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Feeling Low but Learning Faster: Effects of Emotion on Human Cognition

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Abstract

This study examined the effects of emotion on the long-term acquisition of a procedural skill over a five-day period. Two tasks were employed: a word association task (WAT) and a visual discrimination task (VDT). Over the initial four days of the study participants went through a mood induction procedure (MIP) then subsequently completed both tasks. Both tasks showed a reduction in reaction time consistent with the power law of learning. No significant change in reaction time between day four and day five (one week later) was noted suggesting the change in reaction time was robust. These data further suggest that emotion modifies the rate at which the VDT is acquired.

Introduction

That emotion modulates human cognition is now well accepted in contemporary psychology (Damasio, 1994; Ekman & Davidson, 1994; Isen, 1987). However, experimental data supporting this view is principally derived from experiments employing a single session protocol. In consequence, the long-term effects of emotion on cognition have not been addressed. In particular, whether emotions modulate the acquisition of a cognitive skill has not been studied. This paper addresses this issue by running participants on two different tasks over a five-day period. Similar tasks demonstrate a steady reduction in the time required for their completion over a series of days (Anderson, 1990; Karni & Sagi, 1991).

The capacity to learn is a central feature of human ability. This ability has been grouped into two forms: the procedural, incidental, acquisition of repetitive skills, and the declarative, explicit, acquisition of memory for places and events (Squire, Knowlton and Musen, 1993). Acquisition in declarative memory generally occurs on a one shot basis: either you know it or you do not. In contrast, acquisition of a procedural skill can take many days showing a steady improvement over time (Fitts & Posner, 1973).

Emotion has been found to affect episodic memory. Bradley, Greenwald, Petry, & Lang (1992) showed that the (subjectively reported) emotional arousal element of an emotion-eliciting picture predicts recall for that picture up to one year later. More recently, Cahill and McGaugh (1995) found that slides of varying emotional arousal, accompanied by a matched narrative, produce more accurate delayed recall when the level of arousal is highest at the encoding stage. However, administering propranolol, a β-adrenergic antagonist, cancels this effect (Cahill, Prins, Weber & McGaugh, 1994). These data suggest that noradrenalin (NA) may play an important role in memory performance under varying emotional states.

If the effects of emotion on memory are as broad as Bradley, et al. (1992) and Cahill, et al. (1994) findings suggest, then we hypothesize that the acquisition of a procedural skill may also be affected. The same underlying plasticity is believed to facilitate both declarative and procedural learning (e.g. Garcia, 1984).

Oatley and Johnson-Laird (1987) argue that emotion differentially modulates cognition, enhancing some processes over others. Consistent with this modulatory role, Davidson (1998) groups emotion into two forms: those that motivate 'approach' behavior, such as love and hunger, and those that motivate 'withdrawal', such as fear. Moreover, there is now a substantial body of evidence that shows that approach emotions are associated with the activation of anterior regions of the left cerebral hemisphere whereas withdrawal emotions are associated with activation of the right anterior hemisphere (Davidson, 1998).

It has consistently been shown that greater left hemisphere arousal (measured using EEG) is associated with increased verbal and reduced spatial ability. Whereas higher right hemisphere arousal is associated with increased spatial ability and reduced verbal ability (e.g. Levy, Heller, Banich, & Burton, 1983). This leads to the prediction that tasks demonstrating greater right hemisphere activation should show better initial performance in a negative emotional state whereas tasks demonstrating left hemisphere activation will show poorer performance. Moreover, this pattern should be reversed for participants in a positive emotional state. Therefore, when assessing the acquisition of a procedural skill it is of interest to use cognitive tasks that depend differentially on the cerebral hemispheres.

To test the hypothesis that emotion may modulate the rate at which a cognitive skill is learnt we used a standard learning experiment where a task is repeated over a series of days and change in reaction time provides the index of learning. Two tasks were selected that had previously been shown to rely differentially on the two cerebral hemispheres: a visual discrimination task (VDT; adapted from Corbetta, et al., 1993) which relies more on the right hemisphere, and a word association task (WAT; adapted from Vandenburghe, et al., 1996) which relies more on the left hemisphere.

Methodology

Participants performed the same tasks on five separate days. Days one to four ran consecutively with each participant going through one mood induction procedure, one VDT and WAT each day. The fifth day, one week later participants performed only the WAT and VDT.

Thirty-six undergraduate psychology students from the University of Wales, Cardiff participated. Each had English as their first language, was right handed, was between the ages of 18 and 25 years and had normal or corrected to normal eyesight. Prior to the experiment potential participants were first screened. Volunteers scoring 12 or above on the Beck Depression Inventory (Beck & Steer, 1987; post hoc analysis revealed no significant interaction between emotion group and BDI score) or undertaking a course of medication that might effect the variables under consideration in this study (such as psychopharmacological drugs) were not allowed to participate. Both factors were viewed as potential confounds.

Materials.

Positive, neutral and negative emotional states were induced through use of an amalgamation of three procedures (Martin, 1990; Westermann, Spies, Stahl & Hesse, 1996). An adapted version of the Velten mood induction procedure (Velten, 1968). Affectively valenced music and requesting participants to enter the required mood state (Slyker & McNally, 1991).

Lykert scales were used as a mood induction check (Isen & Gorgoglione, 1983; Oaksford, Morris, Grainger & Williams, 1996). Each scale was arranged along a numbered line with two, affectively salient, statements at each end. To the right were presented positive adjectives (refreshed, calm, alert, positive and amused) and to the left affectively negative adjectives (tired, anxious, unaware, negative and sober, respectively).

Visual discrimination task (VDT; figure 1, a & b). Sixteen objects were presented in a circular fashion (the circle subtended a visual angle of 40°, presented until participant response), equally spaced around a central fixation point. There were two types of object: a '∨' and a '∧'. Each trial was one of two conditions, either all sixteen objects were of the '∨' shape or, on half of the total trials, one object was replaced with the '∧'. Participants were instructed to look for the '∧' and respond with a 'yes' if it was present, otherwise respond 'no'. For the VDT there were 64 trials with the inverted shape appearing in all 16 positions equally often. Trials were presented in a pseudo-randomized order, not more than three trials of the same type following consecutively.

Word association task (WAT; figure 1, c & d). Each trial consisted of three words: one target word (presented in the center of the screen, using the Geneva font and for a duration of 1,000ms). This was followed by two probe words (one to the left and one to the right of the screen, with the centers of the two words subtending a visual angle of 32°) which were simultaneously presented until participants responded. The words were selected from the Birkbeck Word Association Norms (Moss & Older, 1995). Each days word set was novel to that day.

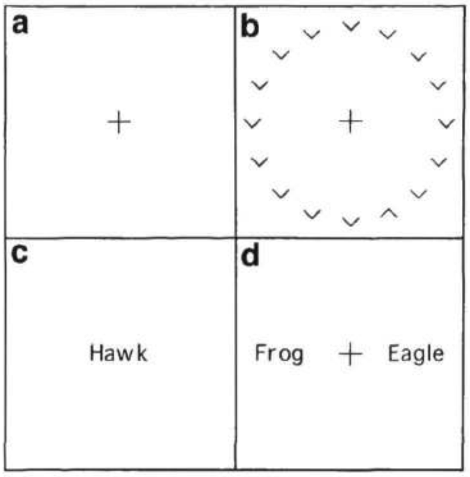

Figure 1: Stimuli. This figure shows example of stimuli from the two tasks used in this study. VDT -- Top row, left to right. Participants were initially presented with a centrally presented fixation point followed by a circular array. Participants were asked to judge whether the '∧' was present or not. WAT -- bottom row left to right, participants were initially presented with a cue word followed by two target words. Participants had to decide which of these two words were most associated with the previously shown target word.

In each task, trials were presented in a pseudo-randomized order with not more than three responses of the same type (left, right) following consecutively. Four practice trials were constructed to allow participants to become familiarized with the procedure. For each WAT there were 64 trials.

All tasks were presented on a Power Macintosh computer (4400/200) and participants used appropriately marked keys on the keyboard to make responses. The MacLab program (Costin, 1988) controlled stimulus delivery and recorded responses and response times. Music used in the mood induction procedure was presented through stereo headphones attached to a Macintosh Power PC (6500/275) located in a separate control room. For all tasks, other than the mood induction procedure, a headrest was placed 44cm from the screen with participants eyes being level with the centrally presented fixation point.

Procedure.

A statement of informed consent was read and signed by each participant. Participants were then randomly assigned to a condition in the experiment.

Participants went through the appropriate mood induction procedure, each undergoing the same procedure for the first four days of the study. Participants were presented with written instructions that asked them to read the Velten statements aloud (in order to ensure they engaged in the

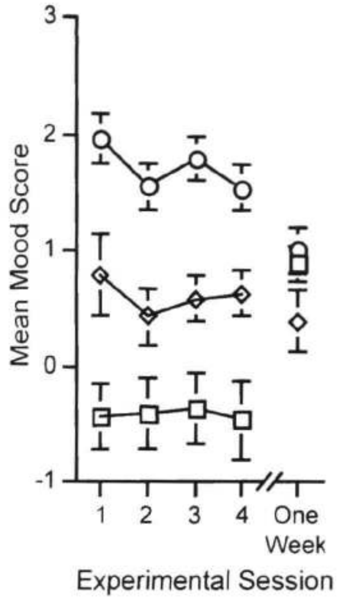

Figure 2: Subjective rating of emotional state. The positive emotion group (circles) rated themselves as more positive than the neutral group (diamonds) who rated themselves as more positive than the negative group (squares). One week later no lasting effects of the MIP were observed.

mood induction procedure). Each statement was presented for 11 seconds followed by a blank screen for 5 seconds. Simultaneously participants listened to music appropriate to their group.

Directly following the mood induction procedure, participants completed the mood induction check. Once the headphones were removed, they performed both the WAT and VDT tasks. Order of task was counterbalanced between participants. Prior to leaving the laboratory, participants were asked to complete a second mood induction check to ensure no one left in an overly negative emotional state. On the fifth day, (one week later) participants performed the same tasks but without the mood induction procedure. Following the tasks participants were debriefed, had all questions regarding the study answered and had the experimental hypotheses explained to them.

Results

Each participant's reaction time (RT) was trimmed to within 2.5 standard deviations from the mean for each task (2.9% of the total data set was removed from analysis). For the VDT, only trials where the inversion was present were analyzed.

MIP. On each day the positive group rated themselves as significantly more positive and the negative group rated themselves as significantly more negative than the neutral group at at least the .05 level (for all eight planned comparisons, $F(1, 33) > 5.0$). Self-report data from the retention session (day 5) where no MIP was performed, revealed no significant emotion state differences between groups (see figure 2).

Learning Rates. Practice and RTs are related as a power function (Fitts & Posner, 1973). We therefore fitted power curves (of the form At^{-k}) to the first four days data: overall, mean r2 = .974 (sd = .05). We also fitted power curves to each individual participant's data: overall, mean r2 = .70 (sd = .3). The exponent (k) is an index of learning rate. We therefore used the exponents for each participant's learning curve as the dependent variable in our subsequent analyses. In the WAT there were no significant differences in learning rate between emotion conditions. However, in the VDT there was a significant effect of emotional state on learning rate, $F(1, 33) = 16.38$, $p < .0005$ (see figure 3). In pairwise comparisons using Scheffe's S test, the learning rate for the negative emotion condition was significantly higher than the neutral, $p < .05$, and the positive conditions, $p < .01$. Between tasks, in simple effects comparisons, the learning rates were identical for positive emotion, $F(1, 33) = .004$, however, they were significantly higher in the VDT than the WAT for both the neutral condition, $F(1, 33) = 7.28$, $p < .025$, and the negative condition, $F(1, 33) = 18.06$, $p < .0001$. The effects of practice were robust: performance levels one week after the final training session were at similar levels indicating that the improvement over the training phase was retained.

Day One and Day Four Reaction Times. On Day 1 there was an interaction between emotion (positive-negative) and task, $F(1, 22) = 6.00$, $p < .025$. However, between group there was no significant interaction on the WAT ($F < 0.7$).

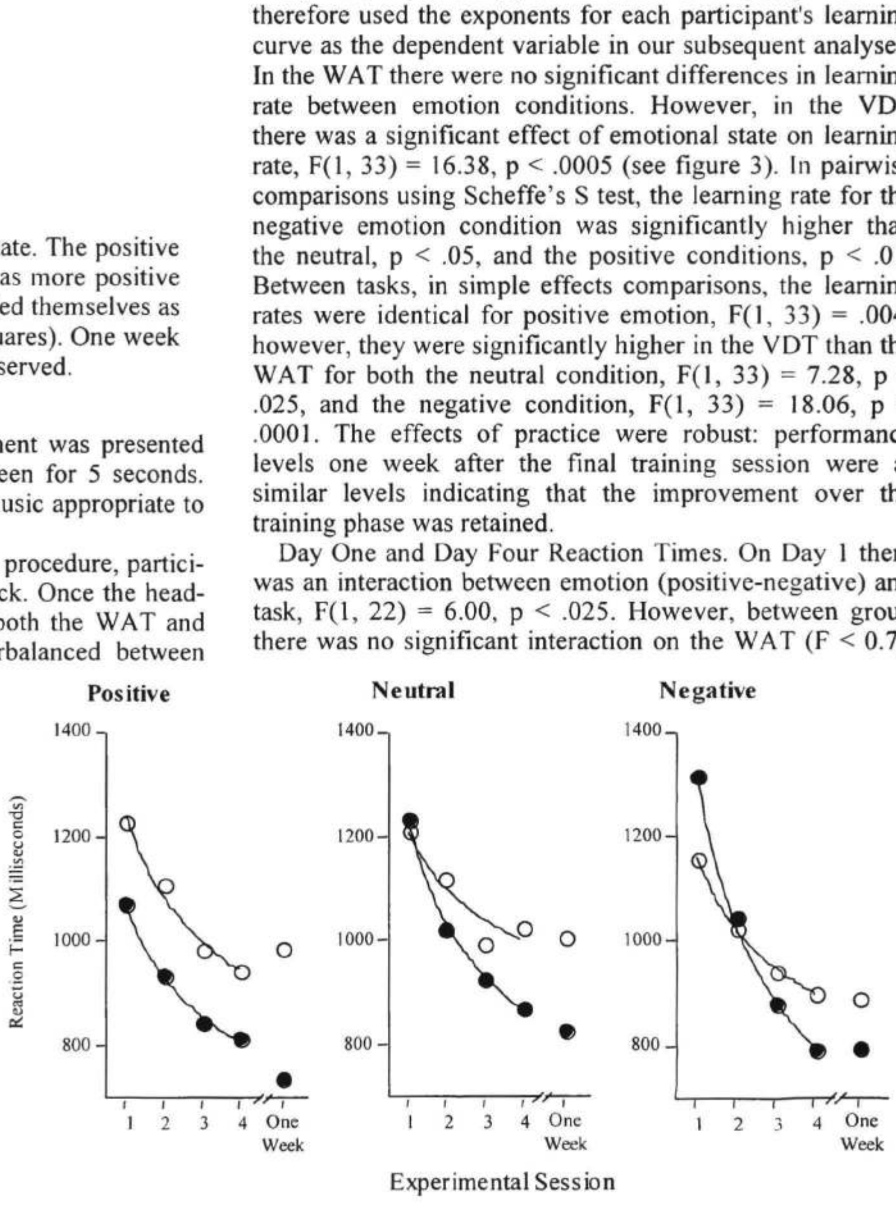

Figure 3: Learning rates. This diagram shows the mean trimmed RTs obtained in each emotion condition, with regression lines fitted, on each day of training (first four consecurive days) for both VDT (filled circles and dashed line) and the WAT (unfilled circles and solid line).

For the VDT participants in a negative emotional state recorded significantly higher RTs than those in the positive emotion state, $F(1, 22) = 5.78$, $p = 0.025$. On Day 4 no interaction was observed, however, there was a significant main effect of task, $F(1, 33) = 12.26$, $p < .0025$. Participants were faster to respond on the VDT than on the WAT. Moreover, no speed accuracy tradeoff was observed across task and across group. 16 trials worth of data were lost on day 5 for one participant in the positive group due to computer error.

Laterality. The RT for associates presented to the left of the fixation point were compared with associates presented to the right of the fixation point on the WAT. Target stimuli presented to the right of the fixation point were compared with target stimuli presented to the left of the fixation point (excluding instances where the target appeared at the top most and lower most positions) in repeated measures ANOVA. We took RTs from the first four days of the study. Participants demonstrated a facilitation effect on RT for associates presented to the left visual field on the WAT and a facilitation effect on RT for targets presented to the right visual field on the VDT ($F(1, 99) = 8.91$, $p < 0.01$).

Discussion

The data presented here show that both tasks (VDT and WAT) demonstrate a reduction in reaction time over the initial four days of the testing period. This reduction is consistent with the power law of learning (Fitts & Posner, 1973). Relative to emotion it is found that the VDT shows a higher rate of learning in the negative group relative to the neutral and the positive groups. Furthermore, the positive group learns both tasks (VDT and WAT) at a comparable rate and the WAT learning rate is consonant between positive, neutral and negative groups. If our assumption that the change in RTs on the VDT is representative of a procedural acquisition of a skill then this data suggests that the rate of learning may be modulated through manipulation of the emotional state of participants.

This view is further consistent with the already discussed research on the effects of emotion on memory. There are data to suggest emotion has long term effects on the encoding of information (Bradley, et al., 1992; Cahill, et al., 1994). Specifically, NA is implicated in the activation of the amygdala. The amygdala is, in turn, implicated in the modulation of long-term memory (Bianchin, Souza, Medina & Izquierdo, 1999; Phelps, La Bar, Anderson, O'Connor, Fulbright & Spencer, 1998); greater stimulation of this region leads to an enhancement. Moreover, heightened activity of the amygdala is associated with negative emotion states, but not positive emotion states (Davidson, 1994).

Triesman and Gormicon (1988) further argue that early visual processes decompose stimuli along a number of dimensions and into a number of separable components. In visual search paradigms 'pop-out', where the target becomes easier to discriminate from its distracters, occurs through the coding of the unique features of that stimulus. Moreover, NA has been implicated in the improvement on visual discrimination tasks across the consolidation period (Karni, et al., 1994). The improvement demonstrated on the VDT is consistent with this view.

The laterality of emotion and cognition predicted that performance on a spatial task, when participants were placed in a negative emotional state should be facilitated relative to a left hemisphere verbal task. It is clear, from day one RTs that the opposite occurred: participants in a negative emotional state took longer to complete the VDT than those in a positive state. These data may be consistent with the view that NA is involved with human emotion.

Usher, Cohen, Servan-Schreiber, Rajkowski and Aston-Jones (1999) present evidence to suggest activity in locus coeruleus (LC) NA neurons correlates with performance on a visual discrimination task. An instance where LC activity is relatively high correlates with a detriment on a visual discrimination task. First, these data support the view that NA may be implicated in the effects observed on the VDT in this study. Second, it provides a plausible route through which the VDT data may be accounted for.

In consequence, the action of NA provides a plausible explanation for both the day one biases on the VDT and the heightened learning rate in the negative condition.

Conclusion

These results suggest that varying a person's emotional state can modulate the rate of procedural learning. A plausible neuroanatomical basis for this effect is proposed that centers on the role of NA and its involvement in memory consolidation and early visual processing.

Further work is required to substantiate this explanation. We need to delineate what aspects of a task make it susceptible to modulation of the learning rate. The differential effects observed on the VDT and WAT may be explained by the fact that in the WAT novel words were used on each day, whereas the VDT employed the same target shape on each day. Similarly, that the data appears inconsistent with the proposed hemispheric effects of emotion requires more work. It may be that the tasks employed are inappropriate.

Although the findings presented here are from a controlled laboratory setting they may have a broader application. Human emotion is pervasive across the life span and hence it might be expected to affect learning of many important skills such as reading. It might be possible to match emotional state to the to-be-learned task, so as to optimize the learning rate.

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