Neuroticism and Attention Towards Sexual and Non-Sexual Images During an Oddball Task: Evidence from Event-Related Potentials

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COMPLIANCE WITH ETHICAL STANDARDS

Detailed written informed consent was obtained from all participants prior to enrolment, and all aspects of the study were performed in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study received ethical approval from the Ethics Committee of the University of Porto, Portugal.

DECLARATIONS

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Conflicts of interest/Competing interests

The authors declare that they have no conflict of interest.

ABSTRACT

While previous research has argued that neuroticism is a vulnerability factor for the experience of sexual difficulties, the basic cognitive processes associated with the impact of such a personality trait on the processing of sexually explicit stimuli are less understood. The current study examined the influence of neuroticism on the attentional processes and its neurophysiological correlates during the perception of sexual and non-sexual images. Event-related potentials from 30 women and 28 men were recorded during a modified oddball paradigm in which participants of both sexes visualized stimuli from three different categories (sexual, non-sexual positive, and non-sexual negative), and two arousal levels (high and low arousal). A P1 latency effect was found for female participants, in which high neuroticism was associated with longer latencies for pornographic compared to romantic sexual images. Higher levels of neuroticism were also associated with higher P3 amplitudes for highly arousing images, with both sexual and non-sexual content. Results were interpreted in light of the information processing model of sexual arousal and showed that neuroticism seems to impact both automatic and conscious pathways of processing of sexual stimuli.

Keywords: Neuroticism; Information processing; Sexual response; Affective stimuli; ERP; P1; P3.

INTRODUCTION

The importance of personality variables in emotional disorders has been widely investigated in the literature (De Fruyt et al., 2017). Regarding sexual health, personality factors have been proposed to be associated with the individuals' sexual well-being and to possibly contribute to the development of sexual dysfunctions (Brotto et al., 2016). Neuroticism, in particular, being characterized by the presence of negative affect and emotional instability (Costa & MacCrae, 1992), is considered a vulnerability factor for the experience of sexual difficulties in both men and women (Crisp et al., 2015; Fagan et al., 1991; Kennedy et al., 1999; Quinta Gomes & Nobre, 2011). Indeed, sexual dysfunctions are assumed to be accounted for by the internalizing spectrum of psychopathology, sharing the same underlying factors as other emotional disorders, including neuroticism-like features (Forbes et al., 2017). One of the current cognitive-emotional models of sexual dysfunction (Nobre, 2013, 2017) emphasizes neuroticism, along with low positive trait-affect and high negative trait-affect, as main risk factors for the development of sexual problems. Neuroticism has been linked to how negative schemas are activated in women in response to unsuccessful sexual situations (Peixoto & Nobre, 2017), but also to low female orgasmic frequency (Harris et al., 2008). Likewise, neuroticism has been related to sexual performance anxiety and erectile dysfunction in men (Rosenheim & Neumann, 1981).

Despite the strong theoretical conceptualization regarding the influence of personality traits on sexual functioning, and the vast evidence of neuroticism as a vulnerability trait for the development of sexual disorders, the literature on the basic cognitive factors explaining such effects is absent. Our understanding of the mechanisms behind the relationship between neuroticism and sexual response may benefit from findings of studies exploring the effects of neuroticism on attention and emotional processing. Past studies have suggested that neuroticism is associated with higher reactivity to stressors and higher susceptibility to negative cues in the environment (Eysenck, 2000; Norris et al., 2007; Reynaud et al., 2012). Elevated levels of neuroticism were further associated with general attention deficits (Wallace & Newman, 1998) and disrupted attention control (Bredemeier et al., 2011; Siyaguna et al., 2019). Hence, it is possible that neuroticism affects sexual functioning by influencing attentional mechanisms towards emotional stimuli in sexual contexts.

Acknowledging the role of attention on sexual response, Janssen, Everaerd, Spiering and Janssen (2000) proposed an information processing model (IPM) of sexual arousal, which emphasizes the interaction between automatic (unconscious) and controlled (conscious) cognitive-affective processes. The automatic processes proposed in this model include an appraisal stage, where encoding processes and matching with implicit memories take place, and a response generation stage, where autonomic events prime genital responding. This model assumes the co-occurrence of controlled processes that orient attention toward the sexual meanings, facilitating or impeding the subjective experience of sexual arousal. Multiple meanings can be associated with sexual stimuli, both sexual and nonsexual, positive or negative, wherein, in the case of sexual dysfunction, the responses generated are predominantly nonsexual and essentially worry-related. The sexual meanings attributed to the stimuli, when integrating with the response and motor plans, will determine subjective arousal and genital response. Hence, this model foresees that dysfunctional sexual experiences may arise after dysfunctional allocation of attentional resources, namely when threat- or worry-related meanings, which are associated with the sexual stimulus, prevent the attentional focus on the erotic cues and positive feelings. Examining the time course of attentional processing through ERPs could allow us to confirm if the latter pattern of distraction predicted by the IPM explains differences in the processing of sexual stimuli between individuals with high compared to low neuroticism.

Attention allocation towards sexual stimuli has been investigated by looking at the modulation of event-related potentials (ERP) in response to visual stimulation (for a review, see Ziogas et al., 2020). Earlier studies have found ERP amplitudes for pictures with erotic content to be differentiated from pictures displaying other human interactions (e.g., Anokhin et al., 2006; Krug et al., 2000). Subsequent studies have compared ERPs elicited by erotic versus other types of emotional images using stimuli selected from the International Affective Picture System (IAPS) (Lang et al., 1999). The IAPS comprises a large number of pictures, which can be grouped into categories, considering different levels of arousal, valence, and motivational relevance. In studies that use these images, erotic couple images are usually included in the high arousing category, jointly with images of sports/adventures, while pictures of romantic couples are allocated to the low arousing category, along with images of animals and babies. Erotic images are also considered to be motivationally relevant stimuli, similar to human mutilation images, since both convey information that is of relevance for survival.

Notably, enhanced neural responses for erotic pictures, when compared to other affective stimuli with similar levels of arousal and motivational relevance, have been repeatedly reported (e.g., Schupp et al., 2004a, b, 2006). When compared to highly arousing pleasant pictures (high-energy sports), van Lankveld and Smulders (2008) found erotic stimuli to elicit higher positivities 300 ms after stimulus onset. Nonetheless, some studies found erotic images to be as attention-grabbing as highly arousing unpleasant pictures (e.g., Schupp et al., 2003). Briggs and Martin (2009) used a modified oddball paradigm to test EEG responses to different types of visual stimuli, differing on valence, arousal, and motivational relevance. Briggs and Martin focused their analysis on P3b amplitude modulations and found that sexual stimuli, compared to all other stimuli, including highly arousing and motivationally relevant unpleasant pictures (e.g., mutilation images), elicited significantly larger amplitudes. By acknowledging the distinct influence of sexual arousal on cognitive processing, Briggs and Martin propose that “sexual arousal may exert an independent effect on cognitive processes such as the allocation of attentional resources” (p. 305). However, because the cognitive processing of sexual stimuli was not the goal of their study, a hypothesis regarding this category of stimuli was left unexplored.

In the present study, we aimed to investigate whether individuals with high and low levels of neuroticism show differentiated ERPs in response to sexual and non-sexual stimuli in a modified visual oddball task, similar to the one used in Briggs and Martin’s (2009) work. In a typical oddball paradigm, participants are presented with two types of stimuli of unequal probability (the standards and the deviants). The standard stimuli are repeatedly presented to the participant, while the deviant stimuli are presented more infrequently. Participants are asked to respond exclusively to the deviant stimuli. The low probability of the targets (deviants) is expected to grab the participants’ attention. However, this process is affected by the specificity of the emotional response elicited by each stimulus: the intensity of attention grabbing evoked by deviant targets is expected to depend on the neural processing relevance of the visual content presented in such stimuli.

Most of the studies using oddball paradigms focus on the analyses of the N2–P3 complex or solely on the P3 component. The N2 is an anterior negativity occurring around 200 ms, while the P3 consists of a later positivity over centro-parietal electrodes. Amplitudes of both components were shown to increase as the frequency of occurrence of the deviant stimuli decreases (Duncan-Johnson & Donchin, 1977; Squires et al., 1976). Additionally, the P3 has been proven to be particularly sensitive to stimulus meaning and significance (Ferrari et al., 2010). Furthermore, the N2 is expected to represent automatic attention, whereas the P3 is thought to relate to strategic, more elaborate, stimulus processing (Sass et al., 2014). Besides these two components, research on the neural correlates of affective stimuli processing has analyzed both P1 and P2 responses (e.g., Bailey et al., 2012; Rozenkrants et al., 2008). The P1 is an early visual ERP component that peaks around 100 ms at occipital electrodes and is considered to reflect the processing of low-level stimulus features while also being involved in early stages of attentional gain control (Hillyard et al., 1998). In a previous oddball study, unpleasant pictures were reported to evoke smaller P100 amplitudes than neutral pictures, while pleasant pictures were associated with smaller latencies than neutral ones (Mardaga & Hansenne, 2009). Other investigations have shown that the P1 is affected by the stimuli's emotional valence and salience (Olofsson et al., 2008). Likewise, the P2 is sensitive to selective attention, reacting differently to emotionally distinct stimuli (Carretié et al., 2001; Kanske et al., 2011). The P2, occurring around 200 ms after stimulus onset at parieto-occipital sites, has been reported to be enhanced in response to erotic pictures compared to other pictures (Feng et al., 2012).

We aimed to analyze the components mentioned above (P1, P2, N2, and P3) to investigate the influence of neuroticism on the processing of sexual and non-sexual images. As neuroticism has been proposed to be associated with disrupted attention control, mainly towards highly arousing images (Siyaguna et al., 2019), we expected that the mentioned neural correlates will reflect differences between participants with high and low neuroticism in the way they attend to stimuli with and without sexual content. Considering Janssen et al.'s (2000) model, if differences in processing occur during the appraisal or response generation stages, which are automatic and unconscious, we expect to find variations mainly in the early components (P1, P2 or N2) that represent automatic stimulus processing. However, if what characterizes the atypical sexual experiences of people with high neuroticism is due to more elaborative attentional and cognitive-control mechanisms, then we expect to find differences in P3, which is considered an index of later, more elaborative stimulus processing (Sass et al., 2014). Lastly, we did not expect to find gender differences in the ERPs, especially in the early components, since studies have found men and women do not differ in the first stages of cognitive processing of visual sexual stimuli (Carvalho et al., 2018; Rupp & Wallen, 2008).

METHOD

Participants

In order to recruit participants with high and low levels of neuroticism, an initial large pool of 1320 volunteers were asked to respond to the Neuroticism scale of the NEO-PI-R questionnaire. Responses from 1251 participants were considered valid based on the following inclusion criteria: being native European Portuguese; reporting an absence of sexual dysfunction (measured by self-report, considering DSM-5 indicators), reporting an absence of medication that could affect the results (i.e., anxiolytics or antidepressants) or psychiatric/neurological disorders; and having a normal or corrected-to-normal vision.

Eighty participants were then selected on the basis of their neuroticism score. In the low neuroticism group, participants' scores ranged from 31 to 59 (percentile 10), and in the high neuroticism group, participants' scores ranged from 114 to 171 (percentile 80). All participants received a reward in the value of 10 € for their participation. Sixteen participants were excluded due to poor quality EEG signal or a high number of artifacts. Another four participants were excluded for being left-handed[1] and two others were excluded for reporting a non-heterosexual orientation, on Kinsey's Likert scale, posteriorly to the online questionnaire. Data from 58 heterosexual and right-handed participants, 30 scoring low (15 women and 15 men; M_{age} = 23.83 years, *SD* = 5.34) and 28 scoring high (15 women and 13 men; M_{age} = 22.25 years, *SD* = 4.19) on the neuroticism scale, were considered for ERP

[1] Left-handers were excluded in order to reduce variance in the data due to possible interhemispheric amplitude asymmetries.

analyses. An independent samples *t*-test confirmed that the difference of neuroticism score between the two groups was statistically significant, $t(38.40) = -23.90$, $p < .001$, $d = 6.50$.

Materials

The Neuroticism scale of the Portuguese version of the NEO–Personality Inventory-Revised (NEO PI-R) (Costa & McCrae, 2000) was used to assess neuroticism. The instrument consists of 240 items, assessing five personality traits (domains): neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness, and 30 facets (six facets for each domain). Each domain comprises 48 items. Items were rated on a 5-point Likert scale, ranging from 0 (strongly disagree) to 4 (strongly agree). The neuroticism trait is associated with anxiety, depression, vulnerability to mood disorders, poor emotional regulation, and difficulties in inhibiting distracting information. The Portuguese version of the neuroticism scale (Lima & Simões, 2000) has a Cronbach's alpha of .85, which points to a good internal consistency. In the present sample, Cronbach's alpha was 0.83. Regarding convergent and discriminant validity, the neuroticism trait from the NEO PI-R correlates significantly ($r = 0.75$, $p < .001$) with the neuroticism trait from the Eysenck Personality Questionnaire (Costa & McCrae, 2000). E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) was used for stimuli presentation and recording of behavioral responses.

Stimuli

The images presented belonged to one of three different categories (sexual, non-sexual positive, and non-sexual negative). Within each category, there were two arousal levels (high and low arousal). Thus, stimuli consisted of 15 sexual and highly arousing images (pornographic), 15 sexual and low arousing images (romantic), 15 non-sexual positive and highly arousing images (e.g., sports/adventure), 15 non-sexual positive and low arousing images (e.g., smiling faces); 15 non-sexual negative and highly arousing images (e.g., mutilations), and 15 non-sexual negative and low arousing images (e.g., poverty, people crying) (please see table 1). Sexual images were selected from the EROSimag/UPUA.pt database of sex pictures[2], which have been previously validated for the Portuguese population (Carvalho et al., 2014). The non-sexual images were selected from the International Affective Picture System (IAPS) (Lang et al., 2008)[3]. The option of not using sexual stimuli from IAPS was deliberate, given that sexual pictures from this database have been considered as outdated both in terms of style and image quality (e.g., Doornwaard et al., 2014). Just as in Briggs and Martin's work (2009), the red and white checkerboard from IAPS (image number 7182) was presented as the standard stimulus.

Procedure

Written consent was obtained from all participants. Recruited volunteers were asked to answer the NEO PI-R Neuroticism scale and a sociodemographic questionnaire, which included questions about sexual functioning and sexual orientation. Based on the answers provided, the selected participants were invited to come to the lab, where they were seated in a dimly lit and sound-attenuated room, at a distance of 80 cm from the computer screen. For the oddball task, the instructions stated that participants should press the <B> key as quickly as possible when presented with any picture other than the standard red and white checkerboard. The experiment consisted of three experimental blocks with 300 trials each, presented in random order. Each block included 210 standard trials (red and white checkerboard) and 90 deviant trials (15 images of each type, as described above). Each trial started with a fixation cross (500 ms) followed by an image (300 ms) and a blank screen with

[2] EROSimag/UPUA.pt stimuli: Sexual and highly arousing (71, 93, 127, 133, 139, 145, 155, 157, 160, 161, 163, 166, 169, 173, 175, 179); Sexual and low arousing (1, 3, 4, 5, 6, 11, 14, 29, 32, 33, 34, 35, 38, 39, 43, 57).

[3] IAPS stimuli: Non-sexual positive and highly arousing (5621, 5629, 8030, 8034, 8080, 8178, 8180, 8185, 8186, 8190, 8200, 8300, 8370, 8400, 8490); Non-sexual positive and low arousing (2222, 2299, 2304, 2310, 2339, 2341, 2358, 2387, 2388, 2395, 2510, 2540, 2598, 7325, 8330); Non-sexual negative and highly arousing (3010, 3053, 3060, 3069, 3130, 3170, 3500, 3550, 6250, 6313, 6550, 6560, 9250, 9410, 9635.1); Non-sexual negative and low arousing (2312, 2399, 2455, 2490, 2590, 2718, 2722, 2750, 2753, 6010, 9046, 9190, 9220, 9330, 9331).

a variable duration between 750 and 1200 ms (see Fig. 1). To avoid fatigue, participants were allowed to take breaks of unfixed duration between blocks.

EEG Recordings

EEG activity was recorded using a SynAmps2 system and Scan 4.3 software (all from Neuroscan) and an Easy-Cap with 40 Ag/AgCl sintered electrodes located according to the 10-20 International System. Vertical and horizontal electrooculogram were recorded above and below the left eye and from the outer canthi of both eyes, respectively. The reference electrode was positioned on the tip of the nose. For all electrodes, impedance was kept under 5 kΩ, and EEG was sampled with a digitization frequency of 1000 Hz. A notch filter for 50 Hz was applied online.

ERP Analyses

Neuroscan software (Scan 4.4) was used for EEG data offline analyses. The EEG signal was band-pass filtered from 0.1 to 30 Hz, segmented in epochs of 1050 ms (150 ms pre-stimuli to 900 ms post-stimuli) and automatically corrected for ocular movements (Semlitsch et al., 1986). Exclusively for two of the participants, one of the EEG channels containing high-frequency and high-amplitude noise was disregarded and reconstructed using a spherical spline interpolation (Frühholz et al., 2011; Hahn et al., 2016; Leppänen et al., 2007). Baseline correction was performed by subtracting the average pre-stimulus amplitude value. EEG waveforms were averaged separately for all conditions (Lehmann & Skrandies, 1986): pornographic, romantic, non-sexual positive high arousal, non-sexual positive low arousal, non-sexual negative high arousal, and non-sexual negative low arousal. Following common procedures in ERP analysis, after visual inspection of the grand average waveforms and their topographic characteristics, each of the relevant components was analyzed in the following electrodes and time windows for all participants: P1 (90–140 ms; electrodes O1, Oz and O2); P2 (180–260 ms; electrodes P3, P4, O1, and O2); N2 (200–300 ms; electrodes

FCz and Cz); P300 (300–500 ms; electrodes CPz and Pz). Taking into account the components' morphology, peak amplitude and latency were considered for early components (P1, P2, and N2), while mean amplitudes in the specified time window were computed for the P3 component (Handy, 2005).

RESULTS

Behavioral and ERP analyses were conducted using SPSS software, applying the Greenhouse-Geisser correction for sphericity violations and reporting corrected degrees of freedom when needed. When testing the significance of differences between individual means, a Bonferroni correction for pairwise comparisons was applied.

Behavioral Data

Response accuracy

Prior to the analysis, all variables were examined for normality of distributions using Shapiro–Wilk tests. Given that, for the percentage of correct responses, most distributions failed the normality tests, we opted to use non-parametric tests in all conditions, applying Bonferroni corrected alphas when performing more than two tests simultaneously. In order to analyze the effect of stimulus category, the overall mean percentage of correct responses for non-sexual positive images, non-sexual negative images, and sexual images were considered. Wilcoxon signed ranks tests revealed that none of the comparisons reached statistical significance (all $p_s > .704$). To explore the possible effect of arousal, we also calculated the overall mean percentage of correct responses for high arousal images and low arousal images. Wilcoxon signed ranks tests revealed that this comparison was also statistically non-significant ($p = .784$). To analyze between-subjects effects of neuroticism and gender of participant, we performed Mann-Whitney tests, for the three stimuli categories and also for the two arousal levels. No significant differences were found based on neuroticism group or participant gender (all $p_s > .068$).

Response time

Again, because some distributions were not normal, non-parametric tests were considered to examine differences in the response times to identify deviant images on the oddball task. Regarding comparisons of stimuli categories, Wilcoxon signed ranks tests revealed that participants responded overall faster to sexual images compared to non-sexual negative images, $Z = -3.12$, $p = .002$, which in turn were associated with faster responses compared to non-sexual positive images, $Z = -2.69$, $p = .007$. Differences between sexual and non-sexual positive images were also significant, $Z = -4.64$, $p < .001$. Overall, participants did not respond differently based on the arousal level of stimuli ($p = .77$). Mann-Whitney tests showed that response times did not differ based on participants' neuroticism level (all $p_s > .148$). Regarding the comparisons between male and female participants, men showed faster responses than women toward non-sexual positive images, $U = 264.00$, $Z = -2.43$, $p = .015$, and towards non-sexual negative images, $U = 263.00$, $Z = -2.44$, $p = .015$. Likewise, compared to female participants, men responded faster when presented with both low arousing, $U = 273.00$, $Z = -2.29$, $p = .022$, and high arousing images, $U = 270.00$, $Z = -2.33$, $p = .020$.

ERP Data

To analyze the ERP data, mixed-design ANOVAs (between-subjects factors: gender of participant and neuroticism group; within-subjects factors: stimulus category, stimulus arousal, and electrode) were performed. Peak amplitude was analyzed for P1, P2, and N2 components, and mean amplitude was considered for the P3 wave. For the sake of simplicity, and acknowledging the extensiveness of ERP analyses, only significant effects will be reported. Also, following (2009) Briggs and Martin's suggestion, because significant main effects or interactions involving electrode sites were not theoretically relevant, those results were not reported, although results from the analyses are available in Table 1 from the supplementary materials. Figures 2 and 3 represent the topographic scalp maps for participants with high and low neuroticism at electrodes O1, P3, Cz, and CPz, when presented with sexual (Fig. 2) and non-sexual images (Fig. 3).

P1 (90–140 ms; electrodes O1, Oz, and O2)

Peak amplitude. Regarding P1 peak amplitude, we found a significant interaction between stimulus category and arousal, $F(1.69, 91.00) = 23.12$, $p < .001$, $\eta_p^2 = 0.300$. For non-sexual positive images, higher P1 peak amplitudes were associated with low arousal (*M* = 4.13 μV, *SE* = 0.61) compared to high arousal images (*M* = 2.31 μV, *SE* = 0.54), while for sexual images, higher P1 amplitudes were observed for high arousal pictures (*M* = 4.53 μV, *SE* = 0.65), with low arousal pictures exhibiting lower amplitudes (*M* = 2.43 μV, *SE* = 0.54).

Peak latency. Regarding P1 peak latency, there was a significant interaction between gender of participant, neuroticism, category, and arousal, $F(2, 108) = 5.06$, $p = .008$, $\eta_p^2 = 0.086$, wherein women with high neuroticism registered longer latencies for pornographic (*M* = 119.93 ms, *SE* = 2.36) compared to romantic sexual images (*M* = 114.47 ms, *SE* = 3.12) (see Fig. 4). We also observed a significant main effect of neuroticism group, $F(1, 54) = 5.68$, $p = .021$, $\eta_p^2 = 0.095$, wherein participants with high neuroticism (*M* = 114.68 ms, *SE* = 1.85) exhibited significantly longer latencies than the group with low neuroticism (*M* = 108.56 ms, *SE* = 1.78).

A significant effect of category, $F(2, 108) = 5.67$, $p = .005$, $\eta_p^2 = 0.095$, indicated longer latencies for sexual (*M* = 113.03 ms, *SE* = 1.27) compared to non-sexual negative images (*M* = 110.53 ms, *SE* = 1.35).

P2 (180–260 ms; electrodes P3, P4, O1, and O2)

Peak amplitude. For P2 amplitudes, we observed a significant interaction between category and arousal, $F(2, 108) = 60.86$, $p < .001$, $\eta_p^2 = 0.530$. While high arousal images registered lower amplitudes than low arousal for sexual ($M_{high\text{-}arousal} = -.40$ µV, $SE = 0.80$; $M_{low\text{-}arousal} = 4.76$ µV, $SE = 0.66$) and non-sexual negative images ($M_{high\text{-}arousal} = 4.97$ µV, $SE = 0.61$; $M_{low\text{-}arousal} = 6.45$ µV, $SE = 0.68$), the reverse pattern (high arousal > low arousal) was found for non-sexual positive images ($M_{high\text{-}arousal} = 6.84$ µV, $SE = 0.63$; $M_{low\text{-}arousal} = 5.80$ µV, $SE = 0.61$).

Peak amplitudes also differed significantly between image categories, $F(2, 108) = 89.91$, $p < .001$, $\eta_p^2 = 0.625$. Sexual images ($M = 2.18$ µV, $SE = 0.70$) registered inferior amplitudes compared to non-sexual positive ($M = 6.32$ µV, $SE = 0.59$) and negative images ($M = 5.71$ µV, $SE = 0.61$). Statistically significant differences were also revealed for different arousal levels, $F(1, 54) = 51.98$, $p < .001$, $\eta_p^2 = 0.490$, with highly arousing images ($M = 3.80$ µV, $SE = 0.63$) exhibiting lower amplitudes compared to low arousal ones ($M = 5.67$ µV, $SE = 0.61$). Moreover, we observed a significant effect of gender of participant, $F(1, 54) = 6.07$, p = .017, $\eta_p^2 = 0.101$, where female participants ($M = 6.23$ µV, $SE = 0.84$) showed higher peak amplitudes compared to male participants ($M = 3.25$ µV, $SE = 0.87$).

Peak latency. Regarding the latency of the P2 component, a significant effect of arousal was observed, $F(1, 54) = 8.06$, $p = .006$, $\eta_p^2 = 0.130$, in which longer latencies were recorded for low arousing ($M = 233.65$ ms, $SE = 2.47$) compared to high arousing ($M = 228.23$ ms, $SE = 2.93$) images.

N2 (200–300 ms; electrodes FCz and Cz)

Peak amplitude. For the peak amplitude of the N2 wave, an interaction effect between category and arousal emerged, $F(2, 108) = 6.03$, $p = .003$, $\eta_p^2 = 0.100$, wherein the arousal effect was significant for the sexual images but not for the other categories, with pornographic images (*M* = -16.23 µV, *SE* = 0.85) being associated with higher peak amplitudes than romantic images (*M* = -14.03 µV, *SE* = 0.76).

A significant main effect of category was found, $F(2, 108) = 8.25$, $p < .001$, $\eta_p^2 = 0.132$, with higher amplitudes for sexual images (*M* = -15.13 µV, *SE* = 0.77), and non-sexual negative images (*M* = -14.14 µV, *SE* = 0.73) compared to non-sexual positive images (*M* = -13.86 µV, *SE* = 0.70). There was also a main effect of arousal, $F(1, 54) = 13.30$, $p = .001$, $\eta_p^2 = 0.198$, showing enhanced amplitudes for highly arousing images (*M* = -14.85 µV, *SE* = 0.74) compared to low arousing ones (*M* = -13.90 µV, *SE* = 0.70).

Peak latency. A significant main effect of category was observed for N2 peak latency, $F(2, 108) = 6.16$, $p = .003$, $\eta_p^2 = 0.102$, such that smaller latencies were elicited after the presentation of sexual images (*M* = 246.43 ms, *SE* = 2.20), compared to non-sexual positive (*M* = 250.97 ms, *SE* = 2.31) and non-sexual negative images (*M* = 251.51 ms, *SE* = 2.29).

P3 (300–500 ms; electrodes CPz and Pz)

Regarding P3 mean amplitudes, we found a significant interaction between gender of participant, category and arousal, $F(2, 108) = 3.97$, $p = .022$, $\eta_p^2 = 0.068$. For male participants, differences in amplitude between high and low arousing levels only emerged for sexual images ($M_{high\text{-}arousal}$ = 16.69 µV, *SE* = 1.35; $M_{low\text{-}arousal}$ = 13.20 µV, *SE* = 1.10), whereas for female participants, differences dependent on arousal level were significant for all image categories.

Moreover, an interaction effect between category and arousal was observed, $F(2, 108) = 18.73$, $p < .001$, $\eta_p^2 = 0.258$, showing enhanced amplitudes for highly arousing images exclusively for sexual ($M_{high\text{-}arousal}$ = 16.79 µV, *SE* = 0.94; $M_{low\text{-}arousal}$ = 13.58 µV, *SE* = 0.77) and non-sexual negative images ($M_{high\text{-}arousal}$ = 13.00 μV, *SE* = 0.77; $M_{low\text{-}arousal}$ = 11.85 μV, *SE* = 0.79). The interaction between arousal and neuroticism, $F(1, 54) = 4.52$, $p = .038$, η_p^2 = 0.077, showed that the difference between the response for high and low arousing images was mainly present in participants with high neuroticism (see Fig. 5).

Lastly, a significant main effect of category was found, $F(1.68, 90.95) = 114.63$, $p < .001$, η_p^2 = 0.680, such that higher amplitudes were found for sexual images (*M* = 15.19 μV, *SE* = 0.82), compared to non-sexual negative images (*M* = 12.43 μV, *SE* = 0.75), which in turn registered higher amplitudes than non-sexual positive images (*M* = 10.82 μV, *SE* = 0.74). The main effect of arousal was also significant, $F(1, 54) = 23.09$, $p < .001$, η_p^2 = 0.300, with enhanced amplitudes for highly arousing images (*M* = 13.58 μV, *SE* = 0.80) compared to low arousing ones (*M* = 12.05 μV, *SE* = 0.74).

DISCUSSION

Driven by the lack of knowledge concerning the basic cognitive mechanisms underlying the relationship between neuroticism and sexual function, we proposed to explore ERPs of participants scoring high and low in neuroticism during a modified oddball paradigm with affective pictures (sexual and non-sexual). Neuroticism has been shown to relate to basic attention and emotion processing mechanisms (Mitchell & Kumari, 2016), which led us to expect that presentation of novel and attention-grabbing stimuli with different emotional content would elicit different brain responses depending on the participant's neuroticism level. The inclusion of sexual stimuli with high and low arousal content, pornographic and romantic respectively, allowed us to make inferences about the influence of this personality trait specifically on the processing of sexual images. Accordingly, differences between neuroticism groups emerged in two neural correlates of attention processing of affective stimuli (the P1 and P3 components). Moreover, when considering exclusively the presentation of sexual stimuli, neuroticism related effects also emerged in the early phases of processing (P1).

In addition, we found a generalized distinct response to sexual stimuli compared to both non-sexual positive and negative images. Participants not only behaviorally responded faster when identifying sexual stimuli but also showed differentiated brain activity towards this category, which was mainly visible after 200 ms post picture presentation. Accordingly, we found a significant main effect of category for P1 peak latencies, for P2 peak amplitudes, for N2 peak amplitudes and latencies, and for P3 mean amplitudes, in which the sexual category elicited a distinctive response compared to all other categories. Such effect was predictable acknowledging the emotional salience of erotic stimuli, which has been frequently noticed in previous studies and has been justified by their importance to survival and reproduction (Schupp et al., 2004a, b). However, as previous researchers have pointed out, such evolutionary reasoning appears to be insufficient to justify why images with sexual content are more attention-grabbing compared to other stimuli also relevant to survival, such as mutilation images (included in the high arousing negative category). Notably, explicit sexual content (highly arousing sexual images, i.e., pornographic) elicited clearly differentiated processing in the P2 and N2-P3 complex. Enhanced P2 and N2-P3 amplitudes towards sexually explicit stimuli were observed in previous studies using implicit tasks (e.g., Feng et al., 2012), and in studies using a similar oddball paradigm (e.g., Briggs & Martin, 2009). Increased amplitudes for both early and late components in response to sexual stimuli suggest a generally increased mobilization of attentional resources, visibly distinct when compared to other image categories, which was in line with Briggs and Martin’s (2009) (see also Bailey et al., 2012) proposal of a differentiated influence of sexual arousal on cognitive processing. Further studies are needed to uncover the specific nature of the effect of sexual arousal on cognition. Meanwhile, some clues can come from recent theoretical proposals that highlight the role of the individual's sexual concerns over involuntary attentional orienting. There has been an increase in research showing that attentional orientation towards erotic stimuli is dependent on the current concerns of the observer (Sennwald et al., 2016). This can also justify our findings, namely the increased amplitudes for pornographic images in participants with high neuroticism. In line with those studies, such result may be indicative of increased attention to sexually explicit stimuli in high neuroticism participants, which are likely to have higher sexual concerns.

Regarding the effects of neuroticism, although there was no significant impact on behavioral performance during the oddball task, there were significant differences between groups on the neural correlates. Specifically, participants with high neuroticism had generally longer latencies for the P1 component and higher P3 amplitudes for highly arousing images compared with the low neuroticism participants. As the P1 ERP component represents early processing of stimuli associated with primary stages of attentional control (Hillyard et al., 1998), the longer P1 response latency observed in participants with high neuroticism may be interpreted as a generalized delayed attention capture towards affective stimuli. Moreover, a difference in P1 latencies between high and low arousal levels was found for sexual images, contingent on the gender of the participant and neuroticism group. Thus, while the arousal level did not induce alterations in the peak latency of our earlier component in other picture categories, this was not the case for the sexual stimuli category, since women with high neuroticism showed increased latencies for pornographic images compared with romantic ones. These P1 effects are very unlikely due to stimulus factors since they emerged only for a specific subgroup of our participants. Moreover, previous research has shown that the P1 wave reacts to emotional visual stimuli independently of low-level features (Smith et al., 2003).

Likewise, the increased P3 amplitudes towards highly arousing images that were observed in participants with high neuroticism is consistent with findings from previous studies (e.g., Rozenkrants et al., 2008). The fact that the high neuroticism group showed higher P3 amplitudes in response to all highly arousing stimuli, irrespectively of the existence of sexual content, implies that such intensified emotional response is not exclusive to the processing of sexual stimuli.

Considering the information processing model of sexual arousal (Janssen et al., 2000; Spiering & Everaerd, 2007), which advocates two cognitive pathways for stimulus processing, it is possible that our P1 results represent alterations in the implicit processing pathway. This pathway is believed to be pre-attentive and responsible for unconscious detection of sexual features. Women with high neuroticism having longer latencies for pornographic images may be interpreted as difficulty in appraising sexually explicit stimuli as such, at the automatic level. Likewise, and because we observed an interaction effect between neuroticism and arousal level on late potentials such as P3 (even though this effect was not exclusive for sexual stimuli), this can be taken to suggest that the personality trait neuroticism may also impact the explicit processing pathway predicted by the IPM. During this stage of processing, a deliberate allocation of attention to the stimulus and an extraction of stimulus meaning is believed to happen. Considering that people with high neuroticism often experience negative thoughts (Soares & Nobre, 2012), such participants were expected to show difficulties in sustaining attention by dealing with negative and highly intrusive thoughts while also trying to focus attention on the sexual image. However, we could not find specific evidence of these putative distraction processes since, in the present study, participants with high neuroticism showed heightened P3 responses to all arousing images when compared to low neuroticism participants. Hence, increased P3 mean amplitudes for individuals with high neuroticism may imply that, at least at this stage, these individuals experience greater attentional resource allocation towards highly arousing stimuli in general. Nonetheless, in the specific case of sexually explicit stimuli, this may result from the processing of the positive/negative sexual meanings associated with the content perceived. Importantly, this will need to be further explored in future research, in order to better distinguish between different stimulus contents.

Because participants in the present study reported an absence of sexual problems, the proposed explanations concerning the reason for the increased vulnerability towards dysfunction in participants with high neuroticism is merely speculative and can be considered a limitation. Also, we decided to not fully address some effects which arose contingently to the gender of participant, namely the P1 neuroticism effect observed only for female participants. Sex differences regarding brain function and neuroticism have been reported in previous research (e.g., Jaušovec & Jaušovec, 2007; Neo & McNaughton, 2011) along with an increased propensity for higher levels of neuroticism in women (Costa et al., 2001). Although in the present study participants were carefully selected in order to obtain a sample without gender differences in neuroticism, it is possible that the increased female predisposition to higher neuroticism may accentuate the consequences of this personality trait on sexual stimulus processing. But again, such an explanation is of speculative nature and highlights the need for new research addressing how personality traits, namely neuroticism, affect information processing of sexual stimuli separately in men and women. Lastly, future studies may try to replicate the current results addressing how other individual traits, namely measures of sexual inhibition-excitation proneness (Janssen et al., 2002), mediate the impact of neuroticism on the processing of sexual stimuli. Research on individual differences can also be helpful to explore learning and priming effects on the processing of sexual stimuli. More electrophysiological research should contribute to understanding the neural underpinnings of the vulnerability factors that impact sexual health and functioning.

Conclusions

Results from the present study suggest an impact of neuroticism in response to visual sexual stimuli that is evident even in the earlier stages of cognitive information processing. Neuroticism appears to influence not only automatic but also more elaborate and controlled stages of attention processing. Particularly, individuals with different neuroticism levels showed differences in attention engagement towards stimuli with sexual and non-sexual content and high and low arousal. We hope that these findings will encourage future studies to explore the basic psychological mechanisms underlying the relationship between identified vulnerability factors and sexual problems and dysfunctions.

REFERENCES

Anokhin, A. P., Golosheykin, S., Sirevaag, E., Kristjansson, S., Rohrbaugh, J. W., & Heath, A. C. (2006). Rapid discrimination of visual scene content in the human brain. *Brain Research, 1093*(1), 167-177. https://doi.org/10.1016/j.brainres.2006.03.108

Bailey, K., West, R., & Mullaney, K. M. (2012). Neural correlates of processing negative and sexually arousing pictures. *PLoS ONE, 7*(9), e45522. https://doi.org/10.1371/journal.pone.0045522

Bredemeier, K., Berenbaum, H., Most, S. B., & Simons, D. J. (2011). Links between neuroticism, emotional distress, and disengaging attention: Evidence from a single-target RSVP task. *Cognition & Emotion*, *25*(8), 1510–1519. https://doi.org/10.1080/02699931.2010.549460

Briggs, K. E., & Martin, F. H. (2009). Affective picture processing and motivational relevance: Arousal and valence effects on ERPs in an oddball task. *International Journal of Psychophysiology*, *72*(3), 299–306. https://doi.org/10.1016/j.ijpsycho.2009.01.009

Brotto, L., Atallah, S., Johnson-Agbakwu, C., Rosenbaum, T., Abdo, C., Byers, E. S., … Wylie, K. (2016). Psychological and interpersonal dimensions of sexual function and dysfunction. *Journal of Sexual Medicine*, *13*(4), 538–571. https://doi.org/10.1016/j.jsxm.2016.01.019

Carretié, L., Martín-Loeches, M., Hinojosa, J. A., & Mercado, F. (2001). Emotion and attention interaction studied through event-related potentials. *Journal of Cognitive Neuroscience*, *13*(8), 1109–1128. https://doi.org/10.1162/089892901753294400

Carvalho, J., Pereira, A. T., Nobre, P. J., & Santos, I. M. (2014). Gender differences in the assessment of sex pictures: Towards the development of an ecologically valid database. *Journal of Sexual Medicine, 11*(suppl. 1), 94–108.

Carvalho, J., Czop, O., Rocha, M., Nobre, P., & Soares, S. (2018). Gender differences in the automatic attention to romantic vs sexually explicit stimuli. *Journal of Sexual Medicine, 15*(8), 1083-1092. https://doi.org/10.1016/j.jsxm.2018.06.008

Costa, P. T., & MacCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO PI-R) and NEO Five-Factor Inventory (NEO FFI): Professional Manual*. Odessa, Fl: Psychological Assessment Resources.

Costa, P. T., & McCrae, R. R. (2000). *NEO PI-R: Manual Profissional: NEO PI-R, Inventário de Personalidade NEO Revisto*. Lisboa: CEGOC-TEA, Lda.

Costa, P. T., Terracciano, A., & Mccrae, R. R. (2001). Gender differences in personality traits across cultures: Robust and surprising findings. *Journal of Personality and Social Psychology*, *81*(2), 322–331. https://doi.org/10.1037/0022-3514.81.2.322

Crisp, C., Vaccaro, C., Fellner, A., Kleeman, S., & Pauls, R. (2015). The influence of personality and coping on female sexual function: A population survey. *Journal of Sexual Medicine*, *12*(1), 109–115. https://doi.org/10.1111/jsm.12735

De Fruyt, F., De Clercq, B., De Caluwé, E., & Verbeke, L. (2017). 24 - Personality development and psychopathology. In J. Specht (Ed.), *Personality development across the lifespan* (pp. 385–400). Retrieved from https://doi.org/10.1016/B978-0-12-804674-6.00024-7

Doornwaard, S. M., van den Eijnden, R. J. J. M., Johnson, A., & ter Bogt, T. F. M. (2014). Exposure to sexualized media content and selective attention for sexual cues: An experimental study. *Computers in Human Behavior*, *41*, 357–364. https://doi.org/10.1016/J.CHB.2014.10.037

Duncan-Johnson, C. C., & Donchin, E. (1977). On quantifying surprise: The variation of event-related potentials with subjective probability. *Psychophysiology, 14*(5), 456–467. https://doi.org/10.1111/j.1469-8986.1977.tb01312.x

Eysenck, M. W. (2000). A cognitive approach to trait anxiety. *European Journal of Personality*, *14*(5), 463–476. https://doi.org/10.1002/1099-0984(200009/10)14:5<463::AID-PER393>3.0.CO;2-3

Fagan, P. J., Wise, T. N., Schmidt Jr., C. W., Ponticas, Y., Marshall, R. D., & Costa Jr., P. T. (1991). A comparison of five-factor personality dimensions in males with sexual dysfunction and males with paraphilia. *Journal of Personality Assessment*, *57*(3), 434–448. https://doi.org/10.1207/s15327752jpa5703_4

Feng, C., Wang, L., Wang, N., Gu, R., & Luo, Y. (2012). The time course of implicit processing of erotic pictures: An event-related potential study. *Brain Research*, *1489*, 48–55. https://doi.org/10.1016/J.BRAINRES.2012.10.019

Ferrari, V., Bradley, M. M., Codispoti, M., & Lang, P. J. (2010). Detecting novelty and significance. *Journal of Cognitive Neuroscience*, *22*(2), 404–411. https://doi.org/10.1162/jocn.2009.21244

Forbes, M. K., Baillie, A. J., Eaton, N. R., & Krueger, R. F. (2017). A place for sexual dysfunctions in an empirical taxonomy of psychopathology. *Journal of Sex Research*, *54*(4-5), 465-485. https://doi.org/10.1080/00224499.2016.1269306

Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011). Time course of implicit processing and explicit processing of emotional faces and emotional words. *Biological Psychology*, *87*(2), 265–274. https://doi.org/10.1016/j.biopsycho.2011.03.008

Handy, T. C. (Ed.). (2005). *Event-related potentials: A methods handbook*. Cambridge, MA: MIT Press.

Hahn, A. C., Symons, L. A., Kredel, T., Hanson, K., Hodgson, L., Schiavone, L., & Jantzen, K. J. (2016). Early and late event-related potentials are modulated by infant and adult faces of high and low attractiveness. *Social Neuroscience*, *11*(2), 207–220. https://doi.org/10.1080/17470919.2015.1059361

Harris, J. M., Cherkas, L. F., Kato, B. S., Heiman, J. R., & Spector, T. D. (2008). Normal variations in personality are associated with coital orgasmic infrequency in heterosexual women: A population-based study. *Journal of Sexual Medicine*, *5*(5), 1177–1183. https://doi.org/10.1111/j.1743-6109.2008.00800.x

Hillyard, S. A., Vogel, E. K., & Luck, S. J. (1998). Sensory gain control (amplification) as a mechanism of selective attention: Electrophysiological and neuroimaging evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *353*(1373), 1257–1270. https://doi.org/10.1098/rstb.1998.0281

Janssen, E., Everaerd, W., Spiering, M., & Janssen, J. (2000). Automatic processes and the appraisal of sexual stimuli: Toward an information processing model of sexual arousal. *Journal of Sex Research*, *37*(1), 8–23. https://doi.org/10.1080/00224490009552016

Janssen, E., Vorst, H., Finn, P., & Bancroft, J. (2002). The Sexual Inhibition (SIS) and Sexual Excitation (SES) Scales: I. Measuring sexual inhibition and excitation proneness in men. *Journal of Sex Research*, *39*(2), 114–126. https://doi.org/10.1080/00224490209552130

Jaušovec, N., & Jaušovec, K. (2007). Personality, gender and brain oscillations. *International Journal of Psychophysiology*, *66*(3), 215–224. https://doi.org/10.1016/J.IJPSYCHO.2007.07.005

Kanske, P., Plitschka, J., & Kotz, S. A. (2011). Attentional orienting towards emotion: P2 and N400 ERP effects. *Neuropsychologia*, *49*(11), 3121–3129. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2011.07.022

Kennedy, S. H., Dickens, S. E., Eisfeld, B. S., & Bagby, R. M. (1999). Sexual dysfunction before antidepressant therapy in major depression. *Journal of Affective Disorders*, *56*(2–3), 201–208. https://doi.org/10.1016/S0165-0327(99)00050-6

Krug, R., Plihal, W., Fehm, H.L., Born, J. (2000). Selective influence of the menstrual cycle on perception of stimuli with reproductive significance: An event-related potential study. *Psychophysiology 37*, 111–122. https://doi.org/10.1016/j.biopsycho.2008.04.016

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual. *Technical Report A-6*.

Gainesville, FL: University of Florida.

Lehmann, D., & Skrandies, W. (1986). Segmentation of EEG potential fields. *Electroencephalography and Clinical Neurophysiology*, 38, 27–32.

Leppänen, J. M., Moulson, M. C., Vogel-Farley, V. K., & Nelson, C. A. (2007). An ERP study of emotional face processing in the adult and infant brain. *Child Development*, *78*(1), 232–245. https://doi.org/10.1111/j.1467-8624.2007.00994.x

Lima, M. P., & Simões, A. (2000). A teoria dos cinco factores: Uma proposta inovadora ou apenas uma boa arrumação do caleidoscópio personológico? *Análise Psicológica*, *2*, 171-179.

Mardaga, S., & Hansenne, M. (2009). Personality modulation of P300 wave recorded within an emotional oddball protocol. *Neurophysiologie Clinique/Clinical Neurophysiology*, *39*(1), 41–48. https://doi.org/10.1016/J.NEUCLI.2008.12.005

Mitchell, R. L. C., & Kumari, V. (2016). Hans Eysenck's interface between the brain and personality: Modern evidence on the cognitive neuroscience of personality. *Personality and Individual Differences*, *103*, 74–81. https://doi.org/10.1016/J.PAID.2016.04.009

Neo, P. S.-H., & McNaughton, N. (2011). Frontal theta power linked to neuroticism and avoidance. *Cognitive, Affective, & Behavioral Neuroscience*, *11*(3), 396–403. https://doi.org/10.3758/s13415-011-0038-x

Nobre, P. (2013). Male sexual dysfunctions. In J. G. Hofmann (Ed.), *The Wiley handbook of cognitive behavioral therapy. Part Two* (pp. 645–672). New Jersey: Wiley-Blackwell. https://doi.org/10.1002/9781118528563.wbcbt28

Nobre, P. J. (2017). Treating men's erectile problems. In Z. Peterson (Ed.), *The Wiley-*

Blackwell handbook of sex therapy (pp. 40-56). Retrieved from https://doi.org/10.1002/9781118510384.ch4

Norris, C. J., Larsen, J. T., & Cacioppo, J. T. (2007). Neuroticism is associated with larger and more prolonged electrodermal responses to emotionally evocative pictures. *Psychophysiology*, *44*(5), 823–826. https://doi.org/10.1111/j.1469-8986.2007.00551.x

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology*, *77*(3), 247–265. https://doi.org/10.1016/J.BIOPSYCHO.2007.11.006

Peixoto, M. M., & Nobre, P. (2017). The activation of incompetence schemas in response to negative sexual events in heterosexual and lesbian women: The moderator role of personality traits and dysfunctional sexual beliefs. *Journal of Sex Research*, *54*(9), 1188–1196. https://doi.org/10.1080/00224499.2016.1267103

Quinta Gomes, A. L., & Nobre, P. (2011). Personality traits and psychopathology on male sexual dysfunction: An empirical study. *Journal of Sexual Medicine*, *8*(2), 461–469. https://doi.org/10.1111/J.1743-6109.2010.02092.X

Reynaud, E., Khoury-Malhame, M., Rossier, J., Blin, O., & Khalfa, S. (2012). Neuroticism modifies psychophysiological responses to fearful films. *PLoS ONE*, *7*(3), e32413. https://doi.org/10.1371/journal.pone.0032413

Rosenheim, E., & Neumann, M. (1981). Personality characteristics of sexually dysfunctioning males and their wives. *Journal of Sex Research*, *17*(2), 124–138. https://doi.org/10.1080/00224498109551107

Rozenkrants, B., Olofsson, J. K., & Polich, J. (2008). Affective visual event-related potentials: Arousal, valence, and repetition effects for normal and distorted pictures. *International Journal of Psychophysiology*, *67*(2), 114–123. https://doi.org/10.1016/j.ijpsycho.2007.10.010

Rupp, H. A., & Wallen, K. (2008). Sex differences in response to visual sexual stimuli: A review. *Archives of Sexual Behavior*, 37(2), 206-218. https://doi.org/10.1007/s10508-007-9217-9

Sass, S. M., Heller, W., Fisher, J. E., Silton, R. L., Stewart, J. L., Crocker, L. D., … Miller, G. A. (2014). Electrophysiological evidence of the time course of attentional bias in non-patients reporting symptoms of depression with and without co-occurring anxiety. *Frontiers in Psychology*, *5,* 301. https://doi.org/10.3389/fpsyg.2014.00301

Semlitsch, H.V., Anderer, P., Schuster, P. and Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology*, *23*, 695-703. https://doi.org/10.1111/j.1469-8986.1986.tb00696.x

Sennwald, V., Pool, E., Brosch, T., Delplanque, S., Bianchi-Demicheli, F., & Sander, D. (2016). Emotional attention for erotic stimuli: Cognitive and brain mechanisms. *Journal of Comparative Neurology*, *524(8)*, 1668-1675. https://doi.org/10.1002/cne.23859

Schupp, H., Cuthbert, B., Bradley, M., Hillman, C., Hamm, A., & Lang, P. (2004a). Brain processes in emotional perception: Motivated attention. *Cognition and Emotion*, 18(5), 593-611. https://doi.org/10.1080/02699930341000239

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science*, 14(1), 7–13. https://doi.org/10.1111/1467- 9280.01411.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004b). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology, 41(3)*, 441–449. https://doi. org/10.1111/j.1469-8986.2004.00174.x.

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2006). Stimulus novelty and emotion perception: The near absence of habituation in the visual cortex. *NeuroReport*, *17*(4), 365–369.

https://doi.org/10.1097/01.wnr.0000203355.88061.c6

Siyaguna, T., Myhre, S. K., Saxton, B. T., & Rokke, P. D. (2019). Neuroticism and emotion regulation predict attention performance during positive affect. *Current Psychology*, 38, 1542–1549. https://doi.org/10.1007/s12144-017-9701-x

Smith, N. K., Cacioppo, J. T., Larsen, J. T., & Chartrand, T. L. (2003). May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia*, *41*(2), 171–183. https://doi.org/10.1016/S0028-3932(02)00147-1

Soares, C., & Nobre, P. (2012). Sexual problems, cultural beliefs, and psychosexual therapy in Portugal. In K. Hall & C. Graham (Eds.), *The cultural context of sexual pleasure and problems: Psychotherapy with diverse clients* (pp. 278–306). New York, NY: Routledge.

Spiering, M., & Everaerd, W. (2007). The sexual unconscious. In *The psychophysiology of sex* (pp. 166–184). Indiana University Press.

Squires, K. C., Wickens, C., Squires, N. K., & Donchin, E. (1976). The effect of stimulus sequence on the waveform of the cortical event-related potential. *Science*, *193*(4258), 1142–1146.

van Lankveld, J. J. D. M., & Smulders, F. T. Y. (2008). The effect of visual sexual content on the event-related potential. *Biological Psychology*, *79*(2), 200–208. https://doi.org/10.1016/j.biops ycho.2008.04.016.

Wallace, J. F., & Newman, J. P. (1998). Neuroticism and the facilitation of the automatic orienting of attention. *Personality and Individual Differences*, *24*(2), 253–266. https://doi.org/10.1016/S0191-8869(97)00153-0

Ziogas, A., Habermeyer, E., Santtila, P., Poeppl, T. B., & Mokros, A. (2020). Neuroelectric correlates of human sexuality: A review and meta-analysis. *Archives of Sexual Behavior*. https://doi.org/10.1007/s10508-019-01547-3

Tables

Table 1. Valence, general arousal and sexual arousal data for each category of stimuli based on IAPS and EROSimag/UPUA.pt original database validations.

	Valence			Arousal			Sexual Arousal		
	Mean	SD	Range[a]	Mean	SD	Range[a]	Mean	SD	Range[a]
Non-sexual NEG HA	2.00	1.41	1.31-2.83	6.84	2.21	5.92-7.21			
Non-sexual POS HA	7.31	1.61	6.5-8.1	6.68	2.12	6.14-7.35			
Non-sexual NEG LA	3.24	1.62	2.06-3.9	4.08	1.97	3.52-4.46			
Non-sexual POS LA	7.12	1.53	6.56-7.63	3.94	2.15	3.55-4.19			
Sexual HA	6.04	1.84	5.39-7.23	6.88	1.44	6.52-7.33	6.59	1.85	5.87-7.23
Sexual LA	7.30	1.64	6.48-7.94	3.26	2.27	2.84-3.57	2.62	1.83	2.04-4.45

Note. NEG HA, Negative and highly arousing; POS HA, Positive and highly arousing; NEG LA, Negative and low arousing; POS LA, Positive and low arousing; HA, Highly arousing; LA, Low arousing.

[a] Range values correspond to the minimum and maximum mean ratings of individual pictures.

Figures

Figure 1. Trial sequence in the oddball task.

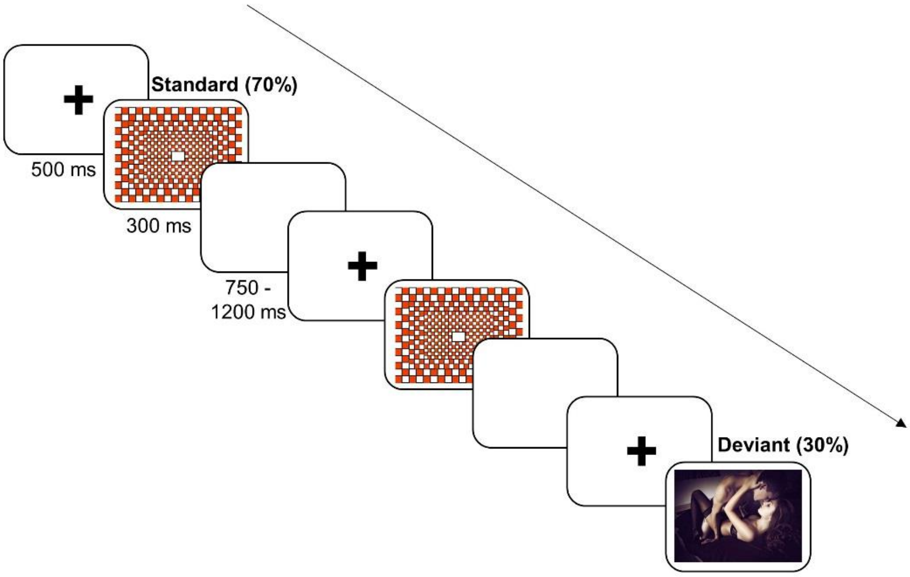

Figure 2. Grand-average waveforms for sexual images in participants with high neuroticism (high N group) and low neuroticism (low N group) over occipital (O1), parietal (P3), central (Cz) and centro-parietal (CPz) sites.

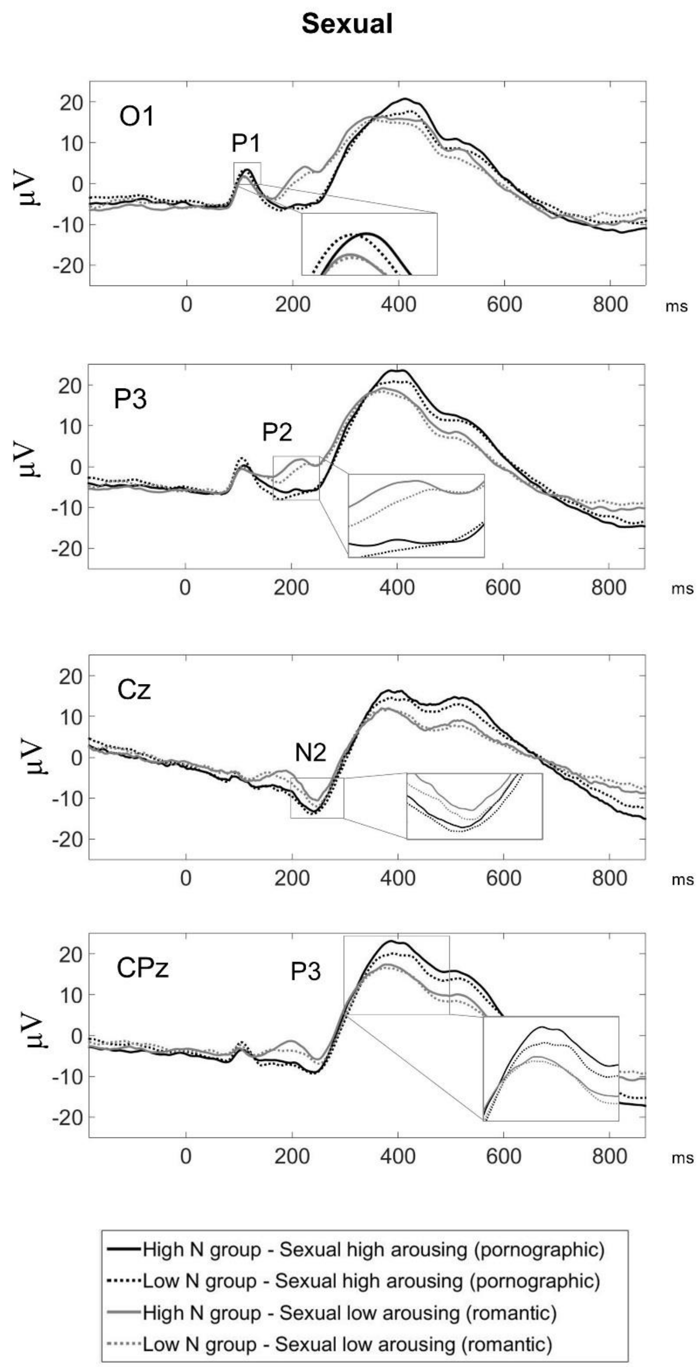

Figure 3. Grand-average waveforms for non-sexual positive (left panel) and non-sexual negative images (right panel) in participants with high neuroticism (high N group) and low neuroticism (low N group) over occipital (O1), parietal (P3), central (Cz) and centro-parietal (CPz) sites.

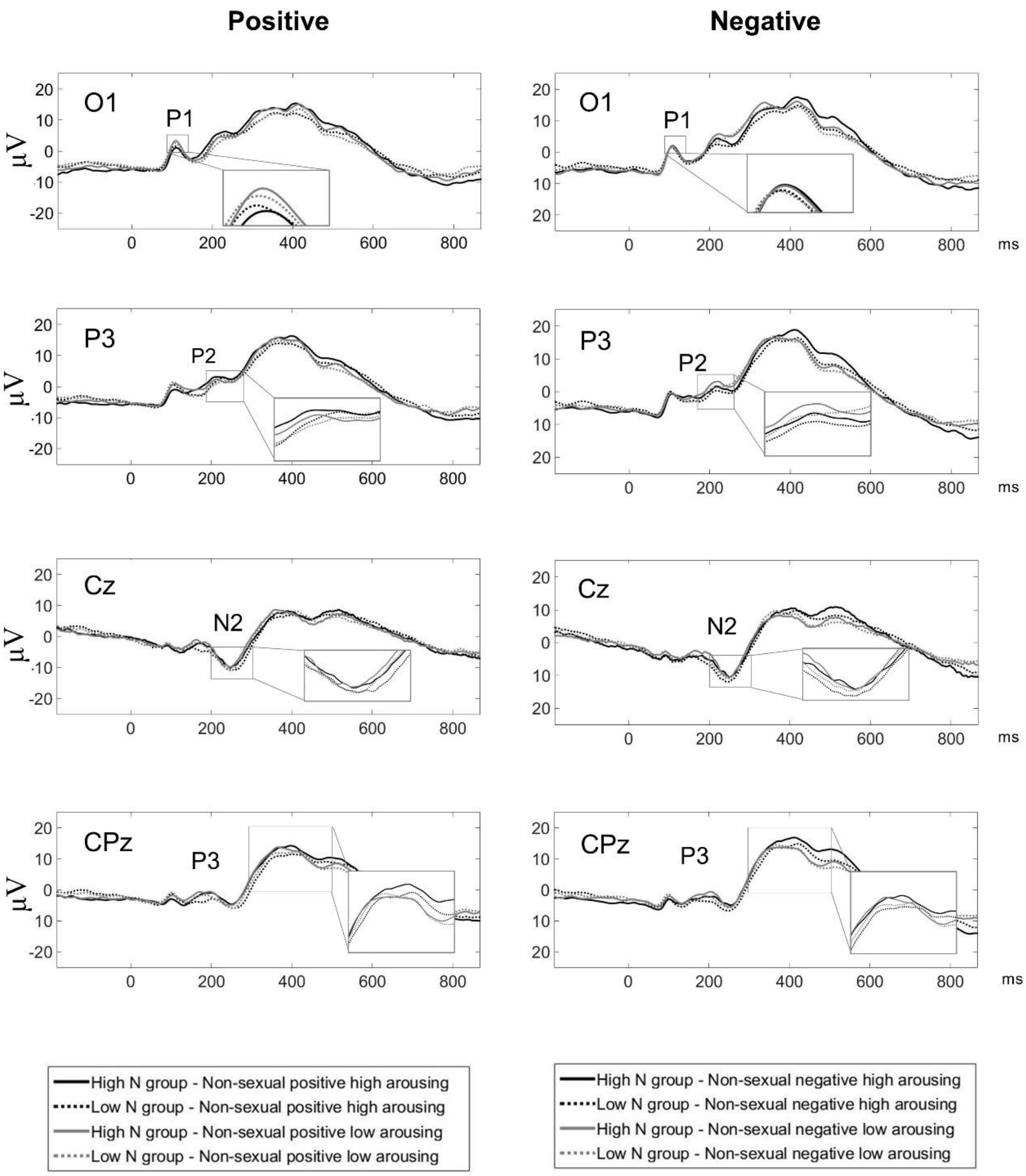

Figure 4. P1 peak latencies for sexual images (romantic and pornographic), for high neuroticism (high N) and low neuroticism (low N) participants of both sexes. Error bars show standard errors of the mean. * $p < .05$.

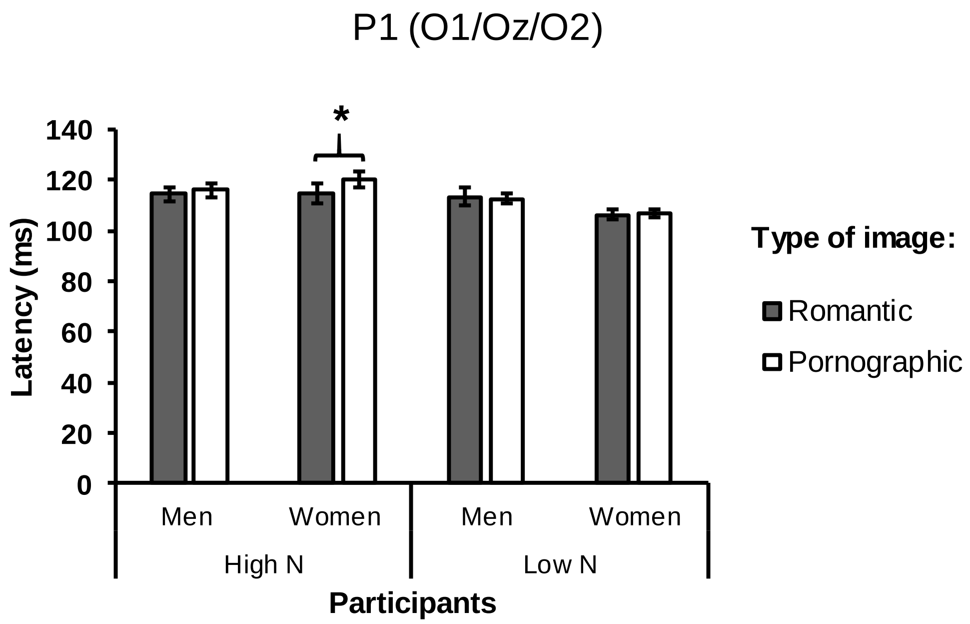

Figure 5. P3 mean amplitudes for high and low arousal images, for high neuroticism and low neuroticism participants. Error bars show standard errors of the mean. *** $p < .001$.

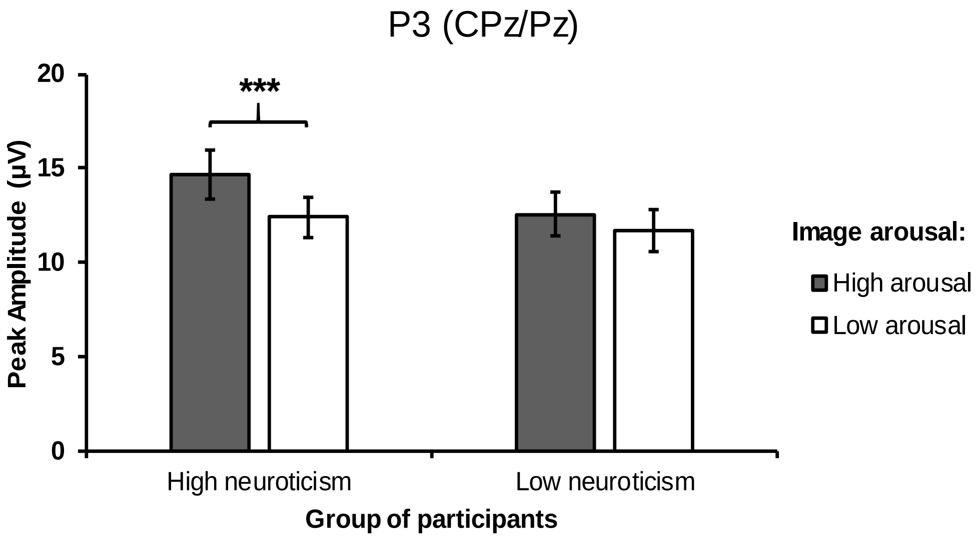

Table 1. Valence, general arousal and sexual arousal data for each category of stimuli based on IAPS and EROSimag/UPUA.pt original database validations.

	Valence			Arousal			Sexual Arousal		
	Mean	SD	Range[a]	Mean	SD	Range[a]	Mean	SD	Range[a]
Non-sexual NEG HA	2.00	1.41	1.31-2.83	6.84	2.21	5.92-7.21			
Non-sexual POS HA	7.31	1.61	6.5-8.1	6.68	2.12	6.14-7.35			
Non-sexual NEG LA	3.24	1.62	2.06-3.9	4.08	1.97	3.52-4.46			
Non-sexual POS LA	7.12	1.53	6.56-7.63	3.94	2.15	3.55-4.19			
Sexual HA	6.04	1.84	5.39-7.23	6.88	1.44	6.52-7.33	6.59	1.85	5.87-7.23
Sexual LA	7.30	1.64	6.48-7.94	3.26	2.27	2.84-3.57	2.62	1.83	2.04-4.45

Note. NEG HA, Negative and highly arousing; POS HA, Positive and highly arousing; NEG LA, Negative and low arousing; POS LA, Positive and low arousing; HA, Highly arousing; LA, Low arousing.

[a] Range values correspond to the minimum and maximum mean ratings of individual pictures.

Table 1. Results from ANOVAs performed with ERP data.

		P1		P2		N2		P3
		Peak Amplitude	Peak Latency	Peak Amplitude	Peak Latency	Peak Amplitude	Peak Latency	Mean Amplitude
Category	F	2.56	5.67	89.91	.24	8.25	6.16	114.63
	df	2, 108	2, 108	1.90, 102.71	2, 108	2, 108	2, 108	1.68, 90.95
	p	.082	.005	< .001	.784	< .001	.003	< .001
	η_p^2	.045	.095	.625	.004	.132	.102	.680
Category x Sex of participant	F	.46	.62	1.19	2.53	2.67	.03	.78
	df	2, 108	2, 108	1.90, 102.71	2, 108	2, 108	2, 108	1.68, 90.95
	p	.632	.541	.306	.085	.074	.967	.444
	η_p^2	.008	.011	.022	.045	.047	.001	.014
Category x Neuroticism	F	.06	.22	.42	1.14	.19	1.72	.05
	df	2, 108	2, 108	1.90, 102.71	2, 108	2, 108	2, 108	1.68, 90.95
	p	.944	.801	.648	.324	.824	.184	.923
	η_p^2	.001	.004	.008	.021	.004	.031	.001
Category x Sex of participant x Neuroticism	F	1.10	1.06	.91	.39	.24	.20	1.70
	df	2, 108	2, 108	1.90, 102.71	2, 108	2, 108	2, 108	1.68, 90.95
	p	.338	.349	.400	.681	.791	.816	.193
	η_p^2	.020	.019	.017	.007	.004	.004	.031
Arousal	F	.05	2.02	51.98	8.06	13.30	1.01	23.09
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.821	.161	< .001	.006	.001	.319	< .001
	η_p^2	.001	.036	.490	.130	.198	.018	.300
Arousal x Sex of participant	F	.36	< .01	.19	.53	.19	.11	2.73
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.554	.995	.665	.470	.667	.747	.104
	η_p^2	.007	< .001	.004	.010	.003	.002	.048
Arousal x Neuroticism	F	.08	.94	.10	.10	.04	.56	4.52
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.774	.337	.919	.748	.840	.456	.038
	η_p^2	.002	.017	< .001	.002	.001	.010	.077
Arousal x Sex of participant	F	.04	.01	.43	1.85	.21	.34	.02
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.836	.919	.513	.179	.648	.564	.877

x Neuroticism	η_p^2	.001	< .001	.008	.033	.004	.006	< .001
Electrode	F	7.24	15.45	13.99	3.01	34.72	47.09	66.36
	df	1.48, 79.89	1.46, 78.87	1.80, 97.00	2.21, 119.14	1, 54	1, 54	1, 54
	p	.003	< .001	< .001	.048	< .001	< .001	< .001
	η_p^2	.118	.223	.206	.053	.391	.466	.551
Electrode x Sex of participant	F	.06	1.64	.51	.16	.03	.07	1.16
	df	1.48, 79.89	1.46, 78.87	1.80, 97.00	2.21, 119.14	1, 54	1, 54	1, 54
	p	.891	.206	.585	.869	.874	.787	.287
	η_p^2	.001	.029	.009	.003	< .001	.001	.021
Electrode x Neuroticism	F	.36	2.18	.23	.15	7.75	.51	.19
	df	1.48, 79.89	1.46, 78.87	1.80, 97.00	2.21, 119.14	1, 54	1, 54	1, 54
	p	.637	.133	.770	.877	.007	.479	.663
	η_p^2	.007	.039	.004	.003	.126	.009	.004
Electrode x Sex of participant x Neuroticism	F	2.37	.34	1.50	.16	.23	.36	1.23
	df	1.48, 79.89	1.46, 78.87	1.80, 97.00	2.21, 119.14	1, 54	1, 54	1, 54
	p	.114	.648	.230	.874	.634	.549	.273
	η_p^2	.042	.006	.027	.003	.004	.007	.022
Category x Arousal	F	23.12	.76	60.86	.13	6.03	1.11	18.73
	df	1.69, 91.00	2, 108	2, 108	1.78, 95.86	2, 108	2, 108	2, 108
	p	< .001	.471	< .001	.854	.003	.335	< .001
	η_p^2	.300	.014	.530	.002	.100	.020	.258
Category x Arousal x Sex of participant	F	.73	.82	.44	.42	2.35	.18	3.97
	df	1.69, 91.00	2, 108	2, 108	1.78, 95.86	2, 108	2, 108	2, 108
	p	.461	.443	.648	.635	.100	.835	.022
	η_p^2	.013	.015	.008	.008	.042	.003	.068
Category x Arousal x Neuroticism	F	.73	.74	.74	1.55	.60	1.33	.37
	df	1.69, 91.00	2, 108	2, 108	1.78, 95.86	2, 108	2, 108	2, 108
	p	.464	.480	.480	.220	.550	.269	.693
	η_p^2	.013	.013	.013	.028	.011	.024	.007
Category x Arousal x Sex of	F	.21	5.06	.26	.99	.97	2.41	1.21
	df	1.69, 91.00	2, 108	2, 108	1.78, 95.86	2, 108	2, 108	2, 108

participant x Neuroticism	p	.775	.008	.769	.367	.382	.095	.301
	η_p^2	.004	.086	.005	.018	.018	.043	.022
Category x Electrode	F	6.97	.39	10.00	.82	34.06	1.39	43.05
	df	3.09, 167.03	4, 216	3.80, 205.16	4.80, 259.02	2, 108	2, 108	1.64, 88.36
	p	< .001	.813	< .001	.535	< .001	.254	< .001
	η_p^2	.114	.007	.156	.015	.387	.025	.444
Category x Electrode x Sex of participant	F	.66	1.51	1.34	.63	1.41	.02	.05
	df	3.09, 167.03	4, 216	3.80, 205.16	4.80, 259.02	2, 108	2, 108	1.64, 88.36
	p	.583	.200	.257	.667	.250	.981	.928
	η_p^2	.012	.027	.024	.012	.025	< .001	.001
Category x Electrode x Neuroticism	F	.69	2.57	.21	.64	.38	.22	.83
	df	3.09, 167.03	4, 216	3.80, 205.16	4.80, 259.02	2, 108	2, 108	1.64, 88.36
	p	.564	.039	.925	.666	.687	.804	.419
	η_p^2	.013	.045	.004	.012	.007	.004	.015
Category x Electrode x Sex of Participant x Neuroticism	F	1.60	3.38	1.65	.80	.20	.85	.96
	df	3.09, 167.03	4, 216	3.80, 205.16	4.80, 259.02	2, 108	2, 108	1.64, 88.36
	p	.191	.011	.167	.544	.822	.432	.373
	η_p^2	.029	.059	.030	.015	.004	.015	.017
Arousal x Electrode	F	2.45	.82	1.09	2.41	22.64	.84	50.80
	df	1.78, 95.87	2, 108	2.29, 123.74	3, 162	1, 54	1, 54	1, 54
	p	.098	.445	.345	.069	< .001	.365	< .001
	η_p^2	.043	.015	.020	.043	.295	.015	.485
Arousal x Electrode x Sex of Participant	F	.16	1.00	.87	.18	1.32	1.01	1.04
	df	1.78, 95.87	2, 108	2.29, 123.74	3, 162	1, 54	1, 54	1, 54
	p	.832	.370	.433	.908	.256	.320	.313
	η_p^2	.003	.018	.016	.003	.024	.018	.019
Arousal x Electrode x Neuroticism	F	1.44	.12	.28	1.45	.40	.30	2.14
	df	1.78, 95.87	2, 108	2.29, 123.74	3, 162	1, 54	1, 54	1, 54
	p	.242	.890	.785	.231	.532	.587	.149
	η_p^2	.026	.002	.005	.026	.007	.005	.038
	F	1.57	.65	.88	.09	.24	.01	.34

Arousal x Electrode x Sex of Participant x Neuroticism	df	1.78, 95.87	2, 108	2.29, 123.74	3, 162	1, 54	1, 54	1, 54
	p	.215	.526	.430	.968	.624	.924	.563
	η_p^2	.028	.012	.016	.002	.004	< .001	.006
Category x Arousal x Electrode	F	2.93	1.06	4.49	1.11	14.95	.11	29.55
	df	3.41, 184.35	3.41, 184.01	4.59, 247.61	4.63, 249.80	2, 108	2, 108	1.76, 94.98
	p	.029	.373	.001	.352	< .001	.899	< .001
	η_p^2	.051	.019	.077	.020	.217	.002	.354
Category x Arousal x Electrode x Sex of Participant	F	.19	.66	2.67	1.45	.62	2.96	.13
	df	3.41, 184.35	3.41, 184.01	4.59, 247.61	4.63, 249.80	2, 108	2, 108	1.76, 94.98
	p	.925	.597	.027	.210	.542	.056	.856
	η_p^2	.003	.012	.047	.026	.011	.052	.002
Category x Arousal x Electrode x Neuroticism	F	.39	.97	.56	.80	.84	.87	2.65
	df	3.41, 184.35	3.41, 184.01	4.59, 247.61	4.63, 249.80	2, 108	2, 108	1.76, 94.98
	p	.783	.417	.715	.542	.434	.424	.083
	η_p^2	.007	.018	.010	.015	.015	.016	.047
Category x Arousal x Electrode x Sex of Participant x Neuroticism	F	.29	.95	1.29	.90	.62	.78	.41
	df	3.41, 184.35	3.41, 184.01	4.59, 247.61	4.63, 249.80	2, 108	2, 108	1.76, 94.98
	p	.857	.425	.271	.473	.539	.459	.638
	η_p^2	.005	.017	.023	.016	.011	.014	.008
Sex of Participant	F	.20	.42	6.07	.18	.16	.90	.35
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.658	.520	.017	.677	.695	.346	.556
	η_p^2	.004	.008	.101	.003	.003	.016	.006
Neuroticism	F	.10	5.68	.14	.43	1.31	.41	.81
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.749	.021	.713	.516	.257	.525	.373
	η_p^2	.002	.095	.003	.008	.024	.008	.015
Sex of Participant x Neuroticism	F	.09	2.64	.45	1.38	.60	.27	.03
	df	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54	1, 54
	p	.761	.110	.507	.245	.444	.605	.859
	η_p^2	.002	.047	.008	.025	.011	.005	.001