Available online at www.sciencedirect.com

SCIENCE DIRECT®

Biological Psychology 72 (2006) 257–264

BIOLOGICAL PSYCHOLOGY

www.elsevier.com/locate/biopsycho

Personality correlates of startle habituation

Steven D. LaRowe [a,*], Christopher J. Patrick [b], John J. Curtin [c], John P. Kline [d]

[a] *Center for Drug and Alcohol Programs, Medical University of South Carolina, 67 President St., P.O. Box 250861, Charleston, SC 29425, USA*

[b] *Department of Psychology University of Minnesota, Elliott Hall, 75 East River Road, Minneapolis, MN 55455, USA*

[c] *Department of Psychology, University of Wisconsin at Madison, 1202 West Johnson Street, Madison, WI 53706, USA*

[d] *Department of Psychology, University of South Alabama, 368 Life Sciences Building, Mobile, AL 36688, USA*

Received 13 December 2004; accepted 24 October 2005

Available online 6 January 2006

Abstract

This study investigated the relationship between extraversion and rates of acoustic startle habituation, a potential biological marker for individual differences. Personality was measured using the Eysenck Personality Questionnaire (EPQ), the Sensation Seeking Scale (SSS), and Tellegen's Multidimensional Personality Questionnaire (MPQ). Higher EPQ Extraversion and higher SSS scores were associated with faster, more rapid startle habituation. Moreover, the relationship between extraversion and faster startle habituation was replicated in a second, follow-up sample. Within the initial study sample, lower scores on the Constraint (CON) factor of the MPQ (reflecting greater impulsiveness, risk-taking, and nonconformity) were also associated with faster startle habituation. Follow-up analyses revealed relationships between EPQ Extraversion, SSS, and low MPQ CON. These results suggest that faster habituation within the CNS may be associated tendencies toward impulsivity and behavioral disinhibition.

Keywords: Acoustic startle response; Habituation; Extraversion; Constraint; Sensation seeking

1. Introduction

A major challenge in personality research involves determining the basic biological underpinnings of individual differences in personality and temperament. Eysenck (1967, 1994) has long attempted to describe individual differences in terms of biological processes. For instance, the theory of extraversion posits that the behaviors associated with this construct – i.e., sociability, liveliness, sensation seeking, and assertiveness (Eysenck, 1994) – result from a relatively lower level of cortical arousal associated with diminished activity in the Ascending Reticular Activating System (ARAS; Eysenck, 1994). Consistent with this, psychophysiological experiments involving measures of arousal such as electroencephalography (EEG) and skin conductance responses (SCR) have found evidence for lower arousal in extraverts (see Eysenck, 1994 for a review).

Extrapolating from the hypothesized lower cortical arousal in extraverts, Eysenck has suggested that extraversion may be associated with faster, more rapid habituation in cortically mediated physiological response systems (Eysenck, 1967, 1994). Habituation, defined as ''decreased response to repeated stimulation'' (Groves and Thompson, 1970, p. 419), is generally believed to be a ubiquitous and fundamental property of living organisms (Davis and File, 1984). Because habituation is such a fundamental biological process, it is arguably a useful physiological index in the ongoing study of the basic biological underpinnings of individual differences in personality and temperament.

The earliest studies investigating habituation in extraverts have been extensively reviewed elsewhere (see O'Gorman, 1977). Relationships between extraversion and habituation have not been uniformly observed across all of the earlier studies (see O'Gorman, 1977; Smith et al., 1990); however, when effects are found, they generally support a relationship between extraversion and faster habituation, consistent with Eysenck's predictions. Early studies linked extraversion to faster habituation of electrodermal responses (EDR) to auditory tones of varied intensity (Crider and Lunn, 1971; Mangan and O'Gorman, 1969). More recently, Jansen et al. (1989) found evidence of faster EDR habituation in response to a series of 1000 Hz 85 decibels (dB) in participants high in sensation seeking, a personality variable related to extraversion (Zuckerman, 1979).

* Corresponding author. Tel.: +1 843 792 5717; fax: +1 843 792 7353.
E-mail address: larowe@musc.edu (S.D. LaRowe).

0301-0511/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.biopsycho.2005.11.008

Similarly, a study by Smith et al. (1990) found that extraverts showed evidence of more rapid habituation of EDR to presentations of 1000 Hz 100 dB tones. The link between faster habituation and extraversion has been found in other physiological responses as well, such as in measures of evoked response potentials (ERPs), which are measures of electroencephalographic (EEG) responses to discrete stimuli. Ditraglia and Polich (1991) measured the P300 ERP brain potential, which is believed to be an index of post-perceptual processing, in response to a target stimulus consisting of a 2000 Hz 60 dB tone. Their results suggested that extraversion was associated with more rapid habituation of the P300. Taken together, the evidence supports Eysenck's hypothesis of more rapid habituation in extraverts, although additional replication in other physiological response systems is needed.

The eyeblink component of the acoustic startle response, is mediated in part by brainstem reticular structures (Davis et al., 1999), suggesting that the habituation of the startle response may serve as a potentially useful measure to investigate the biological underpinnings of extraversion. Two studies to date have found evidence that extraverts show reduced startle reactivity, consistent with the notion of lower CNS arousal in these individuals (Blumenthal et al., 1995; Blumenthal, 2001). While neither of these studies was explicitly designed to measure habituation, one found some indication of slower startle habituation in extraverts (Blumenthal, 2001). However, the study compared the mean of a block of 6 startle responses collected at baseline to the mean of a block of 6 additional startles collected between 5 and 20 min later, rather than assessing habituation trial-by-trial in response to a single continuous series of habituation stimuli. In contrast, the present study assessed habituation of the startle response to probes presented within a single continuous session. In addition, rates of startle habituation were quantified using individual regression techniques that are arguably more sensitive to time-dependent changes in response magnitude than is a block-to-block comparison (Petrinovich and Widaman, 1984).

1.1. The present studies

Here, we report findings from two experiments that examined the extent to which startle habituation is associated with personality trait variables. Experiment I examined whether faster startle habituation was associated with higher levels of extraversion and sensation seeking, as measured by the Eysenck Personality Questionnaire (EPQ; Eysenck and Eysenck, 1975), and the Sensation Seeking Scale (SSS, Zuckerman, 1979), respectively. Experiment I also included the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982), which (like the EPQ) assesses personality in terms of three higher-order factors (Patrick et al., 2002). The Negative Emotionality (NEM) factor of the MPQ is most closely aligned with EPQ Neuroticism (EPQ-N), MPQ Positive Emotionality (PEM) is most closely aligned with EPQ Extraversion (EPQ-E), while the inverse of MPQ Constraint (CON) is most closely aligned with EPQ Psychoticism (EPQ-P; Tellegen and Waller, in press). However, NEM includes a component of aggression, which relates most to EPQ-P, PEM includes a component of well being, which is represented (in reverse) in the EPQ-N factor, and CON includes a component of impulsivity, which is part of the EPQ-E factor. Thus, the factors of the MPQ and those of the EPQ provide overlapping but non-identical mappings of a similar three-dimensional personality space (Tellegen and Waller, in press). Based on the aforementioned studies of individual differences in habituation in other physiological systems, we predicted that higher EPQ Extraversion and higher sensation seeking would both be associated with faster startle habituation. With regard to the MPQ, we predicted that higher scores on PEM (because it relates most strongly to extraversion) and lower scores on CON (because lower scores relate most strongly to higher sensation seeking; Patrick et al., 2002) would also be associated with faster startle habituation rates.

Data for Experiment II were part of a larger investigation of individual differences in physiological reactivity. While the methods and design of Experiment II were comparable to those of Experiment I, they were not identical. Thus, the data from Experiment II not only provided an opportunity to replicate the essential findings of Experiment I, but also provided an opportunity to replicate the results in the context of slightly varied experimental methodology.

2. Experiment I

2.1. Method

2.1.1. Participants

Healthy volunteers were recruited from an introductory psychology course at Florida State University. Participants were 24 males and 24 females who indicated on a brief self-report medical checklist that they had no conditions (e.g., vision or hearing loss) that would affect startle responding. The subjects ranged in age from 18 to 24. All participants attended two experimental sessions; all participants received course credit for attending the first session and monetary compensation ($15) for attending the second.

2.1.2. Stimulus materials

Visual foreground stimuli were simple, affectively neutral black and white slides depicting simple geometric shapes and were designed to minimize the effects of emotion and foreground attentional engagement on startle responding. Slides consisted of 8 basic geometric shapes (circle, square, hexagon, triangle, etc.); each shape had two variants (elongated, and elongated and rotated), for a total of 24 unique shapes. The slides were presented in a semi-random order (i.e., every 3 slides contained a normal shape, an elongated shape, and an elongated and rotated shape). Slides were projected onto a 1 m $\times$ 1 m opaque slide screen using a slide projector positioned behind a one-way mirror in an adjoining equipment room. Participants were administered acoustic startle probes that consisted of 50 ms bursts of 105 dB (Scale A) white noise with instantaneous rise time. Startle probes were presented binaurally to participants through Telephonics (TDH-49) headphones.

2.1.3. Stimulus presentation and design

The timing of stimulus presentation was similar to that of prior picture-startle paradigms (e.g., Stritzke et al., 1995). Each slide was presented for 6 s, with intertrial intervals (ITIs) varying in length from 10 to 20 s. To minimize the predictability of noise presentation, startle probes occurred at one of three times following slide onset (1.8, 3.5, 4.5 s) during 12 of the 24 slide presentations, and at one of four onset times (4, 6, 8, or 10 s) during 12 of the 23 ITIs. Presentation and timing of slide and startle stimuli, along with collection and storage of session data, were controlled by an IBM-compatible computer, using the VPM software package (Cook et al., 1987).

2.1.4. Physiological measures

Blink responses to the startle probes were measured from miniature Ag–AgCl electrodes positioned over the orbicularis oculi muscle beneath the left eye (Fridlund and Cacioppo, 1986). The raw blink EMG signal was sampled digitally at 1000 Hz with a high pass filter of 90 Hz and a low pass filter of 250 Hz. The signal was then rectified and integrated using a time constant of 80 ms. Startle responses were stored in arbitrary A/D units scored off-line using a scoring program developed in our lab (Curtin, 1996). Startle peaks were identified automatically as maximum responses occurring between 20 and 120 ms post probe onset. Peaks had to surpass a minimum of 20 A/D units to be considered a valid response. Automatically scored responses were verified visually by evaluators trained by the second author (CJP). After the startle responses were scored, raw A/D unit values were converted to scores in microvolts. Missing trials (i.e., those containing excessive movement artifact) comprised approximately 3% of the overall data. No participant had more than 25% of missing and/or non-response data. Non-response data were counted as zeros and used in the calculation of habituation, while missing values remained missing. A logistic regression was performed to determine whether later trials were more likely to contain missing data than earlier trials. Trial number was not associated with a greater likelihood of missing data in Session 1 ($\chi^2 = 0.51$, d.f. = 1, $p < 0.48$) or Session 2 ($\chi^2 = 2.56$, d.f. = 1, $p < 0.12$).

2.1.5. Personality/individual difference measures

2.1.5.1. The Eysenck Personality Questionnaire (EPQ). The EPQ (Eysenck and Eysenck, 1975) consists of 90 items and includes three scales that represent the Eysenckian personality structure. These scales are: Neuroticism (N; 23 items), Extraversion (E; 21 items), and Psychoticism/“Tough Mindedness” (P; 25 items). All scales have satisfactory reliability coefficients for normal adults (ranging from 0.68 to 0.85), with acceptable test-retest reliabilities (0.78–0.89; Eysenck and Eysenck, 1975).

2.1.5.2. The Multidimensional Personality Questionnaire (MPQ). The MPQ (Tellegen, 1982) is a 300-item self-report questionnaire with a three-factor structure that includes Positive Emotionality (PEM), Negative Emotionality (NEM), and Constraint (CON; Tellegen, 1982; Patrick et al., 2002). PEM involves individual differences in well being, dominance, achievement, and affiliation, while NEM reflects individual differences in tendencies toward anxiety, alienation, and aggression. The CON factor reflects the tendency to display behavioral restraint and/or inhibition; low levels of CON are associated with high levels of sensation seeking and impulsivity (Patrick et al., 2002; Tellegen and Waller, in press). Internal consistency estimates (Chronbach’s alpha) for these factor scores are very high, ranging from 0.81 to 0.91 (e.g., Tellegen and Waller, in press).

2.1.5.3. Sensation Seeking Scale (SSS) Form V. The SSS (Zuckerman, 1979) is a 40-item forced-choice questionnaire that assesses an individual’s tendency towards thrill and adventure seeking, seeking arousal through a non-conforming lifestyle, the release of social inhibition, and susceptibility to boredom. The total score for this measure shows good internal consistency (0.84 for males and 0.85 for females) and high retest reliability (0.94; Zuckerman, 1979).

2.1.5.4. Quantification of individual habituation. Startle habituation was quantified using individual regression (i.e., regression performed on each individual’s startle data) following the procedure of a number of previous studies (Orr et al., 1997; Shalev et al., 1992). The equation is as follows:

$$Y = a + bX$$

where X corresponds to the log transformed startle stimulus number and Y corresponds to the square root of the magnitude score for that stimulus. The startle stimulus number, X, is log transformed based on the observation that habituation curves tend to resemble negative exponential functions (Thompson and Spencer, 1966). Startle magnitudes, Y, are square root transformed to reduce the variability, skewness, and heteroscedacity associated with extremely large physiological responses that occur in some individuals (Shalev et al., 1992). The intercept, a, corresponds to the level of initial reactivity. The primary variable of interest is the slope, b, which corresponds to the individual rate of habituation. Slope values are invariably negative, as habituation involves decreased responding over time, with larger negative values indicating faster, more rapid habituation.

Because participants attended two identical sessions, it was possible to calculate an individual intercept and slope value for each participant for both Sessions 1 and 2. When intercept and slope values were averaged across participants, the resulting mean intercept value for Session 1, $M = 31.76$ (S.D. = 11.39), was not statistically different, $t = 0.21$, $p < 0.84$, from the mean intercept value for Session 2, $M = 32.13$ (S.D. = 13.19). The mean slope value for Session 1, $M = -9.02$ (S.D. = 5.13), was not significantly different from that of Session 2, $M = -10.86$ (S.D. = 6.12), though there was a trend for larger, more negative slope values in Session 2, $t = 1.85$, $p < 0.08$, suggesting the possibility of faster habituation in that session. Prior to assessing the relationship between slopes, intercepts, and personality variables, Session 1 and Session 2 values were averaged for each participant in order to minimize between-session variability. The Intraclass Correlations (ICCs; Shrout and Fleiss, 1979) for these mean values were 0.68 for the intercepts and 0.41 for the slopes.

2.1.6. Procedure

After informed consent was obtained, participants completed the self-report personality questionnaires. Participants were escorted into a dimly lit, sound attenuated room, where they were seated in a reclining chair approximately 1 m from the projector screen. After electrodes were attached, participants were told that slides would be presented. They were instructed to view the slides the entire time that they appeared on the screen. Participants were informed that they would hear brief “noise clicks” through the headphones that they could simply disregard. The slides and startle probes were then presented over the course of approximately 12 min. Participants completed a second identical Session 1 week later, all participants received identical stimuli with respect to order and timing of presentation. The 1-week interval was chosen because it maximized participant retention, while providing enough time for participants to dishabituate, thus minimizing effects of long-term habituation (Blumenthal et al., 1995).

2.2. Results

Means for personality and startle measures are presented in Table 1; two participants did not have SSS data, and three did not have MPQ data. Overall, personality variables correlated within one another in predictable ways (Table 2). The EPQ-E scale was correlated positively with the PEM factor of the MPQ and with the SSS scale. The EPQ-N scale was correlated positively with the NEM factor of the MPQ. The EPQ-P scale was correlated positively with the SSS, EPQ-N, and NEM. In addition, both the EPQ-P scale and the SSS were inversely related to the CON factor of the MPQ.

A preliminary regression analysis was performed to determine if startle magnitude and rate of habituation differed depending on whether startle probes

Table 1
Means and standard deviations of habituation and personality measures in Experiments I and II

Measure	Experiment I[a] M (S.D.)	Experiment II[b] M (S.D.)
Intercept (initial reactivity)[c]	22.3 (7.5)	3.6 (2.4)
Slope values (habituation)[c]	−6.9 (3.1)	−1.2 (1.1)
EPQ-E	15.2 (3.7)	14.9 (4.7)
EPQ-N	12.6 (5.0)	11.0 (4.3)
EPQ-P	4.3 (2.7)	3.3 (2.4)
SSS	0.48 (0.17)	–
MPQ-PEM	160.4 (11.4)	–
MPQ-NEM	138.6 (16.5)	–
MPQ-CON	157.3 (16.4)	–

[a] $N = 48$, 24 females.
[b] $N = 50$, 38 females.
[c] Values are expressed in square root microvolts. Because different methods were used to smooth the data in each study, these values are not directly comparable across studies.

Table 2
Correlations among personality and habituation variables in Experiments I and II

	Experiment I							Experiment II		
	E	N	P	SSS	PEM	NEM	CON	E	N	P
Average intercept	0.16	−0.06	−0.08	0.13	0.16	−0.17	−0.14	−0.02	0.10	0.08
Average slope[a]	−0.29*	−0.15	−0.28	−0.32**	0.00	−0.11	0.43**	−0.26	0.00	0.06
EPQ-E	–	−0.14	0.05	0.29*	0.57**	−0.03	−0.27	–	−0.10	0.16
EPQ-N		–	0.32*	0.10	−0.13	0.60**	0.04		–	0.19
EPQ-P			–	0.68**	−0.23	0.49**	−0.52**			
SSS				–	0.12	0.26	−0.68**			
MPQ-PEM					–	−0.03	0.16			
MPQ-NEM						–	−0.21			

Note: For Experiment I: $n = 48$, for comparisons involving the EPQ; $n = 45$ for those involving the MPQ; and $n = 46$ for those involving the SSS. For Experiment II, $n = 48$ (after removal of 2 outliers).
[a] Indicates slope value with intercept removed.
* $p < 0.05$.
** $p < 0.01$.

were administered during slide presentations or during ITIs. Square root transformed startle magnitudes were predicted using Log Stimulus Number, Condition (Slide versus ITI), and the Log Stimulus Number × Condition interaction. The overall model was significant, $F(2,2205) = 63.37$, $p < 0.001$, with Log Stimulus Number emerging as the only significant predictor, $t = 9.93$, $p < 0.0001$. No main or interactive effects were noted for the Condition variable, suggesting habituation was not different for startle probes presented during slides versus ITIs. Thus, it was appropriate to simultaneously include all 24 responses in the calculation of habituation slope values.

Habituation slope values were predicted using initial startle reactivity (i.e., the intercept value), along with gender and the three personality scales from the EPQ. The overall regression model was significant, $R^2 = 0.42$, $F(5,42) = 6.09$, $p < 0.001$. Initial reactivity was a significant predictor, $t = 4.10$, $p < 0.001$. In addition, a significant effect for EPQ-E was observed, $t = 2.60$, $p < 0.05$, indicating that individuals with higher extraversion scores exhibited faster startle habituation. The partial correlation between EPQ-E scores and slope values was $r = -.37$; the partial plot of the extraversion-habituation relationship is depicted in Fig. 1, upper panel. No significant effects were noted for gender, $t = 1.85$, $p < 0.08$, EPQ-N, $t = 1.09$, $p < 0.29$, or EPQ-P, $t = 0.35$, $p < 0.73$.

Next, startle habituation slope parameters were predicted using the three personality scales from the MPQ, along with gender and intercept values. The overall regression model was significant, $R^2 = 0.43$, $F(5,39)$, $p < 0.001$. Again, initial reactivity was a significant predictor, $t = 3.51$, $p < 0.001$. Additionally, a significant effect of CON was observed, $t = 2.55$, $p < 0.05$, indicating that individuals with higher CON scores exhibited less rapid startle habituation. The partial correlation between CON and slope values was $r = 0.38$; the partial plot is depicted in the lower panel of Fig. 1. No significant effects were noted for gender, $t = 1.31$, $p < 0.20$, PEM, $t = 1.05$, $p < 0.30$, or NEM, $t = 0.22$, $p < 0.84$.

Finally, startle habituation slope parameters were predicted using the SSS, along with gender and initial reactivity. While the overall regression equation was significant, $R^2 = 0.37$, $F(3,42) = 8.30$, $p < 0.001$, this was primarily due to the influence of the intercept, $t = 4.05$, $p < 0.001$. The contribution of the SSS approached significance, $t = 1.85$, $p < 0.08$. When the SSS was added to the regressions involving the EPQ, EPQ-E remained significant, $t = 2.63$, $p < 0.05$, whereas the SSS did not account for additional variance, $t = 1.11$, $p < 0.28$. The same pattern was observed when the SSS was added to the MPQ regression equation: CON remained significant, $t = 2.64$, $p < 0.05$, whereas the SSS made no independent contribution, $t = 0.55$, $p < 0.59$.

Follow-up regression analyses were performed to investigate why scores on CON were associated with habituation whereas scores on PEM, which were expected to be most associated with the EPQ-E scale, were not. When EPQ-E scores were predicted using PEM, EPQ-P, and CON, the regression model was significant, $R^2 = 0.46$, $F(3,41) = 11.62$, $p < 0.001$, with both PEM and CON emerging as significant predictors, $t = 5.38$, $p < 0.001$ and $t = 2.58$, $p < 0.05$, respectively. Conversely, when CON was predicted using PEM, EPQ-P, EPQ-E, the overall regression equation was significant, $R^2 = 0.38$, $F(3,41) = 8.29$, $p < 0.001$, with both EPQ-P and EPQ-E scores emerging as significant predictors, $t = 3.22$, $p < 0.01$ and $t = 2.58$, $p < 0.05$, respectively. This suggests that EPQ-E and CON share common variance apart from EPQ-P or PEM. Finally, when slope parameters were predicted using CON and EPQ-E scores simultaneously (with gender and initial reactivity also included), the regression

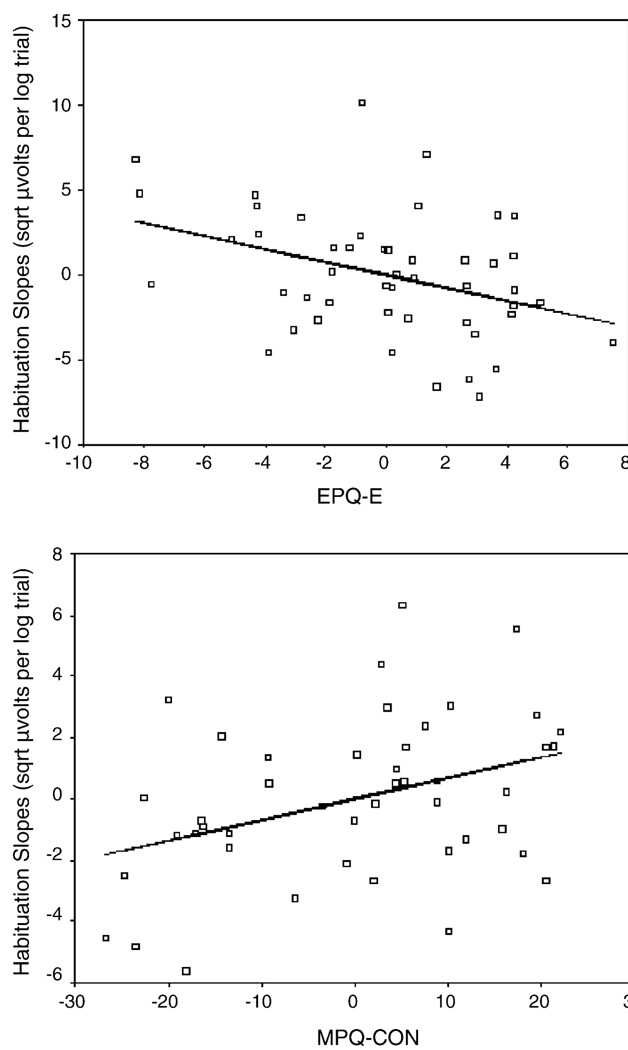

Fig. 1. Scatterplots relating EPQ-E (upper panel) and MPQ Constraint (lower panel) to the slope parameter of habituation in Experiment I. Plots depict residual scores after controlling for reactivity/intercept and other personality variables.

model was again significant, $R^2 = 0.46$, $F(4,40) = 8.52$, $p < 0.001$, but neither predictor seemed clearly superior to the other, with beta values for both CON and EPQ-E approaching significance, p's = 0.06 and 0.07, respectively.

3. Experimental II: replication

3.1. Method

3.1.1. Participants

Participants were 12 male and 38 female undergraduates enrolled in introductory psychology courses at Florida State University. Participants received course credit for their involvement in the study. The age range of participants was 18–25 years. On a brief medical history screening, participants denied history of conditions (e.g., vision or hearing loss) that would affect startle responding.

3.1.2. Stimulus materials

Visual stimuli were similar to those used in Experiment I, and consisted of 66 black and white bitmap files that depicted simple geometric shapes of 22 different types (circle, square, hexagon, triangle, etc.) which were presented in a semi-random order as described in Experiment I. Stimuli were presented on a 19″ monitor positioned approximately 90 cm from the participants. Stimulus presentation was controlled by DMDX, a software control routine developed at Monash University and at the University of Arizona by K.I. Forster and J.C. Forster, loaded on an IBM compatible Pentium III PC. Participants received 64 acoustic startle probes, consisting of a 50 ms burst of white noise with immediate rise time. Startle probes were presented through the stimulus computer sound card at one of two intensities, 74 or 104 dB, each of which was presented 32 times (half during slides, half during ITIs). Startle probes were presented binaurally to participants through Telephonics (TDH-49) headphones.

3.1.3. Stimulus presentation and design

Stimulus parameters were identical to those of the previous study (e.g., slide presentation time, length of ITIs, identical startle probe onset times). The only differences involved the presentation of more slides (66 instead of 24) and more probes (64 instead of 24). In addition, half the probes were presented at the 74 db level, and half were at the 104 dB intensity. Only the data from the 104 db startles are included in the present report.

3.1.4. Measures and quantification

Startle response data were acquired with a Neuroscan amplifier system connected to an IBM compatible computer running Neuroscan Scan 4.1 software. The raw blink EMG signal was digitized on-line at 2000 Hz, with high pass filters set at 30 Hz and anti-aliasing lowpass filters set at 500 Hz. Blink data were amplified, rectified, and smoothed using the Scan 4.1 software. Startle blink responses with onsets occurring between 20 and 120 ms were retained for scoring; baseline values, peak magnitudes, and onset latencies were identified manually by the first author. Participants completed the EPQ (Eysenck and Eysenck, 1975). The MPQ and SSS were not available at the time of data collection. For responses to the 104 dB probes, intercept and slope values were calculated for each participant using the same formula as in Experiment I.

3.1.5. Procedure

Informed consent was obtained at the beginning of the experiment. Participants completed the EPQ, and sensors were placed. Participants underwent approximately 6 min of baseline data collection. Once these initial procedures were completed, automated instructions for the procedure were delivered through headphones, and stimuli were presented over the course of approximately 25 min.

3.2. Results

Mean values for personality variables and startle response measures are presented in Table 1. Correlations for EPQ scales are presented in Table 2. As in Experiment 1, missing data did not covary with trial number ($\chi^2 = 0.36$, d.f. = 1, $p < 0.56$). A preliminary regression analysis also confirmed that slide versus ITI condition had no effect on startle magnitude or habituation—while the overall regression was significant, $F(3, 1514) = 22.58$, $p < 0.001$, only Log Stimulus Number predicted startle magnitude, $t = 6.16$, $p < 0.001$. Slope and intercept values were then calculated for each participant, and slope parameters were predicted using the EPQ personality variables, along with gender and initial reactivity. Visual inspection of the data suggested two outliers (see Fig. 2); this was verified computationally by examining the studentized deleted residuals for these data points, which were −2.6 and −3.0. These outliers were omitted from the subsequent regression analysis. With these outliers removed, the overall regression model was significant, $R^2 = 0.73$, $F(5,42) = 22.97$, $p < 0.001$, mostly due to the influence of initial reactivity, $t = 10.44$, $p < 0.001$; however, the contribution of extraversion was significant as well, $t = 1.86$, $p < 0.05$ (one-tailed).

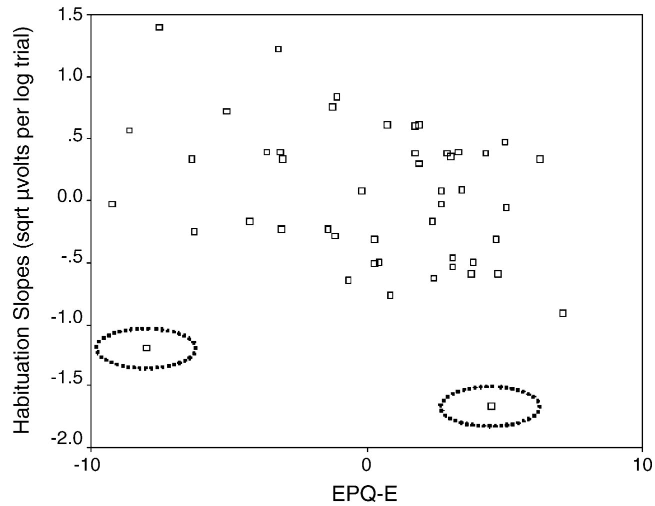

Fig. 2. Scatterplot relating EPQ Extraversion to the slope parameter of habituation in Experiment II. The plot depicts residual scores after controlling for intercept /reactivity, Gender, EPQ-N, and EPQ-P (circled points represent outliers that were removed from the final analysis).

4. General discussion

The results of Experiment I supported the hypothesis that extraversion and low constraint were associated with faster startle habituation, and a similar trend was found for sensation seeking. The results of Experiment II suggested that the relationship between extraversion and startle habituation was replicable. As noted above, the hypothesized relationship between extraversion/sensation seeking and faster habituation was based on Eysenck's suggestion that extraverts possess lower levels of cortical arousal resulting from less activity of the ARAS (Eysenck, 1994). While the startle response itself can be modulated by cortical processes (Davis et al., 1999), it is important to note that the nucleus reticularis pontis caudalis (NRPC), which has been implicated in regulating aspects of cortical arousal (Gottesmann et al., 1995), is a component of the primary acoustic startle pathway (Davis et al., 1999). Thus, a parsimonious explanation for the present results is that rapid habituation of startle in extraverts was directly mediated by the activity of the NPRC rather than indirectly moderated by feedback from cortical structures.

Although consistent with a number of previous reports, the present results must nevertheless be reconciled with other studies that fail to find a straightforward association between extraversion and faster habituation (Coles et al., 1971; Wigglesworth and

Smith, 1976). In the earlier extraversion studies, researchers typically recruited participants scoring at the extreme ranges of both the extraversion and neuroticism dimensions (Coles et al., 1971; Mangan and O'Gorman, 1969; Smith and Wigglesworth, 1978; Wigglesworth and Smith, 1976), despite the observation that the extraversion-habituation relationship was more likely to be observed in moderate scorers on the neuroticism dimension (Mangan and O'Gorman, 1969). In addition, a great majority of the earlier studies (including those cited here) examined habituation of the electrodermal response. EDR habituation has been linked to impaired (i.e., slower) habituation in clinically anxious populations (Birket-Smith et al., 1993; Lader and Wing, 1964; Orr et al., 1997; Shalev et al., 1992). Given that clinically anxious individuals typically score high on the neuroticism dimension (Bienvenu and Brandes, 2005), it is reasonable to assume that individuals within non-clinical samples who score extremely high on neuroticism will occasionally manifest clinical features such as impairments in EDR habituation. Although anxiety's impact on EDR is not always observed (Chattopadhyay et al., 1980; Jensen et al., 1996), particularly in non-clinical populations (see O'Gorman, 1977), it stands to reason that including extreme scorers on the neuroticism dimension increases the chance (though does not guarantee) that anxiety will affect EDR habituation. Therefore, when considering the early extraversion studies that included extreme scorers and measured EDR, it may be that some opposing (but inconsistently occurring) effect of high trait anxiousness on EDR habituation resulted in the failure to find a consistent extraversion-habituation relationship. This might explain why some studies support the predicted extraversion-habituation relationship (Mangan and O'Gorman, 1969; Smith and Wigglesworth, 1978), while others show no personality effects (Wigglesworth and Smith, 1976), and still another shows evidence for a link between neuroticism and slower habituation (Coles et al., 1971).

In contrast to these earlier studies, the participants within the present study were not pre-selected to be high or low on either extraversion or neuroticism. Thus, moderate scorers on both personality dimensions were proportionally represented in the current study sample. If a link between extraversion and faster habituation is indeed more likely to be observed among participants scoring within the moderate range of neuroticism (Mangan and O'Gorman, 1969), then this may explain why the predicted extraversion-habituation relationship was observed in the present data set. Even if extreme scorers had been used, it is possible that the pattern of results would have been observed, as startle habituation appears to be relatively unaffected by neuroticism (Akdag et al., 2003) or by the presence of an anxiety disorder (Larsen et al., 2002; Orr et al., 1997; Shalev et al., 1992). Thus, unlike EDR habituation, the relationship between extraversion and faster startle habituation may not be obscured by the "transient" and inconsistent effects of anxiety. While a full account of the differences in the neurobiological underpinnings of EDR and startle habituation is beyond the scope of the present report, it is conceivable that the more complex underlying neurobiology and longer response latency time of the EDR, compared to the startle response (Davis et al., 1999; Dawson et al., 2000), may render EDR habituation more sensitive to the cognitive/emotional aspects of anxiety.

While the present results are consistent with Eysenck's view of extraversion, it was notable that Positive Emotionality, the MPQ factor that has been most closely linked to EPQ Extraversion in past research (Tellegen and Waller, in press), was not significantly related to startle habituation. Thus, from the present pattern of data, it would appear that more rapid startle habituation is related to the construct of extraversion by virtue of its association with various aspects of a disinhibited personality style, such as risk-taking and behavioral deviance, rather than the sociable, lively, or positive affective aspects of extraversion. This is consistent with recent studies that have linked faster, more rapid habituation to disinhibitory syndromes (e.g., ADHD and conduct disorder, Iaboni et al., 1997; Herpetz et al., 2001) as well as disinhibited and impulsive personality traits (e.g., Bruggermann and Barry, 2002). The broader implication is that rapid startle habituation (along with P300 brain potential amplitude; Patrick et al., in press) might serve as a biological indicator of externalizing psychopathology—which is known to be associated with an impulsive, disinhibited personality style (Krueger et al., 2002; Sher and Trull, 1994).

Given the positive associations among the inverse of constraint, sensation seeking, and psychoticism, it is somewhat puzzling that higher psychoticism scores did not predict faster startle habituation. It may due to the fact that the EPQ-P scale was originally developed to assess proneness to "develop psychiatric abnormalities" (Eysenck and Eysenck, 1975, p. 5), such as Schizophrenia. Typically, such conditions have been linked to impaired, slower habituation (Geyer and Braff, 1982). Thus, the fact that the measure was originally designed to predict aspects of psychopathology associated with slower habituation (i.e., schizophrenia), but also is associated with aspects of personality associated with faster habituation (i.e., disinhibited personality traits) might account for the lack of effects for EPQ-P within the present data.

The present results must be interpreted with a degree of caution. First, even though the extraversion-habituation relationship was replicated, the ICC for habituation slopes in Experiment I was moderate at best and lower than what is typically required for paper-and-pencil measures. Part of the observed between-session instability may be a result of the effects of the long-term habituation, of the length of time between sessions (i.e., 1 week), and/or the number and timing of startle probes. It should be noted, however, that the ICCs observed in the present study were comparable to those found in a recent study that used a longer period of time between sessions, with more probes and shorter ITI times (Ludewig et al., 2003).

Another limitation of the present study was that the samples used in both experiments, aside from being relatively small, consisted primarily of college undergraduates falling within a fairly narrow range with respects to age, education, ethnicity, and SES. In addition, knowledge of each participant's medical status was limited, since it was derived exclusively from a brief self-report form that did not screen for overt pychopathology, patterns of substance use (e.g., alcohol, nicotine), caffeine use, or sleep. Thus, some participants could have had undetected medical conditions or lifestyle patterns that may have influenced startle responding.

Despite these limitations, the present study benefited from using a multi-measure approach (i.e., the use of the EPQ, MPQ, in combination with the SSS). These multiple measures made it possible to identify specific aspects of personality as they relate to startle habituation. Taken together, the present results suggest that startle habituation may serve as a biological marker of individual differences in personality traits – particularly traits related to an impulsive, disinhibited personality style – and may therefore serve as a useful tool in bridging the gap between our understanding of biology and personality theory.

Acknowledgements

Preliminary findings from this study were presented at the 44th annual meeting of the Society for Psychophysiological Research, Santa Fe, NM, October, 2004. Special thanks are extended to David P. LaRowe, B.S., B.M.E. and Abigail Shealy, B.A. for their assistance in the preparation of the final version of this manuscript.

References

Akdag, S.J., Nestor, P.G., O'Donnell, B.F., Niznikiewicz, M.A., Shenton, M.E., McCarley, R.W., 2003. The startle reflex in schizophrenia: habituation and personality correlates. Schizophrenia Research 64, 165–173.

Bienvenu, O., Brandes, M., 2005. The interface of personality traits and anxiety disorders. Primary Psychiatry 12, 35–39.

Birket-Smith, M., Hasle, N., Jensen, H.H., 1993. Electrodermal activity in anxiety disorders. Acta Psychiatrica Scandinavica 88, 350–355.

Blumenthal, T.D., Chapman, J.G., Muse, K.B., 1995. Effects of social anxiety, attention, and extraversion on the acoustic startle eyeblink response. Personality and Individual Differences 19, 797–807.

Blumenthal, T.D., 2001. Extraversion, attention, and startle response reactivity. Personality and Individual Differences 30, 495–503.

Bruggermann, J.M., Barry, R.J., 2002. Eysenck's P as a modulator of affective and electrodermal responses to violent and comic film. Personality and Individual Differences 32, 1029–1048.

Chattopadhyay, P., Cooke, E., Toone, B., Lader, M.H., 1980. Habituation of physiological responses in anxiety. Biological Psychiatry 15, 711–721.

Coles, M.G., Gale, A., Kline, P., 1971. Personality and habituation of the orienting reaction: tonic and response measures of electrodermal activity. Psychophysiology 8, 54–63.

Cook, E.W., Atkinson, L., Lang, K.G., 1987. Stimulus control and data acquisition of IBM PC's and compatibles. Psychophysiology 24, 726–727.

Crider, A., Lunn, R., 1971. Electrodermal lability as a personality dimension. Journal of Experimental Research in Personality 5, 145–150.

Curtin, J.J., 1996. An interactive program for scoring peak analog responses in Windows. Unpublished computer program, Florida State University, Tallahassee.

Davis, M., File, S.E., 1984. Intrinsic and extrinsic mechanisms of habituation and sensitization: implications for the design and analysis of experiments. In: Peeke, H.V.S., Petrinovich, L. (Eds.), Habituation, Sensitization, and Behavior. Academic Press, New York, pp. 287–323.

Davis, M., Walker, D.L., Lee, Y., 1999. Neurophysiology and neuropharmacology of startle and its affective modulation. In: Dawson, M.E., Schell, A.M., Bohmelt, A.H. (Eds.), Startle Modification: Implications for Neuroscience, Cognitive Science, and Clinical Science. Cambridge University Press, Cambridge, pp. 95–113.

Dawson, M.E., Schell, A.M., Filion, D.L., 2000. The electrodermal System. In: Cacioppo, J.T., Tassinary, L.G., Bernston, G.G. (Eds.), Handbook of Psychophysiology. second ed. Cambridge University Press, Cambridge, pp. 200–223.

Ditraglia, G.M., Polich, J., 1991. P300 and introverted/extraverted personality types. Psychophysiology 28, 177–184.

Eysenck, H.J., 1967. The biological basis of personality. Thomas, Springfield, IL.

Eysenck, H.J., 1994. Personality: biological foundations. In: Vernon, P.A. (Ed.), The Neuropsychology of Individual Differences. Academic Press Inc., San Diego, CA, pp. 151–207.

Eysenck, H.J., Eysenck, S.B.G., 1975. Eysenck Personality Questionnaire. EITS, San Diego, CA.

Fridlund, A.J., Cacioppo, J.T., 1986. Guidelines for human electromyographic research. Psychophysiology 23, 567–589.

Geyer, M.A., Braff, D.L., 1982. Habituation of the blink reflex in normals and schizophrenic patients. Psychophysiology 19, 1–6.

Gottesmann, C., Gandolfo, G., Zernicki, B., 1995. Sleep-waking cycle in chronic rat preparations with brain stem transected at the caudopontine level. Brain Research Bulletin 36, 573–580.

Groves, P.M., Thompson, R.F., 1970. Habituation: a dual-process theory. Psychological Review 5, 419–450.

Herpetz, S.C., Wenning, B., Mueller, B., Qunaibi, M., Sass, H., Herpetz-Dahlmann, B., 2001. Psychophysiological responses in ADHD boys with and without conduct disorder: implications for adult antisocial behavior. Journal of the American Academy of Child and Adolescent Psychiatry 40, 1222–1230.

Iaboni, F., Douglas, V.I., Ditto, B., 1997. Psychophysiological response of ADHD children to reward and extinction. Psychophysiology 34, 116–123.

Jansen, A., Klaver, J., Merckelbach, H., Van den Hout, M., 1989. Restrained eaters are rapidly habituating sensation seekers. Behaviour Research and Therapy 27, 247–252.

Jensen, H.H., Hasle, N., Birket-Smith, M., 1996. Electrodermal lability in anxiety disorders. Scandinavian Journal of Psychology 37, 103–108.

Krueger, R.F., Hicks, B., Patrick, C.J., Carlson, S., Iacono, W.G., McGue, M., 2002. Etiologic connections among substance dependence, antisocial behavior, and personality: modeling the externalizing spectrum. Journal of Abnormal Psychology 111, 411–424.

Lader, M.H., Wing, L., 1964. Habituation of psychogalvanic reflex in patients with anxiety states and in normal subjects. Journal of Neurology Neurosurgery and Psychiatry 27, 210–218.

Larsen, D.K., Norton, G., Walker, J.R., Stein, M.B., 2002. Analysis of startle responses in patients with panic disorder and social phobia. Cognitive Behaviour Therapy 31, 156–169.

Ludewig, K., Geyer, M.A., Vollenweider, F.X., 2003. Deficits in prepulse inhibition and habituation in never-medicated, first-episode schizophrenia. Biological Psychiatry 54, 121–128.

Mangan, G.L., O'Gorman, J.G., 1969. Initial amplitude and rate of habituation of OR in relation to extraversion and neuroticism. Journal of Experimental Research in Personality 3, 275–282.

O'Gorman, J.G., 1977. Individual differences in habituation of human physiological responses: a review of theory, method, and findings in the study of personality correlates in non-clinical populations. Biological Psychology 5, 257–318.

Orr, S.P., Solomon, Z., Peri, T., Pitman, R.K., Shalev, A.Y., 1997. Physiologic responses to loud tones in Israeli veterans of the 1973 Yom Kippur War. Biological Psychiatry 41, 319–326.

Patrick, C.J., Bernat, E., Malone, S.M., Iacono, W.G., Krueger, R.F., McGue, M.K., in press. P300 amplitude as an indicator of externalizing in adolescent males. Psychophysiology.

Patrick, C.J., Curtin, J.J., Tellegen, A., 2002. Development and validation of a brief form of the multidimensional personality questionnaire. Psychological Assessment 14, 150–163.

Petrinovich, L., Widaman, K.F., 1984. An evaluation of statistical strategies to analyze repeated-measures data. In: Peeke, H.V.S., Petrinovich, L. (Eds.), Habituation, Sensitization, and Behavior. Academic Press, New York, pp. 155–201.

Shalev, A.Y., Orr, S.P., Peri, T., Schreiber, S., Pitman, R.K., 1992. Physiologic responses to loud tones in Israeli patients with post-traumatic stress disorder. Archives of General Psychiatry 49, 870–875.

Sher, K.J., Trull, T.J., 1994. Personality and disinhibitory psychopathology: alcoholism and antisocial personality disorder. Journal of Abnormal Psychology 103, 92–102.

Shrout, P.E., Fleiss, J.L., 1979. Intraclass correlations: uses in assessing rater reliability. Psychological Bulletin 86, 420–428.

Smith, B.D., Concannon, M., Campbell, S., Bozman, A., Kline, R., 1990. Regression and criterion measure of habituation: a comparative analysis in extraverts and introverts. Journal of Research in Personality 24, 123–132.

Smith, B.D., Wigglesworth, M.J., 1978. Extraversion and neuroticism in orienting reflex dishabituation. Journal of Research in Personality 12, 284–296.

Stritzke, W.G.K., Patrick, C.J., Lang, A.R., 1995. Alcohol and human emotion: a multidimensional analysis incorporating startle-probe methodology. Journal of Abnormal Psychology 104, 114–122.

Thompson, R.F., Spencer, W.A., 1966. Habituation: a model phenomenon for the study of neuronal substrates of behavior. Psychological Review 73, 16–43.

Tellegen, A., 1982. Brief manual for the Multidimensional Personality Questionnaire. University of Minnesota, Minneapolis, unpublished manuscript.

Tellegen, A., Waller, N.G., in press. Exploring personality through test construction: Development of the Multidimensional Personality Questionnaire (MPQ). University of Minnesota Press, Minneapolis.

Wigglesworth, M.J., Smith, B.D., 1976. Habituation and dishabituation of the electrodermal orienting reflex in relation to extraversion and neuroticism. Journal of Research in Personality 10, 437–445.

Zuckerman, M., 1979. Sensation Seeking: Beyond the Optimal Level of Arousal. Erlbaum, Hillsdale, NJ.