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Eric Paul Sparks

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ERIC PAUL SPARKS

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Abstract
This experiment attempts to determine whether procedural learning in a finite state grammar task is driven by evocative conscious contents (Dulany, 1984, 1991) or unconscious implicit processes (Lewicki, Hill, Bizot, 1988; Reber, 1989). The experimental task is a novel adaptation of the typical finite state grammar experiment in its attempts to compel subjects to achieve automatized responses through a discrimination learning procedure. The results demonstrate the achievement of procedural learning, and an assessment of subjects' awareness of grammatical rules is used to determine that evocative conscious contents provide the most defensible interpretation of the learning effects of the task. This is demonstrated through the prediction of the proportion of correct responses by the subjects' reported rule validities, and an alternative characterization of implicit learning is supported.
The role of consciousness in scientific psychology has often been dubious and unstable. Most recently, this can be seen in the research on action, memory, and learning (Graf, Squire, & Mandler, 1984; Klatzky, 1984; Reber, 1989). A new controversy has emerged in cognitive psychology which focuses upon some of the fundamental claims of the field. This controversy is based on the phenomenon of unconscious, or implicit, processes in learning, memory, and action.

In the recent research literature, these unconscious processes are collectively described as the "cognitive unconscious" (Kihlstrom, 1987). Some cognitive psychologists have found this notion to be questionable, both in theory and in practice (Dulany, 1984; Holender, 1986). The fundamental claims of the early cognitive revolution are now facing new challenges. From the use of the computer as a metaphor for the mind, to the information processing view of the mind, the claims of early cognitive science are being questioned. Yet the fundamental claim that is most important for this controversy of implicit processes is that of nonconscious symbolic representation. It is in the context of symbolic or semantic representation that the claim for nonconscious processes must be considered. Few
psychologists would claim that there are no processes which take place in the mind that are inaccessible to conscious thought. For example, all concede that the process which yields depth perception in vision will not be found in consciousness. No one introspectively knows the perceptual mechanisms of the mind. Yet the controversy at hand concerns the notion of semantic, meaningful, and symbolic processes taking place unconsciously.

In the implicit learning literature, all of the experiments follow a certain format. There are four experimental paradigms that investigate the existence of implicit learning; these experimental techniques are the systems (Berry, 1984; Berry & Broadbent, 1988; Dulany & Wilson, 1990; Hayes & Broadbent, 1988;), covariation (Dulany & Poldrack, 1991; Lewicki, 1986a), sequence (Lewicki, Hill, & Bizot, 1988; Nissen & Bullemer, 1987; Perruchet, Gallego, & Savy, 1990), and finite state grammar paradigms (Dienes, Broadbent, & Berry, 1990; Dulany, Carlson, & Dewey, 1984; Perruchet & Pacteau, 1990; Reber, 1976, 1989). Each of these four paradigms consists of a task that is a priori considered to have a learning situation with underlying contingencies which are more complex than the subject is capable of
consiously learning. Yet the results of many of these experiments show that the subjects learn how to perform the experimental task better than do controls. The controversy consists in the interpretations of the experimental findings, where there are two main theoretical characterizations of the various experiments. The first view, which is most common, interprets the results of these experiments to be due to learning tacit (unconscious) knowledge of the experiment's contingencies, since it is often found that the subjects are unable to verbalize what was presumably learned (a rule or contingency the experimenter used in designing the task). The second view proposes that the evidence is either inconclusive on whether the material was unconsciously represented, or that it shows that what was learned was in conscious awareness when it controlled performance of the task. On this view, the fact that the subjects were unable to verbalize the actual underlying contingencies of the stimulus domain is irrelevant. The learning effects can be explained by conscious rules of the subjects which only approximate the actual contingencies, yet the application of these rules could be responsible for the effect of learning. This contrast between a theory of a "cognitive unconscious" and a
theory of conscious learning is what constitutes this controversy.

**An Experimental Paradigm**

The finite state grammar paradigm will be the focus of the present experimental investigation. The original studies that opened the controversy of unconscious implicit learning were examples of this paradigm, and their findings have focussed upon three main issues. The first deals with evidence for and against two separate modes of learning (the implicit and explicit). The second concerns the form of the representation of the acquired knowledge. The third and last issue is based on the awareness of what is learned, with a special emphasis on the methodology of the assessment.

As we begin, it will be useful to explain the general task used in the finite state grammar studies. A complex stimulus is presented to the subjects, where the stimulus is a string of letters (e.g. QXQT) which is formed through the use of a finite state grammar. The subjects are presented several letter strings that

Insert Figure 1 about here

are made from this grammar and are instructed to remember
as much about the letter strings as possible. This constitutes the learning phase of the experiment. The test phase follows by having the subjects judge whether a string is grammatical or not. They are presented with an equal number of grammatical and non-grammatical letter strings (some of which were not seen in the learning phase), and respond either yes or no as to the grammatical status of the strings. Usually the non-grammatical strings are made by violating one of the positions of the grammar (e.g. VXVM). If the subjects are able to categorize these strings with accuracy above chance, then they have learned the grammar to some degree. After or during the test phase, some measurement is taken of the subjects' awareness of the grammar. The measurements that are used to tap into conscious awareness will be one of the major issues addressed in this paper. Now that the general experiment has been described, the first item of interest in this research concerns the evidence for two modes of learning.

The argument for two separate modes of learning, the explicit and the implicit, is based on evidence from two experimental manipulations. First, as we have seen, studies have focussed on the degree to which subjects are aware of the grammar. Secondly, experiments have
attempted to determine if the type of instructions given to the subjects will have an effect on the learning of the grammar. For example, they are usually altered so that one group will receive instructions based on memorization, while the other group's instructions are based on the learning of rules. The memory instructions tell the subjects simply to memorize the letter strings during the learning phase. The learning-based set informs the subjects that there is a rule underlying the strings and that it will help them to learn it. In general, this difference in instructional set is labeled as implicit and explicit. The memorization set gives no information that there is a pattern to the strings, while the rule learning set explicitly mentions the presence of underlying rules. Some researchers have asked that this distinction be known as incidental versus intentional instructions, since it is an empirical issue whether the incidental instructions will ensure implicit learning (Perruchet & Pacteau, 1991). However, the manipulation of instructional set has been empirically investigated to determine if there is an effect on the learning of the grammar. The findings have been in favor of no effect on the amount of learning; the performances of the two groups at test were equal (Dienes et al., 1990; Dulany et
al., 1984; Perruchet & Pacteau, 1990; but see Reber, 1976 for dissent). Yet, it has been considered by some researchers that a result of no effect means that the explicit (or intentional) instructions did not help the subjects in learning the grammar (Matthews, Buss, Stanley, Blanchard-Fields, Cho, & Druhan, 1989). This interpretation seems to have developed from the earlier findings of Reber (1976) where the explicit instructions hindered the learning of the grammar. Perruchet and Pacteau (1991) have criticized this bias in interpretation and have stated that the absence of an effect could be explained by the subjects' conscious use of rules when in the implicit instruction group. They argue it is natural for the implicit group to use rules to try to memorize the letter strings. Thus, the evidence in regard to the instructional set seems to point toward a single mode of learning, rather than separate explicit and implicit modes.

Still another manipulation attempts to determine if there are, in fact, two modes of learning; the addition of a secondary task. Dienes et al. (1990) used a random number generation task during the learning phase of the grammar task to ascertain if an implicitly instructed group would perform differently than the explicitly
instructed group. An earlier finding had shown that there was a selective impairment of performance on a systems task for the dual-task/explicit instruction group (Hayes, 1987). This was considered as evidence for two learning modes. However, Dienes et al. (1990) found that there was an equal impairment of performance and verbal report on the grammar task for both the implicit and explicit instruction groups. This finding demonstrates that the amount of learning for both groups was affected equally by the secondary task (i.e. to generate random numbers). This is further support for a single mode of learning, since the secondary task did not dissociate the groups by changes in performance on the grammar classification task nor by changes in performance of the random number generation task (the secondary task).

The proposal of an implicit and explicit mode of learning has been challenged on two accounts. Both the instructional set and dual task manipulations failed to demonstrate a difference in the amount of learning. Due to several sources of criticism, the distinction between an implicit and explicit mode of learning is becoming less plausible. The only remaining dissociation between the two modes concerns the issue of awareness. Before considering the controversy over that topic, the
representation of the knowledge that is learned in the grammar task will be examined.

This question of representation is a major topic in this paradigm. There are three main views as to the form of the subjects' knowledge of the grammar. That the subjects have some knowledge of the grammar, or of that which overlaps the grammar, is an uncontested finding in the literature. The learning is demonstrated by the above-chance performance of the subjects when judging grammaticality of novel letter strings (Dulany et al., 1984; Reber, 1976). Yet there are different interpretations as to what the knowledge is, what it is knowledge of, and what form it takes. Reber (1976, 1989) has claimed that the knowledge from the grammar task is an abstraction of the grammatical rules. However, it has been implied by other researchers that the knowledge may consist of specific exemplars in memory (Matthews et al., 1989). Currently, the issue is not exactly clear. The problem seems to lie in that the issue of representation becomes muddled with the issue of awareness, and both of the previously mentioned groups of researchers defend the existence of unconscious implicit learning. Others, such as Dulany et al. (1984) and Perruchet and Pacteau (1991), hold a view that the knowledge learned in the task is of
an abstracted nature, yet they contend that the abstraction results in consciously represented knowledge. This is quite antithetical to the view of Reber (1989), where the abstraction process is held to yield an unconscious and inaccessible knowledge. Moreover, this leads to the final topic of this paradigm, the controversy over awareness.

The issue of awareness is inextricably linked to the problem of how to assess it. In the grammar paradigm, this is a fundamental problem. There are two main views on whether the subjects are consciously aware of rules that describe a grammar (the rules which they are learning). And these two views can be separated according to the methods that are considered to be valid when measuring the subjects' awareness of the rules. Those researchers who claim that the subjects are unaware of rules rely upon free recall measures (Reber & Lewis, 1977). (Although in an earlier study, it was simply assumed that the stimulus is too complex for the subjects to learn anything explicitly (Reber, 1976).) On the other side of the theoretical fence, those researchers who claim that the subjects are aware of the rules rely upon recognition measures (Dulany et al., 1984; Perruchet & Pacteau, 1990). There has been considerable discussion
over which methodology is appropriate to measure conscious awareness. In particular, Brody (1989) has noted that a forced-choice recognition assessment is most appropriate. He argues that one must be sure that the assessment adequately exhausts the subject's conscious knowledge of the rules. In the case of Reber and Lewis (1977), the measure used to assess awareness was a verbal report, wherein the subjects were told to give reasons and justifications for the judgments they had made at test. Since none of the subjects mentioned anything like the actual rules of the grammar, the results of the learning were interpreted as being due to a base of implicit knowledge. However, in the case of Dulany et al. (1984) and Perruchet and Pacteau (1990), the measure of awareness was based on recognition. In Dulany et al. (1984), the subjects were instructed to write down what part of the letter string made that string grammatical or non-grammatical. These rules were then analyzed for validity values, which are their correlations with the actual finite state grammar. Dulany et al. (1984) had been open to the possibility that the subjects' knowledge of the grammar may not correspond exactly to the finite state grammar, especially when the amount of learning was imperfect. The results of Dulany et al. (1984) showed
that the subjects' rule validities predicted their amount of learning. Similarly, Perruchet and Pacteau (1990) claimed that the learning that takes place in the grammar task can be explained by conscious, fragmentary knowledge of the letter strings. Their experiment showed that subjects given only fragments of strings during the learning phase (e.g. QX, TM) were able to perform as well as those who had been given the entire string. Furthermore, a forced-recognition assessment of these fragments was able to account for the amount of learning demonstrated by their performance. The authors interpret this as evidence for conscious rules explaining the amount of learning.

The Dulany et al. (1984) study was criticized by Reber, Allen, and Regan (1985). Reber and his colleagues were concerned that the Dulany study was compromised by demand characteristics. They contended that the knowledge represented by the rule validities may be reconstructions or post-hoc justifications (e.g. guessing) for the earlier, implicit judgments about the grammar. In reply to these criticisms, Dulany, Carlson, and Dewey (1985) defended their measure of awareness. They asserted that the critical feature for the assessment was that it took place at the moment of
judgment (during the test phase). Since all of these reports are remembrances of some judgment process, it is most important to assess the subjects' conscious contents at the time of judgment, otherwise there will be a decline in the validity of the report. Thus, Dulany et al. point to the fact that an immediate assessment is the only defensible measure to use. Moreover, as a further defense of the measure, they reaffirm that the data for the rule validities predict the subjects' performance, and that computer simulation shows random guessing would account for the obtained data only once in ten billion occasions. This seems to argue against the criticism that the rules were guesses in response to demand characteristics. Moreover, Dulany et al. (1985) continue in the article to describe a meta-theoretical view of the learning process and its relation with consciousness. This will be examined in the next section.

Throughout the experimental paradigms, the results of many of the studies imply that the view of implicit learning is slowly giving way to the view that supports conscious, fragmented learning. As better methods of assessing consciousness are being developed, the evidence for unconscious implicit learning is fading. There are still many issues of relevance in this domain, especially
the matters of representation and automaticity. Now that the paradigms have been thoroughly examined, the next section will be a deeper exploration of a theory for conscious semantic representation.

**The Paradigmatic Context**

Across the different experimental paradigms, a common set of assumptions can be seen to underlie the experimental interpretations of the researchers who assert the existence of unconscious learning. These assumptions, as demonstrated in this introduction, are also common to the majority of cognitive psychologists. They are the fundamental claims of the science, and in the field of learning, they are active in the distinction between implicit and explicit learning. From many of the studies examined previously (Hayes & Broadbent, 1988; Lewicki, 1986a; Lewicki et al., 1988; Reber, 1976), the implicit mode of learning is considered to be nonanalytic, unintentional, and unconscious. Conversely, the explicit learning mode is thought to be analytic, intentional, and conscious. Yet, according to the results of the challenging studies (Du'any et al., 1984; Dulany & Wilson, 1990; Perruchet, Gallego, & Savy, 1990; Dulany & Poldrack, 1991), the validity of these assumptions is questionable. In regard to these
theoretical and meta-theoretical issues, a detailed and coherent alternative view has been offered (Dulany, 1984, 1991).

Dulany (1984, 1991) criticizes the standard view of consciousness on two points. The first claims that a major problem in this area is the lack of an analytic posture toward consciousness. The second point attacks the "separate systems assumption" which divides the mind into systems of conscious and unconscious processes. For the problem of consciousness, Dulany describes the concept through intentionality (cf. Searle, 1983). He defines consciousness as a state which consists of agency, mode, content, and aboutness. These are four dimensions of consciousness which will produce several variables for investigation, and every state lies at their intersection. Each conscious state is seen as a complex state, which in general will take the form of "I (agent) believe (mode) that Caesar crossed the Rubicon (content), and that content is about an event [i.e. Caesar crossing the Rubicon]" (Dulany, 1984, p. 5). Among these different aspects of a conscious state, the mode and the content are very important in regard to research on learning.

The mode is a varying type of mental state, such as
believing, hoping, or desiring. Whereas these modes are all considered to be propositional attitudes in the field of philosophy, Dulany wants to add another mode which is not propositional. His sub-propositional attitudes are used to make the distinction between the "perception of a blue cup and the propositional perception that the cup is blue" (p. 6). This is important for learning because this idea of propositional contents and sub-propositional contents grounds Dulany's alternative view of implicit and explicit learning (Dulany, 1991). This alternative view considers implicit learning in the context of automatic processes, which are thought to be too fast for conscious deliberation. In this case, the implicit process occurs when one hears a familiar song, and one knows the words before they come, without deliberatively conceiving the outcome. This is a sense of implicit that the earlier experiments (Hayes, 1987; Lewicki, 1986a; Lewicki et al., 1988; Reber, 1989) were thought to possess, yet the new research (Dulany & Poldrack, 1991; Dulany et al., 1984; Perruchet & Pacteau, 1990) seems to have shown that the learning taking place is deliberative (explicit). However, a crucial aspect of Dulany's characterization of implicit and explicit learning is that both processes consist of operations upon conscious
contents, with implicit having sub-propositional contents and explicit having propositional contents. Little research has been done to support this alternative view, and the work described in this paper is one of the first attempts to investigate this claim of an alternative type of implicit learning.

Furthermore, the theoretical importance of conscious contents applies directly to the experimental paradigms, specifically the problem with measures of awareness. As seen earlier, the empirical methods used by Dulany and his associates (1984; Dulany & Poldrack, 1991) to measure awareness were based on the subjects' conscious contents of the underlying rule. In the grammar paradigm, the sets of conscious contents were the "correlated grammars" (Dulany et al., 1984). Dulany (1984) defines the content as providing the subject, predicate, and specific propositional variables of the conscious state. Thus, through this detailed explication of consciousness, Dulany outlines a view that can define several experimental variables in the investigation of consciousness.

In reply to the second criticism, the challenge to the "separate systems assumption", Dulany (1984) develops a systematic outline of mental episodes. Rather than
adhering to the notion that conscious processes are unconnected to unconscious processes, the proposed view considers all mental episodes to consist of an operation working upon a content. The first point made here is that processes cannot be conscious, since consciousness is a mental state rather than an operation. This allows there to be four possible kinds of mental episodes. These episodes differ in the status of the mental contents, where the contents are either conscious or unconscious. Dulany proposes that mental episodes only take the form of a conscious content altered by a nonconscious operation to produce a new conscious content. This challenges all "cognitive unconscious" theories, including those that claim the existence of unconscious learning.

Throughout the research of implicit learning, a new view has come to the forefront, and this view challenges the existence of unconscious learning. New formulations of the learning process are coming to prominence, and the emphasis centers upon the consciously deliberative. However the case may be that the controversy over implicit learning is changing to favor the conscious process view, there still remains the problem of investigating truly automatic processes and their
relation to the control of conscious contents. As mentioned earlier, this area of research is only now beginning, and it is here that we begin the report of our investigation of the automatization of a finite state grammar task.

Procedural learning and automaticity in learning and action have been popularized by examples of complex skills, such as driving a car, which demonstrate the ease with which some complex tasks can eventually be performed, although the initial learning of the task was difficult and deliberate. On the standard interpretation of such learning and action phenomena, Schneider and Shiffrin (1977) have defined two types of information processing: controlled and automatic. Controlled processing (e.g. deliberative learning) is considered effortful, slow (relative to automatic processing), and serial. In contrast, automatic processing (e.g. implicit learning) is relatively effortless, fast, and parallel. The most important distinction for our purposes concerns the accessibility of the processing. The automatic process is "veiled" or unconscious, and the controlled process is primarily conscious (Schneider & Shiffrin, 1977, p. 147). This has been the standard interpretation of automatized action, and the type of learning that
leads to this phenomenon is procedural learning.

The present experiment, a discrimination task, was designed to produce results of procedural learning which could be characterized as automatic responses within the constraint of a one hour session. The number of strings which were presented to the subjects was minimized in order to simplify the complexity of the task in hopes of reaching automaticity. A time limit, or deadline, for response was also minimized to a one second interval in order to compel fast learning and fast automatization. Achievement of learning the discrimination task should be demonstrated by the increasing percentage above chance of correct responses to the grammatical versus non-grammatical strings in a finite state grammar paradigm. The evidence for procedural learning (a foreshadowing of automaticity) should consist of a slowing of response with the introduction of a novel stimulus-- the standard cost criterion (i.e. the shift from old to novel strings). Also, due to the use of a constrained deadline for response time (1 sec), a significant increase in the proportion of correct responses should suggest proceduralization. Since subjects are forced to respond very quickly, any significant increase in correct responses would suggest a trend away from deliberative
learning.

There are two criteria that would not be expected from this experimental design, and due to the widespread use of these criteria for procedural learning research, it is important to mention why they are not expected in this case. One is a continuous decrease and leveling off of response latency until the presentation of novel grammar strings. The second is the fit of the RT data by a power function, a commonly recognized criterion for automaticity (Logan, 1990). If the experiment would allow subjects to respond within a larger time limit (2 or 3 sec), then the RT data might conform to a gradual decrease over blocks, as well as being subject to fit by a power function, yet the deadline of a one second response precludes the expectation of a decrease of RT, which also entails the lack of fit by a power function.

The experiment would then test the claim of Dulany's alternative view of implicit learning by assessing the subjects' awareness of any rules (e.g. F 'MT' -> grammatical, meaning Feature 'MT' of string 'MTQ' evokes a sense of 'grammatical') and determining the degree to which their validities correlate with correct classifications of the finite state grammar. If learning is manifest as awareness of a feature evoking a sense of
grammaticality, subjects should be able to recode that episode as a reportable rule of a similar form. The measurement of the validity of these reported rules is done through the use of VALSCORE, a program first used by Dulany et al. (1984). VALSCORE computes the probability that a reported feature will correspond to a grammatical classification of the finite state grammar. A correlational analysis is then needed to determine the predictability of the subject's task performance from the mean validity of the reported rules (features). If the validity of the subjects' "correlated rules" predicts their performance without significant residual, then it will show that even in cases of proceduralized learning, conscious contents correlated with the grammar are driving the performance of the classification response. This contrasts with claims that procedural learning and automatized responses are driven by unconscious, implicit semantic processes (Baars & Matson, 1981; Klatzky, 1984; Lewicki, Hill, & Bizot 1988; Nissen & Bullemer, 1987). An example of such theorizing is found in a sequence task experiment of Lewicki, Hill, and Bizot (1988), "The results demonstrate that nonconsciously acquired knowledge can automatically be utilized to facilitate performance, without requiring conscious awareness or
control over this knowledge" (p. 24). In response to such claims, the present study attempts to demonstrate that automatized or procedural learning in a modified finite state grammar task is driven by conscious contents of "correlated rules", where the presence of a grammatical string evokes the thought of or a sense of "grammaticality".
Method

Subjects

Subjects were 46 right-handed undergraduates at the University of Illinois, Urbana-Champaign. All participated as requirement for credit in an introductory psychology course. Right-handed subjects were chosen to ensure that response interaction with the computer keyboard would not interfere with response latency. (The positioning of the keys is most comfortable for right-handers.)

Design

The experiment used a within-subjects design. Factors were blocks, string length, and old/novel for the transfer block (11).

Materials

Stimuli consisted of letter strings constructed from a finite state grammar (see Figure 1). Twenty-four strings were used, twelve of which were grammatical and twelve non-grammatical. The non-grammatical strings were constructed by impermissible substitutions of letters in grammatical strings. Each set of grammatical and non-grammatical strings was randomly divided into a training set (old strings) and novelty set (new strings). Each of these sets consisted of six grammatical and six non-
grammatical strings. The length of the string also varied from three, five, or seven letters. There were four strings of each length for both grammatical and non-grammatical sets. These differences in length were preserved in the split into novel and old sets. Selection and construction of the string sets ensured that all possible legal transitions of the finite state grammar were used at least once (see Table 1).

Insert Table 1 about here

Procedure

Instructions. Subjects were told the following: "In this experiment, you will see several pairs of letter strings. One string in each pair has been judged to be well-formed by another group of students. Your task is to judge which string is well-formed as quickly as possible. You should try to judge the pairs of strings by focusing on the overall form of each string. When a pair of strings is presented, press the button marked 'J' if you think that the top string is well-formed. Press the button marked 'N' if you think that the bottom string is well-formed." (These keys correspond to the keys J and N on the IBM PC keyboard.)
The subjects were given no other information about the strings and were instructed to begin selecting the strings by guessing. They were told that they would "soon learn to judge which string is well-formed if you focus on its overall form". The subjects were instructed further that after each response to a pair of strings, the string that was well-formed would be highlighted by flanking "asterisks". They were told to respond within one second to each pair, otherwise their response would not be recorded, although the well-formed string would still be highlighted.

Finally, subjects were told that their accuracy and speed would be reported to them after each block of trials, for both the immediate block and the one preceding it. They were urged to become faster and more accurate over each block of trials.

Training. In the center of the computer screen, a "plus" sign (+) was displayed for 500 ms in the position between the two strings as a preparatory signal for an imminent trial. The subjects then saw a pair of letter strings for one second, e.g.

MTR
MTQ

Once the subject responded to a string pair by selecting
either the top or bottom string, the actual well-formed string was marked by flanking *asterisks* for one second. If the subject did not respond before the one second deadline, then the trial was terminated and recorded as a non-response. As above, the well-formed string was flanked by asterisks once the deadline was exceeded.

Subjects received 10 blocks of 48 trials, where each block consisted of the presentation, in random order, of the set of 12 pairs of old strings. This set consisted of six grammatical and six non-grammatical strings and was presented four times for each training block (see Table 1). After each block, the subjects were given feedback as to their accuracy and average response time for the two preceding blocks. The purpose of this feedback was to help the subjects remain motivated throughout the task.

**Transfer.** Prior to the eleventh block, the subjects were instructed that the following block of trials would no longer involve feedback, neither during the block nor after it. We reasoned that the presentation of feedback with the novel string pairs might cause subjects to revert to an earlier form of deliberative learning rather than relying upon their acquired automatic judgment.

The eleventh block of trials presented the 12 novel
pairs of strings intermixed with the original 12 old pairs used in the training phase (see Table 1). Each set of string pairs was presented twice, in random order, throughout the 48 trials of the block.

Assessment. The subjects were given twenty-four assessment blocks, where each block consisted of 3 training trials of old pairs and a test pair from the set of old and novel pairs. The twenty-four test pairs were each presented once and in a new random order for each subject. Each test pair was presented without feedback as to which string was well-formed, and the subject was asked to "Write down the part or parts of the string that made you think it was well formed at the time of your response". The string chosen as "well-formed" and the instructions for the report of feature(s) were displayed immediately after the subject's response. The instructions told the subjects to place the critical feature(s) of the string in the blanks of the assessment sheet corresponding to the actual position of the feature(s) in the string. The assessment sheet consisted of seven blanks for each of the twenty-four strings.

Due to incorrect usage of the awareness assessment forms, 11 subjects' responses were not used in the assessment analysis. Therefore, N = 35 for the
assessment block.
Results

Learning of the Discrimination Task

Subjects acquired partial knowledge of the finite state grammar and were able to discriminate grammatical strings from non-grammatical strings at a level higher than chance (50%). Across all subjects, proportion of correct responses were .60 and .82 (N = 46) in the first and last training blocks (blocks 1 and 10), respectively.

A repeated measures within-subject analysis of variance with dependent variable of proportion of correct responses (PCORR) showed a significant effect for the factor of block, $F(9, 405) = 39.8$, $p = .0001$. This demonstrates that discrimination learning occurred. There was also an effect for string size, $F(2, 90) = 19.0$, $p = .0001$; and a significant block * string size interaction, $F(18, 810) = 2.29$, $p < .002$, showing that subjects learned differentially for the three string sizes. (See Figure 2.)

Insert Figure 2 about here

Procedural Learning

As expected from the one-second response deadline, there was no evidence of a decrease in RT over blocks. A
repeated measures within-subject analysis of variance with dependent variable of RT showed a significant effect only for string size, $F(2, 90) = 23.20$, $p = .0001$. There was no significant effect of block nor of the interaction of block * string size. (See Figure 3.)

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Cost of Novel Strings. The transfer block (11) did show an increase in RT for the responses to the novel strings relative to old strings, which indicated that the cost criterion for procedural learning was met. The means of the RTs for old and novel strings were 677 ms and 713 ms ($N = 46$), respectively. A T-test (2 tailed) showed this difference to be significant, $t(44) = 3.81$, $p = .0004$. (See Figure 4.)

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Increase PCORR Below 1 Second Deadline. The second criterion of a significant increase in proportion of correct responses (PCORR) was found. As reported above, there was a significant effect for the factor of block in a repeated measures analysis of variance. This
increasing amount of learning occurred below a time constraint of one second, and such evidence supports the interpretation of proceduralization due to the improbability that subjects could respond using deliberation of rules within this constraint.

**Transfer of Learning**

Three indices demonstrated in conjunction that there was no transfer of the discrimination learning from the old strings to the novel strings. At the transfer block (11), PCORR of old and novel strings had means of .78 and .59 (N = 46), respectively. T-test (2 tailed) showed this difference to be significant, $t(44) = 6.96$, $p = .0001$. Something had been learned about the old strings that does not apply directly to the novel strings. (See Figure 5.)

The second index of the specificity of the learning is found in the contrast of PCORR of block 1 versus PCORR of novel strings in block 11 (transfer), $M = .60$ and $.59$, respectively. A contrast analysis of variance for PCORR block 1 and PCORR block 11-novel resulted in no effect, $F(1, 45) = .124$, $p = .72$. Apparently, the subjects
learned the novel strings in a similar fashion to their learning of the old strings at the beginning of the task.

The third index for a lack of transfer of the learning was found in the results of the contrast of RT of block 1 versus block 11-new. A contrast analysis of variance found no significant effect for the above contrast, $F(1, 45) = .376, p = .54$. This supports further the claim that subjects were learning the novel strings at block 11 in the same way that they learned the old strings at block 1.

These three results indicated that the knowledge of the old strings at the end of the task was different than the knowledge of the novel strings and the old strings at the beginning, and there was no transfer of this learned knowledge from the old strings to the novel strings (in block 11).

**Relation of Reported Rules to Performance Judgments**

At assessment, reported rules of features within strings were analyzed using the VALSCORE program in order to obtain validity scores for each subject (cf. Dulany, Carlson, Dewey, 1984 for original explanation of the VALSCORE program). The logic of the VALSCORE program is as follows: (a) Subjects learn that certain features of a string or the whole string signify that it is
grammatical, (b) Subjects select a string as grammatical based on a feature or the whole, and report this feature on the assessment sheet. (c) The proportion of correct responses is computed according to the subjects' classification of the string. (d) Validities are computed according to the probability that the string is grammatical given that the feature is in the string, and therefore (e) if subjects report the feature that actually determined their selection response, then the validities should predict the PCORR without significant residual; otherwise either subjects are not aware of the feature which determined their selection response, or subjects did not faithfully report the feature which drove their response. For each subject, validity scores and PCORR were calculated for the set of all 24 strings, the set of the 12 old strings, and the set of the 12 novel strings.

After first analyzing the VALSCORE data, there was reason to believe that subjects had incorrectly responded to the assessment task by placing features which were not possible for the string selected (e.g. reporting ‘MTQ’ when the string selected was actually ‘MTR’). This type of error was attributed to carelessness and distraction during the experiment (factors which may be the fault of
the experimenter's choice to run four subjects at once), and therefore all of the subjects' responses to the assessment task were checked for misreports and individual errors were discarded from the analysis. A misreport consisted of a subject reporting a feature which was not found in the string which had been chosen as grammatical; such a response violates the instructions of the assessment form since the chosen string was the only string presented for the assessment. Overall, less than ten percent of responses were discarded from the analysis.

Correlations of validity with PCORR resulted in the following: for the set of 24, $r = .449$; for the set of 12 old, $r = .607$; and for the set of 12 novel, $r = .600$. (See Figures 6, 7, 8.)

T-tests (2 tailed) of the mean validities and mean PCORRs for each set resulted in $t(34) = 3.64$, $p = .0009$, for the set of 24; $t(34) = 3.29$, $p = .0023$, for the set of 12 old; $t(34) = 1.99$, $p = .0545$, for the set of 12 novel.

These two sets of analysis revealed that the
prediction of the PCORR by validities was underachieved in both the total set of strings and the old strings alone, while the validities of the novel strings underpredict their PCORR by marginal significance.

The graphs of the residuals for the prediction of PCORR by validities show that for both the old and novel sets of strings the modal residual is zero. Furthermore, the distributions of residuals are skewed such that only a small number of subjects are responsible for the deviation away from a balanced distribution around the modal value of zero. (See Figures 9, 10, 11.)

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Insert Figures 9, 10, 11 about here

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Since the distributions of residuals have one of the characteristics expected for the prediction of PCORR by validities without significant residual, namely the modal value of zero, it is important to consider what the t-test group differences truly signify. The t-test can produce a group difference in means when there are only a few individual subjects responsible for the results of underprediction. Therefore, the skewedness of the distributions calls for an analysis of individual residuals to determine the number of subjects who
actually demonstrate significant underprediction.

The results of the individual analyses showed that only two subjects obtained significant residual with underprediction. Both subjects' residuals were highly significant (p < .01) only for the set of old strings. None were significant for the novel strings (level .05). For the total set of strings, only three subjects' residuals were significant (p < .05). This means that, from the set of all 35 subjects, 33 of them demonstrated the prediction of PCORR by their validities without significant residual for the set of old strings; and all of the subjects showed prediction without significant residual for the set of novel strings.
Discussion

There were two goals of this experiment: (1) achieve procedural learning within a finite state grammar task, and (2) determine whether the knowledge which drove the subjects' responses was consciously or unconsciously represented. The first goal has been met with the evidence of a cost in RT with the presentation of novel strings and of the significant increase in proportion of correct responses while under a response deadline of one second. The issue of conscious or unconscious learning is decided by the following discussion of the awareness assessment, where it is argued that the procedural learning is driven by evocative conscious contents.

The achievement of procedural learning is found in two measures of analysis. One is the criterion of cost when novelty is introduced, revealed by the significant difference of RT for old and novel strings in the transfer block. The means of the RTs for old and novel strings were significantly different, with old having a lower value. The second piece of evidence for procedural learning is based on the highly significant change in proportion of correct responses over blocks when this occurs within time constraints of less than 730 ms. In order for subjects to be responding this quickly while
achieving such marked improvement over trials, there would need to be either progress toward proceduralization from deliberate application of abstract rules or an immediate automatic learning of the task that would seem to require unconscious implicit learning (cf. Lewicki et al., 1988; Reber, 1989).

Before turning to the discussion of awareness, there is an interesting aspect of Dulany's alternative theory of implicit learning which relates to the lack of transfer of learning found in the results of this experiment.

Dulany's (1984, 1991) theoretical characterization of implicit processes as being evocative and automatic episodes which are driven by conscious contents entails the following predictions for transfer effects of learning. In general, discriminative learning tasks are considered to be tasks which require deliberation on the part of the subject. For this experiment, my principle assumption is that the task initially does require deliberation in order to choose the grammatical string of the pair. The goal of the task is to induce or compel the subjects to use less and less deliberation until the responses are automatic, and the proportion of correct responses increases due to the speed of the evocative
process. When the feature 'MT' appears, a sense of grammatical pops to the subject's mind, and the subject chooses that string as grammatical. One no longer needs to deliberately remember a rule to apply to the choice, nor to remember a specific instance in the past. When the subjects reach the transfer block, it has been shown that procedural learning has been acquired, and then there should be no transfer of learning because the subjects no longer deliberate upon the choice, but rather have an evoked sense of the answer 'grammatical'. If the subjects did still deliberate upon the choice, then those abstract rules (in the strict sense of the word) could be applied to the novel strings as easily as to the familiar old strings (with a possible exception that the novelty might shock or jar the subject, which in any case should not produce significant effects of non-transference). The case in which the subjects do not deliberate, but have an evoked knowledge of the grammatical string, should not allow transfer of learning to the novel strings simply because their knowledge is specific to the feature(s) of that particular string. It is only in the case that the novel strings share the grammatical feature(s) of old grammatical strings that there should be transfer of learning effects. Hence, for Dulany's
concept of implicit learning, transfer of learning should appear strongly only when there is great overlap of features for automatized or nearly automatized responses. I argue that the lack of transference of learning from the old strings to the novel strings supports the interpretation that procedural learning has been achieved. This lack of transfer is evident in the results. There it was seen that the proportion of correct responses was significantly different for novel strings compared to the old strings in the transfer block, but was not significantly different for those novel strings to the old strings of block 1.

This experiment was designed to produce procedural learning within a finite state grammar discrimination task. These results were achieved, and the analysis of the awareness assessments will decide the theoretically crucial question: Do proceduralized learning tasks function without the subject's conscious awareness of the contents which drive the responses?

The analysis of individual subjects' residuals shows that the only a few subjects are responsible for the skew of the residuals distributions. Furthermore, the modal value of both distributions (old and novel strings) is zero, and the curve is nearly symmetrical except for the
influence of those few subjects. From these results there are two possible interpretations of the data: (1) The t-tests and skew of the residuals distributions reveal a general process of learning which is inaccessible to consciousness; or (2) the t-tests and skew of the distributions is the result of experimental error, such as the failure of subjects to respond carefully to the assessment due to the presence of multiple subjects.

The second interpretation is superior due to the facts that the distributions are nearly symmetrical around a mode of zero, as opposed to showing an overall phase shift toward underprediction (meaning a general tendency for reports to fail to correspond to performance). But there is still a question as to the difference between the t-tests and skew of residuals distributions for old versus novel strings. Novel strings show less skew in their distribution and have no individual cases of significant underprediction. What feature of the novel strings would allow for closer prediction, while excluding the old strings? The answer for this is found in the relation of the assessment's instructions with the type of knowledge which characterizes the learning of the old and novel strings.
In the results concerning the nature of the knowledge of the strings, it was seen that whatever was learned about the old strings did not transfer to the novel strings in any degree. This leads one to consider if the proceduralization of the responses to the old strings affected the representation of those strings. It seems likely that subjects, after seeing the same 12 pairs of old strings for 480 trials, begin to recognize the whole string, and thus the presentation of those strings holistically evokes a sense of 'grammatical'. This is different from the learning of the novel strings at block 11, where it is likely that subjects notice particular features of those strings which correspond to features in the old strings. This interpretation would predict that the proportion of correct responses would decrease for the novel strings, since the match of features from old to novel would be merely partial. The results showed such a decrease.

The conflict of this dichotomy of representation, holistic and featuralistic, becomes important for the VALSCORE results when contrasted with the instructions of the assessment. The awareness assessment asked subjects to "Write down the part or parts of the string that made you think it was well formed at the time of your
response*. This emphasis on features of strings, without mentioning the option of reporting the entire string, would lead subjects to report arbitrary features of the old strings when it was actually the whole string which evoked the thought 'grammatical'. This would not pose as great a problem for the novel strings since the subjects are already attuned to features of the strings.
Conclusion

The achievement of procedural learning in a finite state grammar task has been met with the evidence of a cost in RT with the presentation of novel strings and of the significant increase in proportion of correct responses while under a response deadline of one second. The major issue concerns the accessibility of the task performance, conscious vs. unconscious.

For two reasons, the results of the awareness assessment should be viewed as supporting the claim that conscious contents are driving the performance of the subjects. The proceduralization of the old strings brought about a change in representation of the knowledge acquired during the task, and the assessment of awareness was not completely attuned to this change. Therefore, the difference in prediction of proportion of correct responses by the subjects' validities (for novel vs. old strings) is due to the assessment procedure rather than the subjects' cognitive processing, and the individual prediction without significant residual for 33 of 35 subjects supports the view that evocative conscious contents are responsible for the learning effects.
References


Matthews, R. C., Buss, R. R., Stanley, W. B., Blanchard-


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Imagine an example of automatized response that is familiar to many people, driving an automobile. For most adults, the skill of driving is automatic in many ways; many decisions and deliberations are no longer necessary although they were when you first learned to drive. It may seem against my argument to point out that we are all capable of entering several different kinds of autos and drive as easily as always. Doesn’t this show transfer of knowledge without deliberation? Yes it does. What it doesn’t show is transfer of knowledge when the features of the stimulus environment have changed to a significant degree. Imagine trying to drive an auto whose interior is significantly different from our common exemplar. Perhaps the steering mechanism (a shared feature) is operated by applying pressure to a head-rest cushion. Now could you drive with ease? I think not. A future experiment should investigate the parameters which define similarity of features and the transfer of automatized knowledge.
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(* = grammatical, left = top position, right = bottom position)
Figure Captions

1. Finite state grammar.

2. Proportion Correct Responses by Blocks, three string sizes.

3. Reaction time by Blocks, three string sizes.

4. Reaction time by Blocks, Novel Strings vs. Old Strings in block 11.

5. Proportion Correct Responses by Blocks, Novel Strings vs. Old Strings in block 11.

6. Correlation of PCORR and Validities. All strings.


9. Distribution of residuals. All strings.


Figure 3
Figure 4

[Graph showing reaction time over blocks]

- X-axis: Blocks
- Y-axis: Reaction Time

Legend:
- New
- Old
Figure 5

![Graph showing the proportion correct over blocks.](image)

- **Old**
- **New**

Proportion correct

Blocks

0 1 2 3 4 5 6 7 8 9 10 11
Figure 6

\[ y = 0.46078 + 0.41740x \quad R^2 = 0.202 \]
Figure 7

\[ y = 0.46516 + 0.444x \quad R^2 = 0.369 \]
Figure 8

$y = 0.19809 + 0.74662x \quad R^2 = 0.360$
Figure 10

A histogram showing the frequency distribution of residuals. The x-axis represents the residual values, and the y-axis shows the frequency. The data is grouped into bins, and the height of each bar indicates how many data points fall within that bin.