

Habituation of P3a and P3b brain potentials in men engaged in extreme sports

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Abstract

Do person characteristics determine when novel, attention-grabbing stimuli lose their novelty? The aim of the present study was to investigate habituation of the visual event-related potentials (ERP) P3a and P3b in men that (1) were engaged in extreme sports, (2) had extremely high scores on the Impulsivity Sensation Seeking scale of the Zuckerman–Kuhlman Personality Questionnaire (ZKPQ), yet were not engaged in extreme sports, or (3) had extremely low scores on ZKPQ. The results showed that P3a habituated significantly more in extreme sporters than in the other groups. The same was not found in comparison of the high and the low ZKPQ scorers. There were no differences between the groups in overall amplitude. It is concluded that ERP habituation may be more relevant than mere amplitude to the sensation seeking trait in extreme sporters, and that they differ from others in ERPs related to automatic alerting-related processes, not controlled cognitive processing.

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1. Introduction

Sensation seeking refers to a personality dimension related to an individual's need for sensory stimulation and willingness to take risks for obtaining such stimulation (Zuckerman, 1979). Persons engaged in dangerous sport activities, as for instance skydiving, are found to have a higher level of sensation seeking than others (Breivik et al., 1998). Zuckerman (1979) argued that the concept of an optimal level of arousal constitutes the physiological basis for the sensation seeking trait. This relates to Hebb's (1955) theory, according to which a relationship exists between arousal and performance. A certain level of arousal is necessary for normal behavioral function. Eysenck and Eysenck (1978) developed this idea further, and suggested that certain personality traits may be explained by chronic under-arousal. Such persons will tend to seek stimulation so that their arousal is heightened to a hedonic point. Carton et al. (1992, 1995) have argued that sensation seekers, through

extreme sensations, try to compensate for anhedonia due to a basal arousal deficit.

By use of event-related potentials (ERP), it should be possible to reveal neurocognitive mechanisms involved in sensation seeking (Hegerl et al., 1989, 1995). Following the line of reasoning outlined above, one might expect that chronic under-arousal is related to lower ERP amplitudes, and vice versa. For instance, several studies have found that higher levels of cortical arousal increase P300 amplitude, especially through positive correlations between introversion and P300 amplitude (Brocke et al., 1996; Daruna et al., 1985; O'Connor, 1983; Polich and Martin, 1992), and also between P300 amplitude and anxiety (Grillon and Ameli, 1994). Still, previous research has not been entirely consistent. Cahill and Polich (1992) found smaller P300 amplitude in introverts, and Pritchard (1989) did not observe any relationship between P300 amplitude and neither neuroticism nor extroversion.

There have been a number of studies of sensation seeking that have used ERP recordings, several focusing on the P300 component. Pierson et al. (1999) found that skydivers had higher frontal P3 to non-target (standard) than controls. This finding is not in coherence with the model of sensation seekers as chronically under-aroused and the studies of P300 and arousal

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states referred above. The authors suggested that the finding reflect that sensation seekers engage in behaviors which improve automatic attentional processes in order to obtain arousing stimulation that could counterbalance an emotional deficit. Further, novelty seeking (Cloninger et al., 1991), a concept related to sensation seeking, has also been reported to correlate positively with P300 amplitude (Hansenne, 1999). However, Wang and Wang (2001) reached the opposite conclusion in a study where they found a negative correlation between auditory passive P300 amplitude and score on Zuckerman's Sensation Seeking Scale. Guillem et al. (2005) found that a memory-related P600 was enhanced in schizophrenic patients with high sensation seeking scores. Thus, to date, clear conclusions cannot be drawn as to whether specific relationships between P300 amplitude and sensation seeking exist.

Correlations between P300 and sensation seeking are probably partly related to neurotransmitter levels. Research supports an association between monoamines (MAO) and major personality dimensions (Cloninger, 1986; Gurrera, 1990). In several studies, a relationship between low activity of platelet MAO and personality characteristics, such as sensation seeking, impulsiveness, and monotony avoidance, has been found (see Oreland, 1993). Further, studies have implicated MAO neurotransmitters as possible mediators of the link between personality traits and P300 amplitude (Hansenne et al., 1995). Still, studies not replicating these hypothesized relationships between personality dimensions and monoamines exist (e.g. Curtin et al., 1997; Hansenne and Ansseau, 1998), so this matter is not settled.

In a very recent study, LaRowe et al. (2006) demonstrated that higher sensation seeking and extraversion scores were associated with faster, more rapid startle habituation. Follow-up analyses also showed relationships between extraversion, sensation seeking and the Constraint factor of Tellegen's Multidimensional Personality Questionnaire, which indicate that sensation seeking and extroversion, and habituation within the central nervous system, are associated with tendencies toward impulsivity and behavioral disinhibition.

The rationale behind the present study was to investigate information processing in sensation seekers by focusing on not only what happens when the brain processes novel or unexpected information, but rather what happens when the novel information loses its novelty, i.e. is repeated over an extended interval. The reasoning was the following: Previous research has not found clear evidence for differences in the amplitude of P3a or novelty-P3. Based on such results, it may be that when novel or attention-grabbing stimuli are presented to sensation seeking participants, their brains do not process this information in ways different from other participants. However, when the novel information is presented repeatedly, as in the often-employed three-stimulus oddball paradigms used to elicit a P3a to task-irrelevant non-targets (distractors) and a P3b to targets, it is possible that sensation seekers will be more prone to habituation. This is in accordance with the conceptual idea of sensation seeking as a trait related to preference for change and novelty. Thus, we expect that the amplitude of the fronto-centrally peaking P3a component,

related to automatic orienting and alerting responses, may show a larger rate of habituation in sensation seekers than in others. P3a has been found to habituate rather quickly (Friedman and Simpson, 1994), indicating that the component is indeed related to habituation. The P3b, on the other hand, is more parietally distributed on the scalp and related to controlled cognitive processing. P3b does not habituate at the same rate as P3a, and thus seems to be less related to the brain's adaptation of stimuli. Since we do not expect controlled cognitive processing to vary as a function of sensation seeking, we do not hypothesize differences in habituation of P3b for groups of high sensation seekers compared to groups of low sensation seekers.

Finally, we wanted to focus on the relationship between high scorers on the Impulsivity Sensation Seeking scale of the Zuckerman–Kuhlman Personality Questionnaire (ZKPQ) (Zuckerman, 2002; Zuckerman et al., 1993) and “real-life” sensation seekers, that is, people engaged in potentially life-threatening sport activities (in this case, mainly base jumping and skydiving) (for simplicity, ZKPQ score is in the following taken to mean score on the Impulsivity Sensation Seeking scale from this inventory). Thus, three groups of participants were used: The first group consisted of participants regularly engaged in risk sports (in the following referred to as extreme sporters), the second group consisted of participants who scored very high on ZKPQ but were not engaged in risk sports, and the third group consisted of participants who scored very low on ZKPQ (and who, needless to say, did not engage in risk sports). Our hypothesis was that the extreme sporters would show higher rates of adaptation to novel or distracting stimuli than the high ZKPQ scorers who did not engage in risk sports. The reasoning behind this was that even though a correlation between ZKPQ score and the tendency to engage in extreme sports exists, a lot of the variance covered by the ZKPQ is only weakly related to arousal-related activities like extreme sports. For instance, there is no direct link between questions like “I enjoy getting into new situations where you can't predict how things will turn out” and “I prefer friends who are excitingly unpredictable”, and preference for activities involving extreme arousal. Given that preference for extreme arousal is more tightly coupled with habituation than preference for novelty or distraction that does not involve extreme arousal, we expect the extreme sporters to show higher rates of adaptation than high ZKPQ scorers who are not engaged in extreme sports.

In the present study, a three-stimulus oddball paradigm is used. It can be argued that the repeated presentation of a distractor stimulus does not relate easily to the psychological concept of novelty. Still, several reports comparing the novelty-P3 and the P3a from three-stimulus paradigms find that they are basically the same component (e.g. Simons et al., 2001). Further, using an ICA approach, Debener et al., 2005 did not find a clear distinction between P3a and novelty-P3. Thus, it seems that the same brain areas and the same neurophysiological mechanisms are responsible for generating the electrophysiological response to a novel stimulus and to a distractor stimulus. Thus, it is probably warranted to use the P3a elicited to repeated distractor stimuli as a measure of the brain's response to novel stimulation. Adding to this, the rationale for the study is to study not only

processing of novel information, but how the brain responds to the process where an initially novel and attention-grabbing distractor stimulus loses its novelty.

2. Methods

2.1. Sample

The sample consisted of 67 healthy males between 20 and 40 years of age, with more than 12 years of education. All were informed about the procedures in the study, and that they could withdraw from the study without giving a reason, and all signed informed consent. Potential participants were informed that they could not participate if they were regularly using drugs, had neurological disorders, or had below normal/corrected to normal vision. In addition, participants were required to be between the ages 20 and 40 years and be free from somatic or mental illnesses. All participants who enrolled in the project were additionally specifically asked about use of psychopharmacological drugs, and were excluded if they confirmed this. Six participants were excluded due to these criteria: Three used psychopharmacological drugs and three were older than 40 years. In addition, one person was excluded due to technical difficulties with the ERP recordings, thus reducing the initial sample from 67 to 60. All participants received a small gift (equal to about 2 USD), while the extreme sporters in addition received a small sum of money (equal to 15 USD), intended to cover travel expenses since they had to come to the lab from various places in the city, while the other participants were students located at campus.

The sample was divided into three groups. Group 1, the extreme sporters, consisted of participants that were regularly engaged in risk sports, that is, mainly base jumping or skydiving, but also hanggliding and high-risk mountain climbing (several of the participants were in fact engaged in a number of such activities). These were recruited through internet ads and skydiving clubs. Group 2 and 3 consisted of students from the University of Oslo and the Police Academy of Oslo. One hundred and seventy persons answered the ZKPQ, and the 30 persons with the highest and the 30 persons with the lowest scores were selected to participate in the ERP study. Of these, some had changed their mind regarding participation, some could not make an appointment during the available lab sessions, and some were excluded according to the criteria described above. In addition, some of the high scorers turned out to be engaged in risk sports (here defined as base jumping, skydiving, hanggliding, or high-risk mountain climbing, while snowboard, skateboard, low-risk mountain climbing, and skubadiving were not defined as risk sports), and these were moved to group 1. Thus, group 1 (extreme sporters) consisted of 27 participants, while group 2 (high ZKPG scorers) and group 3 (low ZKPG scorers) consisted of 15 and 18 participants, respectively. The mean Impulsivity Sensation seeking ZKPQ scores were 1.67 (S.D. = .15), 1.80 (S.D. = .09), and 1.22 (S.D. = .09) for the three groups, respectively (1 being the lower and 2 the higher end of the scale). All between-group differences in ZKPQ scores were significant ($t(30) > 2.4, p < .05$). The mean score in the high ZKPQ group was higher than in the group of extreme sporters, since the ZKPQ scores was the selection criterion for these participants, while the extreme sporters were selected on the basis of their sport activities, not their ZKPQ scores per se. Sample characteristics are presented in Table 1.

2.2. Inventory: ZKPQ

The Impulsive Sensation Seeking (ImpSS) scale from the Zuckerman–Kuhlman Personality Questionnaire (ZKPQ) was used to select participants to group 2 and 3 (Zuckerman, 2002; Zuckerman et al., 1993). The inventory

consists of 19 questions. These were translated to Norwegian by one of the authors and two research assistants, and then translated back by a native English speaker, to ensure an adequate translation. This inventory was chosen because of its good internal validity (Gomà-i-Freixanet et al., 2005), and the relatively few questions, which enhanced the possibility of getting a large number of respondents.

2.3. ERP stimuli

We used a three-stimulus visual oddball task with a total of 500 stimuli, .10 target and .10 distractor probability, based on a paradigm suggested by Comerchero and Polich (1999). Versions of this paradigm have elicited valid P3a and P3b in several previous studies from our lab (Fjell and Walhovd, 2004a, 2004b, 2005a, 2005b; Fjell et al., 2005; Walhovd et al., 2005). The standard stimuli, to which the participant is told not to respond, are blue circles with diameter of 15 cm. The targets, to which the participant is told to press a button, are blue circles with a diameter of 17.5 cm. The distractor stimuli, which the participant is told to ignore, are blue rectangles of 21 cm × 21 cm. The stimuli were presented on a 21-in. computer screen with a black background color, and the distance from the participants' eyes to the screen was about 100 cm, with a visual field of about 9° × 9°, 10° × 10°, and 12° × 12° for the standard, target, and distractor stimuli, respectively. Presentation time was .5 s. ISI was 1.5 s. An example task with 9 stimuli (including 3 targets) was presented to ascertain that all participants could discriminate targets from standards. The main difference between the task from Comerchero and Polich (1999) and the task in the present study is that the stimuli in the latter are much bigger, and the discrimination between the target and the distractor is assumed to be somewhat easier. The small difference between targets and standards and the large difference between targets and distractors were chosen to maximize the P3a component. It has been shown by Hagen et al. (2006), Comerchero and Polich (1998, 1999), and Katayama and Polich (1998) that a difficult target versus standard discrimination will increase the P3a, especially if the distractor is clearly distinct from the target.

2.4. ERP procedures

The task was administered while the participants sat in a reclining chair within an electrically shielded and sound attenuating recording chamber. The electrodes were placed in accordance with the international 10–20-system. A total of six electrodes (Ag/AgCl) were used for recording; Fz, Cz, P3, Pz, P4, and Oz, referred to the left mastoide. A VEOG channel was obtained by placing one electrode above and one below the left eye, and ground was placed anteriorly on the right side. Inter-electrode impedance was generally measured to be less than 10 kΩ. For the recording of EEG-activity, A/D rate was 1000 Hz, and filter setting was .10 Hz (high pass) and 70 Hz (low pass). In addition, a 50 Hz notch filter was applied. The signals were amplified by a SynAmp DC amplifier (Neuroscan Inc.). Epochs were rejected from averaging if amplitude exceeded ±100 μV, and eye blinks were corrected for statistically in accordance with Semlitsch et al.'s recommendations (Semlitsch et al., 1986). Averaging was performed for targets and distractors separately. EEG was segmented in epochs of 900 ms duration (−100 to 800 ms relative to stimulus onset). All data average files were digitally filtered (15 Hz low pass), linearly detrended, and baseline corrected before statistical measures of component amplitude were made. When the recording was split in two equal parts, the percentages of rejected trials were .02 and .01 for distractors in parts 1 and 2, respectively, and .01 and .02 for targets in the two parts. For one participant, the number of accepted trials was 17 and 15 for the distractor in parts one and two, respectively, and 11 and 12 for target. Inspection of the average waves for

Table 1
Sample characteristics

	Group 1: extreme sporters mean (range/S.D.)	Group 2: high ZKPQ mean (range/S.D.)	Group 3: low ZKPQ mean (range/S.D.)
<i>n</i>	27	15	18
Age	28 (22–39/4.2)	24 (20–33/4.1)	25 (20–39/5.1)
ZKPQ score	1.67 (1.32–2.0/1.15)	1.80 (1.95–1.68/0.09)	1.22 (1.0–1.32/0.09)

this participant showed clearly visible and valid P3s. Therefore, this participant was not excluded. No other participants had less than 20 accepted trials in any condition.

Neuroscan software was used to present stimuli, record, and analyze EEG-activity. P300 peaks were defined as the most positive point constituting a peak within 350 and 800 ms poststimulus. An algorithmic, automated approach was used, but all peaks were manually inspected for accuracy. A start point of 350 ms has been used in previous studies with similar paradigms (e.g. Comerchero and Polich, 1999; Bledowski et al., 2004a, 2004b), while a wide time window ensures that late peaks are identified while the risk of getting late non-P3 components is very small.

2.5. Statistics

Statistical analyses were performed at the midline electrodes Fz, Cz, and Pz, since both the P3a and the P3b generally are best pronounced at these midline scalp sites. Analyses were done for the first and the last half of the ERP trials separately (meaning that 25 targets and distractors were included among the 250 stimuli in each half), making it possible to test effects of habituation.

First, ZKPQ scores, independently of groups, were correlated with P3a and P3b amplitude in the first and the last half of the task. Next, an ANOVA with 3 electrodes (Fz, Cz, Pz) \times 2 components (P3a, P3b) \times 2 blocks of stimuli (1st, 2nd half) was conducted to validate the topography of the P3a and the P3b components. Next, ANOVAs were calculated where the first and the second 50% of the trials were contrasted pairwise across groups (2 groups \times 2 repetition blocks [amplitude in two halves of the task] \times 3 electrodes, for group 1 versus 2, 1 versus 3, and 2 versus 3, for P3 to distractor and P3 to target separately). Significant interaction effects between groups and repetition blocks for P3a would confirm our main hypothesis that sensation seekers habituate differently to novel stimuli than other participants. This could have been tested with an ANOVA including all three groups. However, in a situation where only one group is different from the two others, as we hypothesized, such an approach may mask true effects. Thus, we chose to test this hypothesis by pairwise group comparisons. Greenhouse–Geisser corrections of degrees of freedom (d.f.) were used when appropriate.

3. Results

Grand average ERP curves are presented in Fig. 1, showing that clearly identifiable P3a and P3b components are elicited in all groups for all electrodes, peaking between 400 and 500 ms. Mean peak latency across all groups in the first half of the task was 403 and 416 ms for P3a at Cz and Pz, respectively, and 466 and 438 ms for P3b.

ZKPQ scores and amplitude correlated significantly at Cz ($r = -.30, p < .05$) and Pz ($r = -.29, p < .05$) for P3a in the second half, while no relationships were found for P3b or for P3a in the first half. An ANOVA with 3 electrodes (Fz, Cz, Pz) \times 2 components (P3a, P3b) \times 2 blocks of stimuli (1st, 2nd half) was conducted to validate the topography of the P3a and the P3b components. A significant interaction effect of electrode \times component ($F[1.254, 81.529] = 107.78, p < .0001$) showed that the topography of the two components differed. Post hoc *t*-tests revealed that in block 1, P3a amplitude at Cz (19.41 μ V, S.D. 6.12 μ V) was significantly larger than Fz amplitude (13.80 μ V, S.D. 6.90 μ V, $t = 8.93, p < .0001$) and Pz amplitude (15.47 μ V, S.D. 5.89 μ V, $t = 6.99, p < .0001$), while Fz and Pz amplitude was not significantly different ($t = 1.66, n.s.$). In block 2, Cz amplitude (18.39 μ V, S.D. 7.00 μ V) was again significantly larger than Fz (13.26 μ V, S.D. 6.62 μ V, $t = 8.49, p < .001$) and Pz (15.60 μ V, S.D. 6.13 μ V, $t = 5.41, p < .0001$) amplitude, while Pz was larger than Fz ($t = 2.78, p < .01$). For P3b in block 1, Fz amplitude (7.58 μ V, S.D. 3.79 μ V) was lower than both Cz (10.27 μ V, S.D. 4.41 μ V, $t = 5.46, p < .0001$) and Pz (10.86 μ V, S.D. 4.35 μ V, $t = 5.19, p < .0001$), while Pz and Cz did not differ significantly ($t = 1.60, n.s.$). In block 2, the same basic results were found, in that Fz

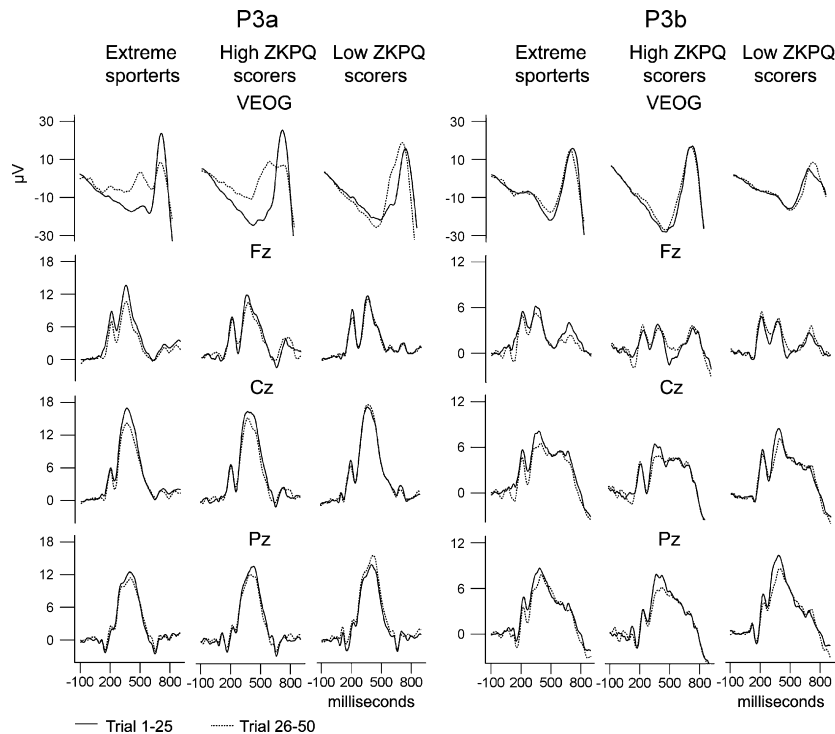


Fig. 1. Grand average curves for Fz, Cz, and Pz for each of the trial three groups. Solid lines represent average of the first 25 repetitions of distractors or targets, while the dotted lines represent repetition 26–50.

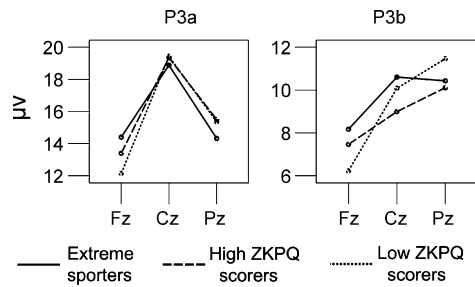


Fig. 2. Mean amplitude for Fz, Cz, and Pz separately, for each of the three groups, for the first 25 trials for distractor and target. As expected, P3a amplitude peaked at Cz for all groups, while P3b showed a more posterior distribution, with higher amplitudes at Pz. This indicates that valid components are elicited. Mean P3b amplitude for extreme sporters were marginally higher at Cz than Pz, but there was no group \times electrode interaction for either P3a or P3b, indicating that topographic distribution of activity did not vary systematically with group.

amplitude ($6.93 \mu\text{V}$, S.D. $3.79 \mu\text{V}$) was smaller than both Cz ($9.57 \mu\text{V}$, S.D. $4.13 \mu\text{V}$, $t = 6.07$, $p < .0001$) and Pz ($9.82 \mu\text{V}$, S.D. $4.60 \mu\text{V}$, $t = 4.74$, $p < .0001$) amplitude, while Cz and Pz did not differ significantly ($t = .73$, n.s.). This distribution of activity indicates that valid P3a and P3b components were obtained. Mean amplitude for each group across Fz, Cz, and Pz, for P3a and P3b, are shown in Fig. 2.

Next, ANOVAs were calculated where the first and the second 50% of the trials were contrasted for two and two groups, in the form of 2 groups \times 2 repetition blocks (amplitude in two halves of the task) \times 3 electrodes (Fz, Cz, Pz), repeated for P3a and P3b. For P3a, it was found that the extreme sporters had an amplitude decrease from the first to the second half of the trials relative to the low ZKPQ scorers ($F[1, 43] = 4.66$, partial $\eta^2 = .10$, $p < .05$). Significant habituation differences were not found between the extreme scorers and the high ZKPQ scorers, or between the high ZKPQ scorers and the low ZKPQ scorers. No interaction effects of group \times repetition block were found for P3b. Finally, no main effects of group were found, indicating that differences in mean amplitude did not exist between the groups. Post hoc ANOVAs with 3 electrodes \times repetition blocks within each group revealed significant habituation of P3a in group 1 ($F[1, 26] = 7.41$, $p < .05$), but not in the two other groups and not for P3b (Fig. 3).

4. Discussion

4.1. P3a habituation

Our first hypothesis was that participants engaged in extreme sports would habituate more to the attention-grabbing but task-irrelevant distractor stimuli than the low ZKPQ scorers. Statistical group comparisons confirmed this hypothesis, in that the P3a amplitude declined significantly more in the group of extreme sporters than in the group of low ZKPQ scorers. In fact, the amplitude of the low ZKPQ scorers did not decline across 50 trials, there was rather some increase in mean amplitude in

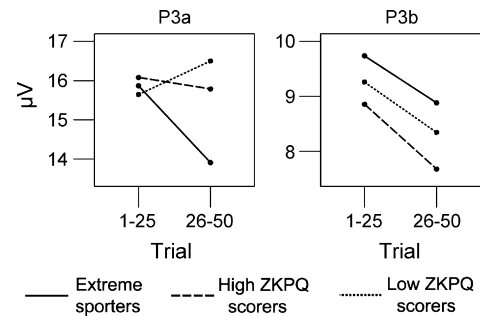


Fig. 3. Mean amplitude across midline electrodes Fz, Cz, and Pz, as a function of repetition block. As can be seen, the extreme sporters show a marked decline in P3a amplitude from the first to the second half of the task, while this pattern does not exist for the other two groups: The low ZKPQ scorers do not show habituation but a slight continued amplitude increase, the high ZKPQ scorers habituated somewhat, while the extreme sporters habituated much. ANOVA showed that the extreme sporters and the low ZKPQ scorers significantly differed in rate of habituation ($p < .05$). For P3b, no group \times repetition block effect was found.

this group, whereas a rather steep amplitude decrease was seen for the extreme sporters across the same number of trials. Thus, it seems that the automatically generated orienting response indexed by P3a habituates sooner in extreme sporters than in other participants. This finding fits with these participants' desire for novel, extreme, and potentially life-threatening sport activities.

No significant group differences in the magnitude of the P3 amplitude were found across the task. The finding that there are no baseline differences in stimulus processing, only in habituation over a number of stimulus repetitions, may explain inconsistent findings in previous literature where P300 and sensation seeking has been correlated. Pierson et al. (1999) found higher frontal amplitudes in skydivers than in controls, and interpreted this as an increase of automatic processes in skydivers. This result is not in coherence with the present findings of equal amplitudes in the first 50% of the trials. Rather, the present findings suggest that the basic neurophysiological difference between sensation seekers and others is more related to how repeated stimulation alters the brain's fast and automatic responses, than to novelty detection and processing per se. The parallel to this is tapped in question number 6 in ZKPQ: "I'll try anything once". It has been suggested in previous literature that chronic under-arousal (Eysenck and Eysenck, 1978) or anhedonia due to a basal arousal deficit (Carton et al., 1992, 1995) constitute the foundation for the sensation seeking trait. Within this framework of thinking, the present results indicate that at a basic, neurophysiological level sensation seekers react to attention-grabbing stimulation in ways comparable to others, but that the novelty or attention-grabbing effect sooner is diminished. Methodological differences between the present study and Pierson et al.'s study exist, however, notably that Pierson et al. used a two-stimulus task, yielding a P3b, while a three-stimulus task was used in the present study, yielding both a P3a and a P3b. As shown by among others Comerchero and Polich (1998), the P3a and the P3b in a three-stimulus task will depend on the ease of the perceptual discrimination of all the stimuli.

Thus, the P3b from a two and a three stimuli task is probably not directly comparable. Further, the standard-target discrimination in the Pierson et al.'s study was probably easier than in the present study. In addition, both males and females were included in the sample, and the P3 amplitude was measured as the difference between the P3 and the N2 peaks, while only males were included in the present study and P3a and P3b was both measured relative to baseline. Finally, the effect in the Pierson et al.'s study seems to be mainly attributable to differences in activation to standards, thus their effect may not be related to the P3 to target at all. Thus, several methodological issues may contribute to explain the differing results between the two studies.

The present results fit nicely with the ones of LaRowe et al. (2006), recently published in *Biological Psychology*. With different methods (acoustic startle response versus the electrophysiological component P3a) and different samples (students with different sensation seeking scores versus groups of student with different scores and extreme sporters), the present study and LaRowe et al.'s both find habituation to be related to sensation seeking. This adds to the generality of the results, and indicates that increased habituation in the central nervous system in sensation seekers may be a general neurophysiological mechanism. The eyeblink component of the acoustic startle response is mediated at least partly by brainstem reticular structures (Davis et al., 1999). In contrast, the P3a component is supported by a widespread network of cortical neural generators (Fjell et al., in press; Linden, 2005; Polich, 2003). Thus, even though the evidence still is preliminary, these two studies may indicate that neurophysiological habituation occurs at different levels in the central nervous system in sensation seekers.

4.2. P3a versus P3b

Our second hypothesis regarded the relationship between P3a and P3b habituation. P3b is related to more controlled cognitive processing than P3a, and we expected no differences in such cognitive processing between the different groups. Thus, we hypothesized that the rate of P3b habituation would not differ between the groups. This hypothesis was supported by the statistical analyses. An implication is that habituation is not a general aspect of the electrophysiological responses in extreme sporters and sensation seekers, but seems to be more specifically related to automatic, startle or orienting related processing. Thus, in terms of electrophysiology, sensation seekers seem to differ from others in basic, automatic processes, not in controlled cognitive activity. Both P3a and P3b is related to processing in large parts of the brain, but P3a is generally found to be more supported by neural circuits involving frontal or prefrontal cortices. Thus, difference between extreme sporters or sensation seekers and others may be related to frontal neural circuits or transmitter systems.

Ditraglia and Polich (1991) observed habituation for the P3 to target in a two-tone auditory discrimination task for extroverts but not introverts. The two-stimulus task will elicit a P3b, which was not found to habituate in the present study.

This discrepancy is probably linked to the above-mentioned point that the P3b in two- and three-stimuli tasks are not directly comparable. The “novelty”-aspect of the target in the two-stimulus task is probably larger than in the three-stimulus task. In addition, the perceptual difference between the standard and the target in the present study was small and not very attention-grabbing, yielding a smaller P3b. However, the finding of Ditraglia and Polich indicates that the relationship between habituation and personality trait may not be specific to sensation seeking, but rather related to a more general difference in cortical reactivity. This warrants further investigation of the relationship between habituation and personality dimensions.

4.3. Extreme sporters versus high ZKPQ scorers

The last focus of the study was to see if results obtained with “real-life” sensation seekers, extreme sporters in this case, could be replicated with participants who scored high on ZKPQ, but were not extreme sporters. Participants in the last group may be termed sensation seekers, but are not necessarily characterized by a wish for activities involving high arousal. For instance, several of the Impulsivity Sensation Seeking questions regard preference for unpredictability (e.g. “I prefer friends who are excitingly unpredictable.”), other regard impulsivity versus planning ahead (e.g. “I would like to take off on a trip with no preplanned or definite routes or timetables.”), neither of which necessarily need to include extreme arousal. Actually, none of the 19 questions targets a preference for extreme arousal directly. Thus, when we moved the high scorers that were also engaged in extreme sports to the group of extreme sporters, we ended up with a group of participants engaging in extreme sports, who also had high scores on ZKPQ, and a group of participants with significantly higher ZKPQ scores that did not engage in such activities. We predicted that the participants preferring extreme arousal and the participants who e.g. did not want to go on holiday to the same place twice, would show differences in cortical reactivity to repeated stimulation. The results showed that the extreme scorers did not habituate significantly more than the low scorers, while the extreme sporters did. This was not surprising, but indicates that the physiological foundation for extreme sports and high ZKPQ scores alone may be different. Thus, persons scoring high on ZKPQ, which is mainly focused on daily life activities and preferences, do not have the same cortical reactivity and habituation that seem to exist for true arousal-seeking persons, i.e. extreme sporters.

5. Conclusion

Three conclusions can be drawn from the present study: Extreme sporters showed significantly higher rates of P3 habituation than low ZKPQ scorers, who actually showed no habituation across 50 trials. Since habituation of P3a is often seen (Friedman and Simpson, 1994), it may be the case that the low ZKPQ participants are more different from the norm than the extreme sporters. The habituation difference was specific to

P3a, and was not found in participants with high ZKPQ scores not engaging in extreme sports. Implications of these findings is that habituation may be more relevant to the sensation seeking trait than baseline amplitude, and that even though participants who voluntarily seek situations with extreme arousal obtain high scores on ZKPQ, significant habituation differences is not found between extreme high and extreme low ZKPQ scorers. Further, sensation seekers seem to differ from other participants in terms of automatic, alerting-related electrophysiological processes, not ERPs related to controlled cognition. Future research should investigate whether the same results can be obtained with use of a novelty-P3 paradigm instead of a 3-stimuli paradigm used in the present study. Even though the P3a and the novelty-P3 are assumed to reflect basically the same processes, a novelty paradigm may be less prone to habituation since the distractor stimuli are varied. If the results from the present study can be replicated with use of a novelty-paradigm, this would imply that sensation seekers habituate to a task per se, and not only the actual stimuli used.

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