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Predicting Performance Breakdown in Pilots Through Objective Measures of Stress Sensitivity: Final Report

Frank P. McKenna and Dinkbar Sharma

University of Reading

for

Contracting Officer's Representative
Milton Katz

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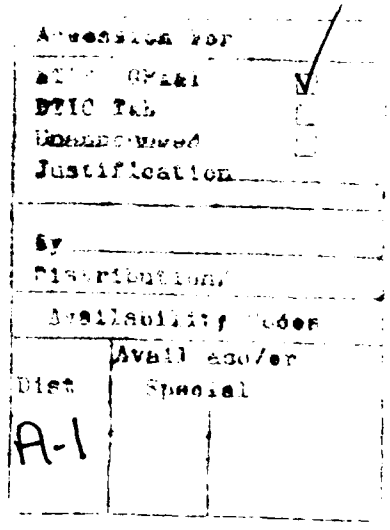

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It is well known that stress can have an adverse effect on performance and that individual differences in responses to stress are varied. This research explores the potential of developing an objective measure of stress resistance and the possibility of developing a laboratory model of the effects of stress on performance. The paradigm developed reveals that (1) emotional stimuli disrupt performance, (2) the disruption is exacerbated by time pressure and task difficulty, (3) repetition of the emotional stimuli (habituation) eliminates the disruptive effect, (4) it is not the emotionality of the stimulus, but rather the threat component that is critical to the disruptive effect. These results parallel effects in everyday life and suggest that the paradigm shows great promise for developing a measure of stress resistance and a laboratory model of the effects of stress.

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PREDICTING PERFORMANCE BREAKDOWN IN PILOTS THROUGH OBJECTIVE MEASURES OF STRESS SENSITIVITY: FINAL REPORT

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GENERAL INTRODUCTION

In order to survive, biological systems require mechanisms to deal with threat. To be effective these mechanisms should be fast acting and take precedence over other less pressing goals. Performance under threat, however, can suffer and perhaps just as important it is not only during the presence of threat that performance may deteriorate. Even at considerable delays following the threat, performance decrements may continue. Post-traumatic stress disorder reflects the psychological problems which may follow exposure to a traumatic experience. Marks (1987)[1] has noted that between 12% and 50% of all battle casualties are psychological in nature. General problems which emerge here concern the prediction of those most vulnerable to stress, the design of techniques which can be used in training to reduce the effects of exposure to threat and the introduction of methods designed to reduce the effects of past exposure to threat.

The development of a test which would indicate those least and most vulnerable to stress is not without difficulty. The most obvious technique for assessing stress resistance would be to consider self report personality questionnaires such as Spielberger's Trait Anxiety and the Neuroticism scale or the Eysenck Personality Inventory since these are assessing characteristics relevant to stress resistance. This general approach has shown some success (Kobasa, Maddi, & Kahn 1982)[2] though see Allred and Smith (1989)[3] for a discussion of some of the difficulties which have emerged. While self-report measures may well be useful in many research situations their use outside of research scenarios is limited by the fact that people are capable of quite sophisticated impression management. As McKenna (1985)[4] has noted, when responding to personality questionnaires people are capable of a) indicating which items belong to which scales (Power & MacRae 1971)[5], b) simulating particular personality profiles (Power & MacRae 1977)[6] and c) simulating particular occupational profiles (Kroger & Turnbull 1975)[7]. In addition McKenna (1990)[8] has evidence that military personnel put these abilities to use when under selection pressure. In other words personality questionnaires are susceptible to the very considerable self presentation skills which people have. For these reasons an alternative to the self assessment technique would be useful.

One such measure which has been developed is the Defence Mechanism Test which is a projective technique which examines the individual's response to threatening stimuli. The test rests heavily on psychoanalytic theory and the scoring procedures rely on considerable subjective assessment. The test has been used by a range of military establishments and some success as a selection measure has been claimed by Kragh (1960)[9], Neuman (1971)[10] and more recently by Lowe, Hayward and Neuman (1989)[11] though

Stoker (1982)[12] failed to support these findings. Overall, considerable controversy has surrounded both the empirical and theoretical status of the Defence Mechanism Test (Cooper 1988; Kline 1987, 1988)[13,14,15].

What would appear to be required is a simple, objective performance based test which is not based on self assessment and does not require complex, interpretative scoring procedures. To this end McKenna (1986)[16] developed a variant of the Stroop test which required the naming of the colours of emotional and neutral stimuli. The hypothesis tested was whether irrelevant emotional stimuli disrupted performance. This hypothesis was confirmed. Since then a number of studies have confirmed that the task is sensitive to a wide range of fears and vulnerabilities, for example, those shown by phobics (Watts et al, 1986)[17], anxious groups (Mathews & MacLeod, 1985)[18], panic attack patients (Ehlers et al, 1988)[19], depressed groups (Williams & Nulty, 1986)[20] and over-dose patients (Williams & Broadbent, 1986)[21]. Although these studies have provided important replications and extensions to the emotional stroop task, the task itself is, partly through limitations in the paradigm, relatively little studied and understood. It has not been possible, for example, to determine which particular stimuli are producing the effects. In addition it has not been possible to determine the time course of the emotional effects. For example, Ehlers el al (1988)[19] have proposed that the interference effects may increase over trials compatible with a flagging attention hypothesis. By bringing the task under computer control the present research will facilitate a more detailed investigation of the nature and time course of the emotional interference effects.

While a great deal of valuable information concerning fear and stress has been gained through animal models (c.f. Marks 1987)[1] the present approach attempts to complement previous research by developing a human experimental model. To that end the disruptive effects of emotional stimuli on the laboratory task just described provides some potential. At a theoretical level, it is being proposed that what is being measured is <u>uncontrolled</u> emotional processing. The contrast which is being considered is with controlled processing which refers to deliberate, scheduled processing which maps onto the intentional goals of the subject. By contrast, therefore, uncontrolled processing refers to unscheduled processing which does not map onto the explicit goals of the subject. Uncontrolled processing can be distinguished from a somewhat similar theoretical construct, automatic processing, which refers to cognitive processes which can be run off without conscious control. The important difference is that automatic processes may map onto an explicit goal e.g. in driving, changing gear may be automatic but it normally maps onto an explicit higher order goal such as changing speed. The importance of uncontrolled processing is that it does not map onto an explicit goal so that in our task the subjects are instructed to ignore the

emotional and neutral stimuli which are irrelevant to the task. The empirical finding is that they are unable to ignore the emotional stimuli. The basic paradigm is therefore able to model the attentional deficits which are characteristic of performance decrements under stress.

We have developed an analog of fear processing by examining the effects of emotional stimuli on a colour categorisation task. There are two major aims of the research. The first is to determine the potential of the emotional Stroop task as a simple objective measure of stress resistance and the second is to examine the potential of the paradigm as a laboratory model of the effects of stress on performance. The overriding concern is for the development of a paradigm which not only is of theoretical importance but also has practical applications.

EXPERIMENTS 1 AND 2

INTRODUCTION

The emotional Stroop effect is of course modelled on the original Stroop (1935)[22] experiment in which words are presented in incongruent colours. For example, subjects may be presented with the word BLUE in red ink. If the word conflicts with the colour then colour naming is disrupted. Although this classic Stroop effect is large and robust it is dependent on output modality. McClain (1983)[23] has shown that when the output is a manual key-press the incongruent words have much less of a disruptive effect than when the output is vocal response. One aim of the present experiment is to determine if the emotional Stroop effect is similarly affected by output modality.

Although most research has concentrated on the incongruent condition in which conflicting words produce an interference effect, there is a well documented, though little discussed, lexical effect. In other words it is not only colour incongruent words which interfere. If the stimulus happens to be a legitimate english word then a disruption of colour naming occurs (Klein 1964; McKenna 1986; McClain 1983)[24,16,23]. Although the lexical effect is large when the output modality is verbal there is evidence to suggest that the lexical effect may disappear when the output is key-press (McClain, 1983)[23]. This result raises the possibility which will be investigated in the present experiments that the emotional Stroop effect is dependent on the lexical effect and may likewise disappear when the output modality is key-press.

Most experiments examining the emotional Stroop effect have failed to take note of the order of presentation effects first noted in a study by McKenna (1986)[16] in which it was found that if emotional stimuli were presented first then no

difference was found between emotional and neutral stimuli. If, on the other hand the neutral stimuli were presented first then there was a clear difference between the emotional and neutral stimuli. The explanation offered was that the disruptive effect of the emotional stimuli may persist beyond their presentation. Once emotional stimuli have been primed they may take some time to decay. This process may parallel the effects of emotional events in everyday life, where a major characteristic is the persistence of self-preoccupying thoughts. As a result the order of presentation will be investigated in the present experiments.

One potential explanation of the extra processing time for the emotional stimuli is that this is due to a defence mechanism operating to keep the emotional stimuli out of awareness. In other words the emotional Stroop effect may be an experimental demonstration of repression. In order to test this hypothesis subjects were given an incidental memory task. From the repression hypothesis one would predict that the emotional stimuli would be less well remembered than the neutral stimuli.

The most obvious alternative hypothesis is that the emotional stimuli have the power to demand and command attention and that it is through attentional priority that the organism is able to rapidly respond to threat. If this latter alternative is the case then the emotional stimuli should be more effectively remembered.

In order to explain this effect it could be suggested that emotional words require more attentional resources, or are given a higher priority for processing, than neutral words. One implication of assuming an attentional bias to emotional stimuli is that it predicts that emotional words will be remembered more than neutral words.

METHOD

Subjects. Forty-eight University of Reading students took part in each of the two experiments, Experiments 1 and 2, 48 in the vocal response condition and 48 in the key-press response condition.

Design. Two experiments were conducted, Experiment 1 involved making a vocal response to the stimuli and Experiment 2 making a key-press response. The design of both experiments formed a 3 X 2 X 2 factorial model with the Emotional Class condition (letter strings, L, neutral, N, or emotional,E) a within-subjects factor, Type of Design and Order (Neutral presented before emotional, NE, and emotional presented before neutral, EN) between-subject factors. Two types of designs were used in Experiment 1 and 2. In the first subjects were presented the three types of word stimuli in counterbalanced order (LNE, NLE, NEL, LEN, ELN

and ENL) across subjects, in the second design subjects were presented only the neutral and emotional words in counterbalanced order (LNE and LEN) with the letter strings presented before the words. The stimulus conditions were all completely counterbalanced.

Materials. The words and letter strings used were all written in capital letters as follows. Letter strings: OOOOO, XXXX, HHHH, SSSSS and PPPPP. Neutral words: CLOCK, GATE, NOTE, THUMB and FIELD. Emotional words: CRASH, FAIL, FEAR, GRIEF and DEATH. The neutral and emotional words were taken from McKenna (1986)[16], which were equated for word length and frequency (Kucera & Francis, 1967)[25].

Procedure. Each of the five words and five letter strings were written in four different colours, red, green, blue and brown. These twenty stimuli were randomized with one restriction, that the same word or colour did not repeat itself on consecutive trials. This formed one block in the stimulus array, five such blocks were formed to produce 100 stimuli which were presented on a computer screen (270 cm X 200 cm) in a 10 X 10 matrix on a white background.

The subjects were introduced to the task as a colour perception task in which they would be presented a word in one of four ink colours. Subjects were shown 20 letter strings written in these colours to familiarize them with the colours. They were instructed to ignore the words and make a response (vocal or key-press) to the colour of the ink as quickly and accurately as possible. If any errors were made they were to correct themselves before continuing. In the vocal response condition subjects called out each ink colour aloud whereas in the key-press response condition subjects pressed one of four black coloured buttons. All subjects positioned their first and second fingers from their left and right hands on top of each of the buttons. Each black button was labelled with one of four words written in black ink, BLUE, BROWN, RED and GREEN. Half the subjects received the red and green labels on the left hand and the blue and brown labels on the right hand whereas the other half in reverse order.

Before conducting the experiment all subjects were given two practice sessions. The type of practice given depended on which design subjects received. When the letter strings were counterbalanced with the neutral and emotional conditions each session involved naming a colour word (red, green, blue and brown) written in black ink. Each of the words were presented twenty times in a random order, and presented on the screen as a 10 X 8 matrix on a white background. When the letter strings were presented before the neutral and emotional words subjects were asked to colour name 200 letter strings with a short break after one hundred.

The experiment involved presenting the emotional class

conditions such that before each condition subjects were informed that letter strings or real words were going to be presented (the difference between the emotional and neutral words was not mentioned to the subjects) however, all subjects were instructed to ignore the word stimuli and report only the ink colours as quickly and accurately as possible. The experimenter measured the time taken for the subjects to respond to 100 stimuli with a stop watch.

At the end of the experiment subjects were unexpectedly asked to free recall all the words seen in the experiment.

RESULTS and DISCUSSION.

(A) Analysis of Emotional Stroop.

The analysis was conducted on the total time taken to respond to 100 stimuli for the vocal and key-press response conditions separately.

Lexical effects.

The first main question asked about the data was, are there lexical effects in a stroop task when subjects make a vocal or a key-press response?

For the vocal response experiment there was a main effect of Emotional Class, $F(2,88)=37.89$ $p<0.0001$. Tukey tests indicated that letter (68.50 sec.) strings were colour named faster than both neutral (75.27 sec.) and emotional (77.57 sec.) words. There were no interactions with Order and type of design (all F values are less than 2.96 $p>0.05$).

For the key press response experiment there was a main effect of Emotional Class, $F(2,88)=6.17$ $p<0.05$. Tukey tests indicated that letter (91.44 sec.) strings were colour named faster than emotional (96.02 sec.) words but not neutral (92.89 sec.) words. There were no interactions with Order and type of design (all F values are less than 1.90 $p>0.1$). Thus the main result from this analysis is that there are lexical effects only in the vocal response experiment but not in the key press experiment.

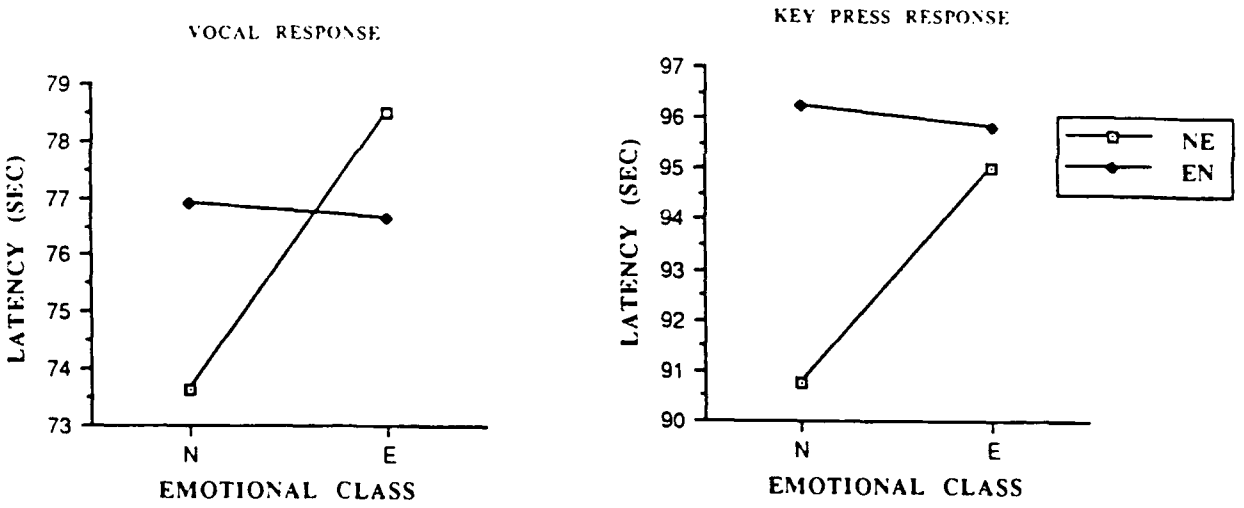
The second main question asked in these two experiments is, are there any effects of Emotional Class for the vocal and key-press response conditions? To address this question we only analyzed the neutral and emotional words without analyzing the letter strings. The main findings are presented in Figure 1.

Vocal response.

For the vocal response condition there was a main effect of Emotional Class, $F(1,44)=6.39$ $p=0.0152$, which indicates that the emotional words took longer to colour name than the neutral words (the emotional stroop effect). However, this interacts with Order, $F(1,44)=7.89$ $p=0.0074$, (see Figure 1).

The two-way interaction was further investigated by simple main effects analyses. This showed that the emotional stroop effect occurred when the emotional words followed the neutral words (NE), $F(1,44)=14.24$ $p<0.001$, but not when the neutral words followed the emotional words (EN), $F(1,44)=0.04$ $p>0.1$. Also, when the neutral words were presented second in the order they took longer to colour name than when presented first, $F(1,44)=6.37$ $p<0.025$, whereas there was no significant difference for the emotional words, $F(1,44)=2.10$ $p>0.1$. The interaction of Emotional Class with Order replicates the findings of McKenna (1986)[16].

Figure 1. Latency to respond to 100 emotional and neutral words in Experiments 1 and 2 for the Vocal and Key-Press response conditions and the two orders NE and EN.



Can these order effects be explained by the effects of practice? If practice was involved in these order effects it would be predicted that when the neutral or emotional words were presented second in the order they would be colour named faster than when presented first. In fact the results go in the opposite direction for the neutral words (which may indicate effects of fatigue) and for the emotional words there is no difference (suggesting that fatigue or practice cannot fully account for the results). McKenna (1986)[16] has suggested an alternative hypothesis involving the general disruptive effects of emotional stimuli. Two assumptions were made to account for the order effects. Firstly, that emotional words disrupt colour naming performance compared to neutral words (which accounts

for the emotional stroop effect). Secondly, that the disruptive effects of emotional stimuli take some time to decay and therefore slow the colour naming of neutral words (which accounts for the result that neutral words take longer to colour name when they are presented after the emotional words than before the emotional words, and also why there is no difference with the emotional words).

Key-press response.
For the key-press response condition there was a main effect of Emotional Class, $F(1,44)=8.20$ $p=0.0064$, indicating that Emotional words take longer to colour name than neutral words. Again the emotional stroop effect interacted with Order, $F(1,44)=4.57$ $p=0.038$, (see Figure 1). Simple main effects analyses suggested that the emotional stroop effect occurred when the emotional words preceded the neutral words (EN), $F(1,44)=15.66$ $p<0.001$, but not when they followed the neutral words (NE), $F(1,44)=0.33$ $p>0.1$. This result is in contrast to the vocal response data which showed the emotional stroop effect for the order NE. Simple main effects also showed that when the neutral words came second in the order they were colour named faster than when they came first, $F(1,44)=7.57$ $p<0.01$, which is in the opposite direction to that found for the vocal response condition. The emotional words showed no significant difference, $F(1,44)=0.07$ $p>0.1$.

These results generalize the findings with the vocal response in showing that emotional words take longer than neutral words to colour name, and extends the results by showing that the effects of order are reversed for a key-press response compared to a vocal response. While the vocal response data supports McKenna's (1986)[16] argument that emotional stimuli disrupt performance, the present results refute McKenna's proposed explanation of the order effect since, for the key-press data the order effects are reversed.

(B) Analysis of free recall.
The analysis of the data was conducted on the Freeman-Tukey Arc-Sine Transform scores of the number of correctly recalled words (Winer, 1971)[26]. A four-way analysis of variance with Type of Design, Order and Type of Response as between-subject factors and Emotional Class a within-subject factor. The main question asked here is, are there any effects of Emotional Class on the frequency with which words are recalled? The main results are presented in Table 1.

The analysis showed (i) that there was no main effect of Type of Design, $F(1,88)=1.29$ $p>0.2$, which indicates that the two designs did not differ in the number of words recalled. (ii) No main or interaction effect with the Type of Response, all F values are less than 2.64 $p>0.1$, indicating that subjects in the key-press and vocal response conditions did not differ in the pattern of their results. (iii) A main effect of Emotional Class, $F(1,88)=10.97$ $p=0.0013$, which

than neutral words. However, this interacted with Order, $F(1,88)=12.27$ $p=0.0007$ (see Table 1).

Table 1. Shows the proportion of words recalled in Experiments 1 and 2 for the emotional and neutral word in the two orders, NE and EN.

Memory Task	Order	Emotional Class	
		Neutral	Emotional
Free Recall	NE	0.21	0.45
	EN	0.33	0.33

Simple main effect analyses showed that emotional words were more effectively recalled than neutral words in the order NE, $F(1,88)=23.22$ $p<0.0001$, whereas this was not significant for the order EN, $F(1,88)=0.02$ $p>0.1$, which suggests that the emotional and recency effects are equally effective in aiding recall. Simple main effects also showed effects of recency, such that when the emotional or neutral words were presented second in the order they were more effectively recalled than when they were presented first in the order, $F(1,88)=4.25$ and 8.37 respectively, $p<0.05$.

The recall data can be accounted for by the operation of two effects, a recency effect in which those stimuli presented last are recalled best and an emotional effect in which emotional stimuli are recalled more effectively than neutral stimuli. These effects can operate in opposition or in an additive manner. For example, when the emotional words are presented after the neutral words (NE) the emotional and recency effects would act in an additive manner. However, when the neutral words are presented after the emotional words (EN) the emotional and recency effects would act in opposition.

DISCUSSION

Overall the results of Experiments 1 and 2 indicate that output modality has an important role to play. In particular the lexical effect which is large and highly significant in the vocal condition is entirely eliminated in the manual condition. This result reinforces the view that there is a 'privileged loop' linking words with vocal output. The fact that there is a lexical effect in the vocal condition is of some theoretical importance since it has implications for response conflict models of the classic Stroop effect. As Stirling (1979)[27] has noted some response conflict models argue that the interference is due to two incompatible responses being activated (one from the colour and the other from the word). The fact that a non-colour

and the other from the word). The fact that a non-colour word produced interference indicates that incompatibility is not a necessary condition for the interference.

In terms of the emotional Stroop effect the interesting feature is that although the lexical effect is eliminated by the change in output modality this does not hold for the emotional Stroop effect which occurred both in the presence and absence of the lexical effect. It seems reasonable to conclude, therefore, that the emotional Stroop effect is not dependent on the lexical effect. The precise nature of the order effect does change with output modality and the emotional persistence explanation offered by McKenna (1986)[16] clearly cannot account for the order effect found in the manual output modality.

The memory results have implications for the stage of information processing at which the interference effect is due to the operation of defence mechanisms designed to keep emotional stimuli out of awareness. Although perceptual defence studies have had a long and controversial history (Dixon 1981)[28] the hypothesis remains attractive. Mathews (1988)[29], for example, proposed that the emotional Stroop effect may be due to defence mechanisms consuming processing resources. The fact that people have more explicit access to the emotional stimuli is not consistent with the defence mechanism hypothesis.

EXPERIMENT 3

INTRODUCTION

The two main results from Experiments 1 and 2 are that, firstly, both vocal and key-press responses show effects of emotional stroop, that is, emotional words take longer to colour name than neutral words; and secondly, that emotional words are more effectively recalled than neutral words. Thus, the main conclusion to be drawn from these results is that emotional words are processed in a different way from neutral words. The previous experiments have used the conventional technique for investigating the Stroop effect by presenting all the stimuli simultaneously, requiring the subject to sequentially colour name the stimuli, and taking an overall measure of latency as the index of performance. There are two major limitations of this paradigm. The first is that it is not possible to determine which particular stimuli are producing the effect and the second is that it is not possible to determine the time course of the effects. For example, it is possible that only certain emotional stimuli are producing the effect. It is of clear importance to know whether all or only some of the emotional words have a disruptive effect. The second major limitation of the conventional paradigm is that it is not possible to determine if the emotional effects occur early in the experiment and habituate, whether they occur throughout the

experiment, or whether they occur predominantly at the end of the experiment.

One of the central techniques in fear reduction is based on the observation that repeated exposure to threat results in decrements in the disruptive effects and a reduction in the fear itself (Foa & Kozak, 1986)[30]. From this perspective it would be predicted that the emotional interference effects would diminish with stimulus repetition. An alternative analysis has been presented by Ehlers et al (1988)[19] who argue first that the interference effects of words is due to the difficulties in maintaining an attentional set and second that the interference effects may increase over trials compatible with flagging attention.

By using a paradigm consisting of sequential presentations of individual stimuli with each latency recorded it is possible to distinguish between the above possibilities and to determine which stimuli are producing the effects. The next step therefore, represents a finer grain analysis of the emotional Stroop effect.

METHOD.

Subjects. Forty-four University of Reading students took part in Experiment 3. Twenty-two in each order (NE and EN).

Design. The design formed a 2 X 2 factorial model with Emotional Class (Neutral or Emotional words) as a within-subject factor and Order (NE or EN) a between-subject factor.

Materials. The words used in the experiment were all written in capital letters and were as follows, Neutral words: CLOCK, GATE, NOTE, THUMB and FIELD. Emotional words: CRASH, FAIL, FEAR, GRIEF and DEATH. In the practice session repeated letter strings were used: OOOOO, XXXX, HHHH, SSSSS and PPPPP.

Procedure. The emotional task involved presenting a single word at the centre of the screen. Each stimulus remained on the screen until a response was made and the next stimulus presented immediately, that is the interstimulus interval was 0 sec. Each of the five neutral or emotional words were written in four ink colours, red, green, blue and brown. These twenty stimuli were randomized with one restriction, that the same word or colour did not repeat itself on consecutive trials. This formed one block in the stimulus array, five such blocks were formed to produce 100 stimuli which were presented sequentially in the centre of the computer screen (270 cm X 200 cm) on a white background.

The subjects were introduced to the task as a colour perception task in which they would be presented a word in

one of four ink colours. They were shown 20 repeated letter strings to familiarize them with the ink colours. They were instructed to ignore the words and make a key-press response to the colour of the ink as quickly and accurately as possible. If any errors were made they were asked not to correct themselves.

Before conducting the experiment all subjects were given two practice sessions using 200 coloured letter string stimuli with a short break after 100 stimuli. The experiment involved presenting 100 emotional and 100 neutral stimuli. Subjects were informed that real words were going to be presented (the difference between the emotional and neutral words was not mentioned) however, all subjects were instructed to ignore the word stimuli and report only the ink colours as quickly and accurately as possible.

All responses were made using one of four black coloured buttons by positioning the first and second fingers from the left and right hands on top of each of the buttons. Each button was labelled with one of four words written in black ink, BLUE, BROWN, RED and GREEN. Half the subjects received the red and green labels on the left hand and the blue and brown labels on the right hand whereas the other half in reverse order.

At the end of the experiment subjects were given an incidental free recall task in which they were asked to recall all the words presented in the experiment.

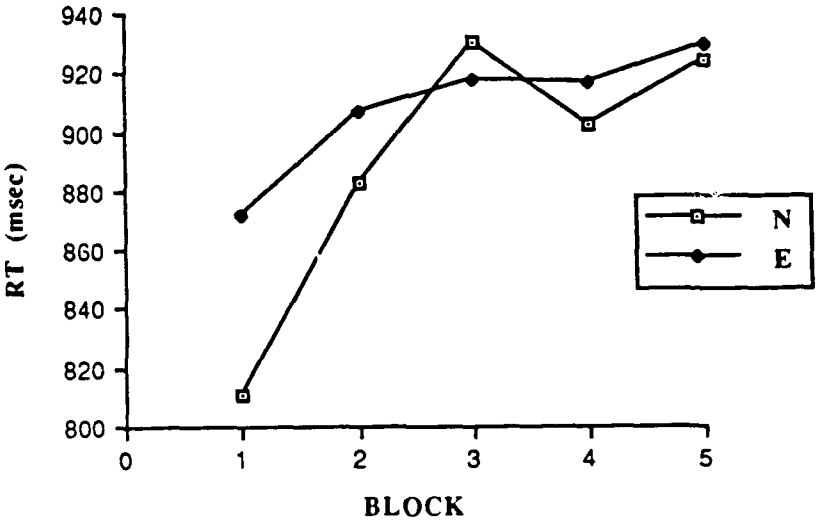
Hence the design and procedure was identical to Experiment 2 except that in Experiment 3 there was only a key-press response and that the stimuli were not presented on a 10 x 10 matrix simultaneously but sequentially in the centre of the screen. Also subjects were asked not to correct their errors if any were made.

RESULTS

(A) Analysis of Emotional Stroop.

The analysis was carried out on the mean correct reaction time to each stimulus and the overall results are presented in Figure 2. The scores were analyzed in a four-way analysis of variance, with Order (NE or EN) a between-subject factor, Emotional Class (neutral or emotional), Block and Words as within-subject factors. Block refers to the way in which the stimuli were presented. One block involves a random presentation of the 20 stimuli (5 words x 4 ink colours), and Words refers to the five emotional or neutral words. This design was chosen so that the time course of the emotional stroop effect could be investigated. Note that this design is exactly the same for Experiments 1 and 2.

Figure 2. Mean manual reaction time to colour name neutral and emotional words for the five blocks in Experiment 3.



The analysis showed that emotional words took longer to colour name (908.53 msec) than neutral words (889.64 msec), $F(1,42)=6.25$ $p=0.012$. There was no interaction with Order, $F(1,42)=0.28$ $p>0.1$. This result is in contrast to the Order effects found in Experiments 1 and 2 and indicates that the order effects are partly a function of the type of stimulus presentation (i.e. sequential or simultaneous).

Are there differential effects of emotional stroop for the five words used in this experiment? There were no main or interaction effects with Words, all F ratios are less than 2.36 $p>0.05$, and the Emotional Class x Word interaction was insignificant, $F(4,168)=0.32$ $p>0.7$, suggesting that all the five words showed an emotional stroop effect.

The analysis also showed a main effect of Block, $F(4,168)=15.43$ $p=0.0001$, which indicated that subjects responded faster in the first Block than the other four blocks (means are 841.34, 894.86, 923.82, 909.76 and 926.60 milliseconds for blocks 1 to 5 respectively).

One other effect was significant, a two-way interaction between Emotional Class x Block, $F(4,168)=2.75$ $p=0.03$ (see Figure 2). Simple main effects analysis showed that the emotional words took longer to colour name than neutral words on the first block, $F(1,168)=12.74$ $p<0.001$, but not on any of the other four blocks, $F(1,168)< 2.7$. A simple main effect of Block on the neutral and emotional words showed significant effects, $F(4,168)=16.56$ and 4.11 for the neutral and emotional words respectively, $p<0.01$. Tukey multiple

comparison tests showed that the response latencies for the first block was significantly faster than the other four blocks.

It should also be noted that as compared to Experiments 1 and 2 there are no effects of Order in Experiment 3, suggesting that the order effects are a function of the type of display used, that is simultaneous or sequential display presentation, as well as response modality.

(B) Analysis of Free Recall.
The number of neutral and emotional words recalled were transformed using the Freeman-Tukey Arc-Sine Transform. These scores were analyzed in a two-way analysis of variance with Emotional Class a within-subject factor and Order a between-subject factor. The main findings are presented in Table 2. The analysis showed that emotional words were recalled more often than neutral words, $F(1,42)=13.69$ $p=0.0006$, and that this interacted with Order, $F(1,42)=4.18$ $p=0.0047$. Simple main effects on the two-way interaction showed that emotional words were recalled more than neutral words for the order NE, $F(1,42)=16.50$ $p<0.001$, but there was no difference for the order EN, $F(1,42)=1.37$ $p>0.1$ (see Table 2).

Table 2. Shows the proportion of words recalled in Experiment 3 for the emotional and neutral words in the two orders, NE and EN.

		Emotional Class	
Memory Task	Order	Neutral	Emotional
Free Recall	NE	0.32	0.54
	EN	0.39	0.45

These results show, as in Experiments 1 and 2, the effect of two factors on recall performance. Firstly, the effect of the emotional class, such that emotional words are recalled more effectively than neutral words, and secondly, the effect of recency, such that those words that are presented last are recalled best. Indeed, an analysis comparing the recall results using the key-press response in Experiments 1 and 2 with Experiment 3 produced no significant differences between the three experiments. The interaction effects with the factor for Experiment were such that all the F ratios were less than 1.2 $p>0.3$. (The main effect of Experiment was marginally insignificant, $F(2,86)=3.06$ $p=0.052$, suggesting that there were more words recalled in Experiment 3 than in Experiments 1 and 2.)

DISCUSSION

The results clearly indicate that temporal factors are of great importance. Over the course of the experiment subjects have difficulty maintaining their attentional set thus supporting the flagging attention hypothesis. However, the emotional interference does not increase over trials as suggested by Ehlers et el (1988)[19]. Quite the reverse, the emotional effect decreases over trials consistent with an habituation response. If the paradigm does accurately reflect an analog of fear processing then the therapeutic effects of repeated exposure to threat have been demonstrated and one technique for reducing the adverse effects of stress on performance has been illustrated. Once again the results indicate that the emotional stimuli are more readily available for subsequent recall. In addition, it is shown that there is no evidence that the disruptive effect on response latency is due to only some of the emotional stimuli. Interestingly, the sequential presentation has resulted in the elimination of the order effects which were observed in the previous manual output experiment.

EXPERIMENT 4

INTRODUCTION

One aim of Experiments 1, 2 and 3 was to investigate whether it was possible to transfer the emotional stroop task onto a computer in order that the task may be automated and facilitate a finer grain analysis. One obstacle to automation concerns the traditional output system for Stroop tasks which has been vocal response. The difficulty is that voice recognition systems are not sufficiently reliable to support automation. By contrast manual output is readily automated. Experiments 1 and 2 revealed that while the output system did make a difference to the lexical effect and the order effects it was possible to demonstrate an emotional Stroop effect with both output systems. Experiment 3 opens up the possibility that the sequential stimulus presentation eliminates the order effects. Although this has been demonstrated for manual output it has not been demonstrated for vocal output. The present experiment, therefore, investigates the possibility that sequential presentation eliminates the order effect in the vocal condition as well as the manual condition. In addition it will also be possible to determine whether emotional interference observed in the vocal condition produces an habituation response similar to that observed in Experiment 3.

Most traditional research on memory relies on tests such as free recall and recognition which rely on explicit reference to, and conscious recollection of, particular learning episodes. In recent years, however, there has been

increasing interest in implicit memory in which conscious recollection is not a necessity but rather memory is indexed by facilitation of test performance. One frequently used technique for investigating implicit memory has been the stem completion task in which a short sequence of letters is presented, and subjects required to complete the letter sequence with the first word which comes to mind. It has been found that prior presentation of a stimulus primes that particular stimulus. In other words it increases the probability that the word will subsequently appear in the stem completed list. What is of great theoretical interest is that it is possible to demonstrate dissociations between implicit and explicit memory. For example, it has been shown that while amnesics perform very poorly on explicit tasks they may perform normally on implicit tasks (Schacter 1987)[31]. Factors which have a clear influence on explicit tasks such as levels of processing manipulations (Craik & Tulving, 1975)[32] do not necessarily have an effect on implicit tasks (Graf & Mandler 1984)[33]. Our previous research has indicated that it is more difficult to control the disruptive effects produced by emotional stimuli and that the emotional stimuli are more explicitly remembered. The present study will investigate whether there is a dissociation between implicit and explicit memory with reference to the memory for emotional material.

METHOD

Subjects. Thirty-six University of Reading students took part in Experiment 4. Six in each order (LNE, NLE, NEL, LEN, ELN and ENL where L refers to letters, N refers to neutral words and E refers to emotional words).

Design. The design formed a 2 X 2 factorial modal with Emotional Class (Neutral or Emotional words) as a within-subject factor and Order (NE or EN) a between-subject factor.

Materials. The words used in the experiment were the same as in experiment 3, such that, Neutral words: CLOCK, GATE, NOTE, THUMB and FIELD. Emotional words: CRASH, FAIL, FEAR, GRIEF and DEATH. Letter strings: OOOOO, XXXX, HHHH, SSSSS and PPPPP. In the practice session the letter strings AAAA and AAAAA were used.

Procedure. The procedure was identical to experiment 3 except that (i) subjects made a vocal response to the stimuli rather than a key press response. This was done by speaking into a head-set microphone, with the microphone positioned just under the chin of the subject, and connected to a computer via a voice box. The voice box effectively acted as a relay switch device that was switched on by the voice of the subject and switched off automatically after a delay of about 0.25 seconds. During the practice session the volume gain on the voice box could be varied for each

individual subject so that a single word (red, green, blue and brown) produced a single pulse in the voice box.

(ii) The letters, neutral and emotional stimuli were counterbalanced. Before conducting the experiment all subjects were given two practice sessions using 200 coloured letter string stimuli with a short break after 100 stimuli. The experiment involved presenting 300 stimuli (100 emotional and 100 neutral words and 100 repeated letter string stimuli in a counterbalanced order across subjects). Subjects were informed that real words or letter stings were going to be presented (the difference between the emotional and neutral words was not mentioned) however, all subjects were instructed to ignore the word or letter stimuli and report only the ink colours as quickly and accurately as possible.

(iii) At the end of the experiment subjects were given two memory tasks, an incidental free recall task and a stem completion task. The stem completion task was introduced to the subjects in the following way. "I would like you now to take part in another experiment. This is an experiment that I will be conducting in the future and involves presenting certain types of words to subjects. What I would like you to do is to help me generate some of these words." A stem completion task was then presented in which the first two letters, and blank lines to represent the length of the word, were provided as partial cues and subjects were asked to complete the stem with the first word that came to mind. However, proper nouns and plurals which could be produced by adding an 's' at the end of the singular, could not be used (eg. trains). Forty stem completions were presented (ten with the same prefixes as the words in the experiment (e.g. DE _ _ _ for DEATH and FI_ _ _ for FIELD), ten were controls that were matched for frequency and number of possible completions as the experimental stimuli, and 20 distracters which were the same as the distracters used in the recognition task. The 40 stimuli were presented on a sheet of paper simultaneously in 7 rows of 6 columns. Four random sets of 40 stimuli were produced and presented to the subjects in a random order. Subjects were given as much time as they needed to complete all the stems and could complete the stems in any order. Subjects were encouraged to complete all the stems, which most of them were able to do.

(iv) Subjects skin conductance levels were automatically recorded using a skin conductance meter (Electronic Developments) and two silver chloride electrodes that were placed on the last two fingers of the left hand.

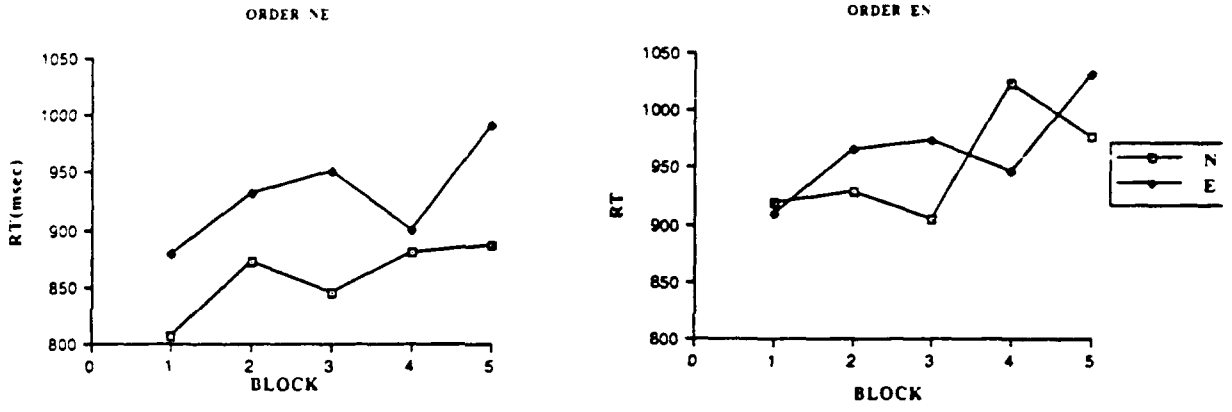
RESULTS

(A) Analysis of Emotional Stroop.

The correct reaction time scores were analyzed in two ways. Firstly in a four-way analysis of variance, with Order (LNE,

NLE, NEL, LEN, ELN and ENL) as a between-subjects factor, and Emotional Class (E and N), Block and Words as within-subject factors. Secondly, with Order (NE and EN) as the between-subjects factor. Since the two analysis produced virtually identical results we only report the analysis with Order (NE and EN) as the between-subjects factor. The main findings are presented in figure 3.

Figure 3. Mean vocal reaction time to colour name neutral and emotional words of the five blocks and the two orders NE and EN in Experiment 4.



The analysis showed that emotional words took longer to colour name (946.97 msec) than neutral words (904.22 msec), $F(1,34)=21.20$ $p<0.0001$. Unlike experiment 3 there was an interaction with Order, $F(1,34)=9.54$ $p<0.005$. Simple main effects analysis showed that emotional words (929.44 msec.) took longer to colour name than neutral (857.94 msec.) words in the order NE, $F(1,34)=29.53$ $p<0.0001$, but not the order EN, $F(1,34)=1.22$ $p>0.1$, (964.40 and 949.95 msec. respectively). This result parallels the finding from Experiment 1 which showed that there was an emotional class effect in the order NE when using vocal responses as the output modality. As in experiment 3 there was a main effect of Block, $F(4,136)=14.31$ $p<0.0001$, indicating an effect of flagging attention. Tukey multiple comparison tests revealed that this was due to the first block showing significantly faster reaction times than any of the other four blocks, and the second, third and fourth blocks showing significantly faster reaction times than the fifth block, but not significantly different from each other.

One important question in this experiment was whether the emotional class effect occurred across all the blocks or only in the first block as in Experiment 3. The analysis showed that there was an interaction between Emotional Class and Block, $F(4,136)=7.43$ $p<0.001$, (see figure 3) which indicated that the emotional class effect was present in only some of the blocks.

Although there was no interaction with Order, $F(4,136)=0.78$ $p>0.5$, it was thought that the peculiar emotional class by block interaction could be a result of the order EN producing no emotional class effects. To investigate this we conducted a simple interaction effects analysis of emotional class by block in the two orders NE and EN. It was found that there was no simple interaction effect of emotional class by block, $F(4,136)=2.26$ $p>0.05$, for the order NE but there was an effect, $F(4,136)=5.95$ $p<0.001$, for the order EN. Since the order EN produced no emotional stroop effect this simple interaction effect of emotional class by block could be interpreted as an idiosyncratic effect of the words in the order EN.

The main conclusion from these results is that emotional words produce slower colour naming times than neutral words but only in the order NE. Also in this order there is no interaction with block. These results are completely different from Experiment 3 which showed no effects of Order and an emotional stroop effect in only the first block.

(B) Analysis of Memory Tasks.
The number of neutral and emotional words recalled were transformed using the Freeman-Tukey Arc-Sine Transform. These scores were analyzed in a two-way analysis of variance with Emotional Class as a within-subject factor and Order as a between-subject factor. The main findings are presented in Table 3.

Table 3. Shows the proportion of words recalled and stem completed in Experiment 4.

Memory Task	Order	Neutral	Emotional
Recall	NE	0.234	0.544
	EN	0.344	0.422
Stem Completion		0.256	0.200
Stem Completion Controls		0.034	0.062

The analysis showed that emotional words were recalled more often than neutral words, $F(1,34)=10.96$ $p<0.003$, and that it interacted with Order, $F(1,34)=5.05$ $p<0.04$. Simple main effects revealed that emotional words were recalled more

than neutral words for the order NE, $F(1,34)=15.44$ $p<0.001$, but not Order EN, $F(1,34)=0.57$ $p>0.1$. These results are identical to experiment 3 in showing an emotional class effect and a recency effect for the recall data.

Due to the large number of zero responses in the stem completion control condition an analysis of variance could not be conducted. Therefore, a difference score was computed to take into account the control condition and then a t-test was calculated to see if there was an effect of emotional class. This showed no effect of emotional class $t(35)=1.61$ $p>0.05$. Thus in contrast to the recall data the stem completion data shows no effect of emotional class. However, there are priming effects such that words presented in the experiment were used more often as stem completions than words not presented, $t(39)=4.25$ and 4.85 $p<0.01$, for the emotional and neutral words respectively.

(C) Skin Conductance

The skin conductance scores (in micro siemens, μS) were analyzed in a four-way analysis of variance, with Order (NE and EN) as a between-subjects factor, and Emotional Class (E and N), Block and Words as within-subject factors.

The analysis showed that skin conductance levels were not significantly different for the emotional (2.75μS) and neutral (2.77μS) words, $F(1,34)=0.02$ $p>0.8$. However, this interacted with Order, $F(1,34)=5.61$ $p<0.03$. Simple main effects analysis showed that this was due to a significant simple main effect of order for the neutral words, $F(1,34)=16.65$ $p<0.001$, but not the emotional words, $F(1,34)=0.53$ $p>0.1$, no other simple effects were significant. Since there were no simple main effects of emotional class these results are not readily interpreted.

The only other effect that was significant was the main effect of block, $F(4,136)=3.34$ $p<0.02$. Tukey multiple comparison tests indicated that the skin conductance levels increased from block 1 to block 5 but only significantly between block 1 and 5.

DISCUSSION

The habituation response observed in Experiment 3 was clearly absent in the present experiment once again indicating the importance of output system. It is also clear that sequential presentation does not guarantee the elimination of order effects for all output systems: sequential presentation eliminates the order effect for manual output but not for vocal output. The order effect observed in the present experiment replicates the previous order effect for vocal output, see figure 1. Interestingly, in the order neutral then emotional the interference effect occurs throughout the experiment showing no signs of a decrease with stimulus repetition.

The explicit memory task once again revealed that emotional stimuli are more effectively recalled. However, no such difference was found for the implicit task. There were clear priming effects for those stimuli previously presented but there was no evidence of any difference between the emotional and neutral stimuli. It is perhaps premature to conclude that emotional class is another factor which differentially effects implicit and explicit tasks. It is possible that the lack of difference in the implicit task reflects a ceiling effect on priming. In other words each stimulus, whether it be emotional or neutral, is repeated so frequently throughout the experiment that the priming due to constant repetition may be so great as to conceal any differences due to emotional class.

EXPERIMENT 5

INTRODUCTION

Perhaps the simplest results in the present series of experiments were observed in Experiment 3 where no order effects occurred and the emotional effect decreased over time. This habituation effect deserves further study. In particular it needs to be determined which attributes of the stimulus result in a decreased disruptive effect over time. Is the habituation effect due to the repetition of the individual stimulus or is it due to the repetition of stimuli within the same semantic category? In other words as the experiment proceeds is the adaptation to any threat related stimulus or to the individual stimulus alone? These two alternative hypotheses can be experimentally distinguished by presenting different emotional stimuli in each block throughout the course of the experiment. If the adaptation process operates at the level of the semantic category then the same decrease in emotional interference demonstrated in Experiment 3 should be observed the present experiment. Alternatively, if the adaptation process operates at the level of the individual stimulus the emotional interference should occur throughout the course of the experiment.

By increasing the number of emotional stimuli and decreasing the number of stimulus repetitions the present experiment permits an investigation of the explanation offered for the implicit memory findings in the previous experiment. It was argued that a ceiling effect on priming may have occurred through stimulus repetition. If this was the case then the present experiment now offers an opportunity for emotional class differences to emerge.

METHOD.

Subjects. Forty University of Reading students took part in Experiment 5. Twenty in each order (NE and EN).

Design. The design formed a 2 x 2 x 5 factorial modal

with Order as a between-subjects factor, Emotional class and block as within-subject factors. In each of the five blocks a different set of five words were used. The first five neutral and emotional words outlined in the materials section were presented in the first block, the second five in the second block etc. The words presented in each block remained the same across all the subjects. But within each block the words were randomly presented to each subjects.

Materials. The words used in the experiment were all written in capital letters and were as follows, Neutral words: GATE, NOTE, CLOCK, THUMB, FIELD, ROSE, LEVER, CURVE, LEAGUE, PATROL, WIRE, BREAD, COVER, AUTUMN, ANCHOR, FOOT, SHOP, NAVAL, SENIOR, EXCEED, CALL, LINK, PLATE, DIVIDE and WILLOW. Emotional words: FAIL, FEAR, CRASH, GRIEF, DEATH, PAIN, GLOOM, ANGRY, MURDER, CANCER, HATE, SHOCK, ENEMY, AFRAID, MISERY, EVIL, KILL, GUILT, TRAGIC, THREAT, FIRE, RAGE, PANIC, BEATEN and SORROW.

Procedure. The procedure for this experiment was identical to experiment 3. At the end of the experiment subjects were given two incidental memory tasks, a recognition and a stem completion task. Half the subjects received the recognition task before the stem completion task whereas the other half in the reverse order. For the recognition task the 50 words used in the neutral and emotional class conditions were presented to the subjects with another set of 50 stimuli as distracters. These one hundred stimuli were presented in a random order simultaneously in a 10 x 10 matrix. Four different random matrices were used and distributed randomly across subjects. All subjects were asked to make three types of responses, to circle the words that they saw in the experiment, to cross out the words they did not see and to leave blank those they were unsure about.

The stem completion task was introduced to the subjects in the same way as experiment 4: "I would like you now to take part in another experiment. This is an experiment that I will be conducting in the future and involves presenting certain types of words to subjects. What I would like you to do is to help me generate some of these words." A stem completion task was then presented in which the first two letters, and blank lines to represent the length of the word, were provided as partial cues and subjects were asked to complete the stem with the first word that came to mind. However, proper nouns and plurals which were formed by adding an 's' at the end could not be used (e.g. trains). One hundred stem completions were presented, fifty with the same prefixes as the words in the experiment (e.g. DE _ _ _ _ for DEATH and FI_ _ _ for FIELD) and fifty were controls that were matched for frequency and number of possible completions. The 100 stimuli were presented on a sheet of paper simultaneously in 20 rows of 5 columns. Four random matrices of 100 stimuli were produced and randomly distributed across subjects. Subjects were encouraged to

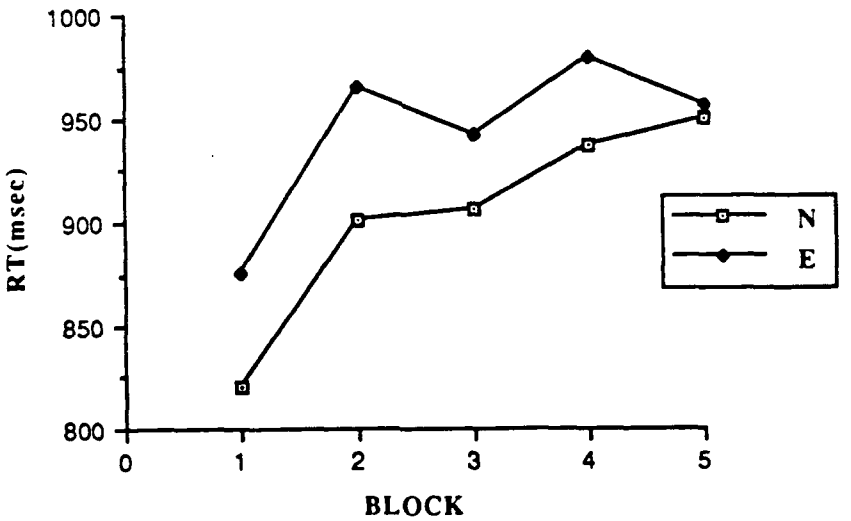
complete all the stems, but were stopped after fifteen minutes of doing this task if they had not completed the task.

RESULTS

(A) Analysis of Emotional Stroop.
The mean correct reaction time across blocks is presented in Figure 4. The reaction time scores were analyzed in a four-way analysis of variance, with Order as a between-subjects factor, Emotional Class, Block and Words as within-subject factors.

The analysis showed that emotional words took longer to colour name (943.89 msec) than neutral words (903.30 msec), $F(1,38)=15.45$ $p<0.0001$. As in experiment 3 there was no interaction with Order, $F(1,38)=1.08$ $p>0.3$, and a main effect of Block, $F(4,153)=18.87$ $p<0.0001$. Tukey multiple comparison tests indicated that this was due to the first block showing significantly faster reaction times than any of the other four blocks.

Figure 4. Mean manual reaction time to colour name neutral and emotional words of the five blocks in Experiment 5.



The main question asked in this experiment was whether using different words in each block would produce an emotional class effect across all the blocks or only in the first block as in experiment 3. The analysis showed that there was no interaction between Emotional Class and Block, $F(4,152)=1.33$ $p>0.25$, which indicates that the emotional

class effect was produced across all the blocks. It can therefore be concluded that the results in experiment 3 were due to a word repetition effect rather than a class repetition effect. Although figure 4 seems to indicate that the emotional class effect is reduced by the fifth block the interaction did not approach statistical significance.

(B) Analysis of Memory Tasks.
The analysis was conducted separately for the recognition and stem completion data.

The recognition data was analyzed by firstly computing a d-prime score for the emotional and neutral words and then conducting an analysis of variance on an arcsine transformed d-prime score (2*arcsine[sqrt[d-prime]]) McNicol(1972)[34]. The analysis was a 2 X 2 X 2 X 5 analysis of variance with *Task Order (recognition task before or after the stem* completion task) and Class order (NE or EN) as the between-subject factors and Emotional Class and Block as the within-subject factors.

The analysis produced two significant effects. Emotional words (d-prime=0.74) were recognized more than neutral words (d-prime=0.62), $F(1,36)=49.67$ $p<0.0001$, and there was a main effect of Task order, $F(1,36)=6.66$ $p=0.014$, such that there were more words recognized if the recognition task was presented immediately after the stroop task (0.74) than if *presented after the stem completion task (0.62).* These results extends the findings from Experiments 1, 2 and 3 in showing an effect of emotional stimuli for a recognition task.

The stem completion data was analyzed by transforming (Freeman-Tukey Arcsine Transform) the number of correct emotional or neutral words reported in an analysis of variance. The analysis was a 2 X 2 X 2 X 2 X 5 analysis of variance with Task order (stem completion task before or after the recognition task) and Class order (NE or EN) as a *between-subject factors and Emotional Class, Experimental* condition (experimental or control words) and block as within-subject factors. The proportion of words stem completed are presented in Table 4.

Table 4 Shows the proportion of words stem completed in Experiment 5.

	Neutral	Emotional
Stem Completion	0.15	0.19
Stem Completion Controls	0.08	0.09

The analysis showed that words presented during the

experiment were stem completed more than the control words, $F(1,38)=59.41$ $p<0.0001$, and that the interaction with Emotional Class approached statistical significance, $F(1,38)=3.41$ $p=0.07$. Simple main effects analysis showed that for the words presented in the experiment there was more priming for the emotional words than the neutral words, $F(1,38)=11.89$ $p<0.01$, but not for the words in the control condition, $F(1,38)=0.70$ $p>0.05$, see Table 4.

DISCUSSION

The results from the present experiment clearly indicate that the habituation response observed in Experiment 3 was due to a stimulus repetition effect and not a semantic category repetition. The fact that there was a tendency for the last block to show a diminished effect raises the possibility that there is also a category repetition effect. However, the most obvious alternative is that the stimuli in the last block were simply less potent than the other stimuli and had they been presented in other positions they might still have produced little effect.

The present results also demonstrate one technique for multiplying the magnitude of the emotional effect, a result which may have practical implications for the design of a robust measure of stress resistance. The lack of order effects replicates the findings in Experiment 3 indicating that sequential stimulus presentation with manual output does not result in order effects.

Recognition of emotional stimuli was shown to be more effective than neutral stimuli. This result extends the previous recall results and generalises the results to another explicit memory task. Implicit memory also showed significant effects of emotional class suggesting that the previous failure to find any effect may have been due to a ceiling effect on priming.

EXPERIMENT 6

INTRODUCTION

One of the most robust findings in the present series of experiments is the general decrement in performance over time. This occurs for both neutral and emotional stimuli and has been labelled flagging attention indicating that subjects may be having difficulty in maintaining an attentional set. One factor which may be critical in producing flagging attention is the considerable time pressure in which the task is undertaken. The stimulus presentation and response sequence is such that as soon as one response has been made the next response is demanded by the immediate presentation of the following stimulus. There is no interstimulus interval in which a recovery and

preparation for the next stimulus may take place. It is hypothesised, therefore, that the introduction of an interstimulus interval will eliminate flagging attention. By introducing an interstimulus interval the task will be made less difficult and a recovery from the previous stimulus enabled. Reducing the time pressure may, of course, eliminate not only flagging attention but also the emotional interference.

METHOD.

Subjects. Forty University of Reading students took part in Experiment 6. Twenty in each order (NE and EN).

Design. The design formed a 2 x 2 x 5 factorial modal with Order as a between-subjects factor, Emotional class and block as within-subject factors. In each of the five blocks a different set of five words were used. The first five neutral and emotional words outlined in the materials section formed a block, the second five also formed a block and so on. The words presented in each block were counterbalanced across all the subjects using a latin square design and within each block the words were randomly presented to each subjects.

Materials. The words used in the experiment were all written in capital letters and were as follows, Neutral words: GATE, NOTE, CLOCK, THUMB, FIELD, ROSE, LEVER, CURVE, LEAGUE, PATROL, WIRE, BREAD, COVER, AUTUMN, ANCHOR, FOOT, SHOP, NAVAL, SENIOR, EXCEED, CALL, LINK, PLATE, DIVIDE and WILLOW. Emotional words: FAIL, FEAR, CRASH, GRIEF, DEATH, PAIN, GLOOM, ANGRY, MURDER, CANCER, HATE, SHOCK, ENEMY, AFRAID, MISERY, EVIL, KILL, GUILT, TRAGIC, THREAT, FIRE, RAGE, PANIC, BEATEN and SORROW.

Procedure. The procedure for this experiment was identical to experiment 5. At the end of the experiment subjects were given two incidental memory tasks, a recognition and a stem completion task. Half the subjects received the recognition task before the stem completion task whereas the other half in the reverse order. For the recognition task the 50 words used in the neutral and emotional class conditions were presented to the subjects with another set of 50 stimuli as distracters. These one hundred stimuli were presented in a random order simultaneously in a 10 x 10 matrix. Four different random matrices were used and distributed randomly across subjects. All subjects were asked to circle the words that they saw in the experiment, cross out the words they did not see and to leave blank those they were unsure about.

The stem completion task was introduced to the subjects in the same way as experiment 5. One hundred stem completions were presented (fifty with the same prefixes as the words in the experiment (e.g. DE _ _ _ for DEATH and FI_ _ _ for

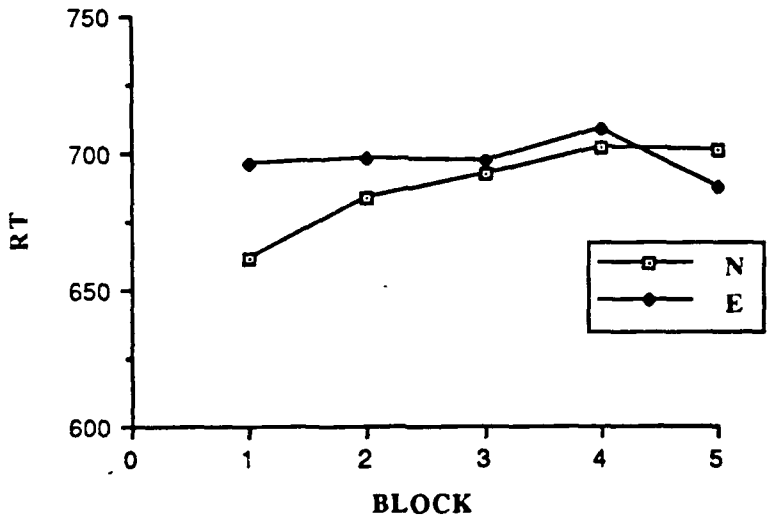
FIELD), fifty were controls that were matched for frequency and number of possible completions as the experimental stimuli. The 100 stimuli were presented on a sheet of paper simultaneously in 20 rows of 5 columns. Four random matrices of 100 stimuli were produced and randomly distributed across subjects. Subjects were given as much time as they needed to complete all the stems and could complete the stems in any order. Subjects were encouraged to complete all the stems, which most of them were able to do.

RESULTS AND DISCUSSION

(A) Analysis of Emotional Stroop.

The mean correct reaction time across blocks is presented in Figure 5. A four-way analysis of variance was conducted, with Order as a between-subjects factor, Emotional Class, Block and Words as within-subject factors.

Figure 5. Mean manual reaction time to colour name neutral and emotional words of the five blocks in Experiment 6 with an interstimulus interval of one second.



The analysis showed that there was no main effect of Block, $F(4,152)=1.89$ $p>0.1$, which indicates that by introducing a one second interstimulus interval eliminates the flagging attention effects found in experiments 3 and 5, see figure 5. Also there were no other main or interaction effects that were significant. There was no difference in the colour naming of emotional words (699.49 msec) over neutral words (687.97 msec), $F(1,38)=1.24$ $p>0.27$.

(B) Analysis of Memory Tasks.
The analysis was conducted separately for the recognition and stem completion data.

The recognition data was analyzed by firstly computing a d-prime score for the emotional and neutral words and then conducting an analysis of variance on an arcsine transformed d-prime score (2*arcsine[sqrt[d-prime]]). The analysis was a 2 X 2 X 2 X 5 analysis of variance with Task Order (recognition task before or after the stem completion task) and Class order (NE or EN) as the between-subject factors and Emotional Class and Block as the within-subject factors. The d-prime scores across the five blocks is presented in Table 5.

Table 5. Shows the proportion of words recognized (d-prime scores) in Experiment 6.

	BLOCK				
	1	2	3	4	5
Emotional	0.80	0.77	0.76	0.78	0.76
Neutral	0.72	0.64	0.68	0.67	0.66

The analysis produced two significant effects. Emotional words (d-prime=0.78) were recognized more than neutral words (0.67), $F(1,36)=34.69$ $p<0.0001$, and there was a main effect of block, $F(4,144)=2.69$ $p=0.03$, such that words in the first block (0.76) were better recognized than words in any other block (0.71), although this was not significant using a tukey multiple comparison test, see Table 5.

The stem completion data was analyzed by transforming (Freeman-Tukey Arcsine Transform) the number of correct emotional or neutral words reported in an analysis of variance. The analysis was a 2 X 2 X 2 X 2 X 5 analysis of variance with Task order (stem completion task before or after the recognition task) and Class order (NE or EN) as between-subject factors and Emotional Class, Experimental condition (experimental or control words) and block as within-subject factors. The proportion of words stem completed are presented in Table 6.

Table 6. Shows the proportion of words stem completed in Experiment 6.

	Neutral	Emotional
Stem Completion	0.15	0.21
Stem Completion Control	0.07	0.08

The analysis showed that words presented during the experiment were stem completed more than the control words, $F(1,36)=20.90$ $p<0.0001$, and that this interacted with Task order, $F(1,36)=3.93$ $p=0.0551$. Simple main effects analysis showed that this was due to more priming for the experimental words when the stem completion task was presented after the recognition task, $F(1,36)=11.49$ $p<0.01$. This was not significant for the control words, $F(1,36)=0.34$ $p>0.1$. This therefore indicated that the recognition task had a carry over effect on the stem completion task in the extent of priming observed. Although the Experimental condition did not interact with Emotional Class, $F(1,36)=2.00$ $p=0.166$, simple main effects analysis showed that for the words presented in the experiment the emotional words were stem completed more than neutral words, $F(1,36)=9.37$ $p<0.01$, but not for the control words, $F(1,36)=1.12$ $p>0.1$, see Table 6. To confirm this interaction the difference between the experimental and control words was computed and a t-test calculated between the differences. This showed that emotional words were stem completed more than neutral words $t(39)=2.021$ $p<0.05$. This result replicates the effect found in experiment 5.

DISCUSSION

The results clearly indicate the importance of time pressure. By allowing a recovery from the previous stimulus and preparation for the next, the very large effects of both flagging attention and emotional interference have been entirely eliminated. The experiment may indicate the presence, therefore, of an adaptive coping process which eliminates the emotional interference. The disruptive effects of emotional stimuli under time pressure may be explained by the "emotional lingering hypothesis". Here the hypothesis is that the emotional stimuli are still being processed after a response has been made. When there is no time pressure the processing of the emotional is completed before the next stimulus is presented. However, when there is time pressure the subject is still processing the previous emotional stimulus when the current stimulus is presented.

The memory results replicate and extend the previous findings. Both implicit and explicit tasks demonstrate the greater availability of emotional stimuli. The primacy effect observed in the recognition task was not present in the stem completion task suggesting that there may be grounds for a dissociation between implicit and explicit tasks. The fact that there are emotional memory effects even though there is no performance decrement indicates that the emotional stimuli are being processed, though in this case in a manner which does not produce interference.

EXPERIMENT 7

INTRODUCTION.

Although the effects of time pressure observed in the previous experiment were interpreted in terms of the emotional lingering hypothesis there is an alternative. It is possible that any manipulation which decreases the competition for limited resources will eliminate the emotional interference. In other words it is possible that task difficulty is the important factor. If emotional stimuli consume resources and these resources are limited then emotional interference may occur. However, if the task is made easier so that fewer resources are necessary then the extra resources required by the emotional stimuli may not exceed the limited resources. An attempt was made to examine this hypothesis by retaining time pressure but making the task simpler and observing whether the emotional interference disappears. This was done by reducing the number of responses required from four to two.

Previous experiments have shown that emotional material is more readily recalled than neutral material. One characteristic feature of free recall tasks is that they show serial position effects. Typically recency effects are found such that the last few items are recalled more effectively than any of the preceding items (Baddeley & Warrington 1970)[35]. This raises the possibility, which will be investigated in the present experiment, that the greater availability of emotional stimuli may be confined to one part of the serial position curve.

METHOD

Subjects. Forty University of Reading students took part in Experiment 7. Twenty in each order (NE and EN).

Design. The design formed a 2 x 2 x 5 factorial modal with Order as a between-subjects factor, Emotional class and block as within-subject factors. In each of the five blocks a different set of five words were used. The first five neutral and emotional words outlined in the materials section formed a block, the second five formed another block and so on. The words presented in each block were counterbalanced across all the subjects using a latin square design and within each block the words were randomly presented to each subjects.

Materials. The words used in the experiment were all written in capital letters and were as follows, Neutral words: GRIP, WAIT, FLEET, VIOLA, PRESS, NARK, LEVER, SOLAR, NOBODY, BARREL, POND, TRUCK, WAGON, SAMPLE, ANCHOR, SEND, FLAT, FEWER, BRANCH, EXCEED, SOON, RUIN, LAYER, POTATO and DIVIDE. Emotional words: HURT, HELL, CHAOS, FATAL, ALONE, LOSS, GLOOM, TENSE, DANGER, INJURY, BORE, SPITE, WORRY, BITTER, HAZARD, EVIL, BEAT, DIRTY, SUFFER, BURNED, MEAN,

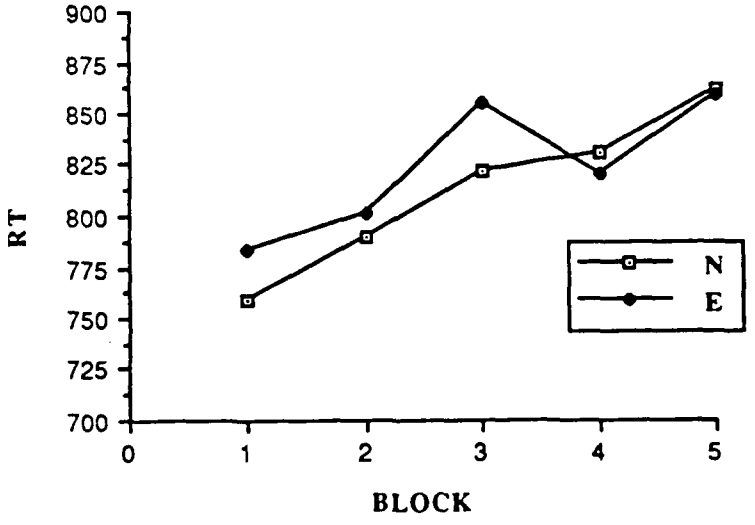
WEEP, HARSH, HORROR and BEATEN.

Procedure. This experiment was exactly the same as experiment 5 except that (i) there was stimulus-response mapping of 4 to 2 such that the responses to the four ink colours (red, green, blue and brown) were made by using the index fingers from each hand. For half the subjects the red and green ink colours were responded to with the left finger and the blue and brown colours with the right finger, and the reverse for the other half of the subjects. (ii) The words used in the experiment were different from those used in experiment 5, (iii) Subjects were unexpectedly given a free recall task at the end of the experiment. (iv) Subjects skin conductance levels were also measured.

RESULTS

(A) Analysis of Emotional Stroop.
The mean correct reaction time across blocks is presented in Figure 6. A three-way analysis of variance was conducted, with Order as a between-subjects factor, Emotional Class and Block as within-subject factors.

Figure 6. Mean manual reaction time to colour name neutral and emotional words of the five blocks in Experiment 7 with a stimulus to response mapping of 4 to 2.



The analysis showed that there were no main or interaction effects that were significant, except for a main effect of Block, $F(4,152)=8.18$ $p<0.001$. There was no difference in the colour naming of emotional words (823.63 msec) over

neutral words (812.29 msec), $F(1,38)=1.47$ $p>0.20$, see figure 6. Tukey multiple comparison tests showed that the main effect of Block was due to block 1 showing significantly faster reaction times than blocks 3, 4 and 5, and block 2 faster than block 5.

(B) Analysis of the Recall task.
The proportion of words recalled are presented in Table 7. The analysis of the data was conducted on the Freeman-Tukey Arc-Sine Transform scores of the number of correctly recalled words. A three-way analysis of variance with Order as a between-subject factor and Emotional Class and Block as the within-subject factors. The main question asked is, are there any effects of Emotional Class and any effects of Block?

The analysis showed (i) that there was a main effect of emotional class, $F(1,38)=7.34$ $p=0.01$, such that emotional words (0.08) were recalled more than neutral words (0.04). However, this interacted with Order, $F(1,38)=7.12$ $p=0.011$. Simple main effects analysis showed that there was an emotional class effect only in the order NE, $F(1,38)=14.46$ $p<0.001$, see Table 7.

Table 7. Shows the proportion of words recalled in Experiment 7.

Order	Emotional Class	Block 1	2	3	4	5
NE	Neutral	0.02	0.00	0.04	0.03	0.10
	Emotional	0.08	0.05	0.09	0.07	0.22
EN	Neutral	0.03	0.01	0.02	0.03	0.15
	Emotional	0.05	0.04	0.03	0.01	0.13

(ii) There was a main effect of Block, $F(4,152)=13.76$ $p<0.001$. Tukey multiple comparison test showed that this was because more words were recalled from the last block than any other block, that is there was a recency effect. The three-way interaction between Order x Emotional Class and Block was not significant, $F(4,152)=0.61$ $p>0.6$, indicating that the order effects found for the emotional stimuli have the same pattern in each of the five blocks. Thus emotional words are processed in the same way in the recency part of the position curve as in the non-recency part.

(C) Analysis of Skin Conductance.
The skin conductance scores were analyzed in a three-way analysis of variance, with Order as a between-subjects factor, Emotional Class and Block as within-subject factors.

The analysis showed that there were no main or interaction effects of any of the factors.

DISCUSSION

Manipulating task difficulty by making the task easier eliminated emotional interference suggesting that competition for limited resources may be a critical feature in the occurrence of the emotional performance decrement. The link between task difficulty and emotional arousal goes back to Yerkes and Dodson (1908)[36] who suggested that high levels of arousal could be tolerated for simple tasks but not for difficult tasks. The uncontrolled extra processing demands which occur for emotional stimuli may result in interference only when there is competition for limited resources.

The re-emergence of flagging attention in the absence of emotional interference has two major implications. First, that time pressure is a critical factor in flagging attention and second it suggests, though does not definitively demonstrate, the independence of flagging attention and emotional interference. Although flagging attention has been demonstrated in the absence of emotional interference the reverse, namely, emotional interference in the absence of flagging attention has not been demonstrated. However, it is clear that a range of factors differentially affect flagging attention and emotional interference. Stimulus repetition and task difficulty eliminate the emotional interference but do not affect flagging attention.

Recency effects were demonstrated for recall though the greater availability of emotional stimuli was not specific to any particular serial position and occurred throughout all positions.

EXPERIMENT 8

INTRODUCTION.

In Experiment 3 the emotional interference occurred early in the experiment and was short lived suggesting that subjects habituate or adapt to the emotionality of the stimulus. It was also shown (Experiment 5) that the elimination of the interference effect was dependent on repetition of the stimulus once again suggesting that habituation is an appropriate description of this phenomenon. As Mackintosh (1987)[37] has noted, habituation may be the most widespread form of learning, having been documented in humans and a very wide range of animals.

Having demonstrated that stimulus repetition is the key factor, one important theoretical issue which emerges concerns the attributes of the stimulus which are critical for habituation. For example, spatial location is an important attribute of the stimulus but is it critical for habituation? In other words is the stimulus "death" presented in one location processed as a repetition of the stimulus "death" in another location, or do the two

locations mean that the stimuli are processed as separate stimuli.

Effects of spatial location have important implications for the level in the system at which the habituation response takes place. The meaning of the stimulus is clearly independent of its' spatial location so if the habituation effect occurs at the semantic level then the repetition of a stimulus with the same meaning should result in an habituation effect independent of spatial location. However, if the spatial location of the stimulus is an integral part of the stimulus then the repetition of a stimulus with the same meaning but different spatial location should result in no habituation. The present experiment endeavours to distinguish between these two hypotheses by varying the spatial location of the stimulus.

METHOD.

Subjects. Forty University of Reading students took part in Experiment 8. Twenty in each order (NE and EN).

Design. The design formed a 2 X 2 factorial modal with Emotional Class (Neutral or Emotional words) as a within-subject factor and Order (NE or EN) a between-subject factor.

Materials. The words used in the experiment were all written in capital letters and were as follows, Neutral words: ROSE, LEVER, CURVE, LEAGUE and PATROL. Emotional words: PAIN, ABUSE, ANGRY, MURDER and CANCER. In the practice session repeated letter strings were used: OOOOO, XXXX, HHHH, SSSSS and PPPPP.

Procedure. The emotional task involved presenting a single word at varying positions on the screen. A 10 x 20 matrix centred around the middle of the screen was chosen to present the stimuli. Each of the one hundred emotional and neutral stimuli could be positioned at any one of the 200 locations at random and without repeating the same location for the same class of word. Each stimulus remained on the screen until a response was made and the next stimulus presented immediately, that is the interstimulus interval was 0 sec. Each of the five neutral or emotional words were written in four ink colours, red, green, blue and brown. These twenty stimuli were randomized with one restriction, that the same word or colour did not repeat itself on consecutive trials. This formed one block in the stimulus array, five such blocks were formed to produce 100 stimuli for each class of words, which were presented sequentially on the screen on a white background.

The subjects were introduced to the task as a colour perception task in which they would be presented a word in one of four ink colours. They were shown 20 repeated letter strings to familiarize them with the ink colours. They were

instructed to ignore the words and make a key-press response to the colour of the ink as quickly and accurately as possible. If any errors were made they were asked not to correct themselves.

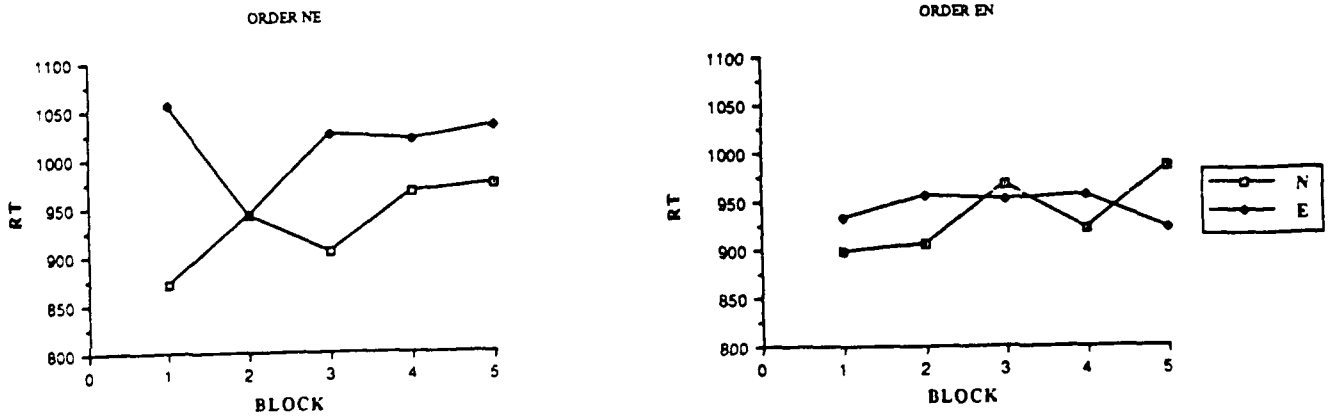
Before conducting the experiment all subjects were given two practice sessions using 200 coloured letter string stimuli with a short break after 100 stimuli. The experiment involved presenting 100 emotional and 100 neutral stimuli. Subjects were informed that real words were going to be presented (the difference between the emotional and neutral words was not mentioned) however, all subjects were instructed to ignore the word stimuli and report only the ink colours as quickly and accurately as possible. All responses were made using one of four buttons as in Experiment 3.

At the end of the experiment subjects were given an incidental free recall task of all the words seen in the experiment.

RESULTS

(A) Analysis of Emotional Stroop.
The mean correct reaction time across blocks is presented in Figure 7. The reaction time scores were analyzed in a four-way analysis of variance, with Order as a between-subjects factor, Emotional Class, Block and Words as within-subject factors.

Figure 7. Mean manual reaction time to colour name neutral and emotional words of the five blocks in Experiment 8. The stimuli were presented randomly at different spatial locations.



The analysis showed that emotional words took longer to colour name (979.01 msec) than neutral words (933.26 msec), $F(1,38)=18.84$ $p<0.0001$. This difference is almost twice as large as that found in Experiment 3, and hence supports the view that spatial location produces greater emotional disruption. Although there was a three-way interaction between Emotional Class, Order and Block, $F(4,152)=2.49$ $p<0.05$, (see figure 7) it can be seen that the main result was the two-way interaction between Order and Emotional Class, $F(1,38)=12.84$ $p<0.001$. Simple main effects analysis indicated that there was an emotional class effect for the order NE, $F(1,38)=31.38$ $p<0.001$, but not the order EN, $F(1,38)=0.29$ $p>0.1$. This analysis also indicated that the emotional words were colour named much slower in the order NE (1014.97 msec) than EN (943.11 msec), $F(1,38)=23.25$ $p<0.001$, but there was no significant difference for the neutral words, $F(1,38)=0.06$ $p>0.1$, (931.48 and 935.04 msec). One other result was significant, the main effect of block, $F(4,152)=2.44$ $p<0.05$. Tukey multiple comparison tests showed that this was due to blocks 1 and 2 being significantly faster than blocks 3, 4 and 5.

(B) Analysis of free recall.
A two-way analysis of variance was conducted with Order as a between-subjects factor and Emotional Class as a within-subjects factor. The analysis showed that emotional words were recalled better than neutral words, $F(1,38)=14.99$ $p<0.001$, and this interacted with order, $F(1,38)=13.66$ $p<0.001$. Simple main effects analysis indicated that the emotional class effect was only present in the order NE, $F(1,38)=28.64$ $p<0.001$. The data also showed an effect of recency such that when the neutral words were presented after the emotional words they were better recalled than when presented before the emotional words, $F(1,38)=11.27$ $p<0.01$, however, for the emotional words this was insignificant, $F(1,38)=3.50$ $p>0.05$.

(C) Skin Conductance.
The skin conductance produced no effects that were significant.

DISCUSSION

The major difference between the present experiment and Experiment 3 was that spatial location was varied in the present experiment. It is clear, therefore, that spatial location has an important effect. In the order neutral stimuli then emotional there was no decrease in the emotional interference over trials, suggesting that the habituation is not to the meaning of the stimulus. This particular result would also suggest that an emotional word presented in different spatial locations is processed as a different stimulus for each location. However, these conclusions must be questioned by the fact that there was no emotional interference in the order emotional then neutral. Although order effects do not generally occur with

sequential presentations and manual output the present experiment demonstrates that there are particular circumstances when they do occur.

EXPERIMENT 9

INTRODUCTION

Throughout this series of experiments it has been clear that emotional stimuli have very clear and potent effects on performance and memory. Emotional stimuli disrupt performance and are readily available to implicit and explicit memory. These general effects have been replicated and extended throughout this series of experiments. One major caveat which must be addressed before these conclusions are firmly established concerns the role of category effects. It is theoretically possible that the observed differences between emotional and neutral stimuli may not be causally related to the emotionality of the stimuli. The emotional and neutral stimuli have two properties which distinguish them, emotionality and category. Although all the emotional stimuli belong to the same category this is not true of the neutral stimuli. Therefore the emotional effects that have been found in the present series of experiments and elsewhere may simply be category effects. In order to address this issue Experiment 5 was repeated but this time the neutral stimuli formed a category. The category chosen was *environmental features*, for example, valley, ocean, forest etc.

The use of a neutral category set also has implications for the memory data. Many studies using different paradigms have shown that people have strong spontaneous tendencies to organize items into categories, and to use imposed groupings of this kind to aid recall (Mandler, 1967)[38]. For example, Tulving & Pearlstone (1966)[39] have shown that items that have been forgotten (e.g. kite) can often be recalled by using a category cue (e.g. toy). It is of interest, therefore, to determine whether the emotionality effects observed in both implicit and explicit memory tasks are in fact category effects rather than true emotionality effects.

METHOD.

Subjects. Forty University of Reading students took part in Experiment 9. Twenty in each order (NE and EN).

Design. The design formed a 2 x 2 x 5 factorial modal with Order as a between-subjects factor, Emotional class and block as within-subject factors. In each of the five blocks a different set of five words were used. The first five neutral and emotional words, outlined in the materials section, were grouped together in a block, the second five in another block etc. Each of the five groups of words were presented equally often in each of the five blocks across all the subjects using a cyclic latin square. Only four

blocks of stimuli were presented to the subjects in the experiment, with the fifth block being used as a control in the stem completion task.

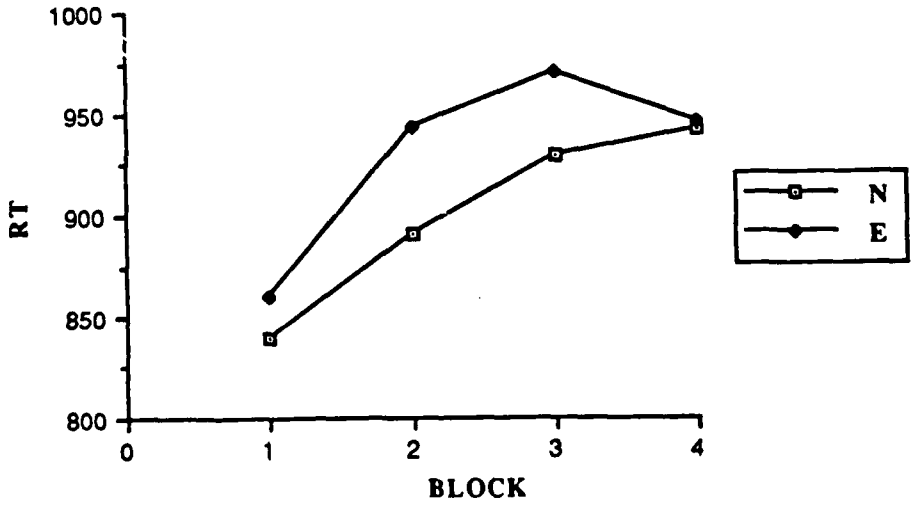
Materials. The words used in the experiment were all written in capital letters and were as follows, Environmental features category: SAND, CLAY, CLOUD, SLOPE, FIELD, BANK, DITCH, PLAIN, FOREST, MARBLE, DIRT, STONE, GLASS, VALLEY, TUNNEL, HILL, TREE, OCEAN, FLOWER, LEAVES, ROAD, BUSH, FAULT, MEADOW and GRAVEL. Emotional words: FAIL, FEAR, CRASH, GRIEF, DEATH, PAIN, ABUSE, ANGRY, MURDER, CANCER, HATE, SHOCK, ENEMY, AFRAID, MISERY, DOOM, KILL, GUILT, TRAGIC, THREAT, FIRE, RAGE, PANIC, SCREAM and SORROW.

Procedure. The procedure for this experiment was identical to experiment 5. In addition to measuring the reaction time to the experimental stimuli, experiment 9 also measured simultaneously the skin conductance levels. At the end of the experiment subjects were unexpectedly asked to conduct two memory tasks, a recognition and a stem completion task. The procedure for the memory task was again the same as Experiment 5, except that there were 30 distracters in the recognition task and 20 distracters in the stem completion task.

RESULTS

(A) Analysis of Emotional Stroop.
The mean correct reaction time across blocks is presented in Figure 8. The reaction time scores were analyzed in a four-way analysis of variance, with Order as a between-subjects factor, Emotional Class, Block and Words as within-subject factors.

Figure 8. Mean manual reaction time to colour name category neutral and emotional words of the five blocks in Experiment 9.



The analysis showed that emotional words took longer to colour name (929.81 msec) than neutral words (900.14 msec), $F(1,38)=7.34$ $p<0.01$. As in experiment 5 there was no interaction with Order, $F(1,38)=0.89$ $p>0.3$, and a main effect of Block, $F(3,114)=20.47$ $p<0.0001$. Tukey multiple comparison tests showed that this was due to the first block showing significantly faster reaction times than any of the other three blocks.

(B) Analysis of Memory Tasks.
The analysis was conducted separately for the recognition and stem completion data.

The recognition data was analyzed by firstly computing a d-prime score for the emotional and neutral words and then conducting an analysis of variance on an arcsine transformed d-prime score (2*arcsine[sqrt[d-prime]]). The analysis was a 2 X 2 X 2 X 5 analysis of variance with Task Order (recognition task before or after the stem completion task) and Class order (NE or EN) as the between-subject factors and Emotional Class and Block as the within-subject factors.

The analysis produced no significant effects indicating that emotional words (0.62) were not recognized more than neutral category words (0.59), $F(1,36)=2.20$ $p=0.15$.

The stem completion data was analyzed by transforming (Freeman Tukey arcsine transform) the number of correct emotional or neutral words reported in an analysis of variance. The analysis was a 2 X 2 X 2 X 2 X 5 analysis of variance with Task order (stem completion task before or after the recognition task) and Class order (NE or EN) as between-subject factors and Emotional Class, Experimental condition (experimental or control words) and block as within-subject factors. The proportion of words stem completed are presented in Table 8.

The analysis showed that words presented during the experiment were stem completed more than the control condition, $F(1,36)=7.75$ $p<0.001$. The Experimental condition did not interact with Emotional Class, $F(1,36)=0.45$ $p=0.51$, see Table 8. To confirm this the difference between the experimental and control words was computed and a t-test calculated between the differences. This showed that emotional words were not stem completed more than neutral words $t(39)=1.03$ $p>0.1$.

Table 8. Shows the proportion of words stem completed in Experiment 9.

	Neutral	Emotional
Stem Completion	0.23	0.23
Stem Completion Control	0.15	0.17

(C) Analysis of Skin Conductance.
The skin conductance scores were analyzed in a four-way analysis of variance, with Order as a between-subjects factor, Emotional Class, Block and Words as within-subject factors.

The analysis showed that there were no main or interaction effects of emotional class. There was only one effect which reached significance, the main effect of Block, $F(3,114)=7.89$ $p<0.0001$. Tukey multiple comparisons showed that this was due to a higher skin conductance for block 1 than blocks 3 and 4.

DISCUSSION

The results are clear and straightforward. There is no evidence to suggest that the emotional interference effect observed on performance is a category effect. Equally clearly there is every reason to believe that the large, robust and replicable memory effects <u>are</u> category effects. This conclusion holds true for both the implicit and the explicit tasks. Although earlier work has demonstrated category effect for explicit tasks it is now clear that the category effect can account for all of the difference between the emotional and neutral stimuli. There appears to be no evidence for any additional effect of emotionality. In addition the present results point, for the first time, to the potentially important role played by category in implicit memory tasks.

EXPERIMENT 10

INTRODUCTION
Although the performance decrement observed in the previous experiments has been labelled an emotional effect it is possible that this description is either too general or inappropriate. It may be too general because all the emotional stimuli have been negative. There have been, for example, no positive emotional stimuli. It is possible, therefore, that the disruptive effect is due to either negative stimuli only or that it is general to other emotional stimuli. The hypothesis discussed in the introduction to this series of experiments argued that it would make good biological sense to have a system which responded to threat which was rapid and took precedence over other goals. If this argument is correct then the performance decrement is likely to be specific to negative emotional stimuli.

An alternative theoretical account of the disruptive effects of emotional stimuli has been presented by Geller and Shaver (1976)[40]. They argued that it is the self relevance of the stimuli which is the critical factor. By examining the differences between positive and negative emotional stimuli it is possible to differentiate between the hypotheses. Brown (1986)[41] has shown that positive stimuli are rated as

more self relevant that negative stimuli. If the self relevance argument is correct then the positive stimuli should show a greater disruptive effect than the negative stimuli. If, however, a rapid response to threat is the critical factor then there should be disruptive effect for negative stimuli but not positive stimuli.

METHOD.

Subjects. Sixty University of Reading students took part in Experiment 10. Ten in each of the six orders involving the neutral, negative and positive emotional words.

Design. The design formed a 6 x 3 x 5 factorial model with Order as a between-subjects factor, Emotional class and block as within-subject factors. In each of the five blocks a different set of five words were used. The first five neutral and emotional words, outlined in the materials section, were grouped together in a block, the second five in another block etc. Each of the five groups of words were presented equally often in each of the five blocks across all the subjects using a cyclic latin square. Only four blocks of stimuli were presented to the subjects in the experiment, with the fifth block being used as a control in the stem completion task.

Materials. The words used in the experiment were all written in capital letters and were as follows, Neutral words: GATE, NOTE, CLOCK, THUMB, FIELD, SEND, PURSE, PILOT, FOURTH, BARREL, WIRE, CABIN, COVER, AUTUMN, ANCHOR, FOOT, SHOP, NAVAL, SENIOR, EXCEED, SOON, LINK, PLATE, DIVIDE and WILLOW. Negative emotional words: HURT, FEAR, CRASH, GRIEF, DEATH, DOOM, GLOOM, WORRY, DANGER, INJURY, HATE, SHOCK, ENEMY, AFRAID, MISERY, EVIL, KILL, GUILT, TRAGIC, THREAT, FIRE, RAGE, PANIC, BEATEN and SORROW. Positive emotional words: GLAD, HOPE, TREAT, BLISS, PEACE, FAIR, SUNNY, SMILE, BRIGHT, CARING, CALM, CHARM, HAPPY, VIRTUE, ADMIRE, NICE, WARM, PRIZE, POLITE, HEAVEN, LOVE, ROSY, LAUGH, SUPERB and JOYOUS.

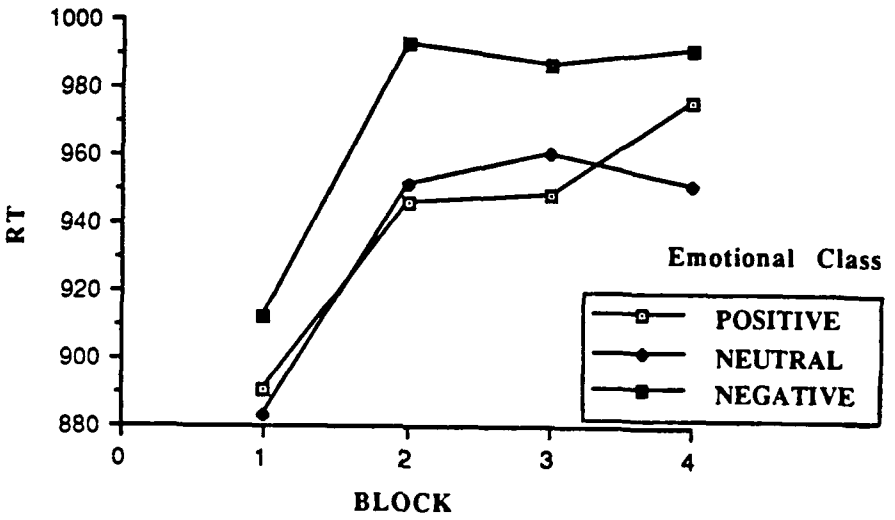
Procedure. The procedure for this experiment was identical to experiment 9. As in experiment 9 both reaction times and skin conductances were measured simultaneously. At the end of the experiment subjects were unexpectedly asked to conduct two memory tasks, a recognition and a stem completion task. The procedure for the memory task was again the same as Experiment 5, except that there were 15 distracters in the recognition task and 15 distracters in the stem completion task.

RESULTS

(A) Analysis of Emotional Stroop.
The mean correct reaction time across blocks is presented in Figure 9. The reaction time scores were analyzed in a four-

way analysis of variance, with Order as a between-subjects factor, Emotional Class, Block and Words as within-subject factors.

Figure 9. Mean manual reaction time to colour name neutral, positive, and negative emotional words of the five blocks in Experiment 10.



The analysis showed that there was a main effect of emotional class, $F(2,108)=5.87$ $p<0.004$. Tukey multiple comparison tests showed that negative emotional words took longer to colour name (970.73 msec) than positive emotional words (940.04 msec) and neutral words (936.48 msec), and there was no significant difference between the positive and neutral words, see Figure 9. There was also an interaction with Order, $F(10,108)=2.06$ $p=0.03$, simple main effect analysis and Tukey multiple comparison tests showed that there were no significant effects of positive emotional words when compared to neutral words for any of the six orders, but for three of the six orders there was a significant effect of negative emotional words. The analysis also showed a main effect of Block as in previous experiments, $F(3,162)=28.97$ $p<0.0001$. Tukey multiple comparison tests showed that this was due to the first block showing significantly faster reaction times than any of the other three blocks. Thus, these results parallel the results from Experiment 9 and extend these results by showing that the emotional class effects found in the stroop task are not due to category effects and that they are only found with negative emotional words.

(B) Analysis of Memory Tasks.
The analysis was conducted separately for the recognition and stem completion data.

The recognition data was analyzed by firstly computing a d-prime score for the emotional and neutral words and then conducting an analysis of variance on an arcsine transformed d-prime score (2*arcsine[sqrt[d-prime]]). The analysis was a 2 X 6 X 2 X 4 analysis of variance with Task Order (recognition task before or after the stem completion task) and Class order (NEP, NPE, ENP, EPN, PNE or PEN) as the between-subject factors and Emotional Class and Block as the within-subject factors.

The analysis produced a significant effect of Emotional class, indicating that positive emotional words (0.61) were recognized more than neutral words (0.56) and negative emotional words (0.57), $F(2,96)=3.12$ $p=0.049$. However, Tukey multiple comparison tests indicated that the positive emotional words were significantly more recognized than the neutral words but not the negative words.

The stem completion data was analyzed by transforming (Freeman Tukey arcsine transform) the number of correct emotional or neutral words reported in an analysis of variance. The analysis was a 2 X 6 X 2 X 2 X 4 analysis of variance with Task order (stem completion task before or after the recognition task) and Class order as between-subject factors and Emotional Class, Experimental condition (experimental or control words) and block as within-subject factors. The proportion of words stem completed are presented in Table 9.

The analysis showed that words presented during the experiment were stem completed more than the control condition, $F(1,54)=18.30$ $p<0.0001$. Also positive and negative words were stem completed more than the neutral words, $F(2,108)=8.69$ $p<0.003$, but this did not interact with the Experimental condition, $F(2,108)=0.59$ $p=0.56$, see Table 9. To confirm this the difference between the experimental and control words was computed and a t-test calculated between the differences. This showed that neither positive or negative emotional words were stem completed more than neutral words $t(59)=0.55$ and 1.20 $p>0.1$ respectively.

Table 9. Shows the proportion of words stem completed in Experiment 10.

	Neutral	Positive	Negative
Stem Completion	0.16	0.22	0.25
Stem Completion Control	0.11	0.15	0.18

(C) Analysis of Skin Conductance.
The skin conductance scores were analyzed in a three-way analysis of variance, with Order as a between-subjects factor, Emotional Class and Block as within-subject factors. The analysis showed that there were no main or interaction effects of emotional class.

DISCUSSION

The results indicate that there are no disruptive effects of positive stimuli but there are disruptive effects of negative stimuli. This pattern of results clearly does not support the self relevance proposition. In arguing for a self relevance effect, Geller and Shaver (1976)[40] used a paradigm which did not allow them to separate the effects of positive and negative stimuli. It is now clear that this distinction is critical. It is also clear that it is possible to be more specific concerning the description of the interference effect. At this stage it is more appropriately labelled as a negative emotional, or a threat effect.

The present results also replicate the category effects observed in the previous experiment. First, although the positive emotional stimuli form a category, this by itself is not sufficient to produce a performance decrement. However, if the memory results are considered it is found that there are no differences between the positive and negative stimuli in both the implicit and explicit memory tasks. The simplest explanation is that the positive and negative effects are category effects thus replicating the results of the previous experiment.

CONCLUSIONS AND RECOMMENDATIONS

There have been two major aims of the research outlined in this report. The first has been to explore the possibilities of developing an objective performance based measure of stress resistance and the second to determine the potential of developing a laboratory model of the effects of stress on performance. There have been attempts to assess stress resistance through self report measures. Although these attempts have, as noted in the general introduction, shown some success there are inherent limitations to this general approach. Quite simply, people have considerable powers of self presentation which allow them to manage the impressions they create. In many scenarios in which a measure of stress resistance might actually be used it would be a major assumption to presume that the individuals had no motivation to manage the impressions they create. For example, in using a test for selection there will be those who wish to do their best in order to be selected and conversely there may be those who wish to avoid being selected. Self report measures are very susceptible to impression management and the use of "lie scales" does not provide the assumed protection, a point which is well illustrated by the fact that Power and MacRae (1977) found that the group with the least lie scores were a group who had been instructed to lie.

The *Defence Mechanism Test* at least partially adopts a more performance based approach to assessing stress resistance. Unfortunately, the scoring procedures are complex, rely on subjective judgment and rest heavily on psychoanalytic theory, resulting in much controversy and little consensus. What is required is a simple performance based test.

The research outlined assesses the potential of the emotional Stoop task. It is shown that the task is sensitive to emotional stimuli which quite clearly disrupt performance. Although this interference effect has been shown in a wide range of studies there has been little previous analytical research investigating the nature of the effect. It has been proposed, for example, that the interference effect operates outside awareness and may reflect the operation of a defence mechanism (Mathews, 1988). It is now shown that the subjects are aware of the interfering stimuli thus refuting the defence mechanism hypothesis.

Although the present approach represents a departure from previous approaches, a body of research is now developing indicating the potential of the paradigm both as a measure of stress resistance and as a laboratory model of the effects of stress on performance. The role of time pressure has been demonstrated not only on overall performance but also on the adaptive process which eliminates the emotional interference effect. Under time pressure emotional stimuli have a large disruptive effect whereas under no time

pressure the emotional stimuli produce no disruptive effect. The important role which time pressure plays in tasks such as this has, up till this point been unacknowledged. Likewise, the role of order effects have been unacknowledged. Although McKenna (1986) did demonstrate order effects most recent research has failed to provide any analyses which would reveal them though they have used paradigms where they might be expected to occur.

The role of task difficulty has had an important part to play in the relationship between stress and performance and the present research, in line with previous work, suggests that disruption will be greater for more difficult tasks. There is evidence in the new computerised paradigm that the effect of the emotional may habituate. It is shown that this habituation is due to stimulus repetition and not to the repetition of a semantic category. There is also some evidence to suggest that spatial location is an important factor in the habituation response.

Throughout this series of experiments it has been shown that emotional stimuli are more available to memory. This is true whether the subject is asked to explicitly recall or recognise the prior stimuli or whether the subject is given a task which demonstrates the facilitation of task performance without the necessity of conscious recollection (implicit memory). However, it is also shown that these apparent emotional memory effects are really category effects, that is, it is the fact that the stimuli form a common class which increases their availability to memory and not their emotionality per se. The category effect cannot, however, account for the performance decrements produced by the emotional stimuli.

It has been possible to more clearly specify the nature of the interference effect. Although, the effect has been labelled an emotional interference effect it was demonstrated that the effect does not occur for positive emotional stimuli but rather occurs for negative or threat related stimuli.

Overall, although the approach is relatively new the paradigm being developed continues to show promise. A more clear understanding of the nature of the disruptive effects of negative emotional stimuli is now beginning to develop. This has ramifications not only for the newly developing field of cognition and emotion but also for the possibilities of producing more objective measures of stress resistance. The demonstrated effects of time pressure, task difficulty and habituation parallel the effects of everyday experience and suggest that the paradigm is of use in investigating the role of stress on performance. It would be recommended that the general approach and paradigm be considered for future development.

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