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The Effect of Mood and Individual Differences on Implicit Learning

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Abstract

This study investigated the relationship between mood, cognitive style, and implicit learning. Ninety-four participants were induced with a positive, neutral, or negative mood. We predicted that a positive mood would enhance implicit learning, while a negative mood would depress it. Additionally, we expected that participants with a more intuitive cognitive style would perform better on implicit learning. Implicit learning was measured using the Artificial Grammar (AG) and Serial Reaction Time (SRT) tasks. Our results suggest surprising differences between the tasks; positive mood and intuitive cognitive style seem to help the SRT, while negative mood and analytical cognitive style seem to help the AG. We postulate that this might result from differences in modality, strategy use, or awareness of the pattern.

The Effect of Mood and Individual Differences on Implicit Learning

It might be surprising to learn that, at this very moment, you are consciously aware of only a small fraction of the information your mind is processing. The mind controls two distinct but intimately intertwined systems: The explicit system and the implicit system (Hogarth, 2001; Pacini & Epstein, 1999). The explicit system accounts for deliberate actions that are available to conscious awareness; it operates consciously and is relatively slow, analytical, and relatively uninfluenced by emotions (Pacini & Epstein, 1999). Reading, studying, and willfully attending to something are all examples of actions which are controlled by the explicit system. However, given the limited amount of attentional resources available to a person, it is not possible to pay attention to everything which could possibly be important in the environment (Hogarth, 2001).

While busy concentrating attention on certain information via the explicit system, the mind is also unconsciously learning associations and processing information from the environment. Processes such as these are part of the implicit system; it is preconscious, operates quickly or automatically, holistically, and is highly associated with the effects of emotion (Pacini & Epstein, 1999). The implicit system operates at a level below conscious awareness and is less dependent on attentional resources (Hogarth, 2001). The implicit system is capable of processing vast and complex sets of information—so vast and complex, that one could not even attempt to attend to all of it consciously (Cleeremans & Jimenez, 1998). Despite being unavailable to consciousness, this implicit information can influence actions. For example, implicit learning might influence social information processing. When in a social situation, individuals may make implicit associations that might lead to hasty judgments of character or stereotyping (Park & Banaji, 2000; Seger, 1994).

Evidence for the existence of these two distinct systems stems from neuroscientific research. For example, some studies have indicated that patients with Korsakoff's syndrome and anterograde amnesia still maintain the unconscious processes of the implicit system, whereas explicit functions are drastically reduced (Nissen & Bullemer, 1987; Roediger, 1990). This evidence indicates that implicit and explicit systems for gaining and processing information are distinct, as the explicit system can be damaged while the implicit system remains intact.

Because the environment is so incredibly rich in information, the individual cannot attend to all of it. Thus, in order to take in as much of that information as possible, individuals are able to learn implicitly, through experience rather than meticulous explicit study. Much of the information that is used in everyday life has not been explicitly taught; rather, it has been gained over time through experience. An expert tennis player, for instance, learns to react to subtle cues in the opponent's movements. The tennis player probably cannot explicate precisely what cues she is reacting to, but her behavior on the court is deeply influenced nonetheless. This is the phenomenon of implicit learning, or the gaining of knowledge at a level below consciousness (Cleeremans & McClelland, 1991; Roediger, 1990). Because so much of one's behavior is influenced by implicit processes such as implicit learning, it is important to understand what affects it, positively and negatively.

Two possible factors which could influence implicit learning are cognitive style and mood. Cognitive style has been demonstrated to influence many aspects of cognition, such as problem solving strategy (Epstein, 1994; Pacini & Epstein, 1999). Its relationship to implicit learning, however, has thus far been overlooked. Likewise, mood has been shown to influence many aspects of cognition, including idea generation, creativity, and information processing (e.g., Isen, 1987, 1999; Vosburg, 1998a, 1998b). However, mood's influence on implicit learning has been sorely underinvestigated. Considering the importance of implicit learning in typical cognition and mood's widespread effects on cognition, the effect of mood on implicit learning seems to be an obvious and important area of study. This study seeks to fill these gaps in the implicit processes literature to provide a more thorough account of how individual differences and mood impact implicit learning performance.

What is Implicit Learning?

According to Berry and Dienes (1993), in implicit learning, "a person typically learns about the structure of a fairly complex stimulus environment, without necessarily intending to do so, and in such a way that the resulting knowledge is difficult to express" (p. 2). In general, implicit learning is learning which is unconscious and results in abstract, tacit knowledge (Reber, 1989; Seger, 1994). Implicit knowledge generally contains information about complex or hidden covariations in the environment (Lewicki, Czyzewska, & Hoffman, 1987; Lewicki, Hill, & Czyzewska, 1997, 1992; Seger, 1994). The information is more complex than a simple association or frequency count; it must be sufficiently complex and abstracted (Seger, 1994). Though psychologists cannot study how expert tennis players detect subtle changes in opponents' movement, they can recreate the phenomenon of implicit learning in the lab. For example, in the Serial Reaction Time task (SRT), participants are asked to view a dot moving among four boxes on a computer screen. Unbeknownst to them, the dot's movements are not random, but are governed by a complex probabilistic pattern. Participants unconsciously recognize this pattern, and thus are able to make very quick and accurate predictions about where the stimulus will appear. At a conscious level, however, participants cannot explicate the pattern; in fact, most are not aware that a pattern even exists (Cleeremans & Jimenez, 1998; Reber, 1989). The ability of the implicit system to pick up on and utilize complex information is a testament to its importance in our everyday cognition.

As stated previously, implicit learning remains intact even in patients with certain cognitive deficits. For example, patients with Korsakoff's syndrome, a disease that impacts working memory, and amnesiacs who have lost their ability to form new memories (anterograde amnesia) can still implicitly learn about covariations that unconsciously influence their behavior (Nissen & Bullemer, 1987; Roediger, 1990). This evidence indicates that implicit and explicit systems for gaining and processing information are distinct, as the explicit system can be damaged while the implicit system remains intact.

To study implicit learning, researchers have created many computer-based tasks involving complex and subtle patterns. Two common measures of implicit learning are the Artificial Grammar task (AG) and Serial Reaction Time task (SRT). The SRT, explained previously, involves a complex pattern of movement which participants become increasingly able to predict. The AG, on the other hand, requires participants to memorize strings of letters generated by a complex set of rules and judge whether novel letter strings follow the same rules.

Though different on the surface, both the AG and SRT require participants to view a stimulus environment which they must learn about in order to perform adequately during the later testing phase. In addition, the structure of each task is unfamiliar, bearing no resemblance to tasks that the participant may know and recognize through previous experience (Reber, 1989). These essential points make it possible for psychologists to use these tasks to measure implicit knowledge gained independently of conscious or explicit learning strategies. Other researchers have developed similar paradigms, such as Berry and Broadbent's (1984) process control tasks, which have likewise proven useful in measuring implicit learning.

A degree of controversy is present in discussion regarding how similar or dissimilar different implicit learning tasks are to each other. The literature comparing various implicit learning tasks is small and limited in scope; many researchers focus only on one specific breed of implicit learning task (e.g., Cleeremans & Jimenez, 1998; Reber, 1989). However, recent research suggests that the different implicit learning tasks may not be as similar as previously thought. Gebauer and Mackintosh (2007) found no significant correlations among scores on an artificial grammar task, a serial pattern task (similar to the SRT), and a process control task. Seger (1994) hypothesizes that because the different implicit learning tasks rely on different response modalities, the tasks may differ in underlying mental representation and attentional requirements. Thus, it will be important to investigate the relationship between the AG and the SRT in this study.

Evolutionarily, the implicit system is thought to be old and "primitive" (Hogarth, 2001; Reber, 1992). According to Reber (1992), consciousness evolved only recently in human history. Implicit functions such as implicit learning evolved because they were beneficial to the organism; that is, members of a species who could learn things implicitly performed better in their environment than their implicitly-deficient counterparts. In addition, evidence from neuroscience suggests that implicit processes such as implicit learning are generally based on lower level brain structures, such as the basal ganglia (Lieberman, 2000). Because implicit learning is such an evolutionarily old function, many researchers assume that individuals do not differ in their ability to learn things implicitly, citing evidence from other evolutionarily old processes, such as reflexes and reactions to hormones (Reber, 1992). This theory stands in stark contrast to those involving individual differences in explicit processes, such as intelligence and cognitive style, in which there is a wide range of variability (Hogarth, 2001; Lewicki, Czyzewska, & Hoffman, 1987; Reber, 1992). However, psychologists such as Kaufman (2006) and Woolhouse and Bayne (2000) hypothesize that individual differences do exist in implicit learning. These researchers point out that many evolutionarily old processes and traits exhibit individual differences, including such as height and general athletic ability. In addition, evidence from the cognitive style literature hints at the existence of individual differences in implicit processes (Kaufman, 2006).

Cognitive Style and Implicit Processes

According to dual process theory, people differ in their cognitive style, preferring to use either implicit or explicit processes more than the other (Pacini & Epstein, 1999). People with an intuitive or "experiential" cognitive style prefer implicit processes, relying on holistic information and "gut feelings" to make decisions, whereas people with an analytical or "rational" cognitive style prefer explicit processes, breaking problems down into steps and making careful, deliberate decisions. According to Pacini and Epstein, preferences for these modes are theoretically uncorrelated; an individual may be high on one or both or neither.

To support their theory of individual differences in implicit processes, many researchers cite evidence from the study of intuition and intuitive cognitive style. Intuition, another aspect of cognition rooted in the implicit system, can be characterized as a mode of thought that operates automatically, subconsciously, and without discrete steps. Epstein (1994), placing intuition in a dual-process framework, describes the intuitive system as automatic, holistic, and associative, while the analytical system is assumed to be deliberative, rational, and rule-based. The Rational-Experiential Inventory reflects this dual-process system (REI; Pacini & Epstein, 1999). The Rational subscale measures preference for and ability to use analytical processes, whereas the Experiential subscale measures preference for and ability to use intuitive processes. The REI is used to compare thought processes among individuals; for example, analytical and intuitive cognitive styles correlate with different problem solving strategies (Pacini & Epstein, 1999).

The literature on intuition and intuitive cognitive style clearly defines intuition as differing among individuals (Pacini & Epstein, 1999). Therefore, there is already evidence for individual differences in at least this one implicit process. From this, one might expect to find individual differences in other implicit processes as well, such as implicit learning. Despite this conclusion, little research has related cognitive style to other implicit processes.

The Effect of Mood on Cognition

There is a rapidly growing literature about the effect of mood on cognitive processes. The effect of positive mood on cognition has been most widely documented: Isen (1999, 1987) found that positive mood impacts pro-social behavior, cognitive processes, and motivation. Positive mood has also been shown to influence creativity; in particular, it has been found that positive mood facilitates creative problem solving (Isen, Daubman, & Nowicki, 1987), increases uniqueness of word associations (Isen, Johnson, Metz, & Robinson, 1985), and increases idea quantity in divergent thinking tasks (Vosburg, 1998a, 1998b). Estrada, Isen, and Young (1997) have shown that positive mood in physicians leads to faster, more integrated diagnoses.

The findings surrounding the effect of positive mood on implicit learning are highly conflicting. According to Isen (2004), positive affect induces careful, thorough thinking and problem solving strategies. In addition, Braverman (2006) found that negative mood enhances performance on a simple covariation detection task. Although she did not specifically control for how implicit or explicit the resulting knowledge was, Braverman found the same results even when focusing on those participants who had only implicit knowledge. Based on this research, we might expect that a negative mood would enhance implicit learning.

However, other researchers have found that positive mood facilitates heuristic use, which might suggest the opposite hypothesis—that positive mood enhances implicit learning. Heuristics lead to quick, snap-judgment decisions made without deliberation, rather than the "careful, thorough thinking" described by Isen. For example, positive mood has been shown to increase stereotyping behavior, a judgment based on heuristics (Bodenhausen, Kramer, & Susser, 1994; Park & Banaji, 2000). Heuristics are closely related to the kind of processing associated with intuition (Hogarth, 2001). Thus, if we predict that intuitive people should perform better at implicit learning, we might also expect people in a positive mood will perform in a similar manner because positive mood naturally induces intuitive, heuristic processing.

Given the contradictory evidence regarding the effect of mood on cognition, we argue that a positive mood will enhance implicit learning. Braverman's (2006) study examined performance on an exceedingly simple covariation, rather than the subtle and complex patterns exhibited by tasks such as the AG and SRT. Because a broad, holistic cognitive style or strategy would be more beneficial in learning these kinds of covert patterns, we believe that a positive mood should benefit implicit learning more.

The effect of negative mood on cognition has been the subject of less study, but researchers have made important developments. Naismith and colleagues (2006) found that clinically depressed patients demonstrated lower performance on implicit learning tasks. This finding suggests that people exhibiting a more negative mood might also perform worse on these tasks. However, another line of research by Rathus and colleagues (1994) found that anxiety, commonly associated with negative mood, negatively impacted explicit, but not implicit, learning performance. This would support the hypothesis that implicit processes are robust and not influenced by environmental factors such as mood.

Some researchers have argued that arousal could be a confounding variable in research on mood (Clapham, 2001; Isen et al., 1987). It is possible that being in a strong mood influences behavior, regardless of whether the mood is positive or negative. However, based on past research, there is little evidence to give credence to this argument. Research using both positive and negative mood conditions has found differing effects of each condition, suggesting that something more than arousal is at work (Bolte et al., 2003; Rathus et al., 1994). Thus, it is important that we measure the relative arousal of the stimuli used to induce mood, but it may not be important to control arousal independent of mood valence.

The Present Study

The present study investigated the effect of mood and individual differences on implicit learning. Research is lacking in relating individual differences and mood to implicit processes such as implicit learning, and current evidence leads to two conflicting hypotheses. Studying both cognitive style and mood in tandem will reveal their possible interaction. In addition, because implicit learning has such a deep impact on our everyday cognitive processing, it is important to understand its relationship to individual differences and mood.

To investigate the effects of mood on implicit learning, we induced mood in experimental participants to be positive, negative, or neutral. Past research has shown that even small manipulations have a significant effect on mood; a simple manipulation such as giving participants a small bag of candy is enough to produce an effective positive mood (Estrada, Isen, & Young, 1997; Isen, Daubman, & Nowicki, 1987). The mood manipulation we have chosen, a slideshow of pictures from the International Affective Picture System (IAPS), has been demonstrated to effectively induce mood in a variety of settings (Smith, Bradley, & Lang, 2006;

Smith, Low, Bradley, & Lang, 2006); we predict that these affective pictures will generate a significant effect on mood.

In general, we predicted that people with a positive mood would score higher on the implicit learning tasks than those in the neutral control group, and that people with a negative mood would score lower on the implicit learning tasks than those in the control group. This prediction was based on evidence relating mood to heuristic processing and a widened scope of attention. In addition, we predicted that intuitive cognitive style would positively correlate with implicit learning, such that the higher people's level of intuitive cognitive style, the better they would do on the implicit learning tasks. We also predicted an interaction between cognitive style and mood. We expected that participants with a positive mood and an intuitive cognitive style type would perform the best on the implicit learning tasks. We expected that participants with a negative mood and a non-intuitive cognitive style type would perform the worst on the implicit learning tasks.

Method

Participants

Ninety-four general psychology students from Illinois Wesleyan University participated in exchange for course credit. They were recruited in their general psychology classes and by advertisements on the study participant bulletin board. Participants ranged in age from 18 to 22 (M=19.18, SD=1.26). The sample consisted of 33 men and 61 women; 87.2% of the sample was white, 6.4% black, 5.3% Asian, and 1.1% Hispanic. Participants were randomly assigned to a mood condition and counterbalanced task order; there were roughly equal numbers of participants in each mood condition.

Materials

Implicit learning measures. Two implicit learning measures were chosen for their widespread and robust use in similar research: The Artificial Grammar task (AG) and the Serial Reaction Time task (SRT). The AG included two phases, the learning phase and the testing phase. In the learning phase, participants memorized a series of 20 exemplary letter strings generated by a finite-state grammar. Each letter string appeared on the computer screen for 3s, after which the participant was prompted to reproduce the string by typing it on the keyboard. If participants reproduced the letter string correctly, they were so informed and a new letter string was presented. If participants made an error, they were asked to try to reproduce the same letter string again. All 20 exemplars were presented twice for a total of 40 learning trials. In the testing phase, participants were informed that the letter strings they had memorized were formed according to a complex set of rules and that the following trials would test their knowledge of those rules. Participants were presented with 50 letter strings, one at a time, and responded either "yes" (by pressing the Y key) or "no" (by pressing the N key) according to their immediate judgment of whether the letter string conformed to the rules of the grammar. The testing stimuli consisted of 25 grammatical letter strings (7 of which will be from the original set) and 25 non-grammatical letter strings, which were formed by introducing one or more violations into otherwise grammatical letter strings. The entire set was presented twice so that 100 judgments were made by each participant. Past research (e.g., Manza, Zizak, & Reber, 1998) shows that participants generally scored significantly above chance in correctly classifying letter strings, yet they were unable to explicate the grammar rules. Learning is determined by how many letter strings were correctly classified as following the grammar. The finite state grammar and sample letter strings used in this study can been seen in Appendix A.

In the SRT, participants saw a stimulus appear at one of several locations on a computer screen and were asked to press the button corresponding to each box when the stimulus appeared there. Unknown to the participants, the sequence of successive stimuli followed a complex repeating sequence. Participants first completed a practice block, followed by six training blocks, each consisting of 120 trials. Past research (e.g., Cleeremans & Jiménez, 1998) indicates that participants' reaction times decreased significantly for patterned sequences but not for random ones, suggesting that participants unconsciously recognized the pattern and used it to their advantage. Participants, however, were consciously unaware of the pattern, even when they were asked to consciously look for it (Cleeremans & Jiménez 1998).

At one point in the task, the pattern switches radically, resulting in a sudden jump in participants' reaction time. This jump in reaction time suggests that participants are no longer able to rely on their implicitly-learned information about the pattern. This task is scored by assessing the gain in reaction time when the pattern switches. The probabilistic pattern used in this study can be seen in Appendix B.

Cognitive style measures. The measure of intuitive cognitive style type used was the Rational Experiential Inventory (REI; Pacini & Epstein, 1999). The REI consists of 40 items, ten for each of the four subscales (Rational favorability, Rational ability, Experiential favorability, Experiential ability). Favorability refers to preference for that mode of thought, while ability indicates a belief in one's personal ability to successfully use that mode. For example, one Rational favorability item is, "I prefer complex to simple problems," whereas an Experiential favorability item states, "I like to rely on my intuitive impressions." Meanwhile, a Rational ability item states, "Using logic usually works well for me in figuring out problems in my life," while an Experiential ability item states, "When it comes to trusting people, I can usually rely on my gut feelings." For the complete questionnaire, please see Appendix C.

At the end of the experimental session, participants were asked to describe if they noticed a pattern in the implicit learning tasks as part of a post-task questionnaire. Demographic information was also collected.

Mood manipulation. To induce a particular mood, photographs from the International Affective Picture System were shown to each participant (Lang, Bradley, & Cuthbert, 1997). The IAPS has been widely used as a standardized set of affective stimuli (e.g., Smith, Bradley, & Lang, 2006; Smith, Low, Bradley, & Lang, 2006). Each photo in the stimulus set was normatively assessed for dimensions of pleasure (valence), arousal, and dominance (see Lang et al., 1997). Participants viewed a different set of pictures according to their experimental condition: Participants in the positive mood condition were shown pleasant pictures such as smiling families, beautiful nature scenes, and food. The mean valence rating for pictures in this category was 7.25, while the mean arousal rating was 4.79. (Both ratings were on a 9-point scale, with 1 being unpleasant/not at all arousing and 9 being pleasant/highly arousing.) Participants in the negative mood condition saw images of drug use, disease, war, and death. The mean valence rating for the set of negative images was 2.75, while the mean arousal rating was 5.47. Participants in the neutral condition were shown mundane pictures, such as everyday objects and landscapes. The mean valence rating for this set of images was 5.00, while the mean arousal rating was 3.60. These sets of photographs were chosen to induce a mood that would last for the duration of the experiment, in order to be a successful experimental manipulation without having significant lasting effects for the participants. Sample photographs from each of the three conditions can be seen in Appendix D.

As a manipulation check, participants completed the Positive Affect Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) following the mood induction procedure. The PANAS is a mood scale consisting of 20 words (10 positive, 10 negative) which describe different feelings and emotions. Participants were instructed to rate each word on a scale of 1 to 5 (1 being very slightly or not at all, 5 being extremely) to indicate the extent to which they felt that emotion at the moment. For the complete PANAS questionnaire, please refer to Appendix E.

Procedure

The cognitive style and implicit learning measures were computer-administered, while the PANAS, demographics and post-task questionnaires were paper-based. Participants were tested individually in small rooms seated at a computer. Participants completed the REI and MBTI, which were counterbalanced to control for effects of order. Then, participants were shown a series of 50 affective photos from the IAPS according to their experimental condition. Each photograph was displayed for 5s, with at 1.5s pause between each one. The mood induction procedure took approximately 5 minutes. After the mood induction procedure was complete, participants were given the mood checklist as a manipulation check. Participants then completed both the AG and SRT, which were also counterbalanced. Participants then completed the mood checklist once more to check for the lasting effect of the mood manipulation; afterward, they completed a post-task questionnaire asking if they could explicate the patterns presented in the implicit learning tasks. Participants also completed a brief demographic questionnaire. To reduce any negative effects of the mood induction, all participants viewed the 20 most positive photographs from the IAPS at the end of the session. The entire testing session lasted approximately 45 minutes.

Results

Reliability Analyses

The Experiential and Rational subscales of the REI were found to be internally reliable (α=.79, α =.78). The positive and negative subscales of the PANAS were also found to be internally reliable (α =.87, α =.92).

Manipulation Check

Two one-way ANOVAs were performed to test the effect of the mood manipulation. The analysis yielded significant effects of mood condition for both the positive and negative subscales of the PANAS, respectively, $F(2, 91) = 7.97, p<.01$; $F(2, 91) = 67.99$, $p< .01$ (For means, see Table 1). A Scheffe post-hoc test revealed that the positive mood condition scored significantly higher on the positive PANAS subscale than the negative and neutral conditions ($p < .01$; $p < .01$), while the negative mood condition scored significantly higher on the negative PANAS subscale than the positive and neutral conditions ($p < .01$; $p < .01$).

Correlations

Correlations were performed among the cognitive style measures and implicit learning tasks to examine the general relationships among them (see Table 2). We expected that intuitive cognitive style would correlate positively with implicit learning scores. As seen in Table 2, the SRT did not correlate significantly with any intuitive or analytical cognitive style measures. The AG also did not correlate with any intuitive cognitive style measures. However, the AG correlated moderately with the REI Rational ability subscale ($r = .32, p < .01$); a weak, positive correlation with the REI Rational favorability subscale was also found ($r = .22, p = .04$). Contrary to our initial hypotheses, this indicates that more analytical participants performed better on the AG.

In addition, we found that the AG and SRT correlated only weakly, $r = .19, p = .09$. This suggests that the two measures are not measuring the same construct.

Factorial ANOVAs

To test the remaining hypotheses, two 2 (high-intuitive/high-analytical, low-intuitive/ low-analytical) x 3 (positive mood, neutral mood, negative mood) factorial ANOVAs were performed. We first performed median splits of the sample to create high-intuitive/low-intuitive and high-analytical/low-analytical groups. Median splits were performed to maintain a reasonable number of participants in each group. For the purposes of this study, results with a significance level of $p<.10$ were interpreted due to the rather small number of participants ($N \approx 15$ per cell); we expect that, if we collected data from more participants, these marginal findings would become significant. Means for each ANOVA can be found in tables 3-6.

Implicit learning and mood: Main effects. For the SRT, no significant effect of mood was found, $F(2, 93) = 1.14, p = .33$. Meanwhile, for the AG, we found a significant effect of mood, $F(2, 81) = 4.26, p = .02$. A Scheffe post-hoc test revealed that participants in negative condition scored significantly higher on the AG than participants in the neutral condition. These findings contradicted our hypothesis that people in a positive mood would perform better on the implicit learning tasks.

Implicit learning and cognitive style: Main effects. The analysis yielded a significant main effect of intuitive cognitive style, showing that high-intuition participants performed better than low-intuitive participants on the SRT, $F(1, 93) = 4.07, p < .05$. This finding supported our hypothesis that more intuitive people would perform better on implicit learning than less intuitive people. No main effect of intuitive cognitive style was found for AG, $F(1, 81) = 1.49$, $p = .23$.

Based on the correlational finding between the AG and REI Rational subscales, we repeated the cognitive style analyses with high-analytical and low-analytical groups. For the SRT, no significant main effect of analytical cognitive style was found, $F(1, 93) = .02, p = .90$. For the AG, however, the high-analytical group performed marginally better than the low-analytical group, $F(1, 81) = 3.32, p = .07$.

Implicit learning, mood, and cognitive style: Interaction effects. For the SRT, a marginal interaction effect between mood and intuitive cognitive style was found, $F(2, 93) = 2.88, p = .06$ (see Figure 1). A simple effects analysis for intuitive cognitive style yielded a significant effect of intuitive cognitive style for the positive mood condition, demonstrating that more intuitive people in a positive mood performed better than less intuitive people in a positive mood, $F(1, 93) = 9.58, p < .01$ (See Figure 1). This finding explained the significant interaction effect between mood condition and intuitive cognitive style and supported our hypothesis that intuitive people in a positive mood would perform the best. A second simple effects analysis for mood yielded a marginal effect of mood for the high-intuition group only, suggesting that the effect of mood on SRT performance was mediated by level of intuitive cognitive style, $F(2, 93) = 2.77, p = .07$. No interaction effect was found between mood and intuitive cognitive style for the AG, $F(2, 81) = 1.56, p = .22$.

Meanwhile, no interaction effect was found between mood and analytical cognitive style for the SRT, $F(2, 93) = .01, p = .99$. For the AG, the analysis revealed a marginal interaction effect, $F(2, 81) = 2.45, p = .09$. A simple effects analysis revealed a significant effect of mood for the low-analytical group, indicating that low-analytical group members in a negative mood performed better on the AG than low-analytical group members in a positive or neutral mood, $F(2, 81) = 5.22, p < .01$ (see Figure 2). Pairwise comparisons revealed that, for the low analytical group only, the positive condition differs significantly from the negative condition ($p < .01$) and the negative condition differs significantly from the positive and neutral conditions ($p < .01$, $p < .01$).

Discussion

Interestingly, the pattern of results differed between the two implicit learning tasks. For the SRT, we found an interaction effect between mood and intuitive cognitive style such that more intuitive people in a positive mood did better on the SRT. Though we found no main effect of mood, this interaction effect qualified the main effect; high-intuition participants showed the predicted effect of mood. In studying our results of the main effect of intuitive cognitive style, we must again interpret this effect in context of the interaction; more intuitive people in the negative and neutral conditions did not actually learn more than less intuitive people in those conditions; the interaction between positive mood and highly intuitive cognitive style gave rise to the large effect.

Our findings for the SRT lended support to our hypotheses; more intuitive people learned more implicitly on the SRT, and more intuitive people in a positive mood seemed to learn the most. As discussed previously, we believe this is due to the holistic, heuristic processing supported by an intuitive cognitive style and positive mood (Bodenhausen et al., 1994; Park & Banaji, 2000). This kind of processing might have helped participants take in more of the complex and subtle pattern of the SRT.

The results for the AG, however, look quite different. We found, contradictory to our hypothesis, that negative mood enhanced performance for the AG. In addition, we found a marginal interaction effect demonstrating that less analytical participants seemed to perform well on the AG only if they were in a negative mood, whereas highly analytical participants seemed to perform well regardless of what mood they were in. What might explain these unexpected effects?

Past research shows that a negative mood narrows one's scope of attention and leads to more careful, deliberate thinking (Ansberg & Hill, 2003). Thus, perhaps a narrow scope of attention and careful, analytical thinking benefited AG performance because the task was not truly implicit. It is possible that explicit knowledge of small aspects of the pattern, as demonstrated by the post-task questionnaires, was more beneficial than the holistic knowledge gained implicitly.

Another possible explanation for our findings for the AG is that participants might have been actively engaging in a form of hypothesis testing. If some aspect about the AG induced analytical thought, and participants consciously recognized part of the pattern, they may have begun to concentrate on that part that they recognized, consciously looking for it in each letter string to "test" the hypothesis that it was part of the pattern. In doing so, participants might have focused so narrowly that they ignored the rest of the letter string, which contained more information about the AG's pattern that they might not have been learning consciously. According to Seger (1994), true implicit learning must be incidental and not the product of hypothesis testing, though some verbal knowledge of the pattern gained from "just noticing" would not necessarily preclude categorizing the process as implicit learning. If the participants were, in fact, engaging in hypothesis testing, this might account for the apparent differences between the AG and SRT. Future research in this area could manipulate the instructions of the AG, instructing some participants to consciously look for the pattern and engage in hypothesis testing, and instructing others to refrain from any conscious problem solving activity and to simply take in the letter strings holistically and passively.

Despite these claims, it is possible that the pattern of the AG is not simply implicit to the participants. The implicit nature of the AG has been somewhat disputed in the literature (Berry, 1998; Seger, 1994). Seger (1994) notes that knowledge of implicit learning tasks such as the AG is often instantiated, meaning that participants can often verbalize surface features of the pattern. In looking at the answers to our post-task questionnaires, we found that the majority of participants seemed to have explicit knowledge of at least some aspect of the AG's pattern, but few participants seemed to have any knowledge of the SRT's pattern. Though participants' instantiated knowledge does not necessarily indicate a lack of abstract, implicit knowledge about the pattern, the degree to which participants could explicate the pattern might raise concern over the validity of the AG's reported implicitness. This debate is certainly present in the literature, and future research might investigate the validity of tasks which result in instantiated knowledge.

In understanding what affects the AG, we may clarify the interesting finding that non-analytical participants only seemed to perform well if they were in a negative mood. A negative mood narrows one's scope of attention and leads to careful, analytic processing (Ansberg & Hill, 2003, Isen et al., 1985); in order to perform well on the AG—that is, to have a narrow attention and use careful, analytical thinking—perhaps participants whose cognitive style was not naturally analytic were able to compensate by having a mood that mimicked the same effects.

Our findings for the SRT contradict those of researchers such as Braverman (2006), who found that a negative mood enhanced detection of covariation. However, our findings for the AG lend support to Braverman's results. Like Braverman's covariation task, the AG seemed to result in a degree of explicit knowledge of the pattern. Thus, perhaps a negative mood enhances tasks involving explicit information while a positive mood enhances tasks involving implicit information.

The current pattern of results lends some support to previous research that has found that different implicit learning tasks bear little relationship to each other (Gebauer & Mackintosh, 2007). We found that the AG and SRT did not highly correlate with each other ($r = .190, p = .092$). Both tasks purportedly measure the same type of implicit learning, yet the fact that they did not correlate in this sample suggests that they may measure different things or rely on different mechanisms. This finding is very important in light of the current controversy over the similarities of various implicit learning measures. One possible explanation for the difference between these tasks is that they seem to rely on different modalities, as suggested by Seger (1994). The SRT is sequential and heavily relies on motor and visual skills. The AG, meanwhile, involves verbal or language processing as well as a heavy focus on memorization; perhaps the AG's reliance on memory makes it more akin to an explicit task. In addition, it is possible that implicit learning is not a unitary construct, but is actually a group of related but dissociable processes which respond differently to the same situations (Seger, 1994). Further research on implicit learning should examine the relative similarities and differences between these two tasks to explain these disparate findings.

An important result of this study was the significant effect of the self-reported REI on behavior. Previous research has found many difficulties with self-report measures, either because people are not accurate in their self-perception of skills and traits or because these measures simply do not predict behavior. The fact that we found significant results using a self-report measure of cognitive style replicates the construct validity of the REI found by Pacini and Epstein (1999) and provides validation of the use of the REI as a predictor of behavior.

A possible concern about the design of this study was that the effect of arousal rather than mood valence may have confounded the results.I It is true that the positive and negative mood conditions were significantly more arousing than the neutral mood condition. We found no such concern supported for the AG, but the results for the SRT might suggest an effect of arousal. We found no main effect of mood on SRT; the negative and positive conditions performed equally. One possible explanation for this finding is that arousal might be more important than mood valence for this task, so the more arousing conditions performed better than the less-arousing neutral condition. The fact that this pattern was not found for the AG suggests that arousal may be important in implicit processing, but not explicit processing. This important implication requires further research manipulating the effects of arousal versus those of mood.

The results of this study hold implications for everyday implicit learning. The theory that a negative mood enhances explicit problem solving because it focuses attention and induces analytical processing might imply that students should put themselves in a somewhat negative mood before a test that requires focus, such as a mathematics exam. This would be particularly important for students who are not analytical by nature. In situations where implicit learning is very important due to subtle and complex changes in the environment, such as learning a new musical instrument or becoming an expert athlete (such as the earlier tennis player example), a person might learn more efficiently when in a positive mood. One might also be more aware of how mood might accidentally influence behavior; following an upsetting event, one may not notice subtle but important changes in work or school related tasks because of the resulting negative mood. By knowing how mood influences behavior, people might be able to better predict when their work will be influenced and be able to take proper steps to ensure they are in the mood that will benefit them the most.

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Table 1

Mean PANAS Scores for Manipulation Check

	PANAS Subscale	
Mood Condition	Positive (*M, SD*)	Negative (*M, SD*)
Positive	27.09 (7.90)	11.47 (1.74)
Neutral	20.91 (6.38)	13.25 (3.24)
Negative	20.93 (6.94)	25.23 (8.05)

Table 2

Correlations Among Implicit Learning Tasks and Intuitive/Analytical Cognitive Style Subscales

	1	2	3	4	5	6
1. REI Rational ability	-					
2. REI Rational favorability	.49**	-				
3. REI Experiential ability	.16	-.13	-			
4. REI Experiential favorability	-.24*	-.19	.50**	-		
5. SRT	.15	.15	.04	-.02	-	
6. AG	.32**	.22*	.05	.01	.19	-

Note: ** indicates a correlation significant at the .01 level. * indicates a correlation significant at the .05 level.

Table 3

Mean SRT Scores for High- and Low-Intuition Groups by Mood Condition

	Intuition Group	
Mood Condition	High-Intuitive (*M, SD; N* = 49)	Low-Intuitive (*M, SD; N* = 44)
Positive	38.06 (24.61)	11.07 (24.44)
Neutral	18.82 (25.24)	14.07 (28.98)
Negative	23.69 (24.39)	24.93 (15.02)

Table 4

Mean AG Scores for High- and Low-Intuition Groups by Mood Condition

	Intuition Group	
Mood Condition	High-Intuitive (M, SD; N = 49)	Low-Intuitive (M, SD; N = 44)
Positive	62.54 (9.85)	58.79 (6.50)
Neutral	58.08 (5.62)	59.93 (5.86)
Negative	65.79 (4.02)	62.39 (6.04)

Table 5

Mean SRT Scores for High- and Low-Analytical Groups by Mood Condition

	Analytical Group	
Mood Condition	High-Analytical (*M, SD; N* = 49)	Low-Analytical (*M, SD; N* = 44)
Positive	25.71 (17.01)	24.14 (37.67)
Neutral	16.79 (17.26)	16.44 (32.77)
Negative	24.33 (19.27)	24.17 (22.48)

Table 6

Mean AG Scores for High- and Low-Rationality Groups by Mood Condition

	Analytical Group	
Mood Condition	High-Analytical (*M, SD; N* = 43)	Low-Analytical (*M, SD; N* = 38)
Positive	63.53 (6.31)	56.92 (9.34)
Neutral	60.33 (4.91)	58.00 (6.26)
Negative	63.69 (4.88)	64.82 (6.00)

Figure 1

Interaction between Mood Condition and Intuitive Cognitive Style for the SRT

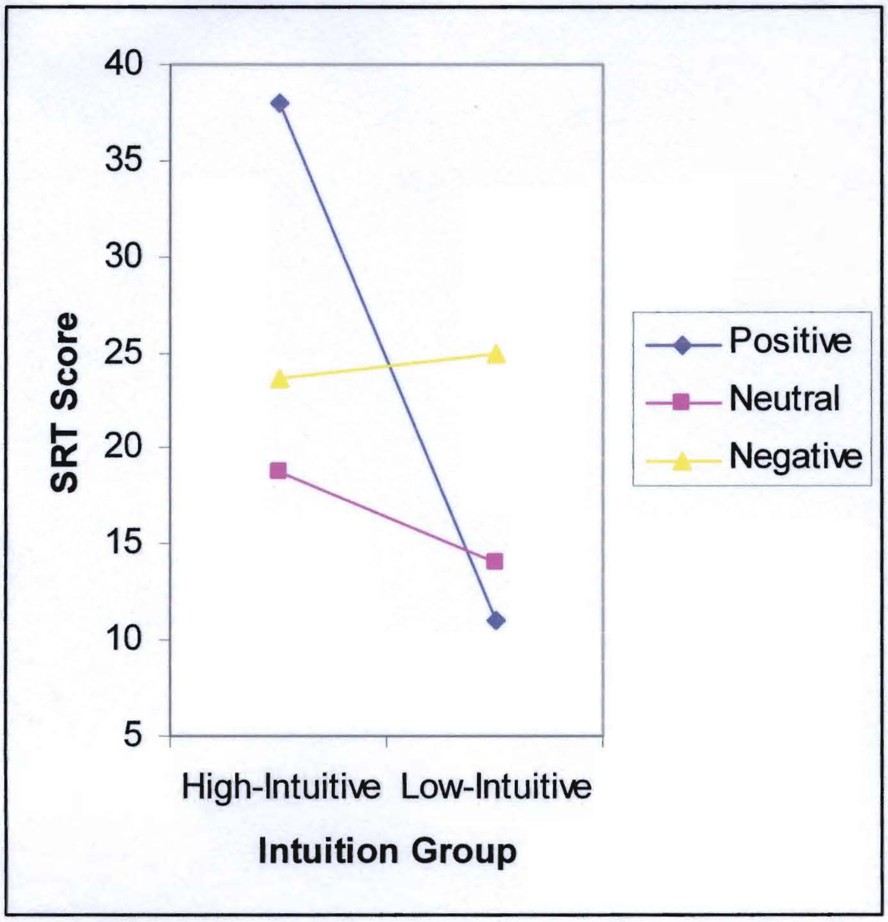
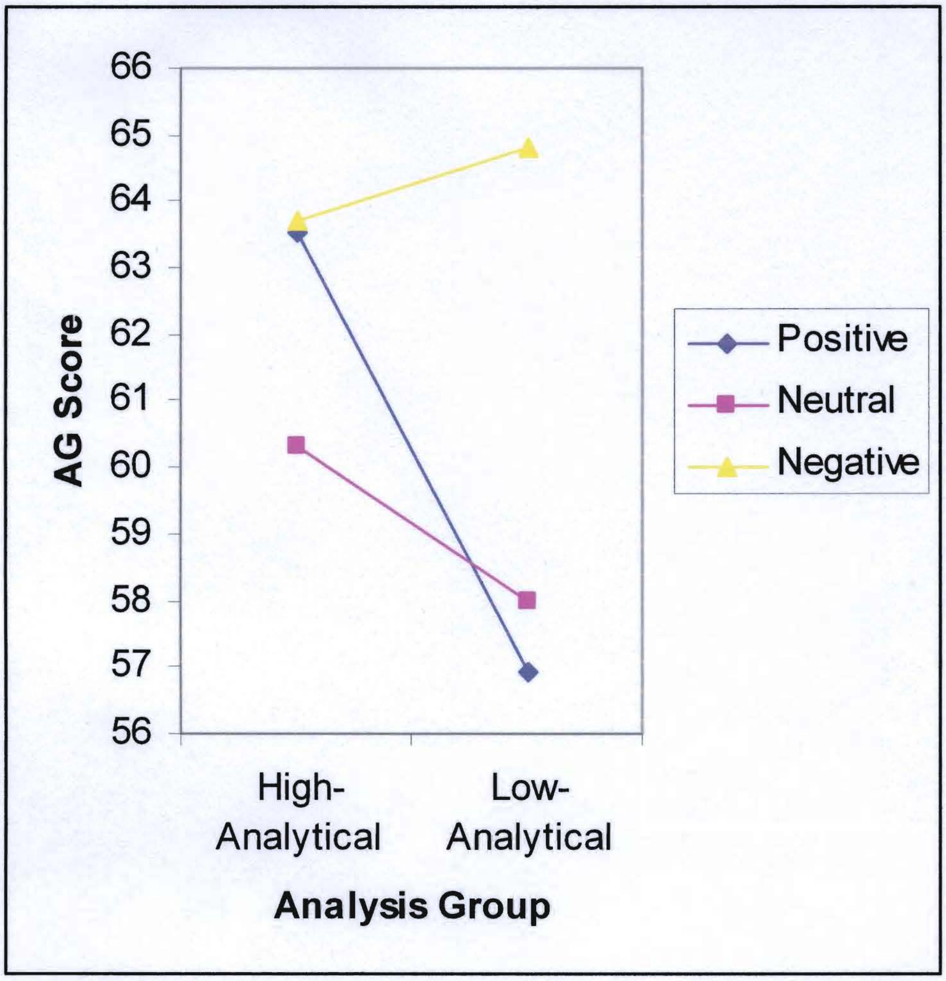


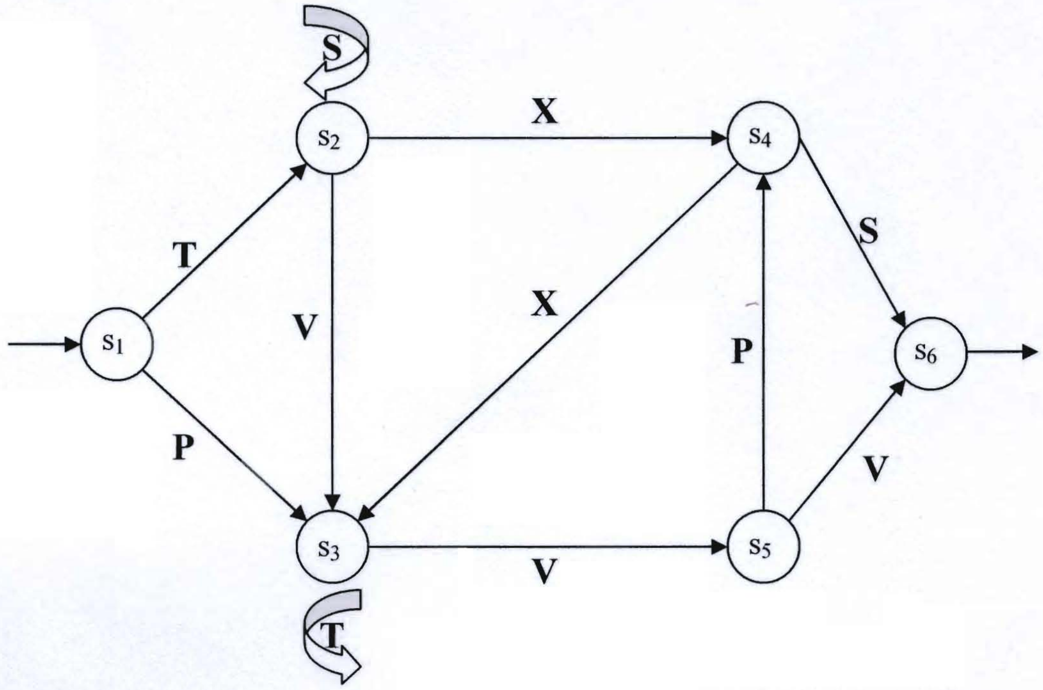
Figure 2

Interaction between Mood Condition and Analytical Cognitive Style for the AG



Appendix A: Finite-State Grammar of Artificial Grammar task (AG)

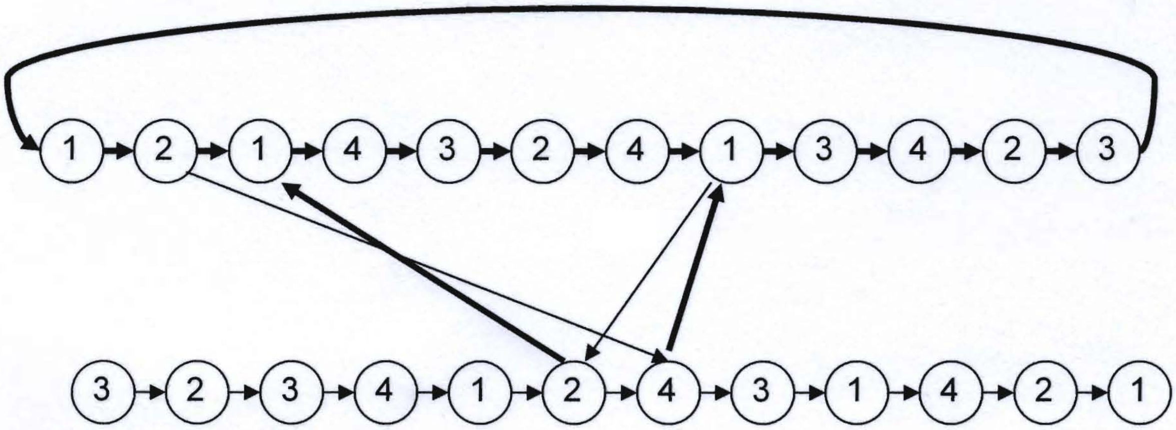
The finite-state grammar used in the current study. The grammar generates letter strings by following the arrows from the input state (s1) to the terminal state (s6). Several examples of "well-formed" strings are presented along with examples of strings that violate the grammar (examples taken from Litman & Reber, 2005).



Well-Formed Strings	Strings with a single-letter violation
PVPXVPS	**PTTVVPS**
TSSXXVPS	**TXXTXPS**
TSXS	**TSSXV**
PTVPXVV	**VTTVV**
PTTTVV	**TSSTVV**
PVPXVPXVV	**PTTTVPV**

Appendix B: Serial Reaction Time task (SRT)

Representation of the strategy used for the SRT probabilistic version. Thick lines represent more probable transitions (.85) whereas thin lines represent less probable ones (.15). Only a partial set of these transitions is represented, to illustrate that both series are communicated precisely at those points in which they share a context: After 1-2, the most probable successor is 1 (upper row) but in 15 % of the cases the next element could be 4 (bottom row).



Appendix C: Rational-Experiential Inventory

Please rate the following statements about your feelings, beliefs, and behaviors using the scale below. Write the number corresponding to your response on the line before each statement.

1	2	3	4	5
Definitely false	Mostly false	Undecided	Mostly true	Definitely true

____ 1. I'm not that good at figuring out complicated problems.

____ 2. If I were to rely on my gut feelings, I would often make mistakes.

____ 3. I prefer complex to simple problems.

____ 4. I generally don't depend on my feelings to help me make decisions.

____ 5. I have no problem in thinking things through clearly.

____ 6. When it comes to trusting people, I can usually rely on my gut feelings.

____ 7. Thinking is not my idea of an enjoyable activity.

____ 8. I like to rely on my intuitive impressions.

____ 9. I am not a very analytical thinker.

____ 10. I believe in trusting my hunches.

____ 11. I enjoy solving problems that require hard thinking.

____ 12. I think it is foolish to make important decisions based on feelings.

____ 13. I suspect my hunches are inaccurate as often as they are accurate.

____ 14. I usually have clear, explainable reasons for my decisions.

____ 15. Knowing the answer without having to understand the reasoning behind it is good enough for me.

____ 16. I would not want to depend on anyone who described himself or herself as intuitive.

____ 17. Using logic usually works well for me in figuring out problems in my life.

____ 18. I enjoy intellectual challenges.

____ 19. I can usually feel when a person is right or wrong, even if I can't explain how I know.

____ 20. I often go by my instincts when deciding on a course of action.

____ 21. My snap judgments are probably not as good as most people's.

____ 22. Reasoning things out carefully is not one of my strong points.

____ 23. I don't like situations in which I have to rely on intuition.

____ 24. I try to avoid situations that require thinking in depth about something.

____ 25. I trust my initial feelings about people.

____ 26. I have a logical mind.

____ 27. I don't think it is a good idea to rely on one's intuition for important decisions.

____ 28. I don't like to have to do a lot of thinking.

____ 29. I don't have a very good sense of intuition.

____ 30. I am not very good in solving problems that require careful logical analysis.

____ 31. I think there are times when one should rely on one's intuition.

____ 32. I enjoy thinking in abstract terms.

____ 33. Using my "gut feelings" usually works well for me in figuring out problems in my life.

____ 34. I don't reason well under pressure.

____ 35. I tend to use my heart as a guide for my actions.

____ 36. Thinking hard and for a long time about something gives me little satisfaction.

____ 37. I hardly ever go wrong when I listen to my deepest "gut feelings" to find an answer.

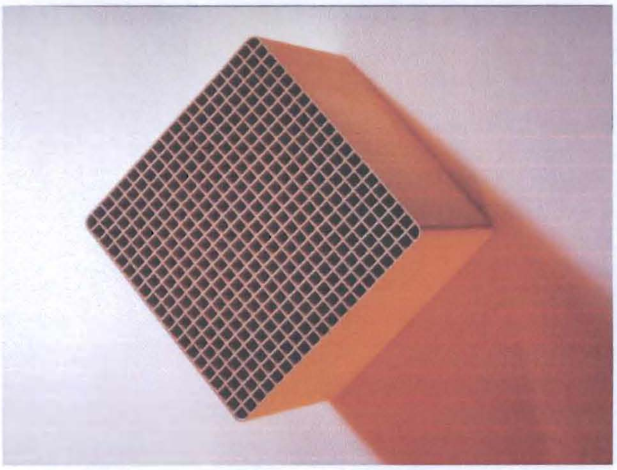
____ 38. I am much better at figuring things out logically than most people.

____ 39. Intuition can be a very useful way to solve problems.

____ 40. Learning new ways to think would be very appealing to me.

Appendix D: Sample Photographs from the International Affective Picture System (IAPS)

Negative mood condition



Neutral mood condition

Positive mood condition

Appendix E: Positive and Negative Affect Scale

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now, that is, at the present moment. Use the following scale to record your answers:

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

___ interested	___ irritable
___ distressed	___ alert
___ excited	___ ashamed
___ upset	___ inspired
___ strong	___ nervous
___ guilty	___ determined
___ scared	___ attentive
___ hostile	___ jittery
___ enthusiastic	___ active
___ proud	___ afraid