Article

Reinforcement, Arousal and Temporal Factors in Procedural Learning

A Test of Eysenck's and Gray's Personality Theories

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Abstract. An experiment examining the effects of reinforcement and personality on a procedural learning task tested H. J. Eysenck's (1968, 1979) incubation theory of the development of fear, relating to a "reminiscence" effect during a rest pause. Eysenck's arousal-based personality predictions for enhanced learning were contrasted with J. A. Gray's reinforcement sensitivity theory (RST) of personality. Measures of Extraversion (E) and Neuroticism (N) and Trait Anxiety were taken. Participants completed six blocks of a procedural learning task, under either punishment or control (no reinforcement) in one of two training conditions: (a) spaced training (four blocks of the task in the first session followed by retest on one block in two subsequent sessions, 24 h and 5 days later); or (b) massed training (six blocks of the task in a single session). Results showed that, under punishment, high trait anxiety led to enhanced learning in both training conditions; however, this increase was not predicted by Eysenck's arousal-based personality theory, but rather high anxiety facilitated learning in a manner consistent with RST predictions. There was no effect of spaced vs. mass training: Procedural learning increased over the course of the testing sessions under both conditions. Results failed to support Eysenck's predictions for reminiscence as a function of personality but suggested that learning was enhanced under punishment in line with RST's predictions for high anxiety. The implications of these data for current theories of personality are discussed.

Keywords: personality, reinforcement, arousal, procedural learning

Introduction

Despite the passing of many years, there remain important unanswered questions as to the relationship between Eysenck's (1967) arousal/activation theory and Gray's (1982) reinforcement sensitivity theory (RST) of personality (for a summary of these theories, see Corr, 2008a). This is nowhere more apparent than in their attempts to explain the development of clinical neurosis. One neglected issue in this area of personality concerns Eysenck's theory of incubation, which argues that temporal factors play an important role in the genesis and maintenance of neurotic reactions. To date, these temporal factors have not been considered in the light of Gray's alternative personality theory. Thus, this is one area of personality research where a set of newly-constructed contrasting hypotheses can be tested: Eysenck's and Gray's predictions can be put to a novel and fair test. As detailed below, the learning task chosen has previously been shown to produce arousal × extraversion (Eysenck's predictions) and punishment × anxiety (Gray's predictions) interactions, so that these theoretical positions may now be combined to test novel predictions of both theories. This is the aim of this article.

Eysenck's Incubation Theory of Neurosis

Eysenck (1968, 1979) proposed a theory of "incubation," defined as an increment in the strength of a conditioned response (CR) occurring during a period of unreinforced presentation of a conditioned stimulus (CS). In a typical classical conditioning paradigm, this is the period in which extinction is expected to occur. However, Eysenck differentiated between two uses of the term "incubation." The first is a traditional notion, defined as "a growth of fear over a time interval which follows some aversive stimulus. The increase in fear is assumed to be spontaneous in the sense that the time interval is free of further exposure to the aversive stimulus" (McAllister & McAllister, 1967, p. 180). This type of incubation involves a rest pause during which it is assumed that the consolidation of learning takes place, which in turn leads to the phenomena of "reminiscence" (Eysenck & Frith, 1977).

This traditional interpretation of the term "incubation" (i.e., reminiscence) – referred to by Eysenck (1968, p. 310) as "empty interval incubation" – can be contrasted with Eysenck's second explanation for incubation, which refers

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to increments in the strength of a CR over time when nonreinforced CS presentations are applied (influenced by such factors as CS exposure duration and UCS intensity). Both types of incubation can be seen to explain the growth of CRs: (a) in the absence of exposure to not only the UCS but also the CS; and (b) in the absence of reinforced CS presentations (UCS excluded). The issue of which of these processes may be, more or less, responsible for the genesis and maintenance of neurotic fears is still in need of clarification. Surprisingly, there has been little direct experimental investigation of these processes. There has been some support for second type of incubation (e.g., Sandin & Chorot, 1989; Chorot & Sandin, 1993); however, it is unclear to what extent the specific process of "reminiscence," as outlined above, may be responsible for the formation and enhancement of a conditioned fear response. Eysenck postulated that rest pauses facilitate consolidation of the memory trace: A process of consolidation transfers the memory trace into long-term storage. In addition, personality and arousal level are considered to be important factors.

With respect to incubation, Eysenck (1965) adapted some theoretical perspectives proposed by Walker and Tarte (1963) on the concept of "action decrement," which, they assert, has three processes:

a) In response to a psychological event, an active perseverative trace process is set up which lasts for a long period of time;
b) Two characteristics accompany this trace: (1) a permanent memory trace, and (2) a degree of temporary inhibition of recall (to protect the consolidating trace against disruption);
c) A state of high arousal during the associative process, which is hypothesized to result in a more intensely active trace process. It is postulated that more "intense activity" should result in better memory, but also a greater temporary inhibition against recall.

This final component to Walker and Tarte's theory, as incorporated by Eysenck, suggests that high arousal should lead to superior "reminiscence" effects, with initial high levels of inhibition. Indeed, Eysenck (1965) provided supportive evidence for the existence of enhanced performance following a rest pause (reminiscence), which cannot be attributed to fatigue alone.

Eysenck and Gray's Personality Theories

Both Eysenck and Gray proposed personality theories based on the biological underpinnings of temperaments. These individual differences in brain functioning can be used to explain the complex pattern of associations between personality traits and behavior. Eysenck's (1967) arousal-based theory of personality proposes that extraversion and neuroticism can be explained in terms of behavioral patterns dependent on genetically determined biological substrates. Extraversion is related to activation of the CNS, and is thought to reflect cortical arousal and individual differences in activity of the ascending reticular activating system (ARAS). Resting levels of the ARAS are higher for introverts than extraverts, so that introverts have higher cortical arousal than extraverts.

Neuroticism is related to limbic system reactivity, which mediates individual differences in response to emotional stimuli. Individuals high on this dimension become more highly aroused than do stable individuals in the presence of highly emotive stimuli. By virtue of neural projections from the limbic system to the ARAS, activation of the limbic system in emotional situations can lead to increases in cortical arousal. Consequently, individual variation in neuroticism may only be apparent in relation to emotional situations; hence, neuroticism is considered to be the underlying personality trait that predisposes an individual to respond to stress with neurotic symptoms (Eysenck, 1967).

Based on their underlying physiological substrates, both of Eysenck's dimensions of extraversion and neuroticism can be used to make testable predictions. Introverts are expected to condition more quickly than extraverts, and their conditioned responses should be more difficult to extinguish; neurotic individuals should show greater autonomic reactivity causing more intense reactions to emotional situations and, consequently, increases in cortical arousal, making them more vulnerable to developing conditioned emotional responses than stable individuals. The concept of arousability, however, is moderated by a process known as transmarginal inhibition (TMI), which under certain circumstances can lead to paradoxical reduction in arousal levels at high levels of stimulation. Taking TMI into account, Eysenck's theory predicts that, under conditions of high arousal (e.g., punishment), introverts should become more highly aroused that extraverts, but the presence of TMI may lead to lower arousal levels compared with extraverts depending on the interaction between personality and the arousability of the situation.

Gray's (1970) original RST represented a modification of the psychometric positioning of Eysenck's dimensions, and it proposes an alternative thesis for their biological underpinning. By rotating E and N by 30 °, Gray came up with two new dimensions of personality in which Anxiety (punishment sensitivity) is correlated most closely with neuroticism, and to a lesser extent with introversion; compared with low-anxiety persons, individuals high in anxiety are said to be more sensitive to signals of punishment. Impulsivity (reward sensitivity) is correlated most highly with extraversion and to some extent with neuroticism. High-impulsive individuals are said to be more sensitive to signals of reward compared to individuals with low impulsivity. Gray's proposed a conceptual nervous system underlying these two dimensions. Under the direction of a septo-hippocampal comparator, he associated Anxiety with activity in the behavioral inhibition system (BIS). Impulsivity is supported by the behavioral activation system (BAS) which, according to Gray, is sensitive to stimuli that signal reward and nonpunishment. Consequently, the BAS is hypothesized to be responsible for approach behavior.

Gray's rotation of Eysenck's factors treats E as a derived dimension reflecting the *balance* between the reactivities of the BIS and the BAS, and N as a derived dimension reflecting the *sum* of the reactivities of the BIS and the BAS. These relationships have since been substantially revised by Gray and McNaughton (2000); however, the implications for incubation theory – and for the current study – are the same in both versions of the theory.

Personality and Reminiscence

Individual differences in reminiscence were reported by Howarth and Eysenck (1968), who found that introverts showed short-term performance impairment (0 minutes after learning), but long-term performance enhancement (24 h later), relative to extraverts. These results can be interpreted in accordance with Walker's (1958) action decrement theory: High arousal produces a longer-lasting active memory trace, leading to enhanced consolidation and superior long-term memory. These data fit Eysenck's (1967) arousal model of Extraversion, especially the observation that high arousal impairs introverts' acute performance, but seems to strengthen chronic learning – another learning-based explanation would struggle to explain the short-term transmarginal inhibition of response under high arousal observed in introverts, yet the introvert's greater susceptibility to (long-term) neurotic disorder.

In further support of Eysenck's position, Kleinsmith and Kaplan (1963, 1964), using emotionally unpleasant words, reported a similar effect to Howarth and Eysenck (1968), namely, that in introverts high arousal (highly emotional words) produces a stronger consolidation process (and superior long-term performance) but impairs performance in the short-term.

Personality and Procedural Learning

Lewicki, Czyzewska, and Hoffman (1987, p. 523) defined the acquisition of procedural knowledge as "a ubiquitous unconscious process involved in the development of both elementary and high-level cognitive skills." Many researchers claim that the measurement of cognitive skills in the form of procedural knowledge reflects a more sensitive method of learning about previous experience than the measurement of declarative (explicit) knowledge (Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982).

The procedural learning task used in this paper was previously used to test Eysenck's arousal theory of personality (Corr, Pickering, & Gray, 1995) and, by manipulating reinforcement, to test RST (Corr, Pickering, & Gray, 1997). Corr et al. (1997) found that trait anxious individuals demonstrated enhanced learning under punishment, relative to control, at the end of the testing session, but not during the early parts of the task. These findings suggest that procedural learning is associated with aversive fear reactions, and that the time course involved in the development of such emotional reactions may be important. In addition, extraversion × caffeine (Corr et al., 1995), and extraversion × haloperidol (Corr & Kumari, 1997) interactions were found with this task, pointing to the role of arousal in personality effects on procedural learning. This learning task is thus appropriate for combining Eysenck's arousal and Gray's RST reinforcement constructs.

Testing Eysenck's and Gray's Predictions

In order to test Eysenck's predictions for enhanced learning following a rest pause, we administered the procedural learning task in the present experiment under two different conditions: (a) spaced training (i.e., three sessions separated by time intervals) and (b) massed training (i.e., three consecutive tests with no temporal manipulation). In order to contrast Eysenck's and Gray's personality perspectives, we used a reinforcement manipulation to assess putative interactions between aversive stimulation (vs. no reinforcement) and measures of the major dimensions of personality. In both training conditions, participants were tested either under punishment or control conditions, the latter consisting of monetary decrements delivered over the blocks of the task, whereas participants in the control condition did not receive reinforcement.

Eysenck's theory predicts that introverts, relative to extraverts, should show improved procedural learning under control conditions (low arousal), but that their learning should decline under punishment conditions (high arousal). In relation to differences in reminiscence (incubation) of procedural learning, Eysenck's theory predicts long-term performance enhancement for introverts under both low- and high-arousal conditions (this effect for long-term enhancement should be especially marked compared with the performance impairment with immediate testing) under conditions of spaced training. In contrast, Gray's RST predicts that aversive stimulation should improve the performance of high-anxiety individuals, and that this improvement should not be affected by temporal factors. A demonstration that high-anxiety individuals show *impaired* learning under punishment would provide strong support for Eysenck's arousal model, namely, that punishment exerts its effect by increasing arousal, which, as a short-term effect, leads to performance decrements from TMI (Eysenck & Levey, 1972).

Aims

The experiment aimed to establish whether there are individual differences in levels of incubation on procedural learning as a function of (a) training (spaced vs. massed) and (b) reinforcement (punishment vs. control). Since Eysenck suggests that incubation (reminiscence) occurs during a rest pause, any incubation effects would be expected to be observed in the spaced training condition as evidenced by greater levels of procedural learning at 24 h and 5 days, compared to learning tested immediately (0 min). Superior learning under punishment in the spaced training condition would provide support for Eysenck's predictions for the enhancement of learning following a rest pause; however, it is necessary to examine the course of learning in the absence of a temporal manipulation, hence the contrast with massed training. Any effects of the temporal delay on procedural learning under punishment may simply be due to time on task rather than "rest-pause" consolidation. The results for the spaced training condition are compared to those in the massed training condition, where participants are tested on an identical number of procedural learning sessions consecutively, thus removing the temporal factor but preserving the time on task factor. The experiment also tests effects of personality on learning in both of the training conditions.

Predictions based on Eysenck's theory are that introverts should show short-term performance impairment (0 min after learning), but long-term performance enhancement (5 days) under high arousal (punishment) in the spaced training condition. These predictions may be contrasted with Gray's predictions of superior learning for high trait anxious individuals under punishment, specifically that high trait anxious individuals should show superior procedural learning under punishment, irrespective of temporal factors.

Method

Participants

A total of 52 participants, aged 18 to 40 years, 27 males (mean age = 27.22, *SD* = 6.23) and 25 females (mean age = 23.64, *SD* = 3.68), were recruited from undergraduate students in the Psychology Department at Goldsmiths, University of London. Participants received £15.00 at the end of the experiment, irrespective of their training condition or performance. A total of 27 participants took part in the spaced training condition consisting of 15 males (mean age = 28.33, *SD* = 6.58) and 12 females (mean age = 24.58, *SD* = 4.48); 25 participants took part in the massed training condition, 12 males (mean age = 25.83 years, *SD* = 5.73) and 13 females (mean age = 22.77, *SD* = 2.65).

Design

Three factors were manipulated: Training (spaced vs. massed), Reinforcement (punishment vs. control), and Session (three temporal training sessions conducted either at (a) 0 min, 24 h, and 5 days under spaced training, or (b) consecutive testing under massed training). The first and second factors were randomized group factors, and Session was a repeated measures factor. Personality was a further between-subjects factor. The temporal sessions under both training conditions will be referred to as (1) Session 1 (0 min for both training conditions), (2) Session 2 (24 h under spaced training; immediately following Session 1 for massed training), and (3) Session 3 (5 days under spaced training; immediately following Session 2 for massed training).

Personality Measures

The Eysenck Personality Questionnaire – Revised (EPQ-R; Eysenck & Eysenck, 1991) was used to assess extraversion (E) and neuroticism (N), and trait anxiety (Anx) was measured by the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).

Learning Task

The procedural learning task was based on Lewicki, Hill, and Bizot (1988), and comprised serial RTs to random and predictable trials. A reduction of RTs to predictable trials, as compared with RTs to random trials, comprised procedural learning. Performance consisted of participants being required to touch (using a wand) a white target (asterisk *), which appeared in one of four quadrants on a computer screen. The asterisk appeared centrally in each of the quadrants, with a surrounding area of 2 cm radius, and moved to a new quadrant only when touched by the wand. Participants were required to follow the asterisk around the screen and touch it with a wand each time it moved to a new location. Two intersecting white lines created the four equally sized quadrants on a black background (for further details, see Corr et al., 1997).

Stimuli

The acquisition phase of the study was composed of 6 separate blocks of trials, each of which contained 48 subblocks, which in turn contained 5 target movements, so that each block consisted of 240 total target movements. The 5 target movements of each of the 48 subblocks contained either random (Trials 1 and 2) or predictable (Trials 4 and 5) trials; trial 3 with each 5-target sequence was excluded (for full details, see Corr et al., 1997). All 48 subblocks were presented randomly to each participant.

Data Reduction

RTs to random and predictable trials were calculated from the mean RT for each of the 5 trials within each of the 48 subblocks. The difference between RTs (trial type) to random and predictable trials was then calculated: This was the measure of procedural learning.

Manipulation of Reinforcement

The number of reinforcers delivered over the blocks of the task was held constant in the punishment condition and was not contingent on participant's performance. (For an explanation of this probabilistic basis of reinforcement, see Corr et al., 1997.) Participants in the punishment condition received £7.00 at the start of the experiment and were told that they could either win or lose money depending on their performance (see Instructions). The manipulation of punishment in the form of monetary decrements has been demonstrated by Corr et al. (1997) to lead to superior learning when contrasted with no reinforcement under control. (Money is an ecologically valid form of reinforcement for human beings and has been widely used in reinforcement-based studies of personality; see Torrubia, Avila, & Caseras, 2008.)

Punishment Criteria

Noncontingent punishment, in the form of monetary decrements, were applied over the blocks of the task (following each 5-trial block). Therefore, irrespective of participant's performance, they were given the following two flashing messages on the computer screen during the interblock intervals during Session 1 (i.e., following each of the first 4 blocks of the task for both the spaced and the massed training conditions), and once following each subblock of the task in Session 2 and Session 3 (i.e., on testing at 24 h and 5 days for the spaced training condition, and following testing in Session 2 and Session 3 for the massed training condition): (a) "Bad Luck"; and (b) "Your payment for this experiment has just decreased by £1."

In the control condition, participants received no feedback on their performance. They were told that they would receive monetary payment for their participation in the study, and like the participants in the punishment condition, left the experiment with £15.00.

Instructions

The following instruction was given to each participant for the practice session in both conditions.

Practice

> "As you can see, the screen is divided into quadrants. A target (*) will move between these quadrants, and your task is to touch each target with the wand in the manner already described to you. A practice period follows to familiarize you with the task. *Remember that your response should be fast and accurate.* Please touch 'GO' to start."

Following the practice session, participants in the punishment condition received only the following instruction.

Punishment

> "Your performance will be compared with a database of all the subjects who have previously taken part in the experiment. If your performance is above average you will win money; however, if your performance is below average you will lose money. Please touch 'GO' to start."

Equipment

The task was run on an ATARI 1040ST microcomputer. The target movements were presented on an ATARI SC1224 monitor with a Microvitec Touchtec 501 touch screen to register responses. The wand used for touching the target consisted of a thin perspex tube approximately 12 inches in length which was required to break the matrix of infrared beams of light that covered the monitor.

Procedure

Participants were randomly assigned to one of the training and reinforcement conditions and tested on six blocks of the task at either three separate time intervals in the spaced condition, or in one continuous testing session without temporal delay in the massed condition. In the spaced condition, participants were tested at (1) 0 min (Session 1; blocks 1–4), (2) 24 h (Session 2; block 5), and (3) 5 days later (Session 3; block 6). In the massed condition, participants were run in one testing session on the 6 blocks of the task, therefore, tested on (a) four blocks of the task (Session 1; blocks 1–4), followed by (b) one block of the task (Session 2; block 5), and (c) the final block of the task (Session 3; block 6).

Participants were tested individually in an experimental cubicle. Those in the punishment condition were told verbally that they would be required to perform a simple computer task in which they could win or lose money. Participants read and then completed a consent form before completing the personality questionnaires. They were then given a brief verbal description of the task and written practice instructions as well as instructions on how to use the response wand.

In the first testing session, following an initial practice session, participants in the punishment condition were told that they had earned £7.00 for taking part in the experiment, but that they may either lose some of this payment – or win additional money – depending on how they performed on the task. Participants then proceeded to complete four blocks of the task. Each block was separated by a 30-s rest

Table 1. Means (*SD*) for random RTs (ms), predictable RTs (ms), and procedural learning (ms) for all sessions in punishment and control under spaced and massed training

	Spaced training			*Massed training*		
	R-RTs	*P-RTs*	*PL*	*R-RTs*	*P-RTs*	*PL*
Punishment						
Session 1						
Block 1	581 (41)	579 (53)	2 (17)	552 (22)	549 (29)	3 (18)
Block 2	565 (67)	561 (62)	2 (17)	552 (21)	540 (31)	3 (18)
Block 3	564 (63)	557 (63)	6 (16)	544 (36)	531 (44)	13 (17)
Block 4	558 (54)	544 (63)	13 (22)	545 (35)	530 (39)	14 (19)
Mean of Blocks 1–4	567 (53)	560 (57)	6 (15)	548 (22)	537 (29)	8 (12)
Session 2						
Block 5	548 (57)	544 (62)	4 (22)	527 (39)	515 (49)	13 (21)
Session 3						
Block 6	550 (42)	533 (56)	17 (20)	526 (37)	496 (50)	30 (24)
Control						
Session 1						
Block 1	580 (47)	574 (50)	5 (18)	553 (46)	550 (44)	4 (20)
Block 2	575 (42)	573 (42)	2 (18)	550 (44)	533 (50)	4 (20)
Block 3	565 (50)	553 (54)	12 (17)	538 (34)	522 (33)	15 (18)
Block 4	565 (40)	556 (44)	9 (19)	530 (37)	511 (35)	19 (21)
Mean of Blocks 1–4	571 (41)	564 (43)	9 (10)	543 (35)	529 (36)	10 (16)
Session 2						
Block 5	554 (47)	546 (56)	8 (18)	527 (50)	514 (50)	13 (12)
Session 3						
Block 6	548 (45)	531 (44)	17 (21)	521 (47)	500 (67)	21 (42)

R-RTs = random RTs, P-RTs = predictable RTs, PL = procedural learning.

period during which participants in the punishment condition received negative reinforcement messages (see above); participants in the control condition received no reinforcement or messages. Termination of the rest period was indicated to participants by the appearance of a message on the screen which instructed them to "press 'GO' to continue."

All participants were retested on one block of the task either 24 h (Session 2) and 5 days later (Session 3) in the spaced training condition, or immediately following Session 1 in the massed training condition. The procedure followed that described above with reinforcement in the punishment condition delivered after each block in all sessions. On completion of all three sessions of the task, participants were verbally debriefed and paid £15.00 each for taking part in the experiment.

Results

Means and standard deviations for RTs and procedural learning for blocks 1–6 for punishment and control in both training conditions are presented in Table 1. The difference between RTs to random and predictable trials represents procedural learning (larger reductions in RT latency reflect better learning).

Task Analysis

The first phase of analysis examined whether RTs to random and predictable trials, over the first 4 blocks of the task (Session 1), produced procedural learning; and whether RTs and procedural learning differences were affected by reinforcement and training. A four-way ANOVA was carried out with repeated measures on (a) Blocks (RTs over blocks 1–4 of the task), (b) Trial Type (difference between random and predictable trials), (c) between-subjects Training (spaced vs. massed), and (d) between-subjects Reinforcement (punishment vs. control).

RTs over Blocks

There was no main effect of Reinforcement nor any Reinforcement × Training interaction, indicating that there were no differences in RTs between the punishment and control conditions over the first four blocks of the task in each training condition. A main effect of Blocks, $F(3, 135)$ =

10.51, $p = .001$, reflected a progressive decline in RTs over the course of the experiment for Session 1. This did not vary according to training as the Blocks × Training interaction was nonsignificant. The Reinforcement × Blocks and the Reinforcement × Training × Blocks interactions were not significant, indicating that RTs across the four blocks of Session 1 did not vary as a function of reinforcement in either training condition.

Trial Type

A main effect of Trial Type, $F(1, 45) = 25.86$, $p = .001$, revealed a difference in random and predictable trials: RTs to predictable trials were faster than those to random trials, indicating that learning took place. A significant Trial Type × Blocks interaction, $F(3, 135) = 3.24$, $p = .024$, reflected the steady increase in the difference between random and predictable trials over the blocks of Session 1. There was no Trial Type × Blocks × Training interaction, indicating that this increase in learning occurred in both training conditions. The Reinforcement × Trial Type, the Reinforcement × Trial Type × Blocks, and the Reinforcement × Trial Type × Blocks × Training interactions were also nonsignificant, indicating that the differences in RTs to random and predictable trials were not affected by reinforcement nor training condition over the blocks of Session 1.

Procedural Learning over Time as a Function of Reinforcement

The second phase of the analysis assessed the usefulness of the procedural learning task as a measure of incubation across the sessions of the experiment. The analysis also examined whether procedural learning across time was affected by reinforcement. The descriptive statistics in Table 1 show that, for the spaced condition, despite a slight decrease in learning at Session 2 (24 h), procedural learning increased under punishment by Session 3 (5 days). A similar pattern of learning was observed for the control condition, although there appeared to be little variation in learning over the first two phases of the task (Session 1; blocks 1–4; 0 min.), and (Session 2; block 5; 24 h). In the massed condition, following Session 1 testing, there was greater learning under control than punishment. However, by Session 3 procedural learning is higher under punishment; the Session 1 and Session 3 difference under punishment was statistically significant, $t(12) = 3.16$, $p = .008$.

A three-way ANOVA on procedural learning was carried out with repeated measures on Session (Session 1 vs. Session 2 vs. Session 3), and between-subjects Reinforcement (control vs. punishment) and Training (spaced vs. massed) in order to assess whether there was an incubation effect on procedural learning over time as a function of reinforcement and training. Specifically, support for Eysenck's notion of incubation would be afforded by a demonstration of incubation of procedural learning over time in the spaced condition as opposed to the massed condition. There was no main effect of Reinforcement; however, there was a main effect of Session, $F(2, 90) = 6.17$, $p = .003$, reflecting an increase in procedural over the testing sessions. This was not affected by training as the Training × Session interaction was nonsignificant. The Reinforcement × Session and Reinforcement × Session × Training interactions were nonsignificant, revealing that the increase in learning did not vary as a function of reinforcement nor whether participants took part in spaced or massed training.

Personality Effects

The effects of personality factors on procedural learning, as a function of reinforcement and training, were explored using a correlational analysis. Procedural learning difference scores were computed to represent a measure of learning over the temporal phases of the experiment. The difference in learning scores on Session 2 and Session 1 (S2–S1), Session 3 and Session 2 (S3–S2), and Session 3 and Session 1 (S3–S1; taken to represent an overall measure of procedural learning over time) were calculated for both training conditions and correlated with personality variables under the punishment and control for each training condition.

Spaced Training

Punishment

In line with predictions derived from Gray's personality theory, trait anxiety was positively correlated with overall procedural learning (S3–S1) under punishment, $r = .77$, $p = .005$. Also under punishment, there was a weak, albeit nonsignificant, positive association between EPQ:N and overall procedural learning, $r = .52$, $p = .099$; however, there were no significant correlations between EPQ:E and procedural learning. These results support Corr et al.'s (1997) findings of greater learning under punishment for high trait anxious individuals. Eysenck would predict that introverted individuals should demonstrate superior learning under control; however, the correlational results did not reveal any significant associations between EPQ:E and learning in the control condition.

Control

Eysenck would predict that introverted individuals demonstrate superior learning under control; however, the correlational results did not reveal any significant associations between EPQ:E and learning in the control condition. Also, there were no significant correlations between procedural learning and EPQ:N or trait anxiety in the control condition under spaced training.

Massed Training

Punishment

EPQ:E was positively correlated with procedural learning difference scores from Session 1 and Session 2 (S2–S1), $r = .62$, $p = .024$; however, this association was negative between Session 2 and Session 3 (S3–S2), $r = –.51$, $p = .072$. There were no associations between EPQ:N and learning under punishment.

Albeit nonsignificantly, trait anxiety was positively correlated with procedural learning difference scores from Session 2 and Session 3 (S3–S2), $r = .52$, $p = .069$, and with overall procedural learning (S3–S1), $r = .52$, $p = .068$. These results suggested that punishment contributed to enhanced learning for high trait-anxious participants.

Control

There were no significant correlations between all procedural learning difference scores and personality in the control condition under massed training.

Personality Moderating Variables

The above pattern of correlations suggested the need to extend the exploration of the effects of personality traits on the manipulation of reinforcement leading to incubation. It would be expected that the relationship between performance on the learning task and reinforcement should vary as a function of personality. As such, any incubation effect observed was expected to be modified by personality factors. From Gray's RST hypothesis, it was expected that high trait anxious participants should demonstrate higher levels of procedural learning under punishment, relative to the control condition. The above results supported this prediction for both training conditions.

In this combined analysis, personality scores (i.e., E, N, and anxiety) were treated as continuous factors. Separate ANOVAs were computed for (a) EPQ:E × EPQ:N and (b) Anxiety (variables were standardized prior to the computation of interaction terms; Aiken & West, 1991). The analyses included the following variables: (a) main effects of Reinforcement, Training, and all personality factors, (b) two-way interactions between Reinforcement and training, (c) two-way interactions between Reinforcement and each personality variable, (d) three-way interactions between Reinforcement, Training and each personality variable, and (e) four-way interactions between Reinforcement, Training, and personality variables.

The analysis was carried out on the procedural learning scores for each session of the task for punishment vs. control. The effects of learning on Session 1 were partialled out in the analysis of Session 2 and Session 3 learning. Using Session 1 learning as a covariate in the analysis of Session 2 and Session 3 learning allowed for a more accurate representation of true procedural learning when comparing performance across the training conditions.

EPQ Model

There were no main or interactive effects for the EPQ model for Sessions 1 and 2 of the task. There was a significant Reinforcement × Extraversion × Training interaction for Session 3 learning, $F(1, 35) = 5.23$, $p = .028$. However, simple effects analysis of Reinforcement × Extraversion interactions in separate analyses of the spaced and massed training conditions did not meet Bonferroni adjusted significance levels.

Anxiety Model

There were no significant main or interaction effects for the Anxiety model for Sessions 1 and 2 of the task. There was, however, a significant Reinforcement × Anxiety interaction, $F(1, 40) = 4.75$, $p = .035$, for Session 3 learning, indicating that anxiety modified the effects of reinforcement over the course of the training sessions (see Figure 1). The Reinforcement × Anxiety × Training interaction was nonsignificant indicating that the moderating effects of anxiety did not vary as a function of training.

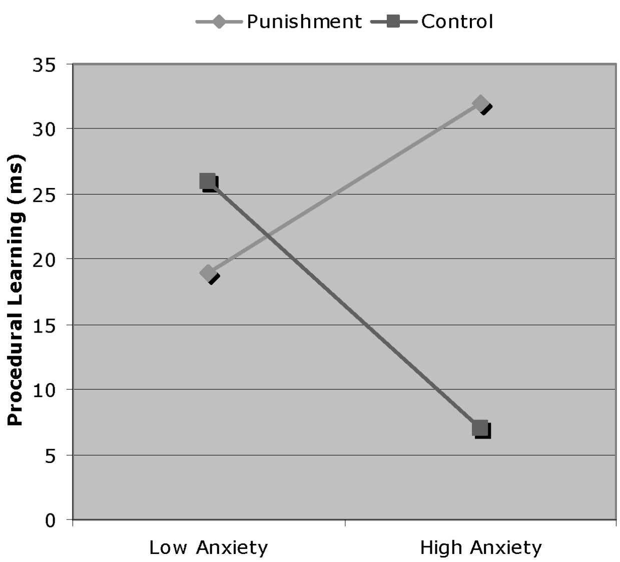

Figure 1. Mean procedural learning for Session 3 showing low- and high-trait anxiety groups in punishment and control conditions.

Discussion

The results provided a clear picture of the relationship between reinforcement, type of training, and personality on procedural learning. Consistent with previous research (Corr et al., 1997), trait anxiety was related to the effects of punishment, and the pattern of findings was consistent with Gray's Reinforcement Sensitivity Theory (RST) of personality. Importantly, this reinforcement × anxiety interaction was not affected by temporal delay between testing (i.e., rest pauses) and neither this nor any other aspect of the results lends any support to Eysenck's arousal-based theory of incubation of learning. It is important to note that Eysenck-type results can be obtained on this learning task when arousal is manipulated by nonreinforcing stimuli (e.g., caffeine; Corr et al., 1995). Consistent with Gray's RST prediction, the introduction of reinforcement abolishes Eysenck's Extraversion × arousal effects.

Turning to the detailed analysis of the task, as expected RTs declined over the first four blocks of the experiment in both the spaced and the massed training conditions, and there was no difference in the rate of decline between punishment and control. Therefore, without consideration of the modifying effect of personality factors, the reduction in RTs seemed not to be affected by reinforcement or training.

The results confirmed that procedural learning took place in both training conditions: RTs to predictable trials were faster than RTs to random trials. There was no difference in the rate of decrement in RTs to random and predictable trials (i.e., learning) over the first four blocks of the task, and this difference did not vary as a function of reinforcement or training. This finding is consistent with Corr et al. (1997), who similarly found a lack of reinforcement during early portions of the procedural learning task.

Procedural learning increased over the temporal sessions of the experiment but this did not vary as a function of reinforcement because there were no differences in learning between the punishment and control conditions. Crucially, there were also no significant effects on learning under punishment and control by the training factor. While there were significant differences in learning from Session 1 to Session 3 under punishment in the spaced training condition, this apparent "incubation" effect under spaced training cannot be assumed to be due to extended rest pause as the same effect occurred in the absence of such rest pauses. The implications of this finding is discussed below.

Overall, procedural learning in the spaced training condition was significantly correlated with trait anxiety, and punishment led to increased levels of procedural learning for high-anxiety subjects. In this condition, punishment facilitated overall learning for anxious individuals, compared to the control condition, where trait anxiety was negatively associated with overall learning. Similarly, in the massed training condition, trait anxiety was weakly associated with overall procedural learning in the punishment condition, again relative to a negative association in the control condition. A more detailed examination of the modifying effects of anxiety revealed a significant Reinforcement × Anxiety interaction for Session 3 learning between the punishment and the control condition. In contrast, there were no moderating effects of E or N on learning during this session.

Results suggest that punishment and personality affected procedural learning, but not in a manner consistent with Eysenck's arousal-based predictions. In contrast, the modifying effect of anxiety on punishment-mediated learning supports Gray's RST punishment predictions for both training conditions. The absence of training effects indicates that incubation (reminiscence) did not occur. Without the manipulation of this temporal factor, the results for the spaced training condition would have been partially consistent with Eysenck's reminiscence phenomenon (i.e., a slight increase in learning at Session 2 followed by a large increase in learning by Session 3); however, the same patterns of learning occurred in the massed training condition, and for both conditions the results were not in the direction that arousal-based predictions would suggest. Eysenck's prediction of impaired learning for introverts under punishment was not observed, even under the massed training condition, where retention intervals were short and more in line with previous "reminiscence" experiments.

Results confirmed that procedural learning increased over the sessions of the task, and that this effect was not influenced by training factor. It would appear that time on task was the crucial variable in this effect. If anything, it appeared that superior learning took place in Session 3 under massed training to that observed in Session 3 of the spaced training condition. The significant Reinforcement × Anxiety interaction in line with Gray's personality predictions represents a major finding of this paper and indicates that high-anxiety individuals learned more even with shorter retention intervals; temporal parameters were unimportant in this effect.

It is clear from the above pattern of results that anxiety interacts with punishment under spaced and massed training and in the same manner. Based on these results, it cannot be concluded that the temporal aspect of the spaced condition led to enhanced learning; that is, reminiscence, as defined by Eysenck as constituting an initial decline in learning for putatively highly aroused introverted individuals (as a result of transmarginal inhibition of response) followed by an upswing in learning following a period of nonpractice, at least not on the procedural learning that has previously been used to test, and in some respects confirm, Eysenck's arousal-based predictions.

The present paper tests whether there was an interplay between arousal and temporal factors as predicted by Eysenck. The results clearly suggest that temporal factors are not of importance in the effects of punishment – and the role played by anxiety in these effects – on procedural learning. In a wider context, these results suggest that Eysenck's "consolidation intervals" are not sufficient for conditioned fear responses to incubate.

Procedural learning is a robust phenomenon with widescale implications for learning in general and personality research in particular. It is also very similar to the types of tasks used by Eysenck in his initial studies of personality (e.g., pursuit-rotor), so that it is unlikely that the results reported here do not generalize to other learning tasks and situations. Indeed, the specific task used here is especially well suited to contrasting Eysenck's and Gray's theories because it has previously been shown to reveal classic arousal × extraversion interactions (Corr et al., 1995), consistent with Eysenck's theory, as well as punishment × anxiety interactions (Corr et al., 1997), consistent with Gray's theory. When pitted against each other, which was achieved for the first time in these two experiments, E and N inconsistently interacted with punishment – and at different stages of the learning processes; in contrast, anxiety and punishment, across two different experiments, consistently interacted in a manner predicted by Gray's reinforcement sensitivity theory of personality.

The manipulation of punishment in the present experiment, according to Eysenck's theory, is arousing. The nature of the UCS in the form of monetary incentive has previously been demonstrated to be strong enough to engage adequate motivational processes to lead to a punishment (vs. control) × trait interaction (Corr et al., 1997), and because Eysenck predicts that reinforcement effects are mediated by changes in level of arousal, his theory should better explain the pattern of effects found. In terms of strong UCS, the present paper is concerned with Eysenck's hypothesis concerning temporal factors in incubation. It is possible that Eysenck's effects are found only with very intense UCSs, but this would render his theory of limited value and would fail to explain typical reinforcement × anxiety effects of the type found here and elsewhere. Eysenck's theory is meant to explain all findings, including those involving weak UCSs, which he ~~would continue to argue~~ interacts with introversion-extraversion, not anxiety.

The results help to resolve the question of the relationship between Eysenck's and Gray's theories. It would appear not implausible to suggest that arousal is important in the initial conditioning of emotive stimuli, which then serve as adequate inputs into Gray's emotion systems; in turn, activation of these systems is expected to augment arousal and thereby influence conditioning processes quite independent of their role in generating emotion and motivational tendencies (Corr, 2008a). If introversion-extraversion reflects the balance of reward and punishment sensitivities, then it may not be incompatible to argue that Eysenckian extraversion-arousal processes in conditioning continue to be relevant in Gray's RST. By this route, it may finally be possible to unify the two theories.

We have not differentiated Gray's theory in terms of the Gray and McNaughton's (2000) revision of the behavioral inhibition system (BIS), which in both the original and revised form is postulated to mediate anxiety (for a research summary, see Corr, 2008b). For the current experiments, this distinction is not important, because in both versions of Gray's theory the form of the punishment used is equally likely to activate the BIS. In the original theory, the loss of money is a form of conditioned punisher and thus an adequate input to the BIS; in the revised theory, the punishment and task manipulations would constitute a form of goal conflict because of the following conflicting states: the subject is attempting to minimize losses (mediated by the fight-flight-freeze system; FFFS, which initiates avoidance/escape behaviors), yet the task demands that the subject engages in BAS-related approach behavior (i.e., following the target movements, which is the very thing that produces the monetary losses). This form of conflict is expected to engage the behavioral inhibition system. The fact that monetary losses were noncontingent upon response further produces a goal-conflict; that is, working toward avoidance of losses, yet this "goal" does not produce behavior that is "going to plan" – thus, there is a conflict between expected and actual outcomes. Hence, in terms of the revised RST, there is a goal-conflict between (a) task requirements (i.e., rapid RTs and lack of awareness of the punishment contingencies) and (b) the effects of punishment (i.e., avoidance of response and inhibition of prepotent behavior): This goal conflict – which, in the revised theory, the BIS detects – should relate to the trait measure of anxiety.

In conclusion, the apparent effect of incubation observed in the spaced condition cannot be construed as resulting from a reminiscence effect following consolidation of the procedural information over extended rest pauses. In the absence of this temporal manipulation (the massed condition), procedural learning similarly increased across the sessions of the task. Extraversion and neuroticism effects, as a function of punishment, were inconsistent and not in conformity with Eysenck's predictions; in contrast, Gray's prediction that high-anxiety individuals would show superior learning under punishment (relative to control) was found in both training conditions therefore was shown not to be affected by temporal factors.

Although based on a rather dated literature, the predictions tested in this article remain highly relevant to testing the respective explanatory powers of Eysenck's and Gray's personality theories, especially the manner in which they attempt to account for the development of negative emotional reactions. To our knowledge, this is the first study to test Gray's RST predictions in terms of temporal delays; accordingly, it is the first study that has pitted the predictions of Eysenck's arousal-based reminiscence theory against Gray's RST. The study shows that, with aversive stimulation, trait anxiety is the important factor – and temporal delay is unimportant – in procedural learning. This may be a theoretically significant set of findings because it may be assumed that procedural learning is involved in many forms of learning that influence behavior. As such, the extension of this experimental procedure to clinical studies may be of some value (e.g., the impairment of procedural learning of negative consequences in psychopathy). In this regard, the implications of the differentiation of fear and anxiety in revised RST (Gray & McNaughton, 2000) in accounting for these reinforcement × personality effects should be a target for future research.

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