



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

Mariana L. Carrito¹ · Joana Carvalho¹ · Ana Pereira² · Pedro Bem-Haja³ · Pedro Nobre¹ · Isabel M. Santos⁴

Received: 19 June 2019 / Revised: 15 February 2021 / Accepted: 16 February 2021 / Published online: 19 July 2021
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2021

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).

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10508-021-01961-6>.

✉ Mariana L. Carrito
mariana.carrito@gmail.com

- ¹ Centro de Psicologia da Universidade do Porto, Faculdade de Psicologia e de Ciências da Educação da Universidade do Porto, Rua Alfredo Allen, 4200-135 Porto, Portugal
- ² Institute for Biomedical Imaging and Life Sciences, Faculty of Medicine, University of Coimbra, Coimbra, Portugal
- ³ Centro de Investigação em Tecnologias e Serviços de Saúde, Departamento de Educação e Psicologia, Universidade de Aveiro, Aveiro, Portugal
- ⁴ William James Center for Research, Departamento de Educação e Psicologia, Universidade de Aveiro, Aveiro, Portugal

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 toward emotional stimuli in sexual contexts.

Acknowledging the role of attention on sexual response, Janssen et al. (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 non-sexual, positive or negative, wherein, in the case of sexual dysfunction, the responses generated are predominantly non-sexual 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 toward 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., 2008). 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 (Carteri  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 toward 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 and two others were excluded for reporting a non-heterosexual orientation, on Kinsey's Likert scale, posteriorly to the online questionnaire.¹ Data from 58 heterosexual and right-handed participants, 30 scoring low (15 women and 15 men; $M_{\text{age}} = 23.83$ years, $SD = 5.34$) and 28 scoring high (15 women and 13 men; $M_{\text{age}} = 22.25$ years, $SD = 4.19$) on the neuroticism scale, were considered for ERP 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

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

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

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

^aRange values correspond to the minimum and maximum mean ratings of individual pictures

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 0.85, 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, which have been previously validated for the Portuguese population (Carvalho et al., 2014).² 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 (2009) work, the red and white checkerboard from IAPS (image number 7182) was presented as the standard stimulus.

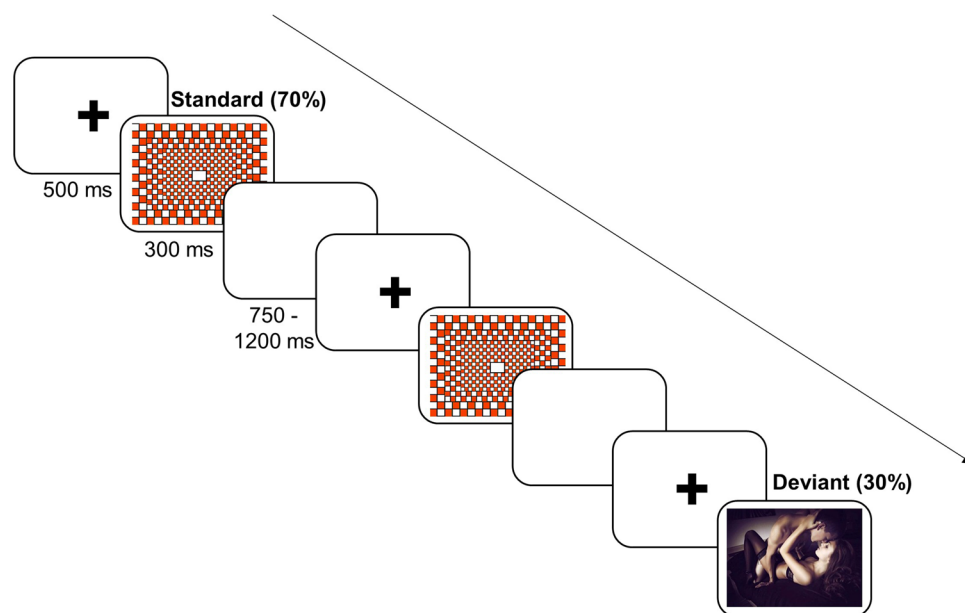
Procedure

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 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 a variable duration between 750 and

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).

Fig. 1 Trial sequence in the oddball task



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 electrooculogram 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 k Ω , 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 nonparametric 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 $p_s > 0.704$). 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 $p_s > 0.068$).

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 toward 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 ($M = 4.13 \mu V$, $SE = 0.61$) compared to high arousal images ($M = 2.31 \mu V$, $SE = 0.54$), while for sexual images, higher P1 amplitudes were observed for high arousal pictures ($M = 4.53 \mu V$, $SE = 0.65$), with low arousal pictures exhibiting lower amplitudes ($M = 2.43 \mu V$, $SE = 0.54$).

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 ($M_{\text{high-arousal}} = -0.40 \mu V$, $SE = 0.80$; $M_{\text{low-arousal}} = 4.76 \mu V$, $SE = 0.66$) and non-sexual negative images ($M_{\text{high-arousal}} = 4.97 \mu V$, $SE = 0.61$; $M_{\text{low-arousal}} = 6.45 \mu V$, $SE = 0.68$), the reverse pattern (high arousal > low arousal) was found for non-sexual positive images ($M_{\text{high-arousal}} = 6.84 \mu V$, $SE = 0.63$; $M_{\text{low-arousal}} = 5.80 \mu V$, $SE = 0.61$).

Peak amplitudes also differed significantly between image categories, $F(2, 108) = 89.91$, $p < .001$, $\eta_p^2 = 0.625$. Sexual images ($M = 2.18 \mu V$, $SE = 0.70$) registered inferior amplitudes compared to non-sexual positive ($M = 6.32 \mu V$, $SE = 0.59$) and negative images ($M = 5.71 \mu V$, $SE = 0.61$). 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 ($M = 3.80 \mu V$, $SE = 0.63$)

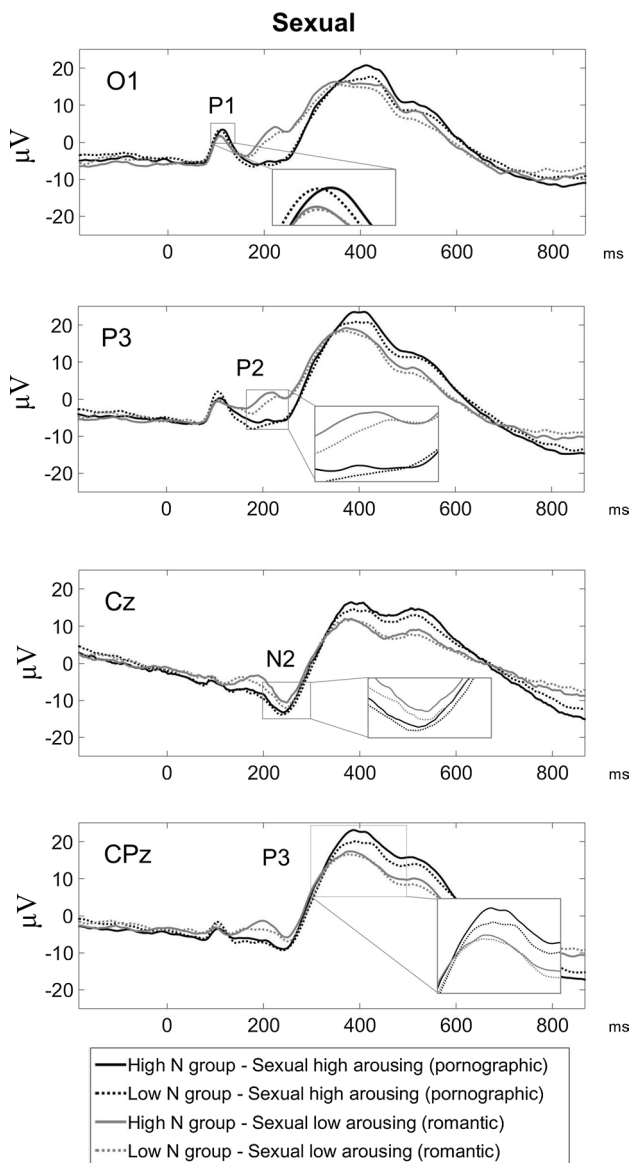


Fig. 2 Grand-average waveforms for sexual images in participants with high neuroticism (high N group) and low neuroticism (low N group) over occipital (O1), parietal (P3), central (Cz) and centro-parietal (CPz) sites

exhibiting lower amplitudes compared to low arousal ones ($M = 5.67 \mu\text{V}$, $SE = 0.61$). 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 ($M = 6.23 \mu\text{V}$, $SE = 0.84$) showed higher peak amplitudes compared to male participants ($M = 3.25 \mu\text{V}$, $SE = 0.87$).

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 ($M = 233.65 \text{ ms}$, $SE = 2.47$) compared to high arousing ($M = 228.23 \text{ ms}$, $SE = 2.93$) 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 ($M = -16.23 \mu\text{V}$, $SE = 0.85$) being associated with higher peak amplitudes than romantic images ($M = -14.03 \mu\text{V}$, $SE = 0.76$).

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 ($M = -15.13 \mu\text{V}$, $SE = 0.77$), and non-sexual negative images ($M = -14.14 \mu\text{V}$, $SE = 0.73$) compared to non-sexual positive images ($M = -13.86 \mu\text{V}$, $SE = 0.70$). 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 ($M = -14.85 \mu\text{V}$, $SE = 0.74$) compared to low arousing ones ($M = -13.90 \mu\text{V}$, $SE = 0.70$).

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 ($M = 246.43 \text{ ms}$, $SE = 2.20$), compared to non-sexual positive ($M = 250.97 \text{ ms}$, $SE = 2.31$) and non-sexual negative images ($M = 251.51 \text{ ms}$, $SE = 2.29$).

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 ($M_{\text{high-arousal}} = 16.69 \mu\text{V}$, $SE = 1.35$; $M_{\text{low-arousal}} = 13.20 \mu\text{V}$, $SE = 1.10$), 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 ($M_{\text{high-arousal}} = 16.79 \mu\text{V}$, $SE = 0.94$; $M_{\text{low-arousal}} = 13.58 \mu\text{V}$, $SE = 0.77$) and non-sexual negative images ($M_{\text{high-arousal}} = 13.00 \mu\text{V}$, $SE = 0.77$; $M_{\text{low-arousal}} = 11.85 \mu\text{V}$, $SE = 0.79$). The interaction between arousal and neuroticism, $F(1, 54) = 4.52$, $p = .038$, $\eta_p^2 = 0.077$, 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, $F(1.68, 90.95) = 114.63$, $p < .001$, $\eta_p^2 = 0.680$, such that higher amplitudes were found for sexual images ($M = 15.19 \mu\text{V}$, $SE = 0.82$), compared to non-sexual negative images ($M = 12.43 \mu\text{V}$, $SE = 0.75$), which in turn registered higher amplitudes than non-sexual positive images

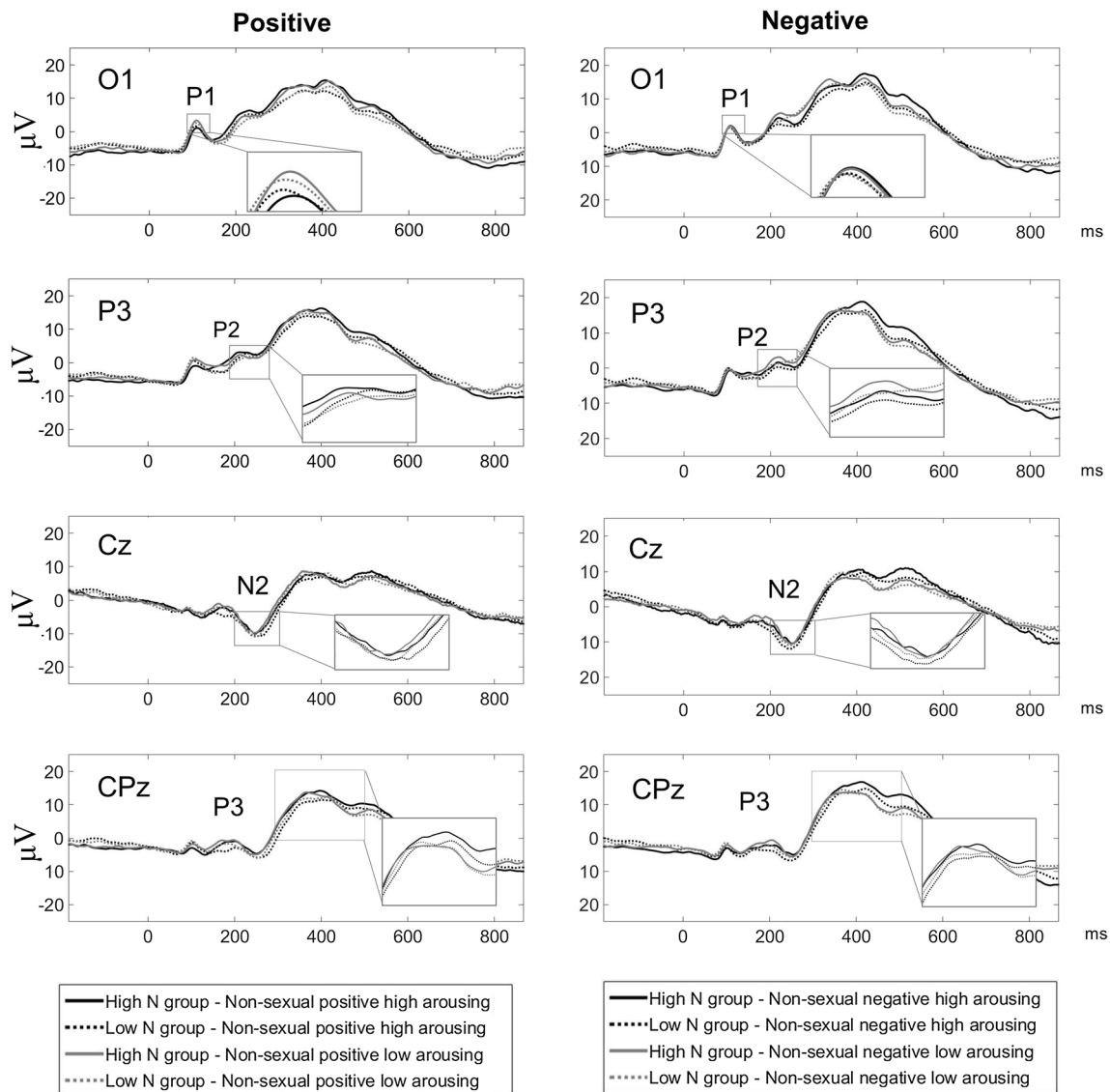


Fig. 3 Grand-average waveforms for non-sexual positive (left panel) and non-sexual negative images (right panel) in participants with high neuroticism (high N group) and low neuroticism (low N group) over occipital (O1), parietal (P3), central (Cz) and centro-parietal (CPz) sites

($M = 10.82 \mu\text{V}$, $SE = 0.74$). The main effect of arousal was also significant, $F(1, 54) = 23.09$, $p < .001$, $\eta_p^2 = 0.300$, with enhanced amplitudes for highly arousing images ($M = 13.58 \mu\text{V}$, $SE = 0.80$) compared to low arousing ones ($M = 12.05 \mu\text{V}$, $SE = 0.74$).

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

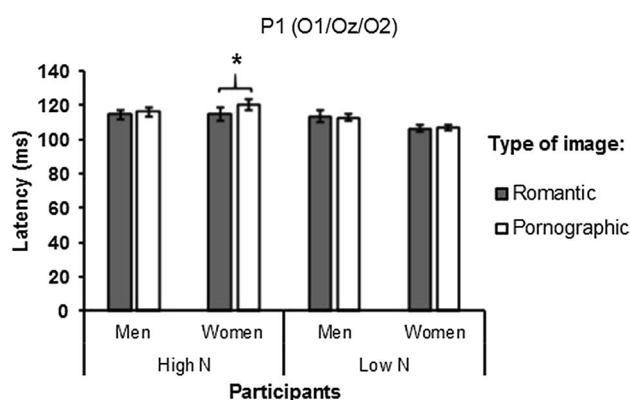


Fig. 4 P1 peak latencies for sexual images (romantic and pornographic), for high neuroticism (high N) and low neuroticism (low N) participants of both sexes. Error bars show standard errors of the mean. * $p < .05$

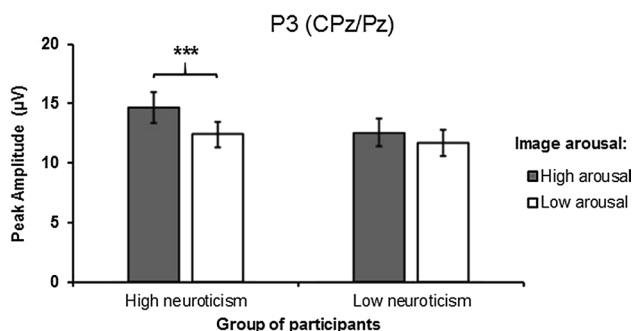


Fig. 5 P3 mean amplitudes for high and low arousal images, for high neuroticism and low neuroticism participants. Error bars show standard errors of the mean. *** $p < .001$

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 toward 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 toward 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 toward 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 toward 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 toward 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 toward 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 toward 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 toward 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.

Funding This research was supported by Fundação para a Ciência e Tecnologia (FCT) with Grant ref. PTDC / PSI-PCL / 117522 / 2010 to

P. N., and by funding from FCT and the POPH/FSE Program with Grant ref. SFRH / BD / 74539 / 2010 to A. P.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Informed Consent 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.

References

- Anokhin, A. P., Golosheykin, S., Sirevaag, E., Kristjansson, S., Rohrbach, 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., Graham, C., & 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/10.1162/08992901753294400>
- 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., & McCrae, R. R. (1992). *Revised NEO personality inventory (NEO PI-R) and NEO five-factor inventory (NEO FFI): professional manual*. Psychological Assessment Resources.
- Costa, P. T., & McCrae, R. R. (2000). *NEO PI-R: Manual Profissional: NEO PI-R, Inventário de Personalidade NEO Revisão*. 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). Elsevier Academic Press. Retrieved <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%3c463::AID-PER393%3e3.0.CO;2-3](https://doi.org/10.1002/1099-0984(200009/10)14:5%3c463::AID-PER393%3e3.0.CO;2-3)
- Fagan, P. J., Wise, T. N., Schmidt, C. W., Jr., Ponticas, Y., Marshall, R. D., & Costa, P. T., Jr. (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*. 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](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 S. G. Hofmann (Ed.), *The Wiley handbook of cognitive behavioral therapy* (Vol. II, pp. 645–672). Hoboken, NJ: 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). Hoboken, NJ: Wiley-Blackwell. 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., Siltan, R. L., Stewart, J. L., Crocker, L. D., Edgar, J. C., Minnaugh, K. J., & 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., & 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: Electrodermal responses to positive and negative stimuli. *Neuropsychologia*, 41(2), 171–183. [https://doi.org/10.1016/S0028-3932\(02\)00147-1](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). Routledge.
- Spiering, M., & Everaerd, W. (2007). The sexual unconscious. In E. Janssen (Ed.), *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.biopsycho.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](https://doi.org/10.1016/S0191-8869(97)00153-0)
- Ziogas, A., Habermeyer, E., Santtila, P., Poepl, 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>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.