pathways, however, learning would be expected to slow down as the extra irrelevant information would make for more associations to select from (implicit learning) as well as extra testable hypotheses (explicit learning). Learning was slower on two irrelevant dimensions than one irrelevant dimension for all levels of awareness, and, as expected, this was particularly true for the explicit learners. Explicit learners made the fewest errors when training involved one irrelevant dimension and the most errors when training involved two irrelevant dimensions. This finding supports the contention that the unconscious can deal with some types of relatively complex information, at least in the learning phase, with more efficiency than the conscious (Lewicki et al., 1992; Reber, 1989; Seger, 1994).

Similarly, it was predicted that the percentage of children learning implicitly would increase as a function of the number of irrelevant dimensions. Since extra information increases the number of possible hypotheses to be tested (Gholson, 1980), the learning rate for the explicit system would slow down as a consequence of the serial processing of additional hypotheses. On the other hand, if the implicit system engages in parallel processing, it would be less affected than the explicit system as the difficulty of the task increases. Consistent with this prediction, it was the case that the number of participants learning implicitly increased while the number of participants learning explicitly decreased when the number of irrelevant training dimensions increased from one to two.

A possible explanation for this shift in learning pathways and learning rates is based on the hypothesis that all individuals have the capacity to learn both implicitly and explicitly. That is, both implicit and explicit processes operate simultaneously, resulting in a race to determine which will solve the problem first. This hypothesis is developed by borrowing some ideas from Miller's (1948) conflict theory. Miller (1948) proposed that response strength to a goal (either positive or negative) was a function of distance, with the avoidance gradient falling off more steeply than the approach gradient as distance increased. Similarly, if implicit and explicit processes for an individual were plotted on a graph where the x-axis represented task difficulty and the y-axis represented learning rate, the explicit gradient would fall off more quickly than the implicit gradient. This assumption is consistent with the data in the present study; although the learning rate decreased for all levels of awareness when training involved two irrelevant dimensions, the decrease was most dramatic for the explicit learners.

Miller (1948) also proposed an intersection of the approach and avoidance gradients. The point of intersection between the two gradients is the distance from the goal where approach and avoidance are equally likely and would yield vacillation between the two responses, resulting in vicarious trial and error behaviour. Similarly, as both the implicit and explicit gradients drop off, there is a point at which the two will intersect. This intercept is defined in the present study as the task difficulty intercept, the task difficulty level at which implicit and explicit learning are assumed to occur at the same rate. The task difficulty level at the point of intersection will vary between individuals. An individual who usually learns implicitly has an intercept at a low level of task difficulty and learns more difficult problems implicitly (see Figure 3a). The average learner has an intercept at a moderate level of task difficulty with explicit processing dominating easy tasks, and implicit processing dominating difficult tasks (see Figure 3b). Finally, the individual who usually learns explicitly has an intercept at a high level of task difficulty with explicit processing dominating on easier problems (see Figure 3c). If we were to plot the proportion of individuals having intercept points at a particular level of task difficulty on a graph with the y-axis representing the proportion of individuals and the x-axis representing task difficulty, we would expect to find low proportions of individuals who have intercepts on either easy tasks or difficult tasks. The largest proportion of individuals would have a task difficulty intercept at moderate task difficulty levels (see Figure 4). As a working hypothesis, we assume this distribution to be normal.

"Smart" Mental Processes

In the present study, most fourth and fifth grade children learned covariations either implicitly or explicitly. The next step is to determine whether or not either of these mental processes are "smart". Loftus and Klinger (1992) define a smart mental process as one that can successfully analyze complex patterns and one that can deal flexibly with novel situations. In the present study, it was found that both conscious and unconscious processes can analyze sophisticated information, although the explicit system slows down more quickly than the implicit system when two irrelevant dimensions are present. Nonetheless, both implicit and explicit learners acquired the covariation rule with two irrelevant dimensions (that is, the more complex stimulus sets). However, with respect to dealing flexibly with novel situations, the implicit system appeared to be less smart than the explicit system. Although implicit learners were able to transfer, explicit learners made more correct transfer responses than implicit learners, regardless of training condition.

This finding contrasts with that of Rabinowitz and Howe (1994), who found that only the participants who could verbalize the middle rule (that is, explicit learners) were successful at transferring the knowledge of that rule to novel stimuli. Note that the transfer tasks employed by Rabinowitz and Howe (1994) and that used in the present study differed. In the present study, the transfer task involved only a minor contextual change to the physical dimension of the stimuli. Participants were required to transfer knowledge acquired during training with three-sided figures to stimulus sets with four-sided figures. Therefore, with the exception of this minor change in stimuli, the context of the training task and the transfer task were similar. This was not the case with Rabinowitz and Howe (1994). Recall that participants were required to respond with the conceptual middle (e.g. the middle number of dots) and not the positional middle. In their transfer task, the dimensions represented in the stimulus sets were completely different than those used in training, thereby eliminating any contextual similarity between training and transfer stimulus sets.

The contextual differences between the present study and that of Rabinowitz and Howe (1994) suggests an interesting possibility regarding the implicit pathway. Because Rabinowitz and Howe (1994) totally changed the physical context on transfer, the contextual cues upon which implicit learners might rely were eliminated. Presuming that implicit learners rely on associative learning, the context in which learning occurred would be fundamental to successful transfer (that is, stimulus generalization). If this were the case, implicit learners would not be able to transfer information acquired in the learning phase to stimuli that lacked contextual support. The physical context in the present study was only minimally changed on transfer. Even so, on the transfer task, implicit learners performed more poorly than explicit learners when trained on one irrelevant dimension, and more poorly than partial and explicit learners combined when trained on two irrelevant dimensions. Should implicit learners rely on contextual cues during associative learning to acquire training information, then even a minor change to transfer stimuli will prove detrimental to performance because the generalization of the associations used in learning would be impeded. Therefore, it would seem that maintenance of contextual cues is necessary for successful transfer performance in implicit learners. It appears that in the absence of contextual congruity, the implicit system is not smart. In fact, a task that maintains contextual cues usually is not novel. Such a conclusion supports Greenwald's (1992) contention that the unconscious is not particularly sophisticated as it can only transfer acquired information to situations that are similar to those experienced in training.

Partial Learners

The results obtained from the partial learners merit additional theoretical speculation. This group of participants provided one dimension of the covariation when initially queried on the verbal awareness test, but were able to provide the second when further prompted. During training, partial learners, in comparison to the implicit and explicit learners, were affected minimally by the added irrelevant dimension of stimulus pattern. During transfer, partial learners performed at the level of implicit learners when training involved one irrelevant dimension, but at the level of explicit learners when training involved two irrelevant dimensions.

Recall the assumptions that: implicit and explicit learning processes are activated upon commencing a learning task; all individuals learn faster explicitly than implicitly on very easy tasks; the explicit gradient falls off more quickly than the implicit gradient; a point of intersection will occur where both implicit and explicit learning are occurring at the same rate (see Figure 3); and this point will vary between individuals. It is also assumed that partial learners acquire information at approximately the same rate implicitly and explicitly (that is, each of the partial learners is at the point of intersection). Thus, the partial learners should be able to access either implicit (associations) or explicit information (hypotheses) on the transfer test. In the present study, partial learners trained on one irrelevant dimension (easy task) performed like implicit learners during transfer, whereas the partial learners trained on two irrelevant dimensions (difficult task) performed like explicit learners.

A final assumption, that learners have a preference for accessing either implicit or explicit information in transfer situations which is based on how they usually solve problems of the same type, can explain the transfer performance. When an individual is a partial learner on one irrelevant dimension their implicit and explicit learning curves are presumed to resemble those of individuals who usually learn implicitly, therefore they would solve most problems of this type implicitly and on transfer would have a preference for accessing implicit information. Similarly, when an individual is a partial learner on two irrelevant dimensions their implicit and explicit learning curves are presumed to resemble those of individuals who usually learn explicitly. Therefore, they solve most problems of this type explicitly, and show a preference for accessing explicit information on transfer. In Figure 5, a possible assumption about the task difficulty intercept point and the preference for accessing either explicit or implicit information is presented. When the intercept is at high levels of task complexity, an individual will prefer to access explicit information. Alternatively, when the intercept is at low levels of task complexity, and individual will prefer to access implicit information.

The only finding that cannot be readily explained is the training performance of partial learners on two irrelevant dimensions. Recall that partial learners trained on two irrelevant dimensions learned at a faster rate than did the explicit learners. It is unclear why this partial group solved the difficult problem so rapidly. This finding may be an anomaly, as the number of participants in this group was small (eight). It would be necessary to replicate the experiment to determine if the finding is representative.

With respect to the transfer performance of the partial learners, advocates of an unsophisticated unconscious may pose another explanation to account for the partial learners transferring like implicit learners when trained on one irrelevant dimension and like explicit learners when trained on two irrelevant dimensions. It may be argued that the participants acquired fragmentary conscious knowledge of the underlying rule that was not uncovered during the verbal awareness test (Greenwald, 1992). However, if the partial learners only acquired fragmentary knowledge, they would have been correct only half of the time on transfer. This was not the case; when trained on one irrelevant dimension, partial learners responded correctly to 65% of the transfer trials and when trained on two irrelevant dimensions, responded correctly to 92% of transfer trials. Thus, this explanation can be discounted with the performance of the partial learners on transfer when trained on two irrelevant dimensions. The partial group in this condition performed at the level of explicit learners, who understood both dimensions of the covariation rule. Clearly, the partial learners could not have performed as well as the explcit learners if they were only using fragmentary knowledge of that rule.

Summary and Conclusions

In their implicit learning studies, Broadbent and colleagues (economic/production simulations; 1978, 1984, 1986), Lewicki and colleagues (probability learning; 1987, 1988), and Reber and colleagues (artificial grammars; 1967, 1976) neither systematically varied task difficulty nor used a transfer task. These studies were designed to determine whether implicit learning, in the verbally unreportable sense, could occur in the paradigm employed. They were not intended to be used as a means of drawing conclusions about the efficiency of the implicit system as a function of task difficulty, nor as a way of investigating participants' ability to transfer implicitly acquired information to a novel task. There appears to be only one study involving adults in which transfer has been used to assess the relative sophistication of the implicit learning system (Stadler, 1989). He replicated the pattern learning findings of Lewicki et al. (1987). However, instead of using a verbal awareness test, Stadler studied the transfer of pattern learning to a prediction task. In the transfer task, the participants saw sets of stimuli similar to those used in training. As was the case in the pattern learning paradigm employed by Lewicki et al (1987), the target location on the final trial could be determined by the sequence of four of the previous simple trials. In the prediction task, however, the participants were exposed to a question mark placed in each of the four quadrants on the final trial and were required to guess the quadrant in which the target would appear. Transfer to the prediction task was poor as participants successfully indicated the target location 11 to 13 times out of 48. Not only was there no evidence for the participants' conscious knowledge of the rule, but it also demonstrated that with a minor task change the participants could not transfer the information acquired during training.

The results of the present study, and those of Stadler (1989) and Rabinowitz and Howe (1994) allow for some interesting speculation about the implicit learning system and the relative "smartness" of the unconscious. It would appear that the implicit system is more efficient than the explicit system in dealing with some types of complex information. Certainly this is the conjecture of Lewicki et al. (1992) and Seger (1994) who propose that the implicit learning system is more sophisticated in structure and able to deal with more complex dependencies than the explicit system. However, the findings reported here and by Stadler (1989) and Rabinowitz and Howe (1994) would appear to suggest that the unconscious is not particularly smart in adapting acquired information to novel situations. It would seem that maintenance of the context used in training is required in order for the implicit system to perform adequately. This is perhaps due to a reliance on associative learning.

In general, it may be the case that learning is not exclusively implicit or explicit, with the level of task difficulty determining which process dominates in the acquisition of information. The results presented here suggest that for most individuals learning is primarily explicit on easy tasks and implicit on difficult tasks. Thus, it would be expected that with a task of sufficient difficulty all participants would learn implicitly. This is probably what has been demonstrated in the economic/production simulation models of Broadbent and colleagues (1978; 1984; 1986), the pattern learning studies of Lewicki et al. (1987; 1988), the artificial grammar studies of Reber (1967; 1977), and the probability learning paradigm of Reber and Millward (1968) where the level of task difficulty left participants unable to verbalize the information acquired despite the evidence for having learned the required relations. Clearly, in these studies, implicit processes, and perhaps associative learning, allowed the participants to acquire the necessary dependencies and relations among stimulus items required for successful performance.

Finally, partial learners, a group that has not yet been thoroughly investigated, were identified in the present study. The complexity of the findings obtained with these participants suggests investigators should look closely at individual differences in learning on a continuum ranging from implicit to partial to explicit. In particular, verbal awareness should be measured on a multi-point scale in order to obtain a more complete assessment of the processes involved in learning.

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Table 1

Number of Participants Per Cell as a Function of Irrelevant Training Dimensions, and Awareness Score

	Grade 4		Grade 5	
	Number of Irrelevant Dimensions		Number of Irrelevant Dimensions	
Awareness Score	1	2	1	2
0	4	3	2	1
1	5	8	2	11
2	6	4	6	4
3	9	9	14	8

N=96

Table 2

Mean Number of Errors to Criterion (Standard Error of the Mean) as a Function of Irrelevant Dimensions and Awareness Score

Number of Irrelevant Dimensions on Training	Awareness Score			Mean Errors
	1	2	3	
1	10.87(1.96)	13.17(3.24)	6.51(.97)	10.18(1.24)
2	22.23(3.64)	13.63(2.35)	28.37(3.90)	21.41(2.23)
Mean Errors	16.55(2.41)	13.39(2.06)	17.43(2.55)	

Table 3

Number of Correct Responses on Transfer (Standard Error of the Mean) as a Function of Awareness Score and Number of Irrelevant Training Dimensions

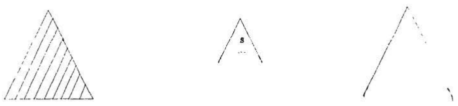
Number of Irrelevant Dimensions on Training	Awareness Score			Mean Correct
	1	2	3	
1	4.51(.79)	5.22(.59)	6.87(.32)	5.53(.35)
2	4.74(.35)	7.33(.30)	6.90(.41)	6.32(.28)
Mean Correct	4.63(.62)	6.28(.42)	6.88(.25)	

Table 4

Number of Correct Responses Transfer (Standard Error of the Mean) as a Function of Grade and Test

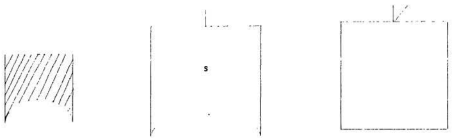
Grade	Number of Irrelevant Test Dimensions			Mean Correct
	1	2	3	
4	6.45(.53)	5.73(.53)	5.50(.43)	5.74(.29)
5	6.05(.50)	6.21(.81)	5.63(.58)	6.04(.34)
Mean Correct	6.23(.36)	5.97(.47)	5.48(.35)	

(a) Training: 1 Irrelevant Dimension



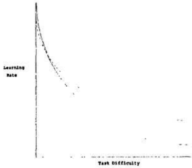
(b) Training: 2 Irrelevant Dimensions

Figure 1
Example Stimulus Sets Used in Training



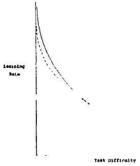
Transfer: 3 Irrelevant Dimensions

Figure 2
Example Stimulus Set Used in Transfer



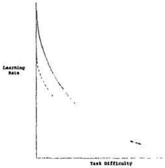
Usually Implicit Learners

(a)



Average Learners

(b)



Usually Explicit Learners
(c)

explicit gradient ________
implicit gradient _ _ _ _ _

Figure 3
Task Difficulty Intercept for Usually Implicit, Average, and Usually Explicit Learners

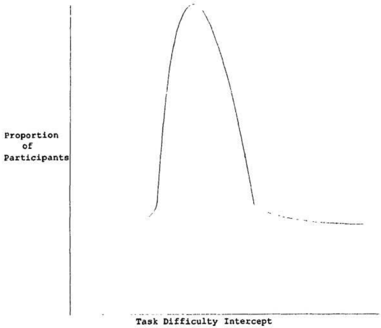


Figure 4
Proportion of Participants Who Learn at the Same Rate Intrinsically and Extrinsically as a Function of Task Difficulty

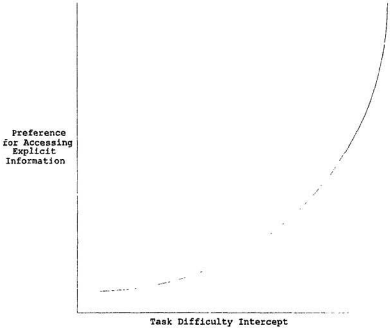


Figure 5
Liklihood That Partial Learners Will Access Explicit Information on Transfer as a Function of the Value of Task Difficulty at the Intercept Point

Appendix A
Verbal Awareness Test

"HOW DID YOU SOLVE THE PROBLEM?"

(A) CORRECT ANSWER (IDENTIFICATION OF COVARIATION)
SCORE=3
*"DID YOU LEARN THIS DURING TRAINING?" YES / NO (if YES, stop)
*"DID YOU FIRST RECOGNIZE THIS WHEN I ASKED YOU?" YES / NO

(B) IDENTIFICATION OF ONLY ONE DIMENSION OF COVARIATION
ASK, "HOW DID YOU KNOW THIS; THERE WERE 2 (DIMENSION) ONES?" IF SECOND DIMENSION IS IDENTIFIED THEN,
SCORE=2
IF SECOND DIMENSION IS NOT IDENTIFIED THEN,
SCORE=1

(C) INCORRECT ANSWER
ASK, "DID YOU NOTICE ANYTHING ELSE?" IF NO,
SCORE=0
IF YES AND ONE DIMENSION ASK, "HOW DID YOU KNOW THIS, THERE WERE 2 (DIMENSION) ONES?" CORRECT IDENTIFICATION OF SECOND DIMENSION;
SCORE=2
INCORRECT IDENTIFICATION OF OR FAILURE TO IDENTIFY SECOND DIMENSION;
SCORE=1

(D) NO ANSWER
ASK, "DID YOU NOTICE ANY PARTICULAR TYPE OF OBJECTS WAS CORRECT?" CORRECT IDENTIFICATION OF COVARIATION;
SCORE=3
IDENTIFICATION OF ONLY ONE DIMENSION ASK, "HOW DID YOU KNOW THIS; THERE WERE 2 (DIMENSION) ONES?" CORRECT IDENTIFICATION OF SECOND DIMENSION;
SCORE=2
INCORRECT IDENTIFICATION OF FAILURE TO IDENTIFY SECOND DIMENSION;
SCORE=1
INABILITY TO PROVIDE ANY ANSWER AT ALL;
SCORE=0