Anxiety and Learning:
A dissociation between explicit and implicit processes.

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A body of evidence has accumulated which suggests that subjects can learn complex tasks over time without necessarily being able to describe explicitly the rules used during such learning. This type of learning, whereby verbalizable knowledge of task rules seems to lag behind performance indicators, has been termed implicit learning. According to Reber (1992), implicit learning predates the conscious executive system in evolutionary terms and as such should be robust in the presence of various disorders and conditions which typically disrupt more explicit processes. This paper examines some of the evidence for this claim with specific reference to anxiety, and describes work in our own laboratory which explores the effects of induced anxiety on the learning of complex motor sequences. In keeping with the literature on implicit memory, the results of the studies examined here suggest that some implicit learning remains under conditions of anxiety. Possible mechanisms for this are discussed.

There is evidence suggesting that subjects who score highly on various measures of anxiety perform poorly on certain types of memory and learning tasks (for a review of some early work in this area see Eysenck, 1977). For example, highly anxious subjects demonstrate less clustering in their recall of categorised lists (Mueller, 1976), are poorer at the digit-span task (Hodges & Spielberger, 1969), and are slower to retrieve task-relevant material (Straughan & Dufort, 1969).

Much of the early work in this area relied on such procedures as recall and recognition to assess learning and retention. To the extent that these tests rely heavily on the ability of subjects to demonstrate an explicit awareness of specific prior events (e.g. a word list), such tests have been termed explicit tests. A defining characteristic of such tests is their explicit instructions to retrieve information about a particular experience. Schacter (1987) notes that "they make explicit reference to, and require conscious recollection of, a specific learning episode" (p.501). In contrast, implicit tests do not test an individual's awareness of specific prior events but attempt to measure the Influence of these prior events through some form of performance indicator (e.g. reaction time: RT). These tests are assumed to tap a type of memory that has been labelled implicit memory or memory without awareness (Schacter, 1987).

There is now a body of evidence showing that, within subjects, performance on each of these classes of test is often quite different. To take one example, Craik and Tulving (1975) have demonstrated that the level to which study words are encoded (i.e. physical vs semantic) has a direct influence on performance at test time when this performance is measured explicitly, through recall or recognition tests. However, level of processing during study has only minimal effects when performance is measured by implicit tests such as RT (for recent reviews of such dissociations see: Richardson-Klavehn & Bjork,1988; Roediger, 1990; Schacter,1987).

Research from brain-injured subjects also provides strong support for two distinct types of learning, one of which can occur in the absence of awareness. Although amnesic subjects have clear deficits with regard to learning as measured explicitly (as, for example, in free recall) their performance on a variety of tasks when measured implicitly has been found to be relatively intact both for verbal material (e.g. Cohen & Squire, 1980; Graf, Squire, & Mandler, 1984), and for motor learning (e.g. Nissen & Bullemer, 1987; Nissen, Willingham, & Hartman, 1989).

While most of the work in this area has concentrated on memory processes, a body of research has accumulated suggesting that subjects can learn complex tasks over time without necessarily being able to describe or explain the rules used in such learning. This type of learning whereby explicit knowledge lags behind performance has been termed implicit learning (Reber, 1989).

Experimental procedures designed to investigate implicit learning generally involve the presentation of some form of complex stimuli, such as a series of location targets on a screen. Unbeknown to the subjects, the stimuli contain some form of nonsalient structure, such as a recurring sequence of target locations. After repeated presentations of the stimuli, an improvement is noted in the subject's performance on the task, (e.g. decrease in RT), and this is typically unrelated to any knowledge the subject can verbalise about the structure or pattern present.

The improved performance is considered by some to represent an increasing sensitivity to the structure present in the stimuli, or more specifically, a registering of the complex, interdependent covariations existing between events or features (Lewicki, 1989; Reber, 1992) and subsequent application of either rule-making or exemplar-based processing to progressively encode the structure or pattern present. The poor introspective accessibility to the knowledge created by these phenomena has led to proposals that the process occurs out of consciousness and is only manifest in some form of performance task (Reber 1989, although see Perruchet & Amorin, 1992, for an alternative view).

Implicit learning has been demonstrated in verbal, visuo-spatial, or mixed stimuli-response formats involving a complex sequencing or a predetermined pattern of associations (Hartman, Knopman, & Nissen, 1989; Howard & Howard; 1989: Howard, Mutter, & Howard, 1992; Lewicki, 1986, 1992; Lewicki, Czyzewska, & Hoffman, 1987; Matthews, Buss, Chinn, & Stanley, 1988; Nissen & Bullemer, 1987; Stadler, 1989, 1992; Willingham, Nissen, & Bullemer,1989), social contexts which involve manipulated personal characteristics of fictitious persons (Hill, Lewicki, Czyzewska, & Boss,1989; Hill, Lewicki, & Neubauer,, 1991), the learning and application of complex organisational rules (Berry and Broadbent,1984; Broadbent, Fitzgerald, & Broadbent,1986), and in letter strings that appear to be random but follow artificial grammatical rules (Cleeremans and McClelland, 1991; Reber, 1967; Reber & Millward, 1968).

At first blush, implicit processes might be seen as representing a comparatively simple form of processing, but it has been argued that implicit learning predates the conscious executive system in evolutionary terms (Reber, 1992) and has an adaptive function as a complex and structurally sophisticated element of cognitive activity (Lewicki, 1986, 1992). The adaptive advantage claimed for implicit learning comes from its role in releasing controlled, conscious processes "from the responsibility of dealing with numerous tasks supporting every act of controlled cognition, like...forming first impressions of social stimuli" (Lewicki et al., 1987, p.529). This facility may help account for evidence that more information about events is stored in the cognitive system than could be processed through channels that are consciously controlled (Lewicki et al., 1987).

Reber (1992) has argued that the evolutionary primacy of implicit processes should distinguish them from those processes which have emerged more recently. In particular, implicit processes should demonstrate robustness in the presence of disease, injury, and other conditions which typically impair more explicit performances. Evidence for this robustness has begun to accumulate with a number of studies showing intact implicit learning among groups who typically display severely impaired explicit processing. Using a serial reaction time (SRT) task, Nissen and Bullemer (1987) showed that Korsakoff patients were able to learn a 10-item stimulus sequence despite being seriously impaired in the explicit aspect of the task. Similar results using a variety of tasks designed to measure implicit learning have been reported with amnesic groups (Abrams & Reber, 1988; Glisky & Schacter, 1989; Johnson, Kim, & Risse, 1985; Knopman & Nissen, 1987; Knowlton, Ramus, & Squire, 1992), and with subjects compromised by the administration of scopolamine (Nissen, Knopman, & Schacter, 1987).

Anxiety and implicit learning.

With specific reference to the effects of affective states on learning, Rathus et al., (1994) comment:

> *The evolutionary hypothesis carries with it the prediction that cognitive processes that are primarily unconscious in nature should be dissociable from those that are primarily conscious. One feature of this dissociation is that the unconscious and implicit should show greater resilience under conditions of high affect that compromise the conscious and the explicit. (p. 168).*

According to the robustness principle, therefore, anxiety should not interfere with implicit processes despite substantial research evidence for the disruptive role of anxiety in explicit cognitive processes generally, (for reviews see; Barlow, 1988; Dalgleish & Watts, 1990; Eysenck, 1988; Eysenck, MacLeod, & Mathews,1987; Ingram & Kendal,1987).

In a recent paper Rathus, Reber, Manza, & Kushner (1994: Experiment 1) used subjects classified as test-anxious and examined their performance using an artificial grammar procedure. This procedure, developed by Reber (1967) involves presenting subjects with lists that are made up of strings of letters. The subject is asked to observe these stimuli but is not instructed to look for any regularities or patterns. Although subjects are not told so, the strings are generated by a set of rules, and these rules constitute an artificial grammer which specifies an acceptable ordering of letters. In the testing phase which follows the stimulus presentation, subjects are presented with a new series of strings and are asked whether or not they conform to the rules operating in the material presented in the learning phase. Previous research using this procedure has indicated that when subjects make judgements about the new stimulus material, they act as if they are following the rules that were implicit during the initial presentations. Put another way, subjects can discriminate above chance level despite being unable to report explicit knowledge of any rules (Abrams & Reber,1988; Reber,1967,1992; Reber & Millward, 1968). In the learning phase of the Rathus et al., (1994) study, subjects classified as high or low in test anxiety, were shown a series of letter strings and were asked to memorise them up to a criterion of two consecutive correct reproductions. Before the test phase, subjects were advised that the strings they had seen had been formed according to a complex set of rules. In the testing phase which followed, subjects judged a set of novel strings as either "acceptable" i.e. conformed to the grammatical rules inherent in the inital set of stimuli, or "not acceptable", i.e. violated these rules. Of the novel strings, half were grammatical, and half were not. The data were analysed both in terms of explicit and implicit performance. The explicit measure was the number of trials taken to memorize the strings. Subjects scoring high in test anxiety took significantly more trials (mean = 58.8) to reach criterion than did subjects scoring low in anxiety, (mean = 39.5). On the implicit test, the results showed that subjects were able to discriminate between grammatical and nongrammatical strings well above chance level, and that this result was independent of anxiety level. Overall the results demonstrated a dissociation between explicit performance, requiring overt strategies, and implicit performance. The overall findings support the view that, for this type of task, implicit learning is relatively intact in the presence of an anxiety state.

Anxiety and the SRT task: A specific example.

Although considerable research has been done on the effects of anxiety and implicit memory, as far as we know the study by Rathus et al., is the only published work on the effects of anxiety on implicit learning. In our own laboratory we have attempted to extend this finding by examining the effects of anxiety on the SRT task (Nissen & Bullemer, 1987). In this task subjects are shown an asterisk which appears along the bottom of a computer monitor in one of four locations. Subjects are required to respond to the stimulus by pressing a key which corresponds to the target's location. Subjects are not told that the stimulus locations follow a particular recurring pattern. After repeated presentations of trials an improvement in RT is usually noted, and this improvement is greater than that shown by a control group who perform the task to stimuli which appear in random order. The SRT task is said to tap implicit learning because improvement in performance is typically unrelated to any explicit knowledge the subject may report about the structure or pattern that is present. Work with the SRT procedure has found that amnesic patients show intact learning in the SRT task despite being unaware of the presence of the sequence in any explicit way (Nissen & Bullemer, 1987). In other studies, the SRT task has been used to demonstrate preserved implicit learning in Alzheimer patients, but not in patients suffering from Huntington's disease (Knopman & Nissen, 1991). The technique has also been used to demonstrate intact implicit learning in elderly subjects (Howard & Howard, 1989), subjects with Closed Head Injury (McDowall & Martin, in press), and in subjects under the influence of scopolamine (Nissen, Knopman, & Schacter, 1987).

In our study, one group of subjects performed the SRT task under conditions designed to induce anxiety. Their performance was compared with a group performing the SRT task under normal conditions. We hypothesised that, in keeping with the robustness principle, anxiety should not impair performance on the SRT task when this performance was measured indirectly (i.e. through RT), but would impair the explicit component of the task defined as an explicit awareness of, and ability to report, the repeating sequence. In this study anxiety was induced rather than inferred through self-report instruments.

We tested 40 undergraduate and graduate students in this study. Twenty subjects were allocated to an induced anxiety group and the remaining subjects served as controls. The stimuli were generated on a monochrome monitor controlled by a Commodore microcomputer. The single stimulus appearing on each trial was an asterisk 3.5 mm in diameter and located in one of four positions, all of them 2.2 cm from the bottom of the monitor and separated horozontally by 3.5 cm. The viewing distance from the screen was approximately 53 cm. Responses were made by pressing the one of four marked keys on the top row of a keyboard which was positioned underneath the stimulus. A correct response erased the stimulus and 400 msec later another appeared in a different location. The location of the stimuli followed a specific sequence consisting of 15 trials which was then repeated 10 times to make up a block of trials (150 trials). Subjects were not informed of the presence of the sequence. All subjects completed 6 blocks of trials with the repeating sequence before switching to a seventh block where the location of the stimuli was determined randomly (with the constraint that no two same locations appeared consecutively). Sequence learning was said to have occurred if a significant increase in RT was obtained for block 7.

Before begining the experiment subjects were told that the computer would allocate them randomly into shock or non-shock condition and that they were free to discontinue participating at any time (In fact no shocks were administered to any subjects). When the subject was seated, a key press initiated the following message: "ALLOCATION TO SHOCK OR NON-SHOCK GROUP IS NOW PROCEEDING". This message was displayed for a period of 1.5 seconds. This was followed by a blank screen for 3 seconds after which the experimental group were shown the following message; "THIS SUBJECT IS ALLOCATED TO THE SHOCK CONDITION GROUP". At this point subjects were fitted with a "shock apparatus" consisting of an electrically wired plastic clip that appeared to be connected to the current generator. The clip was attached to the subjects ear. The subject was then shown the following message: "DURING THE FOLLOWING PROCEDURE YOU MAY RECEIVE ONE OR MORE MILD BUT UNCOMFORTABLE ELECTRIC SHOCKS. THE OCCURRENCE OF THE SHOCK IS NOT RELATED TO HOW WELL OR BADLY YOU DO BUT IS DELIVERED AT RANDOM, I.E. AT ANY POINT DURING THE EXPERIMENT". The control subjects saw a message on the screen which advised them that they had been allocated to the non-shock condition.

In both the control and anxiety-induction groups, subjects were asked to fill out a visual analogue scale (VAS) measure of anxiety prior to the first block of trials, and immediately before the last. The VAS was a 10 cm line with "calm, not at all worried" at one end of the line, and "very anxious, panicky" at the other.

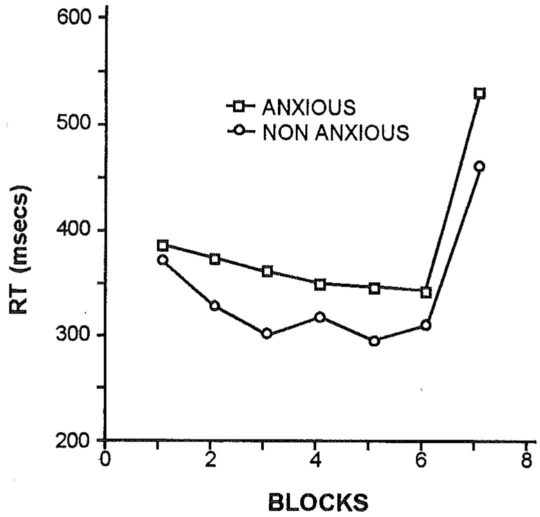
We tested all subjects individually. They were asked to rest their middle and index finger of each hand on the marked keys and were told to press the key that was directly below the location in which the asterisk appeared. They were advised that a correct response would erase the stimulus and that a new one would appear in another location and that they were to respond by pressing the relevant key as quickly as possible. At the conclusion of the SRT task, subjects were given a series of questions designed to assess subject's level of explicit knowledge of the sequence. They were asked if, during the course of the experiment, they noticed anything about the stimuli. If subjects reported being aware of a repeating sequence they were asked to describe this to the experimenter. If they reported not being aware of the repetition they were then told of its presence and asked to guess what it might have been. This procedure followed that of Hartman et al., (1989), and Willingham et al., (1989), who concluded that subjects with less than 4 of the 10 trials correctly reported in response to questioning were effectively unaware of the pattern, whereas subjects who were able to report 4 to 10 elements correctly were considered to be effectively aware. Finally, subjects were told the nature of the study and the purpose of the induction procedure before being thanked and dismissed.

We determined the efficacy of our induction procedure by taking a score greater than 4cm from the 0 position ("calm, not at all worried") at the first measure, as the cut-off for inclusion in the anxiety group. For the non-anxious group, a score of less than 2cm from the 0 position was required. For the anxiety group the first measure on the VAS produced a mean value of 5.4cm. The second measure of anxiety, taken between the 6th and 7th blocks, produced a mean value of 3.8cm. For the control group both measures remained under 2cm.

We examined the impact of the anxiety induction on the explicit awareness of the repeating sequence based on responses to the post-experiment questionnaire. For the non-anxious subjects, 10 (50%) were classified as being fully or partially aware of the sequence, the remaining 10 were unable to report or demonstrate awareness of the sequence. For the anxious group 5 (25%) were classified as being fully or partially aware of the sequence and could demonstrate this awareness. The remaining 15 (75%) reported being unaware of the presence of the sequence and were unable to demonstrate it when asked to do so. A Chi square analysis of the difference between the anxious and non- anxious groups in terms of awareness was significant and demonstrated that the anxiety induction procedure reduced performance on the explicit component of the SRT task.

We next looked at the performance of both groups in terms of their RT across blocks. Response times were collected and median RT were calculated for correct responses in each set of 15 trials within each block for both groups. The means of these medians are shown in Figure 1. Because of the unequal variance in RT across the 2 groups, all data were log transformed. A 2 (Group) X 7 (Block) ANOVA with repeated measures on Block revealed a significant main effect of Group, E(1, 38) = 4.35, p< .05, and a significant main effect of Block, E(6, 228) = 21.73, p< .001. There was no interaction between Group and Block F<1

Figure 1: Mean RT over blocks for anxious and non-anxious subjects: All subjects



An ANOVA restricted to the first 6 learning blocks revealed a significant main effect of Block, E(5,190) = 6.49, p<.001. There was no reliable main effect of Group, E(1,38) = 3.79, p>.05, nor any interaction between Group and Block, F<1. Further analysis of practice effects over the initial 6 training blocks of repeated sequences was carried out by taking the mean RT of each subject on Block 1 and subtracting their RT from Block 6. The resulting scores and standard deviations are shown on the left side of Table 1. The mean practice scores were found to be significantly different from zero for both the anxious group, t(19) = 1.95, p<.05, and the non-anxious group, t(19) = 3.30, p< .05.

Since the practice effects can represent both specific pattern learning and the contribution of the subject's general experience of the task, pattern specific learning was examined separately. A 2(Group) X 2(Block) ANOVA on

Table 1: Means and standard deviations (msec) for practice scores and pattern learning scores in the SRT task across groups: All subjects.

	Practice Score		*Pattern Learning Score*	
	Anxious	*Non-anxious*	*Anxious*	*Non-anxious*
Mean	62.0	91.0	155.1	208.0
SD	65.2	85.3	149.1	79.1

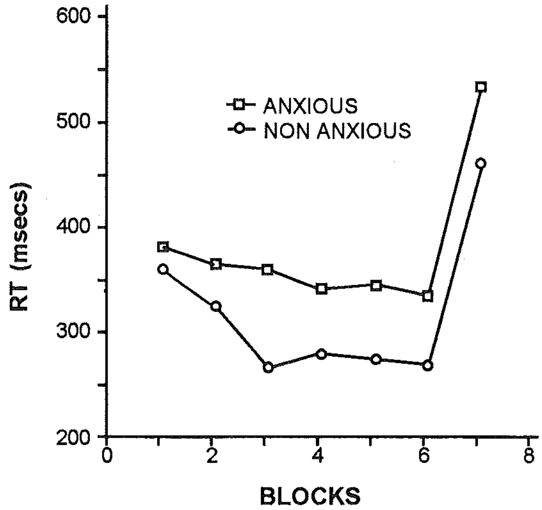
Note: Practice score = Block 1 RT minus Block 6 RT.
Pattern learning score = Block 7 RT minus Block 6 RT.

blocks 6 and 7 revealed a significant main effect of Block, E(1,38) = 39.38, p<.001. There was no significant effect for Group, E(1,38) = 3.44, p>.05, nor any interaction between Group and Block, F<1. Pattern specific learning was also examined by subtracting the mean RT on Block 6 from that of Block 7. The resulting scores and standard deviations are shown on the right side of Table 1. The mean pattern learning scores were found to be significantly different from zero for both the anxious group, (19) = 4.70, p< .05. and for the non-anxious group, (19) = 11.11, p< .001. Taken as a whole these results suggest that sequence learning was taking place for both the anxious and non-anxious groups.

At this point it might be argued that the sequence learning demonstrated by the anxious group is being driven by the small number of subjects who were able to demonstrate explicit knowledge of the sequence. To assess this possibility, subjects from both groups who had demonstrated an awareness of the sequence (i.e. were able to correctly report 4 or more correct locations), were eliminated and an 2(Group) X 6(Block) ANOVA on the remaining subjects across groups for the first 6 learning blocks was performed. The results indicated a significant main effect of Group, F(1,23) = 4.40, p<.05, as well as a significant main effect of Block, E(5,115) = 5.24, p<.001. Of interest was a significant Group X Block interaction, E(5,115) = 2.43, p<.05. Post hoc analysis (Scheffe test) across blocks revealed a significant difference between the groups only for Block 3. The performance of the 2 unaware groups is shown in Figure 2.

Further analysis of practice effects over the 6 training blocks was carried out by taking the mean RT of each subject on Block 1 and subtracting this RT from Block 6. The resulting scores and standard deviations are shown on the left side of Table 2. The mean practice scores were found to be significantly different from zero for both the anxious group, t(14) = 2.07, p<.05, as well as for the non-anxious group, t(9) = 2.04, p<.05. A 2(Group) X 2(Block) ANOVA confined to Blocks 6 and 7 revealed a significant main effect of Block, E(1,23) = 39.90, p< .001. The main effect of Group just failed to reach significance, F(1,23) = 4.08, p>.05. There was no interaction between Group and Block, E(1,23) = 1.41, p>.05. Pattern learning was also examined in these 2 groups by subtracting the mean RT on Block 6 from that of Block 7. The resulting scores and standard deviations are shown on the right side of Table 2. The mean pattern learning scores were found to be significantly different from zero for both the anxious group, (14) = 5.47, p<.001, and for the non- anxious group, t(9) = 5.48, p<.001.

Figure 2: Mean RT over blocks for anxious and non-anxious subjects: Unaware subjects



Preliminary results of this study allow the tentative conclusion that anxious subjects demonstrate some sequence learning in the SRT task when this learning is assessed through performance indicators. At the same time they were relatively impaired on the explicit component of this task. In addition, sequence learning was independent of explicit awareness, a finding which is consistent with those of Nissen and Bullemer (1987). These overall results are consistent with those of Rathus et al., (1994), and extend the findings beyond the artificial grammar procedure. At the same time, there are some aspects of the data which do not allow a strong conclusion to be drawn regarding the robustness principle. Specifically, although anxious subjects demonstrated sequence learning, there was a tendency for their overall RTs to be considerably slower than those of the non-anxious controls. This finding of preserved sequence learning in the presence of overall slowing of RT has been consistently found with the SRT in certain other groups such as Korsakoff patients (Nissen & Bullemer, 1987), normal aged adults (Howard & Howard, 1989), closed head injured patients (McDowall & Martin, in press), and patients

Table 2: Means and standard deviations (msec) for practice scores and pattern learning scores in the SRT task across groups: Unaware subjects

	Practice Score		*Pattern Learning Score*	
	Anxious	*Non-anxious*	*Anxious*	*Non-anxious*
Mean	50.8	86.4	215.7	191.3
SD	95.1	133.8	152.6	110 7

Note: Practice score = Block 1 RT minus Block 6 RT.
Pattern learning score = Block 7 RT minus Block 6 RT.

suffering from Alzheimer's disease (Kopman & Nissen, 1987).

In addition, an analysis of the performance of those subjects who remained relatively unaware of the presence and nature of the sequence, showed that the 2 groups performed differently as evidenced by a significant interaction between Group and Block. Although the sub-group of unaware anxious subjects did demonstrate sequence learning, they deviated significantly from the control group in their RT performance over one of the 6 learning blocks. In other words, despite demonstrating sequence learning, the anxious group were clearly disrupted by the induction procedure in a way which would not be predicted by the strong form of the robustness principle. Of course this finding needs to be interpreted cautiously given the small number of subjects.

Finally, we are unable to account for the very large transfer effects found for both groups as demonstrated on Block 7. Nissen and Bullemer (1987) have shown that when the stimuli appear sequentially, considerable learning takes place within the first block of trials. This could partly explain why RT performance on Block 7 is considerably higher than on Block1

Discussion

Although the data to date do not allow us to fully endorse a strong form of the robustness principle as detailed by Reber (1992), the results do provide some support for the view that implicit processes, as measured by the SRT task, are relatively less disrupted by conditions which disrupt explicit processes. Why should this be so? One possibility is that the attentional demands of the implicit component of the SRT task (and perhaps the artificial grammar task), differ from that of the more explicit component. There is evidence that anxiety acts to reduce the range of cue utilization (Easterbrook, 1959), and this disruption of attention may have a major impact on those tasks which rely on explicit processing, whilst sparing implicit processing. Consistent with this hypothesis are a number of studies which have attempted to examine the role of attention in the SRT task. McDowall, Lustig, and Parkin (in press), had subjects perform the SRT task with or without the addition of a secondary tone counting task. The results of this study showed that the presence of the secondary task severly reduced performance on the explicit component but left the implicit performance relatively preserved. Similar findings have been reported by Cohen, Ivry, and Keele (1990), and by Curran and Keele (1993).

Clearly research in this area is in its infancy. Future work might ask whether intact implicit learning extends to tasks beyond the artificial grammar and SRT paradigms? Is the nature of the anxiety important? Specifically, do these findings apply to subjects who are suffering from severe clinical anxiety or are they restricted to mild sub-clinical states in otherwise normal individuals? Whatever the mechanism involved, the work discussed here lends support to the notion that implicit learning is a process which operates independently of conscious, explicit learning. Moreover, performance on implicit learning tasks is less disrupted by those variables which typically effect explicit learning. These findings are consistent with other work discussed earlier which shows that intact implicit learning exists across a wide range of organically and psychologically disturbed populations.

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continued on page 50

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