



PERSONALITY AND AFFECTIVE MODULATION OF THE STARTLE REFLEX

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Summary—The human startle reflex, as indexed by strength of eyeblink to a sudden, loud noise, has been shown to vary according to the presence of pleasant and unpleasant stimuli. An experiment was conducted to determine whether this effect is in turn dependent on the personality of the subject. Subjects viewed a series of slides classified as pleasant, unpleasant or neutral, with acoustic startle probes being presented unpredictably during and between slides. Electromyographic (EMG) measures of eyeblink responses confirmed the expected pattern of modulation, with pleasant slides reducing and unpleasant slides increasing the amplitude of startle. Harm Avoidance (HA), as measured by Cloninger's Tridimensional Personality Questionnaire (TPQ), mediated these effects: only subjects high in HA showed modulation to unpleasant slides, while only subjects low in HA showed modulation to pleasant slides. Affective modulation, as measured by response latency, was mediated by Extraversion (E) and Neuroticism (N), as measured by the Eysenck Personality Questionnaire (EPQ): only subjects who were extraverted and stable showed the expected linear pattern of modulated startle. The implications of these data for Cloninger's, Gray's and Eysenck's theories of personality are discussed.

INTRODUCTION

The startle reflex consists of a set of involuntary responses to a sudden, intense stimulus, especially when novel and aversive (Landis & Hunt, 1939). The startle response pattern, and its associated neurophysiology, is similar across mammalian species (Davis, 1986, 1989) and is of clear survival significance. In human beings, the most easily measured and the most reliable component of the startle reflex is the magnitude of the eyeblink response to an acoustic probe (Anthony, 1985). There has been increased interest in this measure since the discovery that it can be influenced by prevailing emotional state (for review, see Lang, Bradley, Cuthbert & Patrick, 1992). Fearful or unpleasant emotional states augment eyeblink magnitude, while pleasant hedonic states reduce it (Vrana, Spence & Lang, 1988). This technique offers a promising avenue for investigating the brain basis of emotional arousal (Bradley, Cuthbert & Lang, 1991).

Startle reflex modulation also represents an interesting paradigm for the study of individual differences in emotionality and hence the comparison of theories of the biological basis of personality. It is particularly pertinent to the theory of Gray (1983), concerning the independence of aversive (anxiety) and appetitive (impulsivity) systems in the brain. If anxious individuals are highly sensitive to punishment, then we might expect them to display greater potentiation of the startle reflex in the context of aversive stimuli, whereas impulsive individuals, being more sensitive to reward, should show greater modulation of the startle reflex when exposed to pleasant stimuli. Eysenck's (1967; Eysenck & Eysenck, 1985) theory of personality, in tandem with the Watson and Tellegen (1985) two-dimensional mood structure, might predict that Ss high in neuroticism would be more susceptible to negative emotional states, and hence would show greater potentiation under aversive conditions, whereas extraverts, who typically report more positive affect (happiness), would respond more strongly to positive manipulations of mood. A potential problem with these predictions, however, is that, if neurotics have prevailing negative moods and extraverts happy moods, then they may have less room for environmental manipulation in those directions (since they are already there). Such a

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'ceiling' effect could cancel, or even reverse, the predictions concerning the relationships between personality traits, mood and affective modulation of the startle reflex.

Work on individual differences in startle modulation so far reported has been concerned with clinical syndromes. Ss with a tendency towards fearfulness and phobia as measured by the Fear Survey Schedule show greater reflex potentiation to unpleasant mental stimuli (relative to pleasant or neutral images), though they seem not to be significantly different in overall magnitude of blink responses (Cook, Hawk, Davis & Stevenson, 1991). Similar results have been obtained for positively and negatively-toned slide stimuli, Ss with higher Fear Survey scores showing greater relative startle magnitude to unpleasant slides (Greenwald, Bradley, Cuthbert & Lang, 1991). Hamm, Globisch, Cuthbert and Vaitl (1991) compared Ss having specific phobias with non-phobic controls using slides classified as pleasant, neutral, unpleasant and phobia-related. All groups showed greater startle responses to unpleasant stimuli, but phobic Ss were particularly responsive to slides depicting their own phobic object. Vrana and Constantine (1990) have shown that the startle reflex can be used as a measure of treatment outcome with phobic patients, reduced magnitudes consistent with verbal and behavioural indices being observed following desensitisation. Work on anxiety disorders has been reported by Cuthbert, Patrick and Lang (1991), the most significant finding being that patients suffering from agoraphobia and panic disorder produce larger overall startle responses than patients with other anxiety disorders.

Psychopaths are frequently found to have a deficit in aversive affect, being relatively immune to fear and guilt; hence they might be expected to show less startle in response to negative stimuli. Patrick, Bradley and Lang (1991) found that, whereas non-psychopathic prisoners showed the normal tendency for pleasant slides to inhibit startle responses and unpleasant slides to augment them, psychopathic prisoners (classified according to Hare's criteria) reacted towards unpleasant slides as though they too were pleasant. The authors believe that this indicates a deep-rooted failure of defensive reflex priming, which could account for the psychopath's inability to avoid situations with a potential for pain or punishment.

Britt and Blumenthal (1991) used the basic startle reflex paradigm to test motoneuronal sensitivity to two levels of stimulus intensity [60 vs 85 dB (A)] in introverts and extraverts. The results showed that introverts had smaller response latencies (i.e. faster reactions) to the startle probe at the high stimulus intensity level; extraverts' response latencies at the two intensity levels were the same.

Taken together, the above studies suggest that studies of individual differences in startle reflex modulation, using major temperamental traits, such as those identified by Eysenck and Gray, would be profitable. The aim of the present paper was to explore the possible personality correlates of affective modulation of the startle reflex. To serve this goal (1) basic modulation by pleasant and unpleasant slides was established and (2) personality influences in modulated startle were explored. The personality questionnaires chosen were the best validated instruments relevant to biologically based theories of personality (i.e. the Eysenck Personality Questionnaire and the Cloninger Tridimensional Personality Questionnaire; see below for details).

METHOD

Subjects

Thirty-eight normal volunteers were tested, 20 males (mean age = 28.65, \pm 1SD = 7.52) and 18 females (28.50, \pm 6.24). Ss were picked from a S pool kept at the Psychology Department and each was paid £5 for participation. None had any hearing or visual impairment, or suffered from psychiatric illness, alcohol or drug abuse.

Design and slide material

A split-plot design was employed, with repeated-measures taken on slide valence (pleasant, neutral and unpleasant) and dichotomous personality groups comprising the between-Ss factor.

The general research design (slides, timing of stimuli and recording procedures) replicated that used in a previous study by Bradley *et al.* (1991). Fifty-four slides were selected from the *International Affective Picture System* (Lang, Öhman & Vaitl, 1988). Eighteen slides depicted unpleasant scenes (e.g. mutilated bodies, angry faces, threatening weapons), 18 pleasant events (opposite sex nudes,

outdoor scenes, attractive babies) and 18 neutral scenes (household objects, neutral faces). Two blocks of 27 slides were arranged so that each block included 9 pleasant, 9 unpleasant and 9 neutral slides. Within each block, slides were grouped in 3 sets of 9, with 3 pleasant, 3 unpleasant and 3 neutral slides randomly ordered within each set (note: for the second block one *S* had missing data, so the *N* was reduced from 38 to 37).

Each slide was presented for 6 sec, followed by a randomly determined interslide interval of 10 to 20 sec. The startle probe was presented 24 times within each block. Of these, 18 probes were presented during 6 of the 9 slides in each of three categories (pleasant, unpleasant and neutral). Six startle stimuli were presented during interslide intervals to enhance unpredictability of the startle presentation. The startle stimuli were presented between 3 and 5 sec after slide onset. Note that for each *S* the sequence of slides, intervals and probes remained the same.

Equipment and scoring

EMG activity was recorded with a commercial startle system (SR-LAB, San Diego, California). The acoustic startle stimulus consisted of a 50 msec presentation of a 100 dB (A) burst of white noise with (almost) instantaneous rise time presented binaurally through headphones. EMG activity of the orbicularis oculi muscles was recorded with two disk (4 mm) electrodes (Ag/AgCl), filled with Dracard electrode gel, placed 1 cm below the pupil and 1 cm below the outer corner of the right eye. The electrode area was cleaned with Sterets sterile swabs. The ground electrode was placed behind the right ear over the mastoid.

In order to ensure a strong signal, amplification of the EMG signal was determined individually for each *S*; a vernier dial was used to adjust the amplification gain control. EMG activity was filtered through a 60 Hz 'notch' filter for 250 msec from the onset of the acoustic probe, rectified and stored off-line for analysis. The digital signal was smoothed by a rolling averaging routine that took 10 successive points. Amplitude was calculated relative to 'baseline'; the baseline value was calculated by taking the average of the minimum and maximum values recorded during the 20 msec of the response. Amplitude (in arbitrary, A/D, units) was determined in the 21–120 msec following the stimulus onset. Response latency represented the time interval (msec) between stimulus onset and response onset. Trials were rejected due to unstable baselines (i.e. trials in which there was evidence of an eyeblink during the 20 msec interval) or failure to reach a peak within 95 msec of onset latency; these rejected trials were used to calculate the probability of a response occurring.

A computer controlled the timing of slide onset/offset and recorded all EMG responses. During the entire testing session *Ss* were presented with 70 dB (A) 'masking' white noise in order to reduce the influence of ambient sounds. The equipment was situated in the same room as the *S*, but the *S* was facing a white-washed wall, which served as a projection screen, and not in sight of the equipment or experimenter.

Personality questionnaires

The Eysenck Personality Questionnaire [EPQ (Eysenck & Eysenck, 1975)], which measures Extraversion (E), Neuroticism (N) and Psychoticism (P), and which contains a Lie scale (L), was used to measure the personality factors relevant to Eysenck's and Gray's theories. The Tridimensional Personality Questionnaire [TPQ, version 4 (Cloninger, 1988)] was used to measure Harm Avoidance (HA), Reward Dependence (RD) and Novelty Seeking (NS). The TPQ is a 100 item true/false questionnaire which measures factors relevant to Cloninger's (1986) neurobehavioural personality theory and also to Gray's theory. It 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: HA is related to the tendency to respond intensively to aversive stimuli and to learn to avoid punishment, novelty, and non-reward passively; RD is related to the tendency to respond intensively to reward and succorance and to learn to maintain rewarded behaviour; and NS is related to the tendency toward exploratory behaviour and intense excitement in response to novel stimuli. The TPQ is the most well developed psychometric equivalent of animal models of biological systems underlying emotional responses; and it has been shown empirically to predict reactions to aversive and appetitive stimulation in associative learning (Corr, Pickering & Gray, 1995).

Table 1. Summary statistics for personality measures

Measure	Mean	Median	SD	Range
EPQ: Extraversion (E)	13.66	14.00	4.78	2–21
EPQ: Neuroticism (N)	11.89	12.50	6.10	0–21
EPQ: Psychoticism (P)	5.71	5.00	3.46	0–16
EPQ: Lie (L)	5.87	5.00	3.56	0–17
TPQ: Harm Avoidance (HA)	13.08	13.50	6.80	1–26
TPQ: Reward Dependence (RD)	17.08	18.00	3.92	10–24
TPQ: Novelty Seeking (NS)	19.50	19.00	5.00	10–30

EPQ = Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975).

TPQ = Tridimensional Personality Questionnaire (Cloninger, 1988).

Procedure

After the aims of the study were explained, Ss were asked to complete the personality questionnaires. Then Ss, who were seated in a comfortable chair, had the EMG electrodes attached. Ss were asked to blink several times so that the strength of EMG signal could be assessed (the analog waveform was displayed on an oscilloscope); the amplification gain control was adjusted until a strong signal had been obtained. Ss were then told that they were going to be shown a series of slides, some of them depicting unpleasant events, but that each slide should be viewed the entire time it was on the screen. They were also told that they would hear intermittently a noise through the headphones, but that this should be ignored. A five minute acclimatisation period followed. During presentation of slides the room lights were dimmed. The experimenter remained in the testing room, but out of sight of the S, throughout the session (in order to ensure that Ss paid attention to the stimuli). Ss were seated approximately 5 feet from the screen.

Statistical analysis

Slide valence and sex/personality effects were examined by Multivariate Analysis of Variance (MANOVA; see Jennings, 1987). In the present studies, Wilk's *F*-ratio was used for significance testing, followed by polynomial contrast tests (assessed by *t*). Baseline EMG activity, response latency, probability of response, amplitude and magnitude (i.e. amplitude \times response probability) were used as dependent variables. The amplitude measure represented the mean of recorded responses and not the mean of all possible responses (i.e. startles that did not elicit a blink were ignored by the averaging procedure). The difference between (1) pleasant and neutral slides and (2) unpleasant and neutral slides was calculated in order to derive absolute measures of modulation to pleasant and unpleasant stimuli (both absolute measures are scored in the positive direction, with higher scores indicating higher levels of modulation to slide type). All analyses were performed by SPSS^x. For each personality variable from the EPQ and TPQ, the sample was divided by median split into two groups.

RESULTS

The descriptive statistics for the personality variables are given in Table 1, and their intercorrelations are presented in Table 2. Table 3 gives the intercorrelations between the startle reflex parameters (these are given for responses to neutral slides; intercorrelations for responses to pleasant/unpleasant slides were almost identical).

Table 2. Pearson product-moment intercorrelations of personality measures

	2	3	4	5	6	7
1. EPQ: E	– 0.308	0.030	– 0.226	– 0.391*	0.055	0.256
2. EPQ: N	—	0.045	– 0.030	0.612**	– 0.017	0.101
3. EPQ: P	—	—	– 0.410**	– 0.061	– 0.101	0.642**
4. EPQ: L	—	—	—	0.149	0.223	– 0.370*
5. TPQ: HA	—	—	—	—	0.050	– 0.022
6. TPQ: RD	—	—	—	—	—	0.130
7. TPQ: NS	—	—	—	—	—	—

* $P < 0.05$, ** $P < 0.01$; two-tailed. See Table 1 for abbreviations.

Table 3. Pearson product-moment intercorrelations of startle reflex parameters (for neutral slides)

	2	3	4	5
(1) Baseline EMG	0.026	-0.537*	-0.100	-0.149
(2) Latency	—	-0.594*	-0.585*	-0.621*
(3) Probability	—	—	0.476*	0.549*
(4) Amplitude	—	—	—	0.549*
(5) Magnitude	—	—	—	—

* $P < 0.01$, two-tailed

Slide valence and sex effects

Two way (slide valence \times sex) MANOVAs were conducted for each dependent measure.

Baseline EMG. No effect of slide valence [$F = 1.46$, d.f. = 2,35, $P > 0.05$ (pleasant slides: mean = 8.47, ± 1 s.e.m = 0.98; neutral slides: 8.76, ± 1.30 ; unpleasant slides: 9.26, ± 1.38)], sex ($F = 0.02$, d.f. = 1,36, $P > 0.05$), or slide valence \times sex ($F = 0.33$, d.f. = 2,25, $P > 0.05$).

Response latency. No effect of slide valence [$F = 1.74$, d.f. = 2,34, $P > 0.05$ (pleasant slides: 45.94, ± 1.70 ; neutral slides: 45.28, ± 1.36 ; unpleasant slides: 43.64, ± 1.49)], sex ($F = 1.36$, d.f. = 1,35, $P > 0.05$), or slide valence \times sex ($F = 0.22$, d.f. = 2,34, $P > 0.05$). The Pearson correlation between the degree of modulation to unpleasant and pleasant slides (both relative to neutral slides) was non-significant ($r = -0.206$).

Response probability. No effect of slide valence [$F = 1.13$, d.f. = 2,35, $P > 0.05$ (pleasant slides: 0.811, ± 0.035 ; neutral slides: 0.842, ± 0.029 ; unpleasant slides: 0.836, ± 0.032)], sex ($F = 2.59$, d.f. = 1,36, $P > 0.05$), or slide valence \times sex ($F = 0.59$, d.f. = 2,35, $P > 0.05$). The Pearson correlation between the degree of modulation to unpleasant and pleasant slides (both relative to neutral slides) was non-significant ($r = -0.299$).

Response amplitude. Main effect of slide valence [$F = 8.56$, d.f. = 2,34, $P < 0.001$ (linear component: $t = 4.10$, $P < 0.001$)], but no effect of sex ($F = 0.01$, d.f. = 1,35, $P > 0.05$), or slide valence \times sex ($F = 1.54$, d.f. = 2,34, $P > 0.05$). As expected, startle amplitude increased in a linear manner as a function of slide valence: relative to neutral slides (81.59, ± 11.67), pleasant slides (75.36, ± 11.04) reduced ($t = 1.81$, d.f. = 36, $P < 0.05$; one-tailed) and negative slides (91.87, ± 13.30) increased ($t = 2.11$, d.f. = 36, $P < 0.05$; one-tailed) amplitude. The Pearson correlation between the degree of modulation to unpleasant and pleasant slides (both relative to neutral slides) was significant ($r = -0.558$, $P < 0.01$), indicating that, as measured by amplitude, modulation to pleasant and unpleasant slides were strongly and negatively related.

Response magnitude. Main effect of slide valence [$F = 8.23$, d.f. = 2,34, $P < 0.001$ (linear component: $t = 4.06$, $P < 0.001$)], but no effect of sex ($F = 0.02$, d.f. = 1,35, $P > 0.05$), or slide valence \times sex ($F = 1.29$, d.f. = 2,34, $P > 0.05$). Startle magnitude increased in a linear manner as a function of slide valence: relative to neutral slides (74.85, ± 11.39), pleasant slides (68.77, ± 11.29) reduced ($t = 1.78$, d.f. = 36, $P < 0.05$; one-tailed) and negative slides (84.16, ± 13.11) increased ($t = 2.10$, d.f. = 36, $P < 0.05$; one-tailed) response magnitude. The Pearson correlation between modulation to unpleasant and pleasant slides was almost identical to that already reported for response amplitude (reflecting the lack of a significant effect of slide valence on response probability).

Slide valence and personality effects

Two-way (slide valence \times one personality variable) split-plot MANOVAs were conducted. There were no main or interaction effects found for either baseline EMG or response probability. Therefore, only the effects for response latency, amplitude and magnitude are reported. Given the above results, sex was dropped from subsequent analyses; the main effects of slide valence, which did not differ in the personality models from those reported above, were omitted from further reporting.

Response latency. E interacted with slide valence [$F = 4.65$, d.f. = 2,31, $P < 0.05$ (linear component: $t = 3.09$, $P < 0.01$)], but did not exert a main effect [$F = 0.15$, d.f. = 1,32, $P > 0.05$ (Fig. 1)]. Separate one-way (slide valence) MANOVAs for low and high E groups revealed a non-significant effect of valence for low E Ss ($F = 0.37$, d.f. = 2,15, $P > 0.05$), but a significant effect for high E Ss [$F = 12.35$, d.f. = 2,15, $P < 0.001$ (linear component: $t = 4.44$, $P < 0.0001$)]. Repeated-measures t -tests conducted on the high E group revealed a significant difference for unpleasant (41.02, ± 2.08)

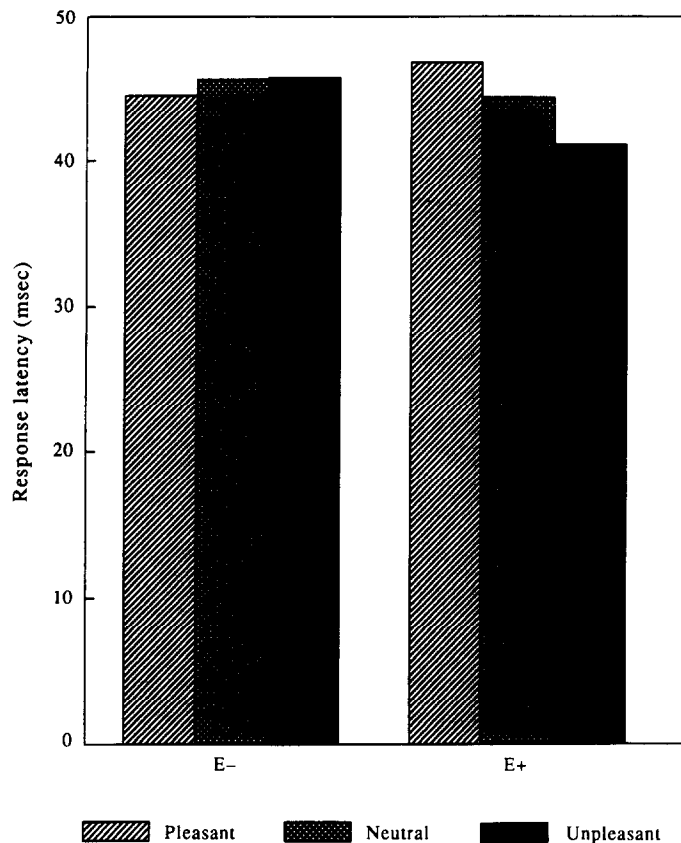


Fig. 1. Mean response latencies (msec) for pleasant, neutral and unpleasant slides for Ss low (E -) and high (E +) on (EPQ) Extraversion. There was a significant linear effect of slide valence only for the E + group.

vs neutral ($44.40, \pm 2.19$) slides ($t = 2.92$, d.f. = 16, $P < 0.01$); between-Ss t -tests revealed no significant differences for either pleasant, neutral or unpleasant slides. N interacted with slide valence [$F = 3.03$, d.f. = 2,34 $P = 0.06$ (linear component: $t = 2.49$, $P < 0.05$)], but did not exert a main effect [$F = 0.56$, d.f. = 1,35, $P > 0.05$ (Fig. 2)]. Separate one-way (slide valence) MANOVAs for low and high N groups showed a significant effect of valence for low N Ss [$F = 8.52$, d.f. = 2,17, $P < 0.01$; linear component: $t = 3.73$, $P < 0.001$], but no effect for the high N group ($F = 1.05$, d.f. = 2,16, $P > 0.05$). Repeated-measures t -tests conducted on the low N group revealed significant differences for unpleasant ($43.42, \pm 1.98$) vs neutral ($46.05, \pm 2.18$) slides ($t = 2.33$, d.f. = 18, $P < 0.05$); between-Ss t -tests revealed no significant difference for either, pleasant, neutral or unpleasant slides.

Response amplitude. HA interacted with slide valence [$F = 3.02$, d.f. = 2,34, $P = 0.06$ (quadratic component: $t = 2.42$, $P < 0.05$)], but no main effect of HA was observed [$F = 1.19$, d.f. = 1,35, $P > 0.10$ (Fig. 3)]. The HA \times valence effect reflected: (1) a reduction in amplitude from neutral ($74.54, \pm 11.98$) to pleasant ($61.02, \pm 9.77$) slides in low HA Ss ($t = 2.60$, d.f. = 18, $P < 0.05$); and (2) an increase in amplitude from neutral ($89.02, \pm 20.53$) to unpleasant ($108.82, \pm 23.71$) slides in high HA Ss [$t = 2.58$, d.f. = 17, $P < 0.05$].

Response magnitude. HA interacted with slide valence [$F = 2.74$, d.f. = 2,34, $P = 0.08$ (quadratic component: $t = 2.36$, $P < 0.05$)], but did not exert a main effect ($F = 1.06$, d.f. = 1,35, $P > 0.05$). The HA \times valence effect reflected: (1) a reduction in magnitude neutral ($68.09, \pm 12.61$) to pleasant ($55.34, \pm 10.26$) slides in low HA Ss ($t = 2.34$, d.f. = 18, $P < 0.05$); and (2) an increase in magnitude from neutral ($81.98, \pm 19.52$) to unpleasant ($100.61, \pm 23.08$) slides in high HA Ss ($t = 2.74$, d.f. = 17, $P < 0.05$) (these effects reflected the fact that slide valence and HA did not affect response probability).

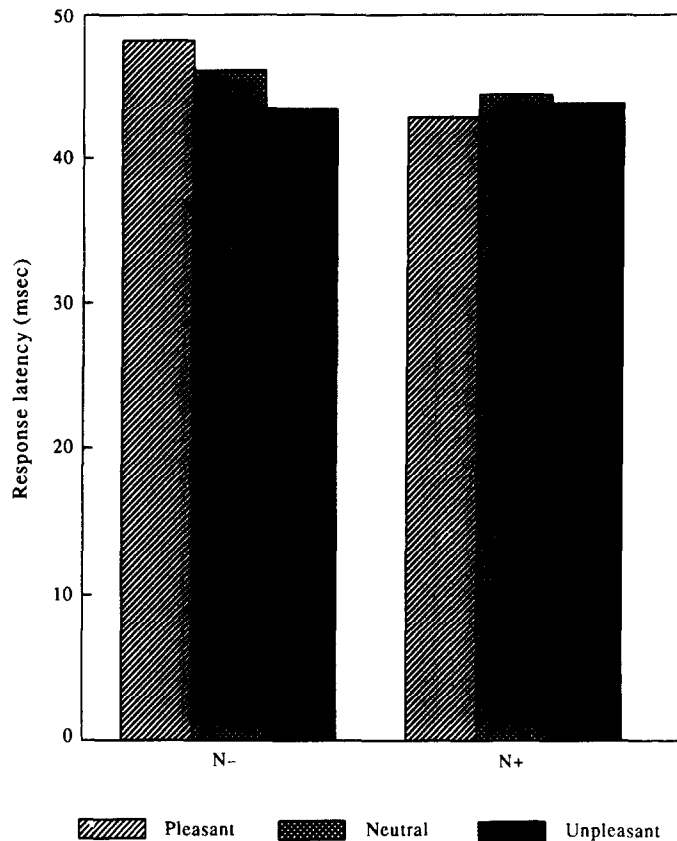


Fig. 2. Mean response latencies (msec) for pleasant, neutral and unpleasant slides for Ss low (N -) and high (N +) on (EPQ) Neuroticism. There was a significant linear effect of slide valence only for the N - group.

DISCUSSION

The results provide a further replication of the frequently found tendency for pleasant and unpleasant stimuli to modulate the amplitude of the startle reflex (Lang *et al.*, 1992), with unpleasant slides increasing the strength of the eyeblink and pleasant slides reduced it. This finding is consistent with the hypothesis that the startle probe is an aversive stimulus which can either summate with another negative stimulus to potentiate the reflex or be antagonised by a pleasant stimulus. Response latency and probability did not show a main effect of slide valence, indicating these measures are less sensitive to slide valence than amplitude. Personality was found to mediate affective modulation as measured by response latency and amplitude.

The intercorrelations of the startle reflex parameters show that baseline EMG was negatively correlated with probability of response, indicating that high baseline EMG activity resulted in a relatively high level of rejected responses (due to 'unstable baseline'; see Method for scoring criteria). Response latency was negatively correlated with response probability and amplitude, showing that faster response onset covaried with high response probability and amplitude. Although these correlated parameters seem to reflect overall strength of response, there is evidence to suggest that each parameter preferentially reflects a different stage or type of stimulus processing (Blumenthal & Berg, 1986). The effects of personality on the different parameters do suggest that it would be unwise to assume that all parameters reflect only overall strength of response.

Extraversion (E) and Neuroticism (N) mediated the effects of slide valence on response latency (Figs 1 & 2), but no such effects were evident for amplitude or probability measures. Assuming that pleasant slides antagonised (slowed response speed) and unpleasant slides potentiated (quickened response speed) the startle reflex, then only extraverted and stable Ss showed the expected linear pattern of modulation. The finding of an effect of E on latency, but not on amplitude, is similar to

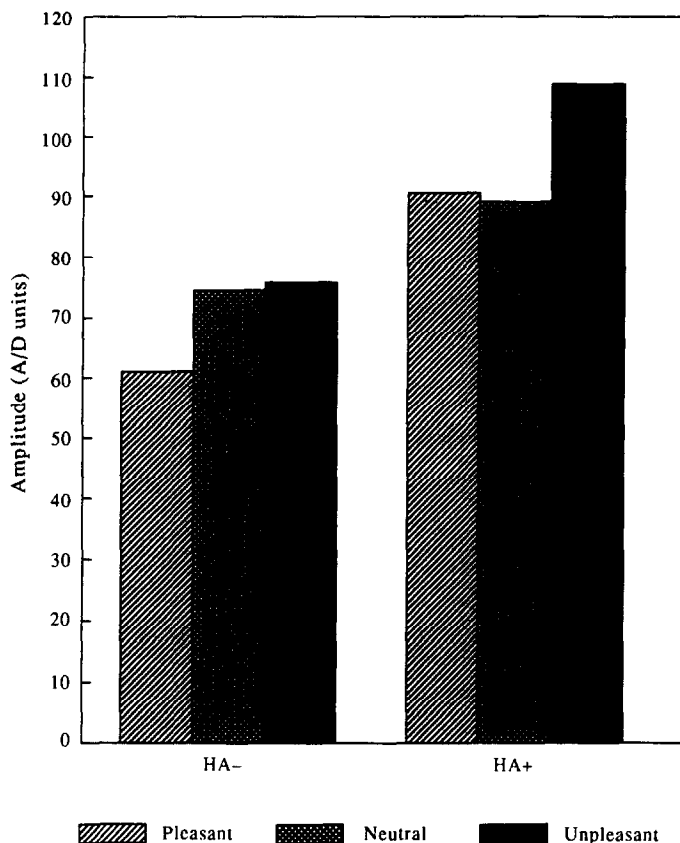


Fig. 3. Mean EMG amplitudes (arbitrary A/D units) for pleasant, neutral and unpleasant slides for Ss low (HA -) and high (HA +) on (TPQ) Harm Avoidance. In addition to significant linear effect of slide valence, only HA + Ss showed significant potentiated startle to unpleasant slides, and only HA - Ss showed significant attenuated startle to pleasant slides.

Britt and Blumenthal (1991), who found that E was related to the latency, but not the amplitude, component of the startle reflex. The finding of an effect of N on response latency is new. Although the precise meaning of these effects is not clear, there are relevant findings in the literature that suggest possible explanations. Firstly, negative emotions are sometimes found to impair accurate appraisal of stimulus-related cues (Roessler, 1973); this might have been sufficient to abolish affective modulation in low E, high N Ss who were in a relatively negative state (i.e. high in state anxiety, as predicted by their higher trait anxiety scores; see Table 2). Secondly, heightened attention to the startle stimulus is known to facilitate response speed, without influencing response amplitude (Silverstein, Graham & Bohlin, 1981); it is possible that negative emotions led to an orienting of attention away from the aversive slide material (this re-orientation of attention might have also affected the pleasant slides, via a process of stimulus generalisation). Therefore, in consequence of inaccurate appraisal of, and/or orientation of attention away from, the slide material, low E, high N Ss might have failed to show response modulation as assessed by response latency. Given that attention is thought to affect response latency, but not amplitude, then the pattern of effects of E and N on latency should not be found for amplitude as different stages or types of processes are reflected by the two response measures.

Potentiated startle, as measured by response amplitude, to unpleasant slides was found only among high Harm Avoidance (HA) Ss (Fig. 3), a finding that is consistent with previous research showing that high fear Ss show the strongest startle response to aversive stimuli (Cook *et al.*, 1991). Reduction of the startle reflex, in response to the presentation of pleasant slides, was found only among low HA Ss, a finding that has not been previously reported in the literature, although it is consistent with other findings showing that low anxiety is a crucial component in positive emotions. For example, Byrne

and Eysenck (1993) reported a positive interpretative bias in individuals low in trait anxiety and who fall in the E + /N - quadrant.

The general conclusion from the data is that modulation of startle by affective slides, as measured by response latency, amplitude or magnitude, is not uniform across all individuals, but is predicted by personality, namely E, N and HA. Personality may thus be seen as a critical factor in the affective modulation of the startle reflex; and affective modulation of the startle reflex may be seen as a valuable experimental paradigm with which to test the predictions of the major theories of personality.

The findings concerning the personality correlates of startle modulation are supportive of the theories of Gray (1983) and Cloninger (1986). HA is defined by Cloninger (1986) as 'a heritable tendency to respond intensely to aversive stimuli and to learn to avoid punishment, novelty and non-reward passively'. Our results do, indeed, show that Ss high in HA were particularly reactive to aversive stimuli (in this case unpleasant images evoked by slides). Cloninger (1986) also identifies HA with Gray's (1983) concept of anxiety, an equation that is supported by the position of HA in relation to Eysenck's N and E dimensions (Table 2), where HA is related to E (negatively) and N (positively), leaning in the direction of N. This finding places HA very much where Gray's theory assumes anxiety to be located within the EPQ system (i.e. 30 degrees from N). Just as Gray predicts that responses to aversive stimuli should be predicted by anxiety, so too Cloninger predicts that a single dimension of HA should predict responses to aversive stimuli.

The prediction from Gray's theory that impulsive Ss would show greater modulation to pleasant stimuli was not supported in the present results. Impulsiveness would be represented by high P, E and N in Eysenck's system, or perhaps more directly by Novelty Seeking (NS), as measured by the TPQ, which Cloninger (1986) defines as a "heritable tendency toward frequent exploratory activity and intense excitement in response to novel stimuli". Within Cloninger's theory, the third dimension, Reward Dependence (RD), might have been even more relevant to modulation by pleasant stimuli, since this is defined as a "heritable tendency to respond intensely to reward and succorance and to learn to maintain rewarded behaviour". In the event, none of these 'approach' measures was predictive of startle modulation by pleasant slides.

Eysenck's (Eysenck & Eysenck, 1985) and Watson and Tellegen's (1985) theories predict that responses to aversive stimuli should be most related to neuroticism, while responses to pleasant stimuli should be most related to extraversion. Although the results do not lend direct support to these predictions, neither do they offer strong evidence against them. Eysenck's (1967) model predicts that anxiogenic stimuli should be related (negatively) to E and (positively) to N, therefore the failure to find a main effect of E and N could have been due to the low statistical power which did not allow the meaningful examination of the E \times N interaction. In the case of E and pleasant slides, the HA effect suggested that E would be positively, and N negatively, correlated with absolute level of modulation, and this, in fact, was found ($r = 0.25$, $P < 0.05$; one-tailed; $r = -0.19$, ns; respectively). This finding suggests that E was indeed positively (although nonsignificantly) correlated with induced positive affect, but N was also involved (none of the TPQ variables even approached more significance; all r s < 0.10). As the experiment was an exploratory study of the possible effects of personality in modulated startle, the present set of results cannot answer some of the finer details of Eysenck's theory. Nonetheless, the effects of E and N clearly indicate that personality factors relevant to Eysenck's model are implicated in affective modulation of the startle reflex, although their precise role in the stage or type of processing of affective modulation is in need of clarification; these preliminary findings should serve to encourage other researchers to use the modulated startle reflex paradigm to test the specific hypotheses of Eysenck's theory.

The negative correlation between modulation to pleasant and unpleasant slides (each compared with neutral slides) suggests an antagonistic relationship between appetitive and aversive motivational systems: strong reactions to pleasant slides were associated with weak reactions to unpleasant slides, and vice versa. Although this finding is not surprising, it does go against the view that appetitive and aversive systems are orthogonal (e.g. Gray, 1983). Although these systems may be independent at the trait level (cf. Watson & Tellegen, 1985), it seems reasonable to suppose that at the behavioural (state) level they are mutually opposed (cf. Gray & Smith, 1969). It is possible that the inter-dependence of appetitive and aversive motivational systems was responsible for the HA effect observed in affective modulation.

The present methodology promised to provide a simple biological measure of emotional state. The

fact that startle reduction due to positive slides (*ex hypothesi*, inducing positive emotion) was not related to impulsivity (i.e. $E + /N +$) may at first sight seem like a serious setback for Gray's theory (and also for Cloninger's theory in the case of NS/RD). However, it needs to be recognised that the sudden, loud noise used to evoke the startle reaction is itself an aversive stimulus, so the startle-probe paradigm is inherently biased in this respect (Lang *et al.*, 1992), perhaps accounting for the appearance of HA in mediating reactions to both pleasant and unpleasant stimuli. If some kind of appetitive probe could be devised (e.g. a bell conditioned to the expectation of food) then an appetitive reflex (such as salivation) might be subject to greater modulation in impulsive or reward-dependent Ss. Thus, the failure of the present results to show greater positive modulation of the startle reflex in impulsive individuals does not necessarily raise an insurmountable problem destructive to the theories of Gray or Cloninger; the imbalance may be due to the nature of the experimental procedure.

The absence of between-S effects of personality, irrespective of slide valence, was not adequately tested in the present experiment. In order for robust within-S valence effects to be observed, Ss' EMG responses were individually calibrated to achieve a strong signal (see Method). Although the adjustments were small, nonetheless between-S effects might have been eliminated; baseline EMG showed no personality effects, suggesting that this indeed was the case. Thus, the results are not applicable to differences in overall levels of startle reflexes between personality groups (cf. Britt & Blumenthal, 1991).

It is concluded that slide valence modulates startle reflex latency and amplitude; and the effect of slide valence is mediated by E and N in the case of latency and by HA in the case of amplitude. These data suggest that EPQ and TPQ measures relate to different parameters of affective modulation of the startle reflex, pointing to preferential role of EPQ and TPQ variables at different levels of attentional/emotional processing. The results highlight the need for further research to investigate the personality factors implicated in startle modulation, especially in relation to responses to pleasant slides.

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