Neuroticism-Anxiety, Impulsive-Sensation Seeking and autonomic responses to somatosensory stimuli

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Abstract

This study focused on autonomic responding in participants who scored high vs. low on the Neuroticism-Anxiety (N-Anx) and Impulsive-Sensation Seeking (Imp-SS) dimensions of the Zuckerman–Kuhlman Personality Questionnaire—Form III. Participants were presented with series of tones (standards, deviants and novels) and they received a mild electric shock (one, two or three pulses) at each 15th tone. Resting pre-stimulus skin conductance level (SCL) and heart rate (HR) level was recorded, as well as the skin conductance response (SCR) and (anticipatory) HR response to the electric stimuli. The autonomic measures differentiated between high- vs. low Imp-SS participants but failed to discriminate between high- vs. low N-Anx participants, with the exception that high N-Anx participants showed smaller SCRs on some trials compared to the low N-Anx participants. High Imp-SS had a lower pre-stimulus SCL and smaller SCRs to deviant stimuli compared to low Imp-SS participants. Additionally, their HR acceleration was smaller in anticipation of the first and the deviant tones whereas their deceleratory response was larger relative to the HR changes observed for the low Imp-SS participants. This pattern of findings was taken to suggest that high Imp-SS participants are more arousable and less prone to defensive reactions to novel or aversive stimulation.

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1. Introduction

Sensation seeking (SS) is a dimension of personality defined by the individual’s need for sensory stimulation and the level of risk taken for the sake of such stimulation (Zuckerman, 1994). For high sensation seeking individuals, the reward of the sensation outweighs most punishment and they are willing to take any risk in an effort to satisfy the need for challenging experiences and sensations. It is believed that individual differences in arousal levels prompt individuals to avoid or seek sensation, so as to maintain an optimal level of arousal (Zuckerman et al., 1980; Kohn, 1987).

Electrodermal measures have been employed widely to assess individual differences in arousal level and arousability (Malmø, 1959; Venables and Christie, 1980). Thus, skin conductance level (SCL) and skin conductance responses (SCRs) are used to provide indices of tonic and phasic arousal (e.g., Fowles, 1980; Boucsein, 1992). Studies focusing on tonic arousal, as indexed by SCL, observed a lower SCL in high SS individuals compared to low SS individuals (e.g., Gatzke-Kopp et al., 2002; Plouffe and Stelmack, 1986) supporting the notion that arousal level is lower in high SS individuals. Likewise, SRC discriminates between high and low SS individuals. The typical finding is that high SS individuals respond somewhat more vigorously to initial or novel stimulation than low SS individuals (e.g., Feij et al., 1985; Neary and Zuckerman, 1976; Robinson and Zahn, 1983; Smith et al., 1986). It should be noted, however, that several studies failed to replicate stronger SCRs in high SS individuals (e.g., Cox, 1978; Ridgeway and Hare, 1981; Zuckerman et al., 1988).

Zuckerman (1990) argued that the apparent inconsistencies across studies might be due to the uni-phasic nature of SCR that does not allow differentiating between orienting vs. defensive reactions. In this regard, the bi-phasic heart rate (HR) response might qualify as a more suitable indicator of individual differences in arousability. HR slowing to a stimulus is interpreted in terms of orienting whereas HR speeding is taken to suggest a...
defensive reaction (e.g., Graham, 1979; see review in Turpin, 1986). Likewise, anticipatory HR slowing is suggestive of stimulus intake whereas HR speeding preceding the stimulus is associated with the rejection of external input (e.g., Lacey and Lacey, 1974; see review in van der Molen et al., 1985). Several studies showed that when low-SS individuals respond to intensive stimulation by speeding their HR (indexing a defensive reaction) a slowing of HR (indexing orienting) is seen in high SS individuals (e.g., Orlebecke and Feij, 1979; Ridgeway and Hare, 1981; Robinson and Zahn, 1983). Looking at anticipatory HR responses, Somsen et al. (1983) observed that HR slowing was much more pronounced when participants expected the delivery of an aversive event (shock threat). This finding suggests that anticipatory HR slowing reflects the focus of attention to external input (see also Van der Molen et al., 1996).

The goal of the present study was to assess individual differences in SS by using both electrodermal and cardiac indices of arousal level and arousability, and by looking at both anticipatory changes and stimulus-induced responses. Individual differences in SS were examined in the context of the ‘five-factor’ model developed by Zuckerman and colleagues that is used widely in psychophysiological studies of personality (Zuckerman et al., 1988; Zuckerman et al., 1991; Zuckerman et al., 1993). The five factors distinguished in the Zuckerman model are Sociability (Sy), Neuroticism-Anxiety (NA), Impulsive Sensation Seeking (Imp-SS), Aggression-Hostility (Agg-Host) and Activity (Act). The primary focus in the current study was on Imp-SS and on NA, as the latter factor may interact with Imp-SS in modulating autonomic responsivity. Electrodermal activity and HR were recorded when participants, high vs. low Imp-SS and high vs. low Anx, were counting tones and receiving, occasionally, a mild electric shock. It was anticipated that high Imp-SS participants would show reduced SCRs and HR slowing to novel or aversive stimulation whereas low Imp-SS participants were expected to show pronounced SRCs and reduced HR slowing or even HR speeding.

2. Methods

2.1. Participants

The participants were 67 (35 females and 32 males) students, aged 18–30 years (M=23.5; S.D. = 3.0). Four participants had to be excluded from the study due to artifacts in the recordings (2 females and 2 males) two other participants (1 female and 1 male) declined to participate when informed of the nature of the experiment. Testing was carried out between 15:00 and 19:00 h. Participants were administered the Zuckerman–Kuhlman Personality Questionnaire—Form III (Zuckerman et al., 1993) providing Imp-SS and N-Anx scores. Median splits resulted in high vs. low Imp-SS groups (median score was 9) and high vs. low N-Anx groups (median score was 7). Thus, each participant belonged to the high or low Imp-SS group and to the high or low N-Anx group. The resulting distribution of participants is presented in Table 1. All participants reported themselves to be healthy and females were not having their period when participating in the experiment. Before testing, participants signed informed consent but they were naïve regarding the specific hypotheses of the study. The experiment was done respecting the guidelines stipulated in the “Ethical norms of the Italian Association of Psychology” (AIP).

2.2. Stimuli

Participants were presented with auditory and somatosensory stimuli. The auditory stimuli were pure tones (rise and decay times of 25 ms)—standards (70 db SPL, 800 Hz), deviants (70 db SPL, 1500 Hz) or novels (90 db SPL, 1000 Hz)—of 80 ms duration and presented with 950 ms intervals. Tones were computer generated by using ‘Cool Edit Pro’ (Phoenix Syntrillium Software Corporation) software and delivered by using ‘E-prime’ (Schneider et al., 2002) through padded earphones.

Somatosensory stimuli were delivered by applying two silver–silver chloride cup electrodes to the palmar surfaces of the distal and medial phalanges of the middle finger of the right hand. The electrode cup (1 cm in diameter) was filled with an electro-conductive hypoallergenic cream and impedance was kept below 30 Kohn. Stimuli consisted of unipolar electrical pulses of 2 ms duration, generated by a constant current stimulator (Digimiter, Mod DS7A).

Sensory thresholds were determined for each participant before testing. Participants received first a series of single, unipolar pulses separated by 10 s intervals, starting with an intensity of .05 mA and increasing with steps of .1 mA until the participant reported that the minimum detectable stimulus was reached. The intensity level of the just noticeable pin-prick was taken as the sensory threshold associated with ascending intensity levels. A similar, but reversed procedure, was used to obtain the sensory threshold associated with descending intensity levels, starting from .5 mA and decreasing with steps of .1 mA. The two thresholds were then averaged to obtain the participant’s sensory threshold. A similar procedure was used for obtaining pain and unpleasantness thresholds. Intensity levels were varied in steps of .5 mA and participants had to indicate whether the stimulus was producing a ‘distinct sharp painful pin-prick’ or a ‘distinct sharp

<table>
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<th>Gender</th>
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Table 1 Mean scores and standard deviations (STD) for Impulsive-SS (Imp-SS) and Neuroticism-Anxiety (N-Anx) dimensions and n for High Imp-SS/High N-Anx, High Imp-SS/Low N-Anx, Low Imp-SS/High N-Anx, Low Imp-SS/Low N-Anx subjects.
distressful pin-prick’, respectively. The thresholds obtained for ascending and descending series were then averaged again to obtain the pain and unpleasantness thresholds.

2.3. Task and procedure

Participants were presented with series of 15 tones, the last one coinciding with the somatosensory stimulus. The series of tones consisted of standard tones with the exception of the 7th tone, being a deviant tone. Each trial block consisted of 215 tone series and had a duration of 4 min, preceded by a 30 s baseline. The 7th somatosensory stimulus that occurred in a block was paired with the novel tone, not a standard one. A schematic of a trial block is presented in Fig. 1.

Participants were required to count the number of deviant tones. They received three trial blocks that differed in somatosensory stimulation. In one block, the somatosensory stimulus was applied in a single unipolar 2 ms pulse. In the other blocks the stimulus consisted of three unipolar 2 ms pulses or train of five unipolar 2-ms pulses. The interpulse interval was always 30 ms. Participants perceived the single-pulse stimulus as a light pin-prick, the two-pulses stimulus was perceived as slightly unpleasant and the five-pulses stimulus as unpleasant. The order of trial blocks was counterbalanced between participants who were seated in a comfortable chair in a soundproof chamber next to the recording equipment. They received a 4 min rest between trial blocks.

A measures of state anxiety was obtained just before and after physiological recordings. State anxiety was measured by using the State Anxiety form (Y1) of the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983). At the end of recording, participants rated whether they felt bored or aroused using a numerical scale (1 to 10). These subjective measures were analyzed, together with the threshold measures, in relation to the autonomic level and responsiveness measures.

2.4. Autonomic measures

Skin conductance (SC) was recorded using two silver–silver chloride cup electrodes applied to the volar surfaces of the medial phalanges of the second and third digits of the left hand with .05 M NaCl in an inert viscous ointment base as electrolyte. SC was detected by a constant voltage (0.5 V) applied to the electrodes so that a SC value of 10 μS corresponded to an observed current of 5 μA (Fowles et al., 1981). The SC was digitized and recorded by a SATEM Biolab 104SC system using a sampling rate of 25 Hz. An epoch of 14 s was used to assess the amplitude of SCR standard stimuli.

Two separate measures of baseline SC level were obtained as indices of tonic arousal: 1) SC levels, averaged during a baseline resting period of 30 s preceding each experimental condition; and 2) averaged SC levels, within a time window of 160 ms, preceding the deliverance of each somatosensory stimulus. SCRs with onset latencies between 1 and 3 s (inclusive) were scored as measures for phasic electrodermal activity (Barry, 1990; Dawson et al., 1990). Two separate measures of SCR were obtained: (a) the phasic SCR score as a function of stimulus repetition (Dawson et al., 1990, pp. 302–309); and (b) the total number of SCRs that were greater than 0.2 μS of pre-stimulus levels. The SCR values were subjected to a square-root transformation to improve the skew commonly associated with small responses in the electrodermal activity.

An electrocardiogram (EKG) was obtained from two pure tin electrodes (1.5 cm in diameter). The electrodes were filled with electrolyte paste and attached to the sternum and to the left rib cage. A ground plate electrode was attached to the right wrist. The EKG signal was detected using a SATEM-Biolab PT 104SC system that measured R–R intervals and yielded one data point every 40 ms (sampling frequency of 25 Hz). The R–R interval time series was processed off-line for artifact correction and then transformed into beats/min. An R–R epoch was rejected if there was at least one value lower than 400 ms or greater than 1200 ms. Measures of cardiac activity were calculated as HR changes within a 10.2 s epoch (an additional 0.22 s was added to the original epoch of 10 s because the five-pulses somatosensory stimulus took up an additional .22 s). The resulting HR scores were then referenced to a 5.0 s baseline preceding standard stimulus onset. Anticipatory HR acceleration was examined by determining the maximum peak during an interval of 5 s preceding stimulus onset. HR deceleration following the stimulus was examined by

![Fig. 1. Example of a single trial block showing the electric pulse stimulations and the auditory tone stimulations which included the deliverance of the novel tone concurrently with the presentation of the seventh electric stimulus.](image-url)
determining the minimum during a 5 s interval post-stimulus. This procedure has been widely used in previous HR change studies (see e.g., De Pascalis et al., 1995; Van der Molen et al., 1987).

2.5. Statistical analyses

A simple split-plot ANOVA with Gender, N-Anx, and Imp-SS serving as between group variables was used to assess the subjective threshold measures and boredom ratings. A repeated measure ANOVA, comprising the same factors, was done to assess state anxiety before and after the conclusion of the experiment.

Baseline SCL and HR measures were analyzed using repeated measures ANOVAs with Gender (2), N-Anx (2) and Imp-SS (2) as between-subjects factors and Stimulation (3; trial blocks with 1-pulse, 2-pulses vs. 5-pulses of somatosensory stimulation) as within-subjects factor. Similar ANOVAs with an additional within-subjects factor Trial (15) were done to assess SRCs and HR change preceding and following the somatosensory stimulus and to evaluate baseline SC and HR scores obtained for the 160 ms interval just preceding the somatosensory stimulus. Huynh–Feldt epsilon correction of significance levels was used when necessary (Jennings and Wood, 1976; Vasey and Thayer, 1987). Post hoc comparisons were carried out by using a t-test procedure with Bonferroni correction of $\alpha = .05$ (Kirk, 1968). SAS-8.02 was used for all statistical analyses.

3. Results

The results will be presented in sections. First, the findings pertaining to the subjective measures will be presented. This section is followed by the presentation of the SC and HR baseline and pre-stimulus results and the third section presenting SC and HR responsivity findings.

3.1. Subjective measures

The ANOVA on sensory threshold scores yielded main effects for Gender, $F(1, 52)=6.83$, MSe =.032, $p=.012$, and Imp-SS, $F(1, 52)=5.27$, MSe =.032, $p=.025$. Males reported a higher sensory threshold than females (.59 vs. .45 mA, respectively) and high Imp-SS participants reported a higher threshold relative to low Imp-SS ones (.57 vs. 0.47 mA). No other main effects or interactions were reached significance.

A similar analysis done on the unpleasantness threshold scores yielded a significant interaction between N-Anx and Imp-SS, $F(1, 52)=8.16$, MSe =0.671, $p<.006$. High N-Anx/high Imp-SS participants were more sensitive to unpleasant stimuli compared to low N-Anx/high Imp-SS participants (.70 vs. 1.79 mA, respectively), $t(21)=3.35$, $p=.0016$. The difference between low N-Anx/low Imp-SS participants vs. high N-Anx/high Imp-SS participants (1.07 vs. 1.25 mA, respectively) was not significant, $t(36)=.48$, $p>.05$.

The ANOVAs for pain threshold scores, boredom ratings and state anxiety failed to reveal any significant main or interaction effect. The only effect that approached significance was for N-Anx, $F(1, 52)=3.25$, MSe =4.91, $p=.077$. Simple effect analyses indicated that high N-Anx participants, relative to...
low N-Anx ones, tended to report a greater level of state anxiety just before the beginning of the experiment, \( F(1, 52) = 6.96, \text{MSE} = 3.73, p = .011 \), while the groups did not differ in state anxiety after the experiment (\( F < 1 \)).

3.2. Baseline and pre-stimulus measures

The ANOVA on baseline SCL failed to yield any significant effect suggesting that groups did not differ in tonic arousal. The ANOVA done on the SC level just prior to the stimulus showed a main effect for Trial, \( F(3.7, 192.0) = 86.8, \text{MSE} = .007, \varepsilon = .264, p < .0001 \), and a significant Stimulation \( \times \) Trial interaction, \( F(4.7, 247.4) = 107.6, \text{MSE} = .006, \varepsilon = .170, p < .0001 \). This interaction is plotted in Fig. 2. It can be seen that pre-stimulus SC level decreases with trial number and increases following the presentation of the deviant stimulus at trial 7. In addition, pre-stimulus baseline was higher for stronger (i.e., five pulses) stimulation compared to weak (i.e., one pulse) stimulation. The personality variables did not alter the effects, with the exception of the interaction between Imp-SS and Stimulation that was close to significance, \( F(2, 104) = 1.99, \text{MSE} = 0.213, \varepsilon = 1.135, p = .12 \). Pre-stimulus SCls tended to be smaller in high Imp-SS subjects in trial blocks using five-pulses stimulation (1.96 vs. 2.25 \( \mu \)S, respectively).

A similar set of analyses was done on baseline and pre-stimulus HR levels. These analyses indicated that HR level was lower for high Imp-SS participants in all three trial blocks compared to low Imp-SS ones (72.8 vs. 80.7, 72.7 vs. 79.2, and 73.8 vs. 79.6 bpm, respectively), \( F(1, 52) = 5.16, \text{MSE} = 335.1, p = .027 \). No other effects were found to be significant for HR baseline.

The ANOVA performed on pre-stimulus HR levels yielded a main effect for the Imp-SS factor, \( F(1, 52) = 5.51, \text{MSE} = 4669.5, p = .023 \); and a main effect for Trial, \( F(5.1, 264.1) = 3.03, \text{MSE} = 13.62, \varepsilon = 0.363, p = .011 \). HR levels were lower for high Imp-SS participants compared to low-Imp-SS ones. In addition, HR levels tended to be somewhat higher early compared to later in a trial block, with an increase again at trials 14, and 15.

3.3. SC and HR responsivity

Stimulation and Trial number each exerted highly significant effects on SCRs, \( F(2, 104) = 20.38, \text{MSE} = .137, \varepsilon = 1.211, p < \)

Fig. 4. Skin conductance (\( \mu \)S) changes and standard errors of the mean of high and low Impulsive Sensation Seeking (Imp-SS) subjects in response to repeated presentations of 15 electric stimuli at low, medium, and high repetition level. A number of Standard (800 Hz, 70 dB) and Deviant rare (1500 Hz, 70 dB) tones were also presented during the ongoing somatosensory stimulation, when a novel tone of higher intensity (1000 Hz, 90 dB) was delivered concurrently with the onset of the 7th electric stimulus (Trial 7).

Fig. 5. Mean heart rate change (bpm) from a pre-stimulus level and standard errors of the mean of high and low Impulsive-Sensation Seeking (Imp-SS) subjects in response to the first electric stimulus (Trial 1, top graph) and to the 7th electric stimulus delivered in parallel with the novel high-intensity tone (1000 Hz, 90 dB; Trial 7, down graph). Stimulus onset at time = 0.
and \( F(11.8, 614.3) = 77.78, \text{ MSe} = .027, \ v = 0.844,\ p < .0001 \), respectively. Their interaction also reached significance, \( F(20.4, 1059.4) = 4.05, \text{ MSe} = .022, \ v = 0.728,\ p < .0001 \), as did the interaction between N-Anx and Trial number, \( F(11.8, 614.3) = 2.19, \text{ MSe} = .027, \ v = 0.844,\ p = .011 \). Finally, a significant three-way interaction was obtained between these variables, \( F(20.4, 1059.4) = 2.99, \text{ MSe} = .022, \ v = 0.728,\ p < .0001 \). This interaction is plotted in Fig. 3. Simple effects indicated that SCRs did not discriminate between trials in the trial block containing strong (i.e., 5 pulses) somatosensory stimulation. In high N-Anx participants, SCRs were more pronounced on trials 1 and 7 (\( ps < .0001 \)) of trial block containing weak (i.e., 1-pulse) somatosensory stimulation and on trials 1, 7, 9, 11, 13, and 15 all (\( ps < .05 \)) of the trial block containing medium (i.e., 2-pulses) somatosensory stimulation.

There was also a significant higher-order interaction between the effects of Imp-SS, Stimulation and Trial number, \( F(20.4, 1059.4) = 1.99, \text{ MSe} = .022, \ v = 0.728,\ p = .016 \). This interaction is plotted in Fig. 4. Simple effects indicated that SCRs for high Imp-SS participants, relative to low Imp-SS participants, were more pronounced on trial 1 when somatosensory stimulation was weak and on trials 1 and 7 (the trial of the deviant stimulus) when stimulation was medium (all \( ps < .05 \)). This difference was significant for trials 1, 7, 10, 11, and 14 when stimulation was strong (all \( ps < .05 \)).

A final analysis considering electrodermal activity focused on the total number of SCRs. This ANOVA showed a main effect of Stimulation and a significant interaction between Stimulation and N-Anx, \( F(2, 94) = 7.72, \text{ MSe} = 10.77, \ p = .0007, \) and \( F(2, 94) = 3.38, \text{ MSe} = 10.77, \ v = 1.101,\ p = .038 \), respectively. The number of evoked SCRs was higher when somatosensory stimulation was medium or high intensity relative to when it was low, and when stimulation was medium the low N-Anx participants produced more SCRs compared to the high N-Anx ones (all \( ps < .01 \)).

The analyses considering HR change included HR baseline as covariate, as previous analyses indicated that high Imp-SS participants had lower HR levels than low Imp-SS ones (see the above section on baselines). The HR changes on the first and
seventh trials are plotted in Fig. 5. It can be seen that HR acceleration was more pronounced for low compared to high Imp-SS subjects. The statistical analysis evaluated this between group effect across trials. The analysis on HR acceleration yielded significant main effects of Imp-SS, $F(1, 51) = 6.44$, $MSe = 12.67, p = .014$, and Trial number, $F(10.2, 519.0) = 1.96$, $MSe = 2.64, \epsilon = .727, p = .034$, and their interaction, $F(10.2, 519.0) = 2.44, MSe = 2.64, \epsilon = .727, p = .007$. This interaction is plotted in Fig. 6. It can be seen that high Imp-SS subjects have a smaller anticipatory HR acceleration than did low Imp-SS ones (1.1 vs. 1.6 bpm). This difference was more pronounced on trial 1 and trial 7 relative to the other trials (all $ps < .0001$).

A similar ANCOVA on post-stimulus HR deceleration yielded a significant main effect of Trial number, $F(10.9, 560.6) = 2.61, MSe = 4.06, \epsilon = .785, p = .003$, showing a more pronounced HR deceleration on trial 7 (i.e., the trial of the deviant tone) relative to the other tones. The main effect of Stimulation was significant also, $F(2, 102) = 3.40, MSe = 5.92, \epsilon = 1.29, p = .042$. HR showed an acceleratory trend in the strong stimulation block compared to the medium and weak stimulation blocks ($ps < .05$). Finally, the ANCOVA yielded a significant Imp-SS $\times$ Trial interaction, $F(10.9, 560.6) = 2.49, MSe = 4.26, \epsilon = .785, p = .0047$. This interaction is plotted in Fig. 7. It can be seen that HR deceleration of high Imp-SS participants increased on trial 7 (i.e., the trial of the deviant tone) relative to the other trials whereas low Imp-SS participants showed the opposite trend, $t(59) = 10.31, p < .001$. A significant difference in HR slowing between Imp-SS groups occurred also on trials 2 and 12.

4. Discussion

This study set out to examine differences between high vs. low N-Anx participants and high vs. low Imp-SS individuals by focusing on subjective measures and indices of arousal and arousability derived from electrodermal activity and heart rate changes. The analysis of subjective measures revealed that, as anticipated, high N-Anx participants were more anxious prior to the start of the experiment and that high N-Anx/low Imp-SS individuals had lower unpleasantness thresholds (i.e., they perceived the somatosensory stimulation as more aversive). This pattern of findings is consistent with Corr’s (2001) interpretation of Gray’s (1987) model distinguishing between a reward-sensitive Behavioral Activation System (BAS) and a punishment-sensitive Behavioral Inhibition System (BIS). According to Corr’s interpretation, aversive stimulation will jointly reduce BAS activity and increase BIS activity whereas appetitive stimulation has the reverse effects. In the current study, BAS prone individuals (i.e., high N-Anx/low Imp-SS participants) perceived mild shocks as more aversive compared to BAS prone individuals (i.e., low N-Anx/high Imp SS participants).

The autonomic findings that emerged from the present study revealed a highly interesting pattern. Considering first the baseline findings, it was observed that HR level was lower for high Imp-SS participants compared to low-Imp SS participants while SCL failed to discriminate between the groups. The between-groups difference in HR level is consistent with previous research suggesting that the level of arousal in high Imp-SS individuals is lower than in low Imp-SS ones (Knyazev et al., 2002; but see Hepioniemi et al., 2003) and it is also consistent with recurrent observation of low resting HR in individuals with conduct disorders and in psychopaths (Ortiz and Raine, 2004). However, the absence of a difference in SCL between groups is inconsistent with this notion. Possibly, in the current experiment, HR level provided a more sensitive indicator of arousal level than SCL. Differential sensitivity of autonomic measures should be examined more closely in future research using conjoint measurement of electrodermal and cardiac activity (Zimmer et al., 1990). Another way of examining individual differences in arousal levels is by focusing on autonomic activity just preceding stimulation. These analyses indicated that SCL was higher preceding the stimulus just following the deviant tone and stimulus-preceding SCLs was stronger during the strong somatosensory trial block compared to the weak and medium stimulation blocks. Individual differences failed to reach an acceptable significance level but there was a trend in the predicted direction showing that pre-stimulus SCLs were somewhat lower in high Imp-SS participants compared to low Imp-SS ones during the strong stimulation block. Moreover, a similar analysis focusing on pre-stimulus HR level showed that high Imp-SS individuals had lower HR levels than low Imp-SS individuals. The latter observations are adding to the pattern of findings suggesting that Imp-SS is related to autonomic arousal (e.g., Gatze-Kopp et al., 2002; Kohn, 1987; Plouffe and Stelmack, 1986).

Considering individual differences in arousability, it should be noted that both SCRs and HR changes around the deviant stimulus indicated that high Imp-SS individuals are less arousable than low Imp-SS ones. First, relative to low Imp-SS individuals, anticipatory HR acceleration preceding the deviant tone is less in high Imp-SS individuals, the amplitude of their SCR to the deviant tone is lower, and they showed increased HR slowing while low Imp-SS individuals responded to this tone by speeding their HR relative to standard tones. Together, these findings point consistently to the higher arousability of high Imp-SS individuals compared to low Imp-SS ones and, in this regard, the results of the present findings are in accord with findings reported previously by Zuckerman and co-workers (e.g., Neary and Zuckerman, 1976; Zuckerman et al., 1980, 1988; Zuckerman, 2005) and others (Ridgeway and Hare, 1981; Smith et al., 1989).

Another piece of evidence supporting the notion of low arousal in impulsive individuals is the observation that during the strong somatosensory trial block, low Imp-SS participants tended to reduce and high-Imp-SS participants to enhance the magnitude of their SCRs (see Fig. 4). In other words, high Imp-SS participants exhibited more sensitization and less habituation than did low Imp-SS ones. This observation is consistent with findings obtained in brain potential studies of the augmenting–reducing typology showing that high sensation seekers are augmenters and low sensation seekers reducers of auditory and visual evoked potentials elicited by strong stimulation (Buchsbaum and Silverman, 1968; Carrillo-de-la-Peña, 1992; Stenberg et al., 1986; Stenberg et al., 1988; Brocke et al., 1999; Zuckerman et al., 1974; Zuckerman et al., 1988).

The current observation that the number of evoked SCRs did not discriminate between Imp-SS groups can be used to refine the arousal interpretation of impulsivity. That is, in accord with...
early results obtained by Neary and Zuckerman (1976), the current finding indicates that Imp-SS differences refer to individual variation in arousability in responding to deviant or intensive stimuli rather than inhibitory processes. Indeed, in the study of Neary and Zuckerman (1976), high sensation seekers oriented stronger only to the first tone of a series not to subsequent tones (see also Smith et al., 1986, 1989).

Similar to high Imp-SS individuals, the electrodermal response to the first and deviant tones of the stimulus series was stronger in low compared to high N-Anx participants. This finding is, again, in accord with previous findings reported by Neary and Zuckerman (1976) who, likewise, observed that SRCs to novel stimuli were larger in low-anxiety compared to high-anxiety participants while groups did not differ in basal SCLs. These findings rule out a common misconception assuming that orienting represents an emotional response to the eliciting stimulus rather than a perceptual alerting response and are consistent with other studies relating anxiety and ego-involvement to responsiveness (Roessler, 1973; Van Veen et al., 1973; Glanzmann and Froehlich, 1984).

In conclusion, the present study provided strong support for the notion that Imp-SS individuals differ both in arousal level (as indexed by HR level and pre-stimulus electrodermal and HR levels) and arousability (as indexed by electrodermal and HR responses to deviant stimuli and the number of SCRs). The current findings are meshing nicely with the idea that, in high sensation-seeking individuals the behavioral activation system, as conceptualized by Gray (1982) and Pickering and Gray (2001), is over-activated, both habitually and in response to stimulation. The finding of a HR deceleration in high Imp-SS participants whereas low Imp-SS ones responded with HR speeding to deviant stimuli might be interpreted to suggest that high Imp-SS individuals orient to these stimuli while the primary response of low Imp-SS is defensive (e.g., Graham, 1979; Turpin, 1986). In day-to-day living the tendency to orient to deviant stimuli may translate into the absence of withdrawal-type behaviors in the presence of risk or physical threat (e.g., Patrick, 1994; Herpetz et al., 2001; Deforest and Johnson, 1981; Zuckerman, 2002; Raine, 2002).

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