

# PERSONALITY AND REINFORCEMENT IN ASSOCIATIVE

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# AND INSTRUMENTAL LEARNING

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**Summary**—A two-stage (associative and instrumental) learning task was developed to examine the role of personality in mediating: (1) the development of appetitive and aversive CS-UCS associations; and (2) passive avoidance of aversive CSs, and approach to appetitive CSs, in instrumental learning. The results showed: (1) that *harm avoidance* [as measured by the Tridimensional Personality Questionnaire (TPQ)] predicted aversive CS-UCS associations, while [TPQ] *reward dependence* predicted appetitive CS-UCS associations (no personality factors predicted neutral CS-UCS associations); and (2) that subjects high in impulsivity [as measured by the IVE scale of the Eysenck Personality Scales (EPS)] showed poor passive avoidance to the aversive-CS, while subjects high in trait anxiety [as measured by the State-Trait Anxiety Inventory (STAI)] showed poor approach behaviour to the appetitive-CS. A correlational study with TPQ and Eysenck Personality Questionnaire [EPQ] factors revealed the structural comparability of these two descriptive systems. The results suggest that associative and instrumental learning under appetitive and aversive conditions do not reflect a general (arousal-based) learning factor, and that specific personality factors mediate reward and punishment in the two stages of learning. The findings are discussed in relation to Eysenck's, Gray's, Cloninger's, and Newman's models of personality.

# GENERALINTRODUCTION

The relationship between personality and learning has been extensively studied within the theoretical framework of Eysenck's (1957, 1967) model of personality. Making use of the assumptions of Hull's (1943, 1951) learning system, Eysenck attempted to account for introversion–extraversion in terms of excitatory and inhibitory processes (1957), latterly expressed in terms of differences in cortical arousability (1967). Eysenck's (1967) model postulates that introverts are chronically more aroused (and also more arousable) than extraverts; therefore, on average, introverts form conditioned responses with greater ease than extraverts. Experimental data does indeed suggest that, on simple tests of conditioning, introverts outperform extraverts under low to moderate levels of stimulation, but under high levels of stimulation extraverts tend to outperform introverts (e.g. Eysenck & Levey, 1972); the performance impairment observed for introverts under high levels of stimulation are assumed to result from the evocation of transmarginal inhibition [TMI (a protective mechanism that breaks the link between increases in arousal and increases in response strength at high levels of stimulation)].

Now, experimental support for Eysenck's theory has come largely from eye-blink conditioning studies in which a CS (e.g. coloured light) is conditioned to a UCS (a puff of air to the cornea); but, as noted by Levey and Martin (1981, p. 144), "The dearth of conditioning studies on appetitive stimuli is one of the serious limitations of work both on conditioning and personality". The suggestion that appetitive and aversive stimuli exert different effects on behaviour, coupled with the paucity of studies concerned with appetitive stimuli in associative learning, raises the question of the validity of Eysenck's general arousal-based theory of learning.

The fact that associative learning studies have concentrated on aversive stimuli to the virtual exclusion of appetitive stimuli is of little consequence to Eysenck's theory which has focused on a single factor underlying individual differences in learning: arousal/arousability. This focus in Eysenck's model follows Hull's emphasis on the single factor of drive reduction as underlying reinforcement. As noted by Gray (1975, p. 265), the "Hullian concept of general drive, to the extent that it is viable, does not differ in any important respects from that of arousal". To the extent that both

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Hull and Eysenck argue that one causal factor affects learning, their joint position may be termed the 'Hull-Eysenck perspective'.

The 'Hull-Eysenck perspective' may be contrasted with the 'Mowrer-Gray perspective' which argues for a two-factor theory of learning based upon separable reward and punishment systems [see Konorski (1967) and Mackintosh, (1983) for a review of relevant learning studies]. Gray's (1970, 1975, 1987, 1991) theory of personality incorporates Mowrer's (1960) general theoretical approach, neurophysiological findings of intracranial self-stimulation (reviewed by Olds & Fobes, 1981), and the effects of barbiturates on approach and passive avoidance behaviour (e.g. Miller, 1959), in arguing for the importance of reward and punishment systems underlying Eysenck's extraversion and neuroticism factors. Gray (1970) suggested that, at the descriptive level of analysis, extraversion and neuroticism should be rotated (approx.) 30° to form two new dimensions: anxiety (running from E - /N + to E + /N -) and impulsivity (running from E + /N + to E - /N -). The causal model upon which this proposed rotation was based has been elaborated in recent years to include three major neuropsychological systems: (1) the behavioural inhibition system [BIS (Gray, 1976, 1982)], the behavioural approach system [BAS (Gray, 1987)], and the fight/flight system [FFS (Gray, 1987)].

- (1) The BIS is the conceptual substrate for sensitivity to secondary aversive stimuli, and is the proposed causal basis of anxiety. It is sensitive to: (a) conditioned stimuli associated with punishment, and the omission or termination of reward (frustrative nonreward), (b) extreme novelty, (c) innate fear stimuli (conspecifics and "special evolutionary dangers", e.g. snakes, dead bodies, etc.), and (d) high-intensity stimuli. Upon activation by these adequate inputs, the BIS produces behavioural inhibition (i.e. interruption of ongoing behaviour) and an increase in level of arousal and attention. The purpose of the BIS is to suppress behaviour that is expected to lead to punishment.
- (2) The BAS is the conceptual substrate for sensitivity to secondary appetitive stimuli, and is the proposed causal basis of impulsivity. It is sensitive to: (a) conditioned stimuli associated with reward, and (b) conditioned stimuli associated with the termination/omission of punishment. The purpose of the BAS is to initiate exploratory, approach behaviour that brings the organism closer to final biological reinforcers (e.g. food, sexual partners, etc.).
- (3) The FFS is the conceptual substrate for sensitivity to primary aversive stimuli, and is the proposed causal basis of psychoticism. The adequate inputs to this system (unconditioned punishment or frustrative nonreward) produce an output of defensive, or intra-species, aggression or escape behaviour. Activation of the FFS is accompanied by anger (in the case of defensive aggression) and/or panic (in the case of escape). Whether escape or defensive aggression occurs depends on the environment: if escape is possible, then the animal will take flight; if the animal cannot escape, then it will fight; and there is often rapid alternation between these two behavioural patterns.

Within Gray's model, introversion may be seen to reflect a strong BIS and weak BAS, extraversion a strong BAS and weak BIS; emotional stability reflects a weak BIS and weak BAS, and emotional instability a strong BIS and strong BAS (Derryberry & Reed, 1994). (The statement that introversion-extraversion represents the balance of reward-punishment sensitivities while neuroticism represents the sum of reward-punishment sensitivities applies strictly only to a 45° rotation of extraversion and neuroticism; it is somewhat misleading when applied to a 30° rotation of extraversion and neuroticism.)

Gray's two-factor theory of learning, concerning the greater sensitivity of the neurotic-introvert to aversive stimuli, is almost indistinguishable, at the empirical level, from Eysenck's arousal-based theory. However, the two theories are clearly different when applied to the reactions of neurotic-extraverts to appetitive stimuli: Gray predicts that, irrespective of arousal level, neurotic-extraverts should show a strong reaction to appetitive stimuli.

In addition to separable reward and punishment systems (two-factor theory), theoretical attention has also been drawn to separate associative and instrumental phases of learning (two-process theory). Mowrer's (1960) two-process learning theory lays particular emphasis on the role that associations

between initially neutral stimuli (CSs) and environmentally important unconditioned stimuli (UCSs) play in the conditioning of emotional states. Neutral stimuli (CSs) conditioned to emotion (UCS) by simple associative learning serve as motivational inputs to the instrumental learning of appropriate behavioural responses aimed at: (1) the approach of reward, and (2) the avoidance of punishment (Gray, 1975; Mowrer, 1960). Associative and instrumental processes thus represent different components of emotion-related learning.

Past personality research has almost exclusively concentrated upon either associative processes (e.g. Eysenck & Levey, 1972; see Levey & Martin, 1981) or upon instrumental learning (e.g. Gupta, 1976; Newman, 1987; Zinbarg & Revelle, 1989); in the latter case, associative and instrumental processes have been conflated by the initial associative learning component of the task (i.e. the requirement that Ss learn first which CSs predict which UCSs before they can proceed to learn how to avoid punishing UCSs and approach rewarding UCSs). The possibility that the relationship between reinforcement and personality in associative and instrumental learning may not be identical has yet to be evaluated. Despite the theoretical importance of distinguishing between associative and instrumental phases of learning, few attempts have been made to separate these phases in laboratory-based studies.

The general aim of the three experiments reported in this paper was to contrast the Hull–Eysenck and Mowrer–Gray perspectives in two-process learning. Experiment 1 considered the psychometric description of reinforcement–sensitivity. A two-stage learning task was developed which provided separate measures of associative and instrumental learning processes, and which allowed reward and punishment to be manipulated. Experiment 2 aimed to explore the effects of reward/punishment and personality in the associative learning phase; and Experiment 3 aimed to examine the same effects in the instrumental learning phase of the task, which consisted of approach to an appetitive stimulus and avoidance of an aversive stimulus.

## EXPERIMENT 1

## Introduction

Gray's causal theory of personality does not have a comparable descriptive system in the form of well-established questionnaire-based measures of reinforcement-sensitivity. Although attempts have been made to develop such questionnaires (e.g. Ball & Zuckerman, 1990; MacAndrew & Steele, 1991; Torrubia & Tobena, 1984; Wilson, Barrett & Gray, 1989; Wilson, Gray & Barrett, 1990), the majority of studies conducted with these instruments have been correlational in nature, attempting only to locate putative reinforcement-sensitivity factors in Eysenckian three-dimensional personality space; attempts to relate these factors to actual behavioural responses have led to inconsistent findings, especially as regards the relationship between putative measures of reward sensitivity and behaviour (e.g. Ball & Zuckerman, 1990). The aim of Experiment 1 was to examine the potential value of one major psychometric model of reinforcement-sensitivity, namely Cloninger's (1986, 1989) Tridimensional Personality Questionnaire [TPQ].

In an attempt to relate reinforcement sensitivity to the major dimensions of human personality, Cloninger (1986) proposed an alternative structure of personality to Eysenck's system. The Tridimensional Personality Questionnaire [TPQ (Cloninger, 1989)] purports to measure three genetically independent, but phenotypically related, dimensions which are "... related to heritable variation in patterns of response to specific type of environmental stimuli" (p. 167): *harm avoidance* [HA] is related to the tendency to respond intensively to aversive stimuli and to learn to avoid punishment, novelty, and non-reward passively; *reward dependence* [RD] is related to the tendency to respond intensely to respond intensely to reward and succorance and to learn to maintain rewarded behaviour; and *novelty seeking* [NS] is related to the tendency toward exploratory behaviour and intense excitement in response to novel stimuli.

Each of these factors is composed of four lower-order factors [Cronbach  $\alpha$  coefficients for U.S.A. white males/females are given in parentheses (Cloninger, Przybeck & Svrakic, 1991)]. (1) HA (0.85/0.85): (a) anticipatory worry vs optimism (0.67/0.65), (b) fear of uncertainty vs confidence (0.65/0.65), (c) shyness vs gregariousness (0.75/0.74), and (d) fatigability and asthenia vs vigour (0.75/0.74); (2) RD (0.69/0.61): (a) sentimentality vs insensitivity (0.45/0.39), (b) attachment vs

detachment (0.58/0.57), (c) dependence vs independence (0.67/0.64) and persistence vs irresoluteness (0.44/0.38); and (3) NS (0.75/0.73): (a) exploratory excitability vs rigidity (0.53/0.54), (b) impulsiveness vs reflection (0.56/0.55), (c) extravagance vs reserve (0.64/0.63), and (d) disorderliness vs regimentation (0.48/0.47) [higher Cronbach  $\alpha$  coefficients are reported by Cloninger (1993)]. Test-retest correlations (over 6 months) are in the 0.70's for the three main factors, and, mostly, in the 0.50–0.60's for the individual scales (Cloninger, Przybeck, Svrakic & Wetzel, 1994).

The TPQ was developed from a rationally chosen set of items, has been confirmed by factor analysis in different countries (Cloninger *et al.*, 1991; Waller, Lilienfeld, Tellegen & Lykken, 1991), and is undergoing continual development and extension (e.g. Cloninger, Svrakic & Przybeck, 1993). Cloninger *et al.* (1994) present a review of the evidence supporting the factor structure, reliability and validity of the TPQ; this includes: clinical and epidemiological applications in anxiety, mood, eating and personality disorders, and substance abuse; quantitative genetics; brain imaging and neurocognitive correlates; neurochemical and neuroendocrine correlates; and behavioural studies in criminals.

The theoretical basis of Cloninger's (1986) causal model is highly similar to that of Gray's, suggesting that the TPQ may provide psychometric markers for Gray's reward and punishment systems (via RD and HA respectively, see below). HA seems very close to Gray's anxiety (BIS) system and may be assumed to provide a measure of trait anxiety (located in the low introversion, high neuroticism quadrant in Eysenck's system); however, it is less clear to what Gray's impulsivity (BAS) system corresponds in Cloninger's model. The statement that NS is related to the tendency toward exploratory behaviour and intense excitement in response to novel stimuli suggests that this should be the important BAS dimension; whereas, the statement that RD is related to the tendency to respond intensely to reward and succorance and to learn to maintain rewarded behaviour suggests a secondary role for this factor.

Cloninger (1986) suggests that HA is, indeed, similar to Gray's (1982) anxiety dimension; and NS is similar to the impulsivity dimension; so, presumably, RD goes with the third and remaining dimension, psychoticism. However, prima facie RD seems more comparable to Gray's BAS/impulsivity dimension; this would leave NS to go with Gray's FFS/psychoticism dimension [psychoticism is where novelty seeking is to be found in Eysenck's system (Eysenck & Eysenck, 1976)]. In support of this claim, Waller et al. (1991) found that NS was negatively correlated with Tellegen's (1985) constraint factor, and although constraint has been aligned with Gray's BIS [Depue & Spoont (1987), largely by virtue of its response-inhibition character], Waller et al. (1991) found no relation between harm avoidance and constraint, as measured by the Multidimensional Personality Questionnaire [MPQ (DiLalla, Gottesman & Carey, 1993)]; NS is also negatively related to the California Psychological Inventory (Gough, 1969) socialization scale (Earlywine, Finn, Peterson & Pihl, 1992), which itself is negatively correlated with (EPQ) psychoticism; and NS is positively related to psychoticism-like traits such as criminality, aggressive acts and impulsivity (Nagoshi, Walter, Muntaner & Haertzen, 1992). Therefore, RD and not NS may be associated with Gray's BAS system. (The one remaining argument in favour of NS reflecting Gray's BAS system is its strong correlation with impulsivity.) If the above argument is correct, then it would be RD and not NS which should predict reactions to reward. Cloninger (1993) has recently suggested that persistence, formerly a lower-order component of RD (RD2), represents a separate dimension, but the significance of this modification to the basic model has yet to be explored.

The purpose of Experiment 1 was to examine the relationship between TPQ factors and the well-known EPQ factors. Once this relationship was known, then TPQ factors could be used to predict behavioural responses to reward and punishment in associative and instrumental learning (Experiments 2 and 3).

#### Method

# Subjects

Eighty-two Ss were tested, 41 males [age = 26.61 yr,  $\pm$  (SD) 6.21] and 41 females (25.73,  $\pm$  6.71). Ss were normal volunteers, whose names were picked from a S pool kept at the Psychology Department. Each was paid £5 for participation.

## Psychometric materials

The TPQ (Cloninger, 1989), which measures harm avoidance [HA], reward dependence [RD] and

#### Personality, reinforcement and learning

Table 1. Means and standard deviations (SD) for EPQ and TPQ scales used in Experiment 1

	Mean	SD
ТРО	<u></u>	
Harm Avoidance	13.71	6.78
Reward Dependence	17.79	5.00
Novelty Seeking	19.35	5.71
EPQ		
Extraversion	13.68	4.35
Neuroticism	12.50	5.28
Psychoticism	4.79	3.35
Lie	6.21	3.10

N = 82.

TPQ, Tridimensional Personality Questionnaire (Cloninger, 1989); EPQ, Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975).

novelty seeking [NS], and the Eysenck Personality Questionnaire [EPQ (Eysenck & Eysenck, 1975)], which measures extraversion [E], neuroticism [N], psychoticism [P] and response distortion (Lie), was administered.

# Design and procedure

A correlational design was employed in which TPQ and EPQ factors were compared. Ss were either asked to come to the Psychology Department (where they also participated in Experiments 2 and 3) or to complete the questionnaires in their own time and return the completed forms in pre-addressed envelopes provided.

## Results and Discussion

Table 1 presents the means and standard deviations (SD) for EPQ and TPQ factors.

In order to explore the relationship between EPQ and TPQ factors, and to determine whether RD rather than NS better reflects activity in Gray's BAS (*ex hypothesi*, E + /N +), three multiple regression models were computed. Each TPQ factor was regressed on the four EPQ factors. Stepwise inclusion of variables with the 'probability to enter' (PIN) of 0.10 was used. EPQ:Lie was forced into the model before E, N, and P to control for response distortion artefact. The results for the final regression models are given in Table 2. These data show that: (1) RD was related to E (positively), N (positively) and P (negatively); (2) HA was related to E (negatively) and N (positively); and (3) NS was related to E and P (both positively). These regression estimates for P, E and N were not altered by omitting Lie scores from the analysis. The (adjusted) squared multiple *R* was reasonable for HA (0.54) and RD (0.45) and poor for NS (0.29), indicating that a high percentage of TPQ variance was not shared with the EPQ. This suggested that the TPQ and EPQ are not equivalent models and do not differ only in terms of rotational position in a common factor space. Thus the TPQ and EPQ may not be equally predictive of reactions to reinforcement.

In terms of the structural relationship between EPQ and TPQ variables, HA was positioned roughly equidistant between (low) E ( $\beta = -0.42$ ) and (high) N ( $\beta = 0.52$ ). This is the position in Eysenckian factor space where Gray (1970) has located anxiety. The position of reward dependence in Eysenckian

Table 2. Regression results showing significant EPQ predictors of TPQ factors

		Predictor ( $\beta$ )					EPQ Model	
TPQ Criteria	E	N	P	L	F	R	$A_{dj}R^2$	
Reward Dependence	0.34	0.55	- 0.28	0.17	17.77*	0.69	0.45	
Harm Avoidance	- 0.42	0.52			24.63*	0.75	0.54	
Novelty Seeking	0.28	—	0.35	- 0.28	9.46*	0.56	0.29	

\**P* < 0.001. *N* = 82.

All  $\beta$  values are significant at the 5% level.

space is also loosely consistent with Gray's (1970) conception of impulsivity, as a combination of high E and high N. NS was comprised of equal parts of E and P.

Experiments 2 and 3 will be important in showing whether E + /P + (NS) or E + /N + /P - (RD) is more related to learning under rewarding conditions. An effect of RD over NS would suggest that high N is more important that high P in the effects of E upon reward-mediated learning. On the face of it, it seems that RD should be more related to Gray's impulsivity (BAS) dimension as compared with NS which appears very close in conception to Eysenck's P (Eysenck & Eysenck, 1976), and Zuckerman's sensation seeking (Zuckerman, 1994), dimensions.

## EXPERIMENT 2

#### Introduction

Associative learning of stimulus-stimulus regularities is a ubiquitous process of significant evolutionary advantage. The conjoint analysis of spatio-temporal parameters of stimuli, innate and conditioned, is a fundamental prerequisite to all forms of learning, including higher cognitive functions in human beings. Interest in associative learning has given rise to a large research literature devoted to the study of the influence of personality on the build-up and maintenance of conditioned responses (CRs). This research has been largely concerned with the attempt to establish the theoretical basis of the conditioning of fear, both in terms of its over-development (neurosis) and its under-development (psychopathy).

Eysenck's (1967; Eysenck & Eysenck, 1985) model predicts that levels of associative learning, irrespective of reinforcement contingencies, should be proportional to levels of arousal (taking into account the arousal properties of reinforcement); and that introverts should manifest better associative learning than extraverts unless the conditions are so arousing so as to lead to TMI in introverted Ss and hence to superior performance in extraverted Ss. In accordance with the Hullian one-factor conception of learning (see General Introduction), Eysenck's theory implies that the personality factor which influences learning under appetitive conditions will be the same as that which influences learning that reward is less arousing than punishment, one strong prediction is that extraverts should *never* show superior performance to introverts under reward (low arousal) if introverts are showing superior performance to extraverts under punishment (higher-arousal).

Gray (1970) suggested that Eysenck's general conditionability postulate concerning the superior performance of introverts should be replaced by the postulate of *fear* conditionability. Now, Gray (1975) agrees with Mowrer (1960) that fear is established by a classical conditioning process which associates innately punishing stimuli (UCSs) with initially neutral stimuli (CSs), therefore Gray's theory is clearly applicable to associative learning. For this reason, Gray's theory predicts that two separate personality factors should affect associative learning under appetitive and aversive stimuli, reflecting the two reward and punishment systems that mediate responses to these stimuli. Specifically, *Ss* high on measures of punishment-signed sensitivity (i.e. neurotic-introverts who are anxious) should show superior learning under aversive stimuli; while *Ss* high on measures of reward-signed sensitivity (i.e. neurotic-extraverts who are impulsive) should show superior learning under appetitive stimuli.

Most conditioning studies have used either neutral or aversive stimuli (see Levey and Martin, 1981), so these studies are not relevant to the contrast of Eysenck's and Gray's predictions. A smaller number of studies have used appetitive stimuli, but these results have been inconclusive. Kantorowitz (1978) found that E was correlated positively with appetitive conditioning [r = 0.88] and negatively with aversive conditioning [r = -0.76 (but see Eysenck & Eysenck, 1985 for an arousal-based interpretation of these data)], lending support to the Mowrer-Gray two-factor perspective. Other studies have either failed to find a correlation between appetitive conditioning and E (e.g. Lovibond, 1964; Mangan, 1974) or revealed complex relations between conditioning parameters and personality (e.g. Paisey & Mangan, 1988). Conditioning of the skin conductance response (SCR) has also been studied, but again the results have been inconclusive; for example, Barr and McConaghy (1974) found that anxious Ss showed the greatest appetitive electrodermal conditioning; and Mangan (1978) found that high E and low N Ss showed superior GSR conditioning using sexual UCSs. Thus, the effects of appetitive stimuli in associative learning are clearly in need of further research.

The aim of this second experiment was essentially twofold: (1) to determine the effects of reward and punishment on a simple computer-based associative learning task; and (2) to test the predictions of Eysenck's and Gray's causal models of personality.

## Method

# Subjects

Thirty-two Ss participated, comprising 16 males [age = 27.75 yr,  $\pm$  (SD) 7.61] and 16 females (27.88,  $\pm$  7.61). Ss were normal volunteers, whose names were picked from a S pool kept at the Psychology Department. Each was paid £5 for participation.

## Psychometric materials

Along with the TPQ and EPQ (see Experiment 1), the following scales were used: the impulsivity scale from the Eysenck Personality Inventory [EPI (Form A; Eysenck & Eysenck, 1964)]; the impulsiveness (IVE) and venturesomeness (VENT) scales from the Eysenck Personality Scales [EPS (Eysenck & Eysenck, 1991)]; trait anxiety from the State-Trait Anxiety Inventory [STAI (Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983)]; and the UWIST Mood Adjective Checklist [UMACL (Matthews, Jones & Chamberlain, 1990)], which provides state measures of energetic arousal, tense arousal and hedonic tone.

# Design

The associative learning task utilized a repeated-measures design comprising four CS-UCS conditions: (1) neutral, (2) random, (3) appetitive, and (4) aversive conditions. Each condition contained 25 trials, giving a total of 100 trials for the whole task. The 100 trials were grouped into blocks of four trials containing one of each of the four types of CS-UCS combination. Types of trials were randomly ordered within the blocks for each *S*. Ss were run between 10 a.m. and 1 p.m.

## Associative learning task

A trial consisted of the presentation of a CS followed by the delivery of an appetitive, aversive, or neutral UCS (see below). Crossed coloured lines, which dissected the computer screen into equally sized quadrants, served as CSs: purple was used for random trials, white for neutral trials, and green and blue for appetitive and aversive trials; half of the *S*s had the aversive-blue and appetitive-green combination and the other half, the alternate reinforcement-colour combination. A neutral trial was defined as one in which the CS signalled neither an appetitive nor aversive UCS; an appetitive trial as one in which the CS always signalled an appetitive UCS; an aversive trial as one in which the CS always signalled an appetitive UCS; and a random trial in which the CS signalled an equal distribution of neutral, aversive and appetitive UCSs (i.e. was equally, randomly, correlated with all UCS types).

CSs were presented against a black background, appearing on the screen for 2 sec. After the 2 sec CS presentation, the CSs were replaced by an empty box  $(8 \times 2 \text{ cm})$  appearing in the centre of the screen; in the upper half of the screen a message box  $(10 \times 5 \text{ cm})$  displayed: "GUESS NOW". Ss were required to 'guess' (CR) the direction of movement of a 'thermometer bar' in the centre box on the basis of the preceding CS. The 'thermometer bar' moved either to the right (appetitive-UCS) or to the left (aversive-UCS); for some trials (neutral-UCS) the bar did not move left or right but stayed motionless in the middle of the box. Ss recorded their guess (CR) by pressing one of three buttons on a button box: the middle button indicated no movement of the bar; the left button a leftward movement; and the right button a rightward movement (see instructions in Procedure).

Once Ss had made their guess, the UCS was presented (i.e. left/right movement of the thermometer bar plus pleasant/unpleasant sound and increment/decrement to money): a bar movement to the left was accompanied by a 90 dB low pitch sound, and '-' signs were printed underneath the box to indicate that money was being deducted. A bar movement to the right was accompanied by a 90 dB high pitch sound and '+' signs were printed underneath the box to indicate that money was being increased. The movement of the bar took 2.5 sec. Upon completion of the trial, a message appeared in a box in the upper half of the screen  $(10 \times 5 \text{ cm})$ ; this read: "READY?". The next trial was initiated by the experimenter pressing a computer key, and the above sequence was repeated. The random CS-UCS combination was included on the basis of pilot work which showed that fewer CS-UCS combinations made the task too easy for many Ss, with the result that some Ss achieved perfect scores after only one or two exposures; more than four CS-UCS trial types made the task too difficult and confusing, producing a high percentage of non-learners.

# CS affectivity ratings

Immediately following the associative learning task, Ss completed the UMACL for each CS type to assess levels of energetic arousal, tense arousal, and hedonic tone in the presence of aversive, neutral and appetitive conditioned stimuli. Order of presentation of the appetitive-CS and the aversive-CS was counterbalanced such that they were presented either first or third, with the neutral-CS always being presented second.

# Computer program and equipment

The computer program used to randomize the trials, present the stimuli and record responses was controlled by an ATARI ST1040 microcomputer. The stimuli were presented on a ATARI SC1224 monitor. The button box was  $12 \times 4$  cm, containing three 1.5 cm buttons in a row separated by 3 cm.

# Procedure

Ss gave informed consent by signing a consent form which stated that the study was investigating the relationship between personality and learning. Ss then completed the scales from the UMACL, STAI, EPQ, EPS, TPQ and EPI (in that order). Then Ss were presented with instructions for the associative learning task:

The computer will shortly present a series of trials. You will see a coloured line appear on the screen for a few seconds, and then a box will appear. When you see this box you must decide whether you think the computer will shade the left side or the right side. Sometimes neither side of the box will be shaded. You should concentrate on the individual colours as they predict shading (sequences of colours do not). The buttons are used to record your guesses and do not affect shading. Your task is to learn which colours predict the direction of shading. To do this, you must pay careful attention to everything that is presented on the monitor. When the left side of the box is shaded the computer will deduct money from you. When the right side of the box is shaded the computer will give you money. When neither side is shaded you will not gain or lose money. Please be as accurate as possible and try to learn to predict as fast as you can. Are you ready for the practice session?

Before undertaking the task, the experimenter verbally emphasized to Ss that their 'guess' would not alter the direction of the thermometer bar and monetary increments/decrements (i.e. the UCS), but that their speed and accuracy of response would affect the total amount won or lost. The latter instruction was designed to motivate learning. Pilot trials revealed that without such a motivation many Ss 'could not see the point' of the task (largely as a product of the non-contingent nature of the reinforcement: i.e. their responses and effort did not affect how much they would win/lose).

Following the associative learning task, CS affectivity was immediately assessed. Ss were instructed to look at the screen which presented the CSs and spend a few moments thinking about how they felt as they did this. They were then required to complete a UMACL. Testing took place in a sound-attenuated experimental cubicle. The procedures were approved by the Ethics Committee of the Institute of Psychiatry.

## Statistical analysis

Repeated-measures analysis of variance on the effects of appetitive, aversive and neutral CSs on associative learning scores and UMACL mood ratings were followed by Dunn's *t*-tests, using the appropriate error term from the ANOVA and with Bonferroni adjustment to the alpha level (Howell, 1987). In order to partial out variance attributed to non-specific learning, learning scores for the neutral conditions were forced into the regression models showing the effects of personality in associative learning scores under aversive and appetitive conditions.

#### Personality, reinforcement and learning

Table 3. Means and standard deviations (SD) for personality variables and associative learning scores under appetitive.

						es anae	appen.
avers	sive	and	neutr	al CS-	UCS	condition	ons

	Mean	SD
ТРО		
Harm Avoidance	15.47	6.88
Reward Dependence	17.53	4.00
Novelty Seeking	19.28	5.59
EPO		
Extraversion	12.06	4.27
Neuroticism	13.65	4.06
Psychoticism	4.94	3.36
Lie	5.37	3.65
EPI		
Impulsivity	4.22	2.03
EPS		
Impulsiveness	8.31	3.50
Venturesomeness	9.66	3.31
STAI		
Trait Anxiety	39.63	9.78
UMACL		
Energetic Arousal	22.18	4.00
Tense Arousal	16.94	4.94
Hedonic Tone	22.44	4.71
Learning		
CS-UCS: Appetitive	20.31	5.31
CS-UCS: Aversive	16.16	6.09
CS-UCS: Neutral	20.16	5.09

*N* = 32.

EPI, Eysenck Personality Inventory (Eysenck & Eysenck, 1964); EPS, Eysenck Personality Scales (Eysenck & Eysenck, 1991); STAI, State-Trait Anxiety Inventory (Spielberger et al., 1983); UMACL, UWIST Mood Adjective Checklist (Matthews et al., 1990).

#### Results

Descriptive statistics for the personality measures and associative learning scores are given in Table 3.

## Associative learning

The measure of associative learning taken was total number of correct responses (i.e. 'guesses') to: (1) aversive-CS, (2) appetitive-CS, and (3) neutral-CS. These scores ran from 0 to 25, with chance performance for any one CS type represented by a score of approx. 8, i.e. 25/3 (number of button choices). The intercorrelations showed that learning scores between: (1) appetitive and neutral conditions were unrelated [r = 0.15, ns]; (2) appetitive and aversive conditions weakly but significantly related [r = 0.34, P = 0.05]; and (3) aversive and neutral conditions more highly related [r = 0.48, P < 0.01].

To test the effects of positive and negative reinforcement on associative learning scores, and the possible influence of the colour of CSs, a two-way split-plot ANOVA was conducted with appetitive-CS, aversive-CS and neutral-CS comprising the repeated-measures factor and CS colour the between-Ss factor. This revealed a large main effect for type of reinforcement [F = 8.74, d.f. = 2,60, P < 0.001], but no effect for CS-colour [F = 1.56, d.f. = 1,30, P > 0.05] or for the interaction between CS-colour and type of reinforcement [F = 1.25, d.f. = 2,60, P > 0.05]. Associative learning (d.f. = 31) under aversive conditions was less than that under either neutral [t = 3.53, P < 0.01] or appetitive [t = 3.67, P < 0.01] conditions; and the appetitive condition did not suffer from the neutral condition [t = 0.14, P > 0.05].

# CS affectivity

Figure 1 shows the mean difference between reinforcing-CSs (appetitive and aversive) and neutral-CS for levels of each arousal/emotion measure: energetic arousal, tense arousal and hedonic tone. Two-way split-plot ANOVAs were computed for each response measure, comprising three levels of CS-type and two levels of order of presentation of reinforcement type. As there was no effect of colour of CS this factor was ignored in subsequent analyses. In all cases, there were no significant effects (P > 0.05) for either order of CS presentation or the interaction of CS presentation order and

Table 4. Pearson product-moment correlations between personality and learning under reinforcement conditions

	Neutral	Reward	Punishment
TPQ			
Harm Avoidance	0.20	0.05	0.40*
Reward Dependence	-0.20	0.30*	- 0.19
Novelty Seeking	0.10	- 0.06	0.07
EPQ			
Extraversion	- 0.03	-0.13	- 0.32*
Neuroticism	0.29	0.07	0.10
Psychoticism	0.11	- 0.01	0.03
EPI			
Impulsivity	- 0.01	- 0.30	-0.17
EPS			
Impulsiveness	0.07	0.05	- 0.01
Venturesomeness	0.06	0.06	0.09
STAI			
Trait Anxiety	0.14	0.08	0.13
UMACL			
Energetic Arousal	- 0.23	-0.22	- 0.22
Tense Arousal	- 0.06	0.21	0.44÷
Hedonic Tone	- 0.16	0.08	0.08

\*P < 0.05; one-tailed; †P < 0.05; two-tailed.

reinforcement type. Therefore the following results report only the significant effects of reinforcement type.

*Energetic arousal.* The main effect of reinforcement type [F = 3.71, d.f. = 2,60, P < 0.05] related to higher scores under the appetitive-CS [t = 2.25, P < 0.10] and under aversive-CS [t = 2.60, P < 0.05], as compared with the neutral-CS.

*Tense arousal.* The main effect of reinforcement type [F = 52.92, d.f. = 2,60, P < 0.001] reflected the finding that the aversive [t = 10.36, P < 0.01] and appetitive [t = 6.18, P < 0.01] CSs induced more tension that the neutral-CS; and the aversive-CS induced more tension than the appetitive-CS [t = 4.18, P < 0.01].

Hedonic tone. The main effect of reinforcement type [F = 21.19, d.f. = 2,60, P < 0.001] related to



Fig. 1. Mean differences and  $(\pm 1)$  standard errors between appetitive/aversive-CSs and neutral-CS showing the effects of appetitive-CS and aversive-CS on (UMACL) energetic arousal (EA), tense arousal (TA) and hedonic tone (HT).

Table 5. Final model statistics for regression of associative learning scores on EPQ and TPQ variables (stepwise regression with two-tailed 'probability to enter' of 0.10)

CS-UCS Condition	Predictors	β	t-value	R	$_{\rm sd} R^2$
Neutral Appetitive† Aversive†	None [TPQ] RD [TPQ] HA CS-UCS:Neutral	0.30 0.31 0.42	1.75* 2.01* 2.66**	0.30 0.57	0.06 0.28

N = 32

\*P < 0.05, \*\*P < 0.01; one-tailed.

\*Associative learning scores for the neutral condition were entered into the model in order to partial out non-specific learning variance.

the finding that the aversive-CS [t = 6.64, P < 0.01] and appetitive-CS [t = 3.27, P < 0.01] produced lower hedonic tone relative to the neutral-CS, although the aversive-CS did this to a greater extent that the appetitive-CS [t = 3.37, P < 0.01].

## Personality and associative learning

Simple correlations between personality (state and trait) and learning measures are presented in Table 4. Table 5 shows the regression models for each of the associative learning measures: associative learning under neutral conditions was unrelated to EPQ and TPQ variables; under appetitive conditions, (TPQ) RD was positively correlated with learning; and under the aversive condition (TPQ) HA was positively correlated with learning (learning was correlated with tense arousal). Learning scores under neutral and aversive conditions were positively related suggesting that learning under neutral conditions may have been, to some extent, aversively-mediated. Therefore, the procedure of forcing learning scores obtained in the neutral condition into the regression of aversively-mediated learning. In order to eliminate this possibility, the regression was rerun omitting learning in the neutral condition: this had no effect whatsoever on main personality predictor, harm avoidance; no other predictors entered the model.

The fact that N did not enter the regression model containing learning under neutral conditions (with a two-tailed probability to enter of 0.10; Table 5), despite the relatively high correlation of 0.29 (Table 4) reflects the fact that the exact probability was 0.106, so therefore just falling outside the entry criterion.

The effect of RD was restricted to two of its lower-order components: the correlation between RD1 (*sentimentality*) and appetitive learning was 0.22 (P < 0.15, one-tailed) and between RD2 (*persistence*) and appetitive learning 0.30 (P < 0.05, one-tailed). The correlation of the sum of RD1 and RD2 with appetitive learning was 0.36 (P < 0.05, one-tailed). From the data collected in Experiment 1, RD1 was correlated with E [r = 0.27, P < 0.05] and P [r = -0.44, P < 0.01], while RD2 was exclusively correlated with N [r = 0.38, P < 0.01].

## Discussion

The results show that associative learning of stimulus-stimulus regularities in a simple computer task was influenced by appetitive and aversive CS-UCS contingencies, and that these influences were mediated in part by personality factors. Overall, punishment exerted a large deleterious effect on associative learning; under both reward and neutral conditions learning was significantly higher than under punishment. The correlations between personality and associative learning revealed that HA influenced the effects of punishment, with Ss high in this trait showing greater learning as compared with Ss low in this trait; RD influenced the effects of reward similarly, with high reward-dependent Ss learning more than low RD Ss. The effects of RD were restricted to two of the four lower-order components; their relationship with EPQ variables suggested that associative learning under appetitive conditions was highest among high E and N and low P Ss. This suggests that all three of the EPQ factors are implicated in associative learning and that some of the lower-order factors of RD contain the correct mixture of these EPQ influences. In general, however, the effects of personality in reinforcement mediated learning were rather weak.

As predicted on the basis of a theoretical analysis of the comparability of TPQ and EPQ factors, NS did not affect learning with appetitive stimuli (nor approached statistical significance). Thus it appears that RD, and not NS, is related to Gray's approach (BAS) system and reactions to appetitive stimuli in associative learning (Gray, 1987). At this point, the alignment of Cloninger's theory (1986) would seem to be in need of modification.

The positive correlation between associative learning under neutral and aversive conditions suggested that neutral learning was, in part, aversively mediated. The fact that N correlated with neutral learning is consistent with this interpretation. Further research investigating the transfer of negative properties of punishing stimuli to apparently neutral stimuli would seem worthwhile. The results suggest one interesting hypothesis: neurotics tend to overgeneralize the effects of aversive stimuli to neutral stimuli and potentially appetitive stimuli.

Before discussing the results in detail, it is necessary to introduce several caveats concerning the interpretation of these data. Although a strong case was made in Experiment 1 for RD acting as the personality marker of responses to appetitive stimuli (thus supporting a one-tailed test in the analysis of the data), Cloninger does not associate RD with *learning* under appetitive conditions. Furthermore, the correlation between RD and learning under appetitive conditions was no greater than that found between [EPI] impulsivity and the same measure of appetitively-mediated learning. In Gray's (1981) theory, the impulsivity scale from the EPI is assumed to reflect sensitivity to appetitive stimuli, but in the present study (EPI) impulsivity was actually negatively correlated with appetitive responses [r = -0.30], suggesting that it does not in fact facilitate associative learning with appetitive stimuli (therefore the correlation could not be tested with a one-tailed test). However, the fact that (EPS) impulsiveness, which is highly similar to (EPI) impulsivity, was unrelated to learning may indicate that impulsivity *per se* is of less importance to appetitively-mediated associative learning than the correlation for (EPI) impulsivity may at first suggest. Indeed, the direction of effects of (EPI) impulsivity was the same under reward and punishment, indicating that it was measuring some general aspect of reinforcement (perhaps arousal) rather than specific reinforcement variance. Therefore, the effect of RD in appetitive responses was considered more important than impulsivity. However, these data require replication on a larger sample of Ss.

Although the prediction from Gray's model that impulsivity would be positively correlated with learning of appetitive stimuli was not confirmed, the more general prediction that such learning would be superior among neurotic-extraverts was supported by the association of RD1 (*sentimentality*) and RD2 (*persistence*) with E and N (and low P); the influence of low P in this regard may account for the failure of impulsivity (itself positively correlated with P) successfully to predict appetitively-mediated learning.

Consistent with previous studies (e.g. Eysenck & Levey, 1972; Levey & Martin, 1981), E was negatively related to associative learning with aversive stimuli; inconsistent with some previous data (e.g. Kantorowitz, 1878), but consistent with other data (e.g. Lovibond, 1964; Mangan, 1974), in the present study E was unrelated to learning under appetitive conditions. These findings indicate that E may mediate learning only under punishing conditions, and that the arguments for a general, arousal-based, conditionability factor require careful scrutiny.

Reward and punishment led to higher levels of energetic and tense arousal, with tension greatest for punishment, as compared with neutral conditions. Although punishment led to reduced hedonic tone, as expected, so too did reward (although not to the same extent). Both findings suggest that reward and punishment lead to a state of tension. Tense arousal is known to be related to caffeine-induced arousal (Corr, 1994; Thayer, 1989); therefore the finding that both reward and punishment lead to tension supports the hypothesis that reinforcement increases physiological arousal (Gray & Smith, 1969).

State measures were not found to be superior to trait measures of personality in predicting associative learning; although tense arousal was as good as HA in predicting responses to aversive stimuli. These data therefore are consistent with the view that sensitivity to reinforcement reflects trait components of personality, not transient states with little temporal stability.

In conclusion, two separate personality factors of reinforcement sensitivity, RD and HA, appear to mediate responses to appetitive and aversive stimuli, respectively, in associative learning; this finding supports the Mowrer-Gray perspective on reinforcement and learning and suggests that previous work in support of the Hull-Eysenck one-factor perspective may have been biased by focusing only on responses to aversive stimuli (or neutral stimuli that were aversely-mediated).

## **EXPERIMENT 3**

#### Introduction

Study of the effects of appetitive stimuli in learning has been most assiduously investigated using instrumental paradigms. Drawing upon early work (Forlano & Axelrod, 1937; Thompson & Hunnicutt, 1944), showing an association, albeit an inconsistent one, between introversion–extraversion and reinforcement, several studies have explored the interaction of reward/punishment and Eysenck's E factor, with results in general agreement with Gray's theory (e.g. Boddy, Carver & Rowley, 1986; Gupta, 1976, 1990; Gupta & Nagpal, 1978; Gupta & Shukla, 1989; Nicholson & Gray, 1971, 1972; Seunath, 1975). Other work supports Gray's more specific hypothesis that N enhances the effects of E in reward-mediated learning (e.g. Nagpal & Gupta, 1979). Less often, however, has the effects of P been examined, although there are exceptions (e.g. McCord & Wakefield, 1981).

Studies which have specifically focused on anxiety and behavioural inhibition-disinhibition also lend support to Gray's theory. For example, Wolwer and Erdmann (1989) found that anxious Ss were superior at passive avoidance behaviour and that this superiority was lost under alcohol; Avila, Molto, Segarra and Torrubia (1991) found that punishment sensitive Ss make fewer commission errors in university examinations (where such errors are punished by a reduction in total mark). However, other evidence fail to support Gray's theory (e.g. Gorenstein & Newman, 1980; Newman, 1987; Zinbarg & Revelle, 1989).

The common finding that introverts show greater passive avoidance under punishment, while extraverts show greater approach behaviour under reward, in appropriate instrumental paradigms (e.g. verbal operant conditioning), seems to provide clear evidence for Gray's BIS and BAS systems (see General Introduction). However, less recognized, is the fact that such findings are open to an Eysenckian interpretation in terms of under and over-arousal stimulus-seeking (approach) and stimulus-avoiding (avoidance) behavioural tendencies.

Now, the general predictions from Eysenck's (1967) model, that introverts should learn more than extraverts under low to moderate levels of arousal with extraverts showing a learning advantage only at high levels of arousal, may be more complex when applied to learning behaviour which consists in response activation (approach) and suppression (passive avoidance): extraverts may be superior in approach behaviour, and introverts may be superior in passive avoidance (i.e. Gray's prediction) even if the effects of personality in learning are arousal-mediated (i.e. Eysenck's model). Couched in Eysenckian terms, passive avoidance may represent a form of reduced sensory stimulation (i.e. a reduction in contact with arousal-inducing aversive UCSs) while approach may represent a form of increased sensory stimulation (i.e. increase in contact with arousal-inducing appetitive UCSs). Therefore, introverts may be more aroused than extraverts under approach conditions and therefore be less motivated to increase sensory stimulation (i.e. by engaging in behaviour which elicits sensory stimulation, UCSs). Thus, it could be predicted that extraverts should be superior in learning of approach behaviour. Conversely, extraverts may be under-aroused under passive avoidance conditions (i.e. reduction in UCSs), seeking to increase stimulation by exploratory behaviour, and thereby showing poor passive avoidance behaviour.

Eysenck's and Gray's theories thus seem indistinguishable when applied to approach and passive avoidance. How may these theories be contrasted empirically? Eysenck predicts that one causal influence (arousal), as represented by one personality factor (introversion-extraversion), should mediate instrumental learning (the 'Hull-Eysenck perspective'). A strong prediction from Eysenck's model is that approach behaviour (*ex hypothesi*, sensation seeking) should be negatively correlated with passive avoidance behaviour (*ex hypothesi*, sensation reducing). In contrast, Gray predicts that two separate causal influences (reward and punishment sensitivity) should differentially affect passive avoidance and approach (the 'Mowrer-Gray perspective'); and given the independent influence of reward and punishment systems upon learning, the correlation between approach and passive avoidance is hypothesized to be weak or zero (reflecting only cognitive ability, e.g. general intelligence). Specifically, Gray predicts that, as with associative learning, the personality system that

mediates reward (impulsivity) is independent to that which mediates punishment (anxiety), and that impulsive Ss (neurotic-extraverts) should be most responsive to appetitive stimuli and therefore show the most approach behaviour; and anxious Ss (neurotic-introverts) should be most responsive to aversive stimuli and therefore show the most passive avoidance behaviour.

Cloninger's (1986) hypotheses are similar to Gray's in predicting superior responses to aversive stimuli in high HA (anxious) Ss; responses to appetitive stimuli are hypothesized to be associated with high NS scores, but this assertion has been challenged by the results of Experiment 1, which showed that RD, rather than NS, relates to appetitively-mediated learning.

Predictions based on Newman's model (Gorenstein & Newman, 1980; Newman, Patterson & Kossom, 1987; Patterson, Kossom & Newman, 1987) stand somewhat apart from those of Gray and Cloninger. Newman's (1987) focus is not on sensitivity to cues of reward and punishment (central to Gray's and Cloninger's theories) but on extraverts' disinhibition of response, and reflectivity failure, following presentation of punishment when reward is available. Newman argues that extravert/impulsive Ss suffer from a response modulation deficit in passive avoidance behaviour because of their over-sensitivity to reward: that is, extraverts (more easily than introverts) develop dominant response sets to reward and these serve to antagonize appropriate response-suppression to punishment. It is also assumed that punishment leads to arousal in extraverts, facilitating reward dominant responding and thereby leading to a further reduction in information processing of response-punishment contingencies. Newman thus predicts that high extraversion/impulsivity will be negatively related to passive avoidance behaviour. In addition, Newman argues, exactly as for Gray's BIS, that introverts respond to punishment with an interruption of approach behaviour and increased information processing due to arousal increments. Therefore, in general, Newman's model predicts a cross-over of personality and instrumental learning relations, such that dominance of response set impairs responses to alternate reinforcers.

The aim of this study was to investigate the relationship between personality and responses to reward and punishment in a relatively pure instrumental learning task which has been stripped of its associative component. This task was appropriate for contrasting Eysenck's, Gray's, Cloninger's and Newman's theoretical predictions.

## Method

## Subjects

The same Ss as in the associative phase of the experiment served in the instrumental phase.

## Design

Three repeated-measure reinforcement factors were employed: (1) neutral-CS, (2) appetitive-CS and (3) aversive-CS. The whole task was divided into 11 sections, within each section one block of neutral, one block of appetitive and one block of aversive CSs were presented. Each block comprised 16 five-trial movements, or sub-blocks, making a total of 48 five-trial sub-blocks per section. The order of the three blocks was random within each section and random across *Ss*. The first section contained three neutral-CS blocks to establish a baseline of responding.

## Instrumental learning task

The screen background was black; and two intersecting lines (dividing the screen into equally sized quadrants) served as the CSs. The CSs were identical to those used in the associative phase and comprised crossed colour lines, the colours corresponding to appetitive, aversive and neutral contingencies. A target (i.e. asterisk, \*) moved between these quadrants and the Ss' task was to follow this target around the quadrants. The movement time of the target was (almost) instantaneous, and was initiated by the S 'touching' the screen with a wand. The target area was defined as a 2 cm radius around the target. The target moved only if it had been 'touched' with the wand.

# Reinforcement manipulation

Reinforcement was manipulated by the following means: (1) during the performance of the task, reinforcement comprised a '+' (for reward) and '-' (for punishment) sign appearing in a box in

the centre of the screen for 0.5 sec; this was also accompanied by either a pleasant or unpleasant sound (identical to that presented in the associative learning phase; Experiment 2); and (2) each reinforcer represented an increment or decrement of 5 pence. The amount of money won and lost was shown separately during the inter-block intervals, along with the current cash balance. No actual money was given to Ss during the task. (The decision not to show the running cash total was used in an attempt to separate monies lost from monies gained and provide Ss with information regarding their performance in the aversive and appetitive blocks.)

Reinforcement criteria for each five-trial sub-block was contingent upon the following rules:

*Passive avoidance.* Mean RT to the aversive-CS (for the sub-block of five target movements) had to be at least 5% slower than that for the grand mean RT of the preceding neutral-CS block (with the proviso that this neutral mean RT was not itself slower than the corresponding mean from the first section).

Approach. Mean RT to the appetitive-CS (for the sub-block of five target movements) had to be 5% faster than the grand mean RT of the preceding neutral-CS block (also with the above proviso but in the reverse direction).

During the interval between the sections the following message was shown: "YOU HAVE WON  $\times$  PENCE/YOU HAVE LOST  $\times$  PENCE/YOUR CASH BALANCE IS\*.\*\*" (0-20 sec) then "THE AMOUNT OF MONEY YOU GAIN DEPENDS ON YOUR RESPONSES TO THE TARGET" (21–25 sec), and then "TOUCH GO TO CONTINUE" (26 sec).

## Performance measures

Dependent variables comprised: (1) speed of response to CSs, and (2) total number of reinforcers delivered throughout the task (the basis on which reinforcers were given is described below). Mean speed of response for the sub-blocks of five target movements were compared with the grand mean baseline response established in the preceding (neutral-CS) block. Pilot work revealed that some Ss deliberately increased their reaction times (RT) in the neutral-CS condition in order more easily to achieve relatively faster RTs in the appetitive-CS condition, leading to a high rate of reward. In order to prevent this response strategy, baseline responses (from the immediately preceding CS-neutral block) were used only if they were faster than the mean for section 1 (which served as the initial baseline condition). If baselines were not faster in subsequent sections then the baseline from section 1 was substituted.

Approach behaviour within a section was defined as mean RT to neutral-CS minus mean RT to appetitive-CS (i.e. an increase in speed) averaged across the 16 five-trial sub-blocks of each block.

Passive Avoidance was defined as mean RT to aversive-CS minus mean RT to neutral-CS (i.e. a decrease in speed) averaged across the 16 five-trial sub-blocks of each block.

In all statistical analyses, RT differences for approach and passive avoidance were represented as a positive value, with higher scores indicating more approach and passive avoidance learning.

The number of actual reinforcers (i.e. amount of money) delivered during passive avoidance and approach behaviour was also recorded. High values indicate higher sums of money won (good approach) and lost (poor passive avoidance). Therefore a large number of rewards reflects superior approach behaviour, while a large number of punishments reflect poor passive avoidance behaviour.

Data from sections 9, 10 and 11 were used for the main asymptotic (RT) measure of learning. Two separate one-way repeated-measures ANOVAs, with these three sections comprising the levels of the repeated-measures factor, showed that these RTs were stable across sections, with no significant differences for either approach behaviour [F = 0.27, d.f. = 2,62, P > 0.05] or passive avoidance behaviour [F = 1.81, d.f. = 2,62, P > 0.05].

## Computer program and equipment

The computer program used to randomize the trials, present the stimuli and record responses was controlled by an ATARI ST1040 microcomputer. The stimuli were presented on a ATARI SC1224 monitor. A 'Microtec' touch screen was used to register responses. The 'wand' used by Ss comprised a 12 in. long thin perspex tube. The wand did not have to touch the screen for a response to be registered,

rather, the wand had to break a matrix of infrared beams which crossed the touch screen and covered the monitor screen. The spatial position of the target position on the touch screen corresponded exactly with the target position on the computer monitor. An elbow rest was provided for the comfort of Ss and the reduction of fatigue due to repetitive arm and hand movements.

## Procedure

Prior to commencing the instrumental learning task, Ss completed the associative learning task (Experiment 2). Before starting the instrumental task, Ss were asked to read the instructions for the practice session and commence the short practice (any problems with the use of the wand were corrected at this stage).

*Practice instructions.* "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 as accurately as possible with the wand in the manner already described to you. A practice period follows to familiarise you with the task. Please touch 'GO' to start."

Once the practice session was complete, the instructions for the acquisition stage of the study were issued.

Acquisition instructions. "During the next computer task, you will have total control over how much you win and lose. You will win money on the same screen colour as before. You will lose money on the same screen colour as before. This time you will win money when you respond correctly and only lose money when you respond incorrectly. When you win a '+' sign will appear in the centre of the screen. When you lose money a '-' sign will appear in the centre of the screen. When you lose money a '-' sign will appear in the centre of the screen. 'Your task is to work out how best to respond to win money and how best to respond to avoid losing money. You should try different ways of responding until you discover the correct ones. The amount you win and lose will depend entirely on how you respond to the target. You start with the amount of money you earned on the previous computer task. There is no limit to the amount you may gain on this task—this is entirely in your hands. Whatever you earn you may keep at the end of the experiment. This will be your payment for participating in the study. Please touch 'GO' to start."

Each section was initiated by the S touching 'GO' which appeared in a  $2 \times 2$  cm box located at the intersection of the two coloured, CS, lines. All Ss started the experiment with £2.50 (bogus 'earnings' from the associative learning phase).

# Results

Means and standard deviations for personality factors have already been given in Table 3. Figure 2 shows the RTs for neutral, appetitive and aversive blocks over the acquisition (2-11) sections. Figure 3 shows the absolute levels of approach and passive avoidance at asymptote (mean of sections 9–11). Figure 4 shows that distribution of rewards and punishments over the acquisition sections.

## Acquisition measures

Multivariate analysis of variance (MANOVA) was performed on the acquisition measures. Looking at the acquisition RTs (Sections 2–11; Fig. 2), there was a slight but non-significant decline in RTs in neutral blocks [F = 1.56, d.f. = 9,23, P > 0.05]; in the appetitive blocks, RTs significantly declined [F = 2.83, d.f. = 9,23, P < 0.05; Linear component, t = 3.51, P < 0.01 (representing approach behaviour)]; in the aversive blocks, RTs did not show an increase over the sections [F = 0.98, d.f. = 9,23, P > 0.05], but rather showed a dramatic increase from Section 2 onwards reflecting rapid response suppression.

Paired *t*-tests for the mean values of blocks over the three sections (9–11), which comprised the asymptote learning, showed: (1) RTs on appetitive trials (mean = 586 ms,  $\pm$  SD = 135) were significantly faster (reflecting approach behaviour) than those on neutral trials (631 ms,  $\pm$  147 [t = 1.70, d.f. = 31, P < 0.05; one-tailed]); and (2) RT on aversive trials (1141 ms,  $\pm$  385) were significantly slower (reflecting passive avoidance behaviour) than those on neutral trials [t = 7.42, d.f. = 31, P < 0.001; one-tailed]. It was obvious that over the total sample passive avoidance tendencies were much stronger than approach tendencies; however, this was partly an artefact of the task: it was easier to reduce RT speed (passive avoidance) than to increase RT speed (approach [presumably because neutral RTs were close to ceiling]). These measures are shown in Fig. 3 (for



Fig. 2. Means and  $(\pm 1)$  standard errors for RT in neutral (section 1, baseline), and neutral, aversive and appetitive blocks over the acquisition (2–11) sections. Relative to neutral RTs, shorter latencies to the appetitive-CS represent approach behaviour and longer latencies to aversive-CS represent passive avoidance.

illustrative purposes, passive avoidance is presented in terms of increases, and approach as decreases, in RT as compared with RTs in neutral blocks).

As expected, the frequency of punishments was relatively high during the early part of the task, whereas the frequency of rewards was relatively high during the latter part of the task (Fig. 4). The mean number of punishments during the first reinforcement section (mean = 4.69,  $\pm$  SD = 3.30) was greater than the mean number of rewards (3.09,  $\pm$  2.90; t = 2.62, d.f. = 31, P < 0.05); the reverse was true for the last section with the mean number of rewards (6.78,  $\pm$  3.68) being very much greater than the mean number of punishments (0.53,  $\pm$  1.11; t = 8.80, d.f. = 31, P < 0.001). The increase in rewards over the course of acquisition was significant [F = 4.04, d.f. = 9,23, P < 0.01] with a strong linear component [t = 4.85, P < 0.001]; the decrease in punishments was also significant [F = 5.00, d.f. = 9,23, P < 0.001] also with a strong linear component [t = 6.80, P < 0.001].

The correlations between approach and passive avoidance performance showed: (1) approach (RT) responses were positively correlated with the total number of rewards [r = 0.65, P < 0.01; one-tailed] and (2) passive avoidance (RT) was negatively correlated with the total number of punishments [r = -0.32, P > 0.05; one-tailed]. The sign of the latter correlation reflects the fact more passive avoidance (i.e. a higher score) led to a low level of punishment. The correlation between approach (RT) and passive avoidance (RT) behaviour was meagre and non-significant [r = 0.16]; and neither passive avoidance nor approach was significantly correlated with CS-UCS learning under neutral [rs = -0.15 and 0.15], aversive [rs = -0.05 and 0.17] or appetitive conditions [rs = -0.23 and 0.15; respectively].

## Effects of personality

RT measures were taken at asymptote while number of reinforcers represented the total number



Fig. 3. Means and  $(\pm 1)$  standard errors of asymptotic approach and passive avoidance behaviour (mean of sections 9–11). RTs represent the decreased latencies to the appetitive-CS (approach), and increased latencies to aversive-CS (passive avoidance), relative to the neutral condition.

accumulated over the whole task. Table 6 presents the results for the final regression models of performance on personality. Each performance measure was regressed on personality measures with a stepwise algorithm to enter variables into the model (with the 'probability to enter', PIN, set at 0.10). EPQ:Lie scores were forced into the models in order to partial out possible response bias in the personality measures (a comparable analysis with the omission of EPQ:Lie scores was conducted but with no effect on the results).

The results show that: (1) NS was negatively related to RT under neutral blocks; (2) Ss high in impulsiveness showing the least passive avoidance behaviour (defined in terms of number of punishments received; Fig. 5) and (3) trait anxiety impaired approach behaviour (defined in RT terms; Fig. 6), with Ss high in trait anxiety showing the least approach behaviour.

Interactions between impulsivity and anxiety with type of reinforcement have been previously reported by Zinbarg and Revelle (1989). The possibility that the interaction of these two factors might have predicted performance in the present task was tested by re-running the above multiple regression

Table 6. Significant personality predictors of acquisition under reward and punishment. Performance consists of: (1) RT under baseline neutral condition, (2) approach and passive avoidance behaviour, defined in terms of (a) RT differences (both scored in positive direction), and (b) total number of rewards and punishments received

Performance measure	Predictors	β	Overall Model: F	$_{\rm ub}R^2$
(1) NEUTRAL RT (2) ACQUISITION	[TPQ] NS	- 0.39	5.28*	0.39
(a) RT (b) No. of Rewards	[STAI] Trait Anxiety No predictors	- 0.38	5.10*	0.38
(a) RT (b) No. of Punishments	No predictors [EPS] Impulsiveness	0.65	5.75**	0.53

\**P* < 0.05, \*\**P* < 0.01.

All  $\beta$ s significant at 5% level.



Fig. 4. Means and  $(\pm 1)$  standard errors of the distribution of positive and negative reinforcement over the acquisition sections (2-11), showing the decline in punishments due to successful passive avoidance and accumulation of rewards due to successful approach behaviour.



Fig. 5. Means and (±1) standard errors of the distribution of positive and negative reinforcement over the acquisition sections (2-11) for low and high [EPS] impulsiveness Ss (grouped on basis of median split; low Imp <9, high Imp >9). High impulsiveness Ss received more punishments at asymptote than low impulsiveness Ss reflecting relatively poor passive avoidance behaviour.



Fig. 6. Regression slopes showing the relationship between trait anxiety and RTs to appetitive [ $\beta = 0.52$ , t = 3.38, p < 0.01] and neutral-CSs [ $\beta = 0.08, t = 0.45, p > 0.05$ ]: low anxiety Ss showed a marked increase in RT speed to appetitive-CSs with no effect of neutral-CSs.

models with the addition of the interaction term of anxiety  $\times$  impulsivity (the interaction variable was computed from the cross-product of standard scores for impulsivity and anxiety). The results completely replicated those represented in Table 6 (with trivial changes in  $\beta$  values), but failed to find significant interaction effects for any of the performance measures.

# Discussion

Poor passive avoidance behaviour, as measured by the number of negative reinforcers received, was predicted by (EPS) impulsiveness, with Ss high in this trait incurring a higher level of punishment (Table 6; Fig. 5). Approach behaviour, as measured by speed of response, was greatest among low trait anxious Ss (Table 6; Fig. 6). These findings suggest that high anxiety antagonises approach behaviour while high impulsivity antagonizes passive avoidance behaviour.

The finding that high impulsiveness Ss were not distinguished from low impulsiveness Ss in terms of mean increase in RTs in punishment, relative to neutral conditions, may indicate that high impulsiveness Ss incurred a high level of punishment because of a failure to maintain a *consistent* level of slow responding (passive avoidance) over the five-trial sub-blocks on which negative reinforcement was based. This inability to maintain a consistent level of response suppression might reflect an important characteristic of impulsive behaviour, namely disinhibited responding. This interpretation may suggest that the *variation* in response suppression is greater among high impulsives than among low impulsives. In the present experiment, the failure to find a positive relation between approach behaviour and impulsivity might also reflect the inconsistency of response on behalf of highly impulsive Ss (in the task approach behaviour was defined to a large extent in terms of consistency, i.e. sub-block means of five-trial RTs). A task in which reward was based on peaks of approach behaviour might better reveal an effect of impulsivity, but where consistency is demanded impulsivity seems to impair performance. If the above speculation on the role of consistency of response suppression during punishment is tenable then these results cannot be cited as a disconfirmation of Gray's theory.

The finding that high impulsive Ss incurred a higher level of punishments for *not* slowing their RTs to the aversive-CS is consistent with Newman's (1987) model of disinhibitory behaviour in impulsive Ss. This finding suggests that impulsive individuals suffer from a response-modulation problem.

The failure to find a simple relationship between high levels of anxiety and high levels of passive avoidance is in striking contrast to animal data (Gray, 1982), which shows a clear association between passive avoidance and conditioned fear (i.e. anxiety). It is a possibility that in the present experiment, a functional ceiling effect was operating in passive avoidance. Perhaps the ease with which Ss acquired passive avoidance responses very early in the task abolished the effects of individual differences. However, analysis of passive avoidance in the first and second reinforcement sections did not suggest that highly anxious Ss were superior at passive avoidance learning in the early stages of the task.

The fact that low anxiety Ss showed the greatest reward-mediated approach behaviour is similar to those findings showing greater positive emotions among low anxiety, whether measured in terms of induced mood (Larsen & Katelaar, 1991), self-report questionnaire (Ball & Zuckerman, 1990), or affective modulation of the startle reflex (Corr, Wilson, Fatidou, Kumuri, Gray, Checkley & Gray, submitted).

Extending the Newman-type argument, if impulsive Ss have a dominant set for reward, which impairs passive avoidance, then it could be argued that anxious Ss have a dominant set for punishment which impairs approach behaviour. This would provide a pleasing symmetry, as well as being perfectly consistent with the hypothesis that high levels of anxiety do actually facilitate fear conditioning (Experiment 2). The combination of high fear conditioning and insensitivity to appetitive stimuli (Experiment 3) may help to explain the disabling nature of clinical anxiety states.

The above line of argument may go some way to reconciling Gray's theory with that of Newman's. In particular, Gray's hypothesis that high impulsivity is associated with a *relative* dominance of approach behaviour and high anxiety is associated with a *relative* dominance of passive avoidance behaviour. In turn, this general statement is consistent with the idea that the behavioural effects of reward and punishment systems are determined by the reciprocal inhibitory link that is assumed to exist between these systems (Gray & Smith, 1969). Clearly these issues are in need of further investigation. A clear prediction is that, in a pure punishment or a pure reward situation, the interaction will disappear and Gray's theory should receive clearer support, barring ceiling effects. However, the problems of obtaining such pure punishment and reward situations should not be underestimated; indeed, these theoretically ideal situations may, in practice, be virtually impossible to achieve because of the basal activity of the BIS and BAS (suggested by the persistence, as in clinical anxiety, of emotional states long after the disappearance of actual reinforcing stimuli).

NS was negatively correlated with RTs under neutral conditions (Table 6), showing that high NS Ss had faster reaction times than low NS Ss. The significance of this finding is unclear. One possibility is high NS is related to appetitive responses, as hypothesized by Cloninger (1986), and that this sensitivity was generalized from the appetitive conditions to the neutral conditions; the difference score used in the present study may therefore have concealed the true effects of NS in appetitive responses. However, this possibility was ruled-out by the observation that there was no relationship between NS and RT under appetitive conditions (ignoring neutral RTs; r = -0.11, ns). Perhaps NS is concerned with exploratory behaviour in general and 'go' responses, but is unrelated to reactions to specific types of reinforcement. Future research should monitor the effects of this factor in order to clarify its role in performance.

In conclusion, consistent with other evidence (e.g. Zinbarg & Revelle, 1989), Gray's theory, in contrast to Eysenck's theory, is supported by the finding that impulsivity and anxiety, and not extraversion and neuroticism, exerted main effects on instrumental behaviour. The weak positive correlation between approach and passive avoidance behaviour discounts an interpretation of the data in terms of arousal-mediated response activation/suppression (the 'Hull-Mowrer perspective'); the alternative 'Mowrer-Gray perspective' is supported by the relative independence of separate appetitively (approach) and aversively-mediated (passive avoidance) behaviours. However, Newman's model seems best able to account for the anxiety and impulsivity effects observed.

# GENERAL DISCUSSION

The general aim of the study was to explore the relationship between personality and reactions to reward and punishment in two-process (associative and instrumental) learning in order to contrast the

Hull-Eysenck (one-factor) perspective with the Mowrer-Gray (two-factor) perspective (see General Introduction). The specific hypotheses were taken from the main biological models of personality: Eysenck (1967), Gray (1987, 1991), Cloninger (1986) and Newman (Gorenstein & Newman, 1980; Newman & Kossom, 1987; Patterson *et al.*, 1987).

Experiment 1 considered the psychometric description of reinforcement-sensitivity, and established that (TPQ) *harm avoidance* (HA) was associated with low extraversion and high neuroticism: *reward dependence* (RD) with high extraversion, high neuroticism and low psychoticism; and *novelty seeking* (NS) with high extraversion and high psychoticism. However, the TPQ variance explained by the EPQ was not impressive, indicating that the two models are not interchangeable, and therefore likely to differ in their power to account for individual differences in reinforcement-sensitivity.

Experiment 2 showed that aversive CS-UCS associations produced a lower level of learning that either appetitive or neutral CS-UCS learning; and that HA mediated aversive CS-UCS associations, while RD mediated appetitive CS-UCS associations. The role of the lower-order factors of RD in mediating appetitive associative learning was highlighted by the finding that only two lower-order factors affected learning: RD1 (*sentimentality*) and RD2 (*persistence*). The correlation of EPQ factors with RD1 (E + P -) and RD2 (N + ) suggests that Gray's BAS system, so far as it affects associative learning, is associated with high extraversion and neuroticism and low psychoticism.

Experiment 3 showed that, in an instrumental learning task that had been divested of its associative learning component, the more familiar measures of impulsivity and anxiety mediated reactions to reward and punishment. The results are consistent with those of other workers (e.g. Zinbarg & Revelle, 1989) in showing the importance of anxiety/impulsivity over extraversion/neuroticism in instrumental learning. Interpreted in terms of Newman's model, the pattern of results suggest the following relationship between personality, reinforcement-sensitivity and instrumental learning. (1) Impulsive *Ss*, putatively with a dominant response set for reward, are poor at adopting responses which optimally serve punishment contingencies when reward is present. In particular, it appeared that the specific passive avoidance deficit found in Experiment 3 reflected the fact that high impulsiveness *Ss* could not maintain a *consistent* level of slow responding over the five-trial sub-blocks which served as the criterion of performance. Future research should address the question of whether the *variability* in appetitively and aversively-mediated behaviour is a more powerful predictor of responses to reward and punishment than the absolute *level* of response. (2) Anxious *Ss*, putatively with a dominant response set for punishment, are poor at adopting responses which optimally serve reward contingencies when punishment is present.

Therefore, in accord with Gray's model, impulsivity and anxiety were related to reward and punishment sensitivity; however, inconsistent with Gray's model, but consistent with Newman's model, the interaction of reward/punishment and impulsivity/anxiety suggested that sensitivity to one reinforcement type led to a dominant response set which impaired adoptive responses to the alternate reinforcement type. Although it could be argued that this effect could be an, unspecified, artefact of the design of the task, it should be borne in mind that Newman and associates (e.g. Gorenstein & Newman, 1980; Newman & Kossom, 1986; Patterson *et al.*, 1987) have reported similar effects using a variety of different behavioural measures.

The results provide general support for the Mowrer–Gray perspective on the relationship between reinforcement, personality and learning. In Experiment 2, the separate effects of HA and RD suggested that at least two causal factors were affecting associative learning. The Hull–Eysenck perspective would have been supported if the personality factor that mediated the effects of punishment was the same as that which mediated the effects of reward.

Consistent with previous research, introversion was related to aversive CS-UCS associations, but E had no effect on appetitive or neutral CS-UCS associations. If appetitive (or, indeed, neutral) stimuli had not been used in this study, then the conclusion might have been drawn that superior conditioning is found among introverts, a conclusion that would have been consistent with a plethora of previous findings (see Levey & Martin, 1981, for review). The finding that E was not even related to learning under neutral CS-UCS conditions suggests that previous work with the eye-blink conditioning paradigm (e.g. Eysenck & Levey, 1972), might have been aversive in nature, thus revealing only effects of introversion. Certainly, an air-puff, which serves as the UCS in the classic eye-blink conditioning, is not neutral with respect to reinforcement. In addition, the robust E effect in classical conditioning might be explained by the importance of HA and RD (both correlated with E) found in

the current associative learning task; it would be interesting to use this HA/RD in the eye-blink conditioning in order to explore this possibility.

Although a plausible account of passive avoidance and approach behaviour, couched in Eysenckian arousal-based terms, was attempted (i.e. superior sensation-seeking, approach, in extraverts and superior sensation-avoiding, passive avoidance, in introverts; due to under and over-arousal, respectively), the pattern of results did not permit a one-factor explanation of the data: passive avoidance and approach were uncorrelated, and each was predicted by separate, and orthogonal, dimensions of personality, suggesting two, not one, reinforcement-related causal factors.

Despite the lack of support for the one-factor, arousal-based, theory of learning in the present data, other evidence suggests that some forms of learning/performance are mediated by general arousal (at least when reinforcement is not used). Experiments in our laboratory (e.g. Corr, Pickering & Gray, 1995) have shown than an automatic form of acquisition (also known as procedural learning), and the more familiar measure of critical flicker/fusion frequency, show a highly similar (caffeine-induced) arousal by extraversion effect in accordance with Eysenck's (1967) model.

Therefore, in contrasting Eysenck's and Gray's personality theories, it seems necessary to distinguish between behaviour which is arousal-mediated from that which is reinforcement-mediated, as well as between processes within a given behaviour type [e.g. skilled behaviour in which a declarative learning process precedes a procedural process (cf. Anderson, 1982; Fitts & Posner, 1967)]. Thus, Eysenck's and Gray's theories may relate to different types of behaviour (the question of the role of reinforcement in inducing arousal, and vice versa, remains an important but unresolved question).

In conclusion, the pattern of results suggest that the Mowrer–Gray two-factor theory (i.e. separable reward and punishment systems) is valid in both associative and instrumental phases of learning. However, the effects of personality in mediating reinforcement are not simple. The results indicate that the role of Cloninger's TPQ factors in associative learning is worthy of further attention; and the respective power of Gray's and Newman's models in explaining the pattern of anxiety and impulsivity in instrumental learning requires systematic investigation was highlighted. The value of distinguishing between theoretically relevant phases of learning/performance in biologically-based personality research was highlighted.

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