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Autistic Traits and Brain Responses to Facial Expressions in Adults

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"Recomeça… se puderes, sem angústia e sem pressa. E os passos que deres, nesse caminho duro do futuro, dá-os em liberdade. Enquanto não alcances, não descanses. De nenhum fruto queiras só a metade."

- Miguel Torga

Resumo

O papel dos traços autísticos nas respostas neurais, nomeadamente nos potenciais relacionados a eventos (ERPs), às expressões faciais de emoção continua a ser um tema de debate. Assim, este estudo pré-registado investiga como os traços de autismo, medidos pelo Autism Quotient (AQ-50), influenciam a amplitude e a latência dos componentes P1 e N170 dos ERPs, conhecidos respetivamente pelos seus papéis no processamento visual inicial e no processamento de faces, ao longo das dimensões emocionais de valência e excitação. Uma amostra não clínica de 74 participantes adultos (M_{idade} = 23.41, *SD* = 2.71) foram avaliados através de uma tarefa de processamento emocional incidental utilizando o conjunto de estímulos faciais *NimStim*, onde as expressões faciais foram categorizadas com base nos seus níveis de valência e excitação. Os resultados indicam que os estímulos de baixa excitação elicitaram latências P1 mais longas e amplitudes maiores, sugerindo um maior envolvimento neural com rostos menos emocionalmente intensos. Para o componente N170, o hemisfério direito apresentou amplitudes consistentemente maiores, destacando o seu papel no processamento das emoções faciais. Além disso, os resultados revelaram interações significativas entre os traços de autismo e as dimensões emocionais, com traços de autismo mais elevados associados a respostas neurais moduladas, particularmente em termos de categorização emocional e covariáveis de competências sociais. Esta investigação contribui para a compreensão das subtilezas da perceção emocional em adultos com traços autistas subclínicos, sugerindo implicações para futuras intervenções direcionadas ao funcionamento social e emocional.

Palavras-chave: expressões faciais emocionais, traços de autismo, ERPs, respostas cerebrais.

Abstract

The role of autistic traits on neural responses, namely event-related potentials (ERPs), to facial expressions of emotion is still a topic of debate. As such, this pre-registered study investigates how autistic traits, as measured by the Autism Quotient (AQ-50), influence the amplitude and latency of the P1 and N170 ERP components, known respectively for their roles in early visual and face processing, across emotional dimensions of valence and arousal. A non-clinical sample of 74 adult participants (M_{age} = 23.41, *SD* = 2.71) was assessed through an incidental emotion processing task utilizing the NimStim face stimulus set, where facial expressions were categorized based on their valence and arousal levels. Results indicate that lower arousal stimuli elicited longer P1 latencies and larger amplitudes, suggesting increased neural engagement with less emotionally intense faces. For the N170 component, the right hemisphere showed consistently larger amplitudes, highlighting its role in facial emotion processing. Moreover, findings revealed significant interactions between autistic traits and emotional dimensions, with higher autistic traits associated with modulated neural responses, particularly regarding emotion categorization and social skill covariates. This research contributes to understanding the subtleties of emotion perception in adults with subclinical autistic traits, suggesting implications for future interventions targeting social and emotional functioning.

Keywords: emotional facial expressions, autistic traits, ERPs, brain responses.

Introduction

In contemporary discourse, Autism Spectrum Disorder (ASD) has garnered significant societal focus, primarily attributed to heightened awareness and earlier detection practices. This trend towards earlier diagnoses has catalyzed more effective clinical interventions, thus enhancing the overall management and intervention of ASD. The behavioral characteristics associated with this disorder typically manifest in early childhood and persist throughout developmental stages. However, a subset of individuals who receive their initial diagnosis in adulthood, often report the use of compensation strategies and coping mechanisms to conceal their social difficulties. ASD is associated with neurodevelopmental deficits, characterized by difficulties in communication and social interaction and restricted and repetitive patterns of behavior, interests, and activities (American Psychiatric Association, 2013). These characteristics are distributed across a continuous spectrum of individuals, considering their abilities and levels of functioning. Some may exhibit mild traits and function effectively in social and professional contexts, while others may face more substantial challenges. These traits encompass a range of dimensions, including behavioral, cognitive, and emotional factors, such as sensory sensitivities, detailed patterns of thinking, and fixation on specific interests (Happé & Frith, 2020; Masi et al., 2017). Additionally, many individuals outside the formal diagnosis of ASD may still exhibit certain autistic traits due to genetic overlap, reflecting the neurobiological and genetic basis of these traits (Charman et al., 2017). Importantly, these traits should not be viewed solely as deficits but as variations contributing to cognitive diversity, as individuals with autistic traits often display strengths in areas such as attention to detail, creativity, and innovative thinking (Baron-Cohen, 2009). Thus, autistic traits are personality characteristics that reflect the expression of the ASD phenotype across the general population.

Autistic Traits and Facial Expressions of Emotion

The face is essential for communication and social interaction, facilitating the rapid conveyance of pertinent information regarding identity, emotional expression, and the focus of attention with gaze direction (Nomi & Uddin, 2015). Central to this non-verbal communicative prowess is the recognition of facial expressions, enabling the interpretation of muscular configurations and movements to discern underlying emotions to which a given expression is most similar (Wilhelm et al., 2014). The cognitive processing of emotional stimuli encompasses initial perception, the generation, and recognition of physiological responses and emotional cues, as well as semantic and cognitive categorization (Faja et al., 2016). Such processes enable individuals to modulate their behavior through perceived stimuli, thereby selecting positive stimuli and avoiding negative ones (Gross et al., 2006).

Despite the critical role of facial expression processing in social interaction, individuals with higher autistic traits often exhibit challenges in this domain, characterized by reduced precision and longer reaction time (Nomi & Uddin, 2015). Consequently, their ability to engage in global recognition, wherein the face is perceived holistically to convey expressions, is notably compromised. This impairment underscores the dynamic nature of emotional perception and judgment, contributing to variations in individual interpretations (Sander, 2013).

Furthermore, facial expressions convey crucial information about emotional states and intentions rapidly and efficiently, allowing individuals to adjust their behavior according to the emotional responses of others. However, individuals with ASD often experience difficulties in recognizing facial expressions, which can significantly impair their social interactions. These challenges not only affect immediate communication but also have long-term implications for developing social skills throughout life (Uljarevic & Hamilton, 2013).

Within the scientific discourse surrounding the conceptualization of emotion, Russel (1980) suggested the circumplex model of affect, which elucidates the intricate composition of emotions, distilling them into non-emotional elements discernible along independent, distinct dimensions (Russell, 2005). This model scrutinizes two major dimensions, namely valence and arousal, emphasizing their significance along a unidimensional continuum. Therefore, emotions are typically categorized along a spectrum of positive or negative valence, reflecting the evaluative processes directed toward the stimuli that elicit them. This paradigm shift has catalyzed advancements in bidirectional theories and elucidated hemispheric disparities (Sander, 2013). Moreover, alongside valence (pleasant and unpleasant), arousal is also important in discerning an individual’s activation level in response to emotional stimuli (Russell & Barrett, 2009). Whether a theory prioritizes the primacy of valence and arousal or not of emotion, it is widely acknowledged that only specific events perceived as salient provoke emotions within a particular time course (Sander, 2013)**.**

ERPs and Face Processing

As previously highlighted, the discernment of facial expressions of emotions and their cognitive processing are intrinsically linked to distinct cerebral networks and specialized brain regions. Consequently, a methodological avenue facilitating the observation of these cognitive mechanisms entails Electroencephalography (EEG), which elucidates the temporal dynamics of neural activity. Specifically, the examination of event-related potentials (ERPs), represented by distinctive waveforms, delineates various stages of sensory and cognitive processing elicited by the response to a specific stimulus (Feuerriegel et al., 2015). Studies utilizing ERPs in populations with ASD have revealed distinct neural activity patterns, suggesting fundamental differences in the processing of social and emotional information. Notably, the P1 and N170 components are recurrently used in face perception and processing investigations.

The P1 component manifests as a positive deflection within the ERPs, typically emerging around 100 milliseconds after the onset of a stimulus presentation (Hileman et al., 2011) and is associated with initial visual processing. Empirical investigations have consistently underscored a significant enhancement in P1 amplitude in response to facial stimuli relative to alternative stimuli categories, indicative of a sensitivity directed towards faces (Itier & Taylor, 2004). Furthermore, scholarly inquiry suggests that the magnitude of the P1 response is subject to modulatory influences, such as individual developmental trajectories as well as the nature of the task under consideration (Hileman et al., 2011). Regarding the developmental aspect, the latency and amplitude of the P1 component decrease with age, reflecting the maturation of stimulus processing speed (Itier & Taylor, 2004; Taylor et al., 2001). Consequently, variations in P1 latency and amplitude are linked to the allocation of attentional resources toward the stimulus (Mangun, 1995).

In turn, the N170 component, characterized by a negative waveform, is a prominent feature within the paradigm of ERPs, typically elicited approximately 170 milliseconds post-stimulus presentation, with a temporal range spanning from 140 to 200 milliseconds (O'Connor et al., 2005). Remarkably, many studies consistently underscore the heightened sensitivity of the N170 response to human facial stimuli in contrast to other stimuli categories. This component seems to have a larger amplitude within the right hemisphere of the cerebral cortex in the presence of facial stimuli (Bentin et al., 1996), particularly localized in the posterior temporal region, where there is a larger negative amplitude and a shorter latency in response to such stimuli (Webb et al., 2012). Moreover, scholarly literature suggests a modulation of N170 amplitude contingent upon the emotional valence of facial expressions. Some studies indicate a larger N170 amplitude to facial expressions portraying emotional affect compared to neutral expressions, and it is sometimes suggested that this effect is more prominent in response to unpleasant emotional expressions (Faja et al., 2016). However, when the activation of facial expressions was controlled, the modulation of the N170 was found to depend on the emotional activation/intensity perceived in the emotional expression, regardless of valence (Almeida et al., 2016).

Autistic Traits: Brain Responses to Facial Expressions and ERPs Modulation

The literature suggests that certain ERPs hold promise in elucidating neuronal differences associated with ASD (Kang et al., 2018). However, there is a notable paucity of studies examining autistic traits in the adult population, as compared to the extensive body of research focused on children with the same conditions.

A study by Stavropoulos et al. (2018) associates individuals with higher autistic traits with delayed ERP components, which means longer latencies, suggesting a reduced facial perception in this group. Specifically, about the latency of the P1 component, individuals with higher autistic traits exhibit longer latencies compared to those with lower autistic traits (Stavropoulos et al., 2018). Additionally, a meta-analysis encompassing 18 studies reveals that P1 latency in ASD groups is substantially longer compared to control groups (Kang et al., 2018). This finding aligns with existing literature, which indicates that individuals with lower autistic traits demonstrate a faster N170 response than those with higher autistic traits (DuBose Sherman, 2016; McPartland et al., 2004). Consistent with other studies, individuals with higher autistic traits appear to exhibit larger P1 amplitudes compared to those with lower autistic traits (Cygan et al., 2014).

Regarding the amplitude of the N170 component, the literature presents contradictory findings. Some studies report larger (more negative) N170 amplitudes in the control group compared to the ASD group (Churches et al., 2012), while others identify a negative relationship between N170 amplitude and autistic traits, with individuals exhibiting higher autistic traits having larger N170 amplitudes for faces (DuBose Sherman, 2016). Additionally, several studies have found no statistically significant differences in N170 amplitude across varying levels of autistic traits (Churches et al., 2010; Kang et al., 2018; McPartland et al., 2004; Stavropoulos et al., 2018). In addition to the previously mentioned, some studies report no significant differences in amplitudes and latencies of the P1 e N170 components, regardless of the level of autistic traits (De Pascalis et al., 2020; Desai et al., 2019).

Current Study

In addition to the limited literature on autism traits and ERPs for stimuli of facial expressions of emotion in the adult population, the existing studies exhibit significant disagreements regarding the effects of higher or lower autistic traits on the neural processing of facial expressions. This variability in findings poses challenges for understanding the underlying mechanisms and necessitates further investigation to elucidate the neural correlates of emotion processing in individuals with varying levels of autistic traits. Understanding these dynamics can inform both clinical practice and provide valuable insights for the development of more effective interventions and support policies.

Therefore, this study aims to evaluate whether different levels of autistic traits influence the modulation of the amplitude and latency of P1 and N170 in the perception of facial expressions of emotion. The study was pre-registered on February 26, 2024 on the OSF platform (see https://doi.org/10.17605/OSF.IO/2VMB7). According to the literature mentioned above and the postulated objective, the proposed hypothesis is as follows: (H1) higher autistic traits in adults are related to longer P1 latencies; (H2) higher autistic traits in adults are related to longer N170 latencies; (H3) higher autistic traits in adults are related to larger P1 amplitudes. Due to the contradictory literature regarding the relationship between autistic traits and N170 amplitude, an exploratory analysis will be conducted to better understand the association. For the same reason, an exploratory analysis will be conducted to better understand the association between emotional categories and autistic traits.

Method

Participants

Ninety-six adults were recruited from the community via email and social media posts to participate in the study. The exclusion criteria were lack of normal or corrected vision, history of possible motor, neurological, sensory, and psychiatric developmental problems, such as cognitive and linguistic disability or delay, epilepsy, and cases of head trauma, among others. Participants who presented substance abuse or had a history of such abuse were also excluded. Likewise, taking medications related to the disorders previously presented was an exclusion criterion. A total of 22 participants were excluded from the sample for the following reasons: 4 participants did not meet the initial inclusion criteria described above, 7 participants had less than 50% of the total EEG channels available, and 11 participants had less than 40% of epochs per condition. Thus, the final sample consisted of 74 participants between 19-30 years old (38 female, M_{age} = 23.41, *SD* = 2.71).

The study procedures followed the Declaration of Helsinki, ensuring compliance with ethical principles for conducting clinical research involving human participants. This project is part of a larger PhD project undertaken by Rita Almeida, funded by the FCT (PD/BD/150480/2019; COVID/BD/153567/2024), and has received a favorable opinion from the Ethics Committee of the Faculty of Psychology and Educational Sciences of the University of Porto. Permission to use the NimStim stimuli set was obtained in the context of the aforementioned PhD project. All participants provided informed consent at the beginning of the experiment, and the procedures and tasks to be performed were thoroughly explained to them.

Materials

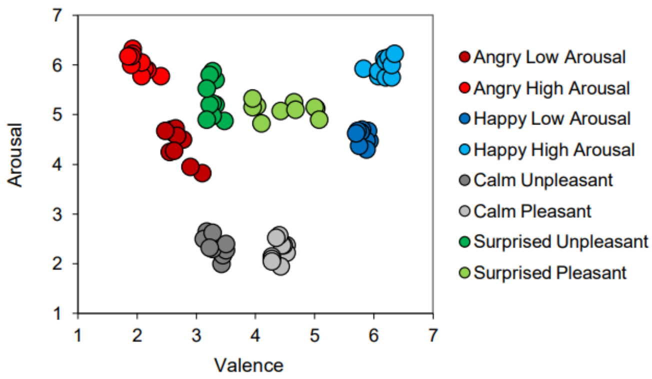
Experimental Task

To collect ERP data, a Facial Emotion Viewing Task was carried out, utilizing the NimStim Face Stimulus Set (Tottenham et al., 2009). From this set we selected 80 distinct facial expressions of emotion, selected based on their valence and arousal levels, and validated through prior self-report assessments (Ferreira Santos, 2013). To maintain participant attention, a neutral stimulus, specifically an image of a chair, was intermittently displayed. Participants were instructed to press a button in response to this chair image, which appeared randomly among the facial stimuli.

The task was designed to contrast different emotional expression categories but also different levels of valence and arousal: anger (intrinsically unpleasant) and happiness (pleasant) facial expressions were selected to create subsets of low and high activation, while calm (intrinsically low arousal) and surprise (high arousal) expressions were selected to generate pleasant and unpleasant valence subsets. Each condition (anger low arousal, anger high arousal, happiness low arousal, happiness high arousal, calm pleasant, calm unpleasant, surprise pleasant, surprise unpleasant) included 10 different stimuli. Each stimulus was presented five times during the task. These final stimuli (see Appendix 1) were selected from expressions derived from a reference database (N = 40, young adults, 20 female) that were obtained and tested in a prior study (Ferreira Santos, 2013). Figure 1 illustrates the distribution of each stimulus in terms of arousal and valence.

Figure 1

Scatterplot of valence and arousal ratings for the selected stimuli



Note. This figure was from reference data, reprinted with permission from Ferreira-Santos, 2013, p. 208.

Each trial began with a fixation cross displayed at the center of the screen with a variable duration (800 – 1000 ms), followed by a facial stimulus presented for 500 ms. The entire experiment had a total of 430 trials, segmented into eight conditions with 50 trials each, plus 30 trials featuring the target chair image. The primary focus of the analysis will be on the mean amplitude and peak latency of the P1 and N170 components of ERPs.

Measures

Additionally, participants were assessed for autistic traits using the Autism Quotient (AQ-50) (Baron-Cohen et al., 2001) in the adult version, adapted for the Portuguese population as the Spectrum Quotient Autistic Adult Version (16+ years) (Castro & Lima, 2010). This assessment was administered online. The AQ-50 allows the quantification of the presence of autistic traits through 50 statements, which participants respond to using a 4-point Likert scale (Definitely agree, Slightly agree, Slightly disagree, Definitely disagree). Responses indicative of typical autistic behaviors are scored as 1 point, while other responses receive 0 points, leading to a maximum possible score of 50.

The AQ-50 evaluates five subscales: social skill, attention switching, attention to detail, communication, and imagination. In the original version, the internal consistency of each of these five subscales ranged from moderate to high, with Cronbach's alpha values as follows: Communication = .65, Social Skill = .77, Imagination = .65, Attention to Detail = .63, and Attention Switching = .67.

However, the Portuguese adaptation of the AQ-50 revealed a very poor fit with the original dimensions, indicating that the imposed hypothetical structure mentioned above was problematic. The final model supported the factor structure of three factors: Social Skills, Communication, and Restricted Interests and Detail Orientation (RIDO). The Social Skills factor comprised 10 items, yielding a Cronbach's alpha value of .83. The Communication factor included 7 items, with a Cronbach's alpha of .74. The RIDO factor consisted of 6 items, with a Cronbach's alpha value of .68. All three factors demonstrated good levels of internal consistency (Barros et al., 2022). The assessment utilizing these three factors provided a comprehensive measure of autistic traits using the AQ-50 adapted for the Portuguese population among the participants.

Procedure

Before the data collection day, participants completed the AQ-50 measure via Qualtrics in an online format, having provided their consent to be able to respond.

On the scheduled day for the in-person portion of the study, participants once again provided informed consent, this time signed on paper. They were given all the necessary information and had the opportunity to clarify any doubts they had. In the data collection chamber, the EEG device was then set up while participants were seated comfortably. During the EEG Emotional Visualization task previously described, participants were instructed to view different faces and press a button on the controller whenever an image of a chair appeared. The presentation of the target chair stimuli served to maintain the participants' attention throughout the experiment. To minimize fatigue, the trials were divided into two equal blocks with a short break in between. The stimuli were presented in a random order. The task was administered using E-Prime v2.0 software (Psychology Software Tools, Pittsburgh, PA, USA) on a 17-inch screen positioned 1.15 meters from the participant. The facial stimuli subtended a horizontal visual angle of 7.46° and a vertical visual angle of 11.91°. EEG data were recorded using a 128-channel NetAmps EEG system (Electrical Geodesics Inc., EGI, Eugene, OR, USA).

EEG Recording and Signal Pre-Processing

In order to ensure that the collected EEG data were suitable for analysis, pre-processing was conducted using the Harvard Automated Processing Pipeline for Electroencephalography (HAPPE; Gabard-Durnam et al., 2018), specifically employing the event-related extension (HAPPE+ER; Monachino et al., 2022). This process utilizes analysis functions from EEGLAB 2.1 (Delorme & Makeig, 2004), with the script running in the MATLAB Release (2021a, The

Mathworks, Inc., Massachusetts, USA), as detailed in Appendix 2. The sensitivity of the HAPPE procedures facilitates the retention and averaging of a greater number of trials, even in cases of high-variance data.

During pre-processing, firstly, channels with bad data were detected and removed, such as those that exhibited excessive noise, flatlining, or significant. A hard wavelet threshold was applied to eliminate artifacts from the continuous EEG data, improving upon earlier artifact detection methods by retaining more of the EEG signal rather than discarding entire segments at this stage. Then filtering and segmentation were performed. A bandpass filter ranging from 0.1 to 30 Hz was applied to focus on the frequencies of interest. The data were then segmented into epochs, spanning 200 milliseconds before stimulus presentation and 800 milliseconds post-stimulus. Afterward, the segmented data underwent baseline correction, a technique in which the average EEG signal recorded during the pre-stimulus period for each epoch is subtracted from the post-stimulus data. This process reduces noise and ensures data standardization across trials. Finally, in cases where corrupted data were detected within segments, these bad channels were replaced via spherical spline interpolation based on data from surrounding electrodes. Additionally, data were re-referenced offline to the average of all electrodes. Finally, segments were rejected based on a joint probability criterion and amplitude cutoffs of -150 to 150 microvolts. There were no significant differences between conditions in the final number of valid trials (repeated measures ANOVA with condition as factor (8 levels), $F(7,511) = 0.74$, $p > .005$, $\eta^2 = .01$), so no other subject was excluded other than those previously reported. In this manner, the components of interest were subsequently extracted, specifically the mean amplitude and peak latency of the P1 and N170 components of ERPs. Table 1 provides a summary of the extracted measures.

Table 1

Summary of the parameters used to ERP components quantification regarding amplitude

Component	Hemisphere	Electrodes	Equivalent 10-20 region (aprox.)	Latency window	Measure
P1	Left	65, 66, 69, 70, 71	O1	[90, 190] ms	Mean amplitude Peak latency
	Right	76, 83, 84, 89, 90	O2	[90, 190] ms	Mean amplitude Peak latency
N170	Left	50, 51, 58, 59, 64, 65	PO7	[120, 220] ms	Mean amplitude Peak latency
	Right	90, 91, 95, 96, 97,	PO8	[120, 220] ms	Mean

	101	amplitude Peak latency

Note. Electrode notation corresponds to the 128-channel HydroCel Geodesic Sensor Net (EGI).

Statistical Analysis

Data analysis was performed using SPSS version 27 (IBM Statistics, 2020, New York, USA).

To investigate the effect of emotion and the affective properties on our dependent measures of P1 and N170 amplitudes and latencies, we implemented two experimental designs, each addressing different levels of emotional categories related to facial stimuli: the Arousal Design (which allows for the distinction of various arousal levels within the same emotional categories) and the Valence Design (which allows for the distinction of different valences within the same emotional categories). In this framework, the factor of affective properties varied: when comparing happiness and anger expressions, the within-category affective property manipulated was the level of arousal, while when comparing calm and surprised expressions, the affective property varied in terms of valence. This is because there is collinearity between emotional categories and affective properties (e.g., the emotion happiness is always positive in valence so that it cannot be dissociated from the valence level).

Therefore, in the Arousal Design, we employed ANCOVA with three within-participants experimental factors (Hemisphere, with the right and left; Emotional Categories, with levels of Anger and Happiness; and Arousal, with levels Low and High) and a covariate corresponding to the AQ total score. In the Valence Design, we utilized ANCOVAs with two within-participants experimental factors (Hemisphere, with the right and left; Emotional Categories, with levels Calm and Surprise; and Valence, with levels Pleasant and Unpleasant) and a covariate corresponding to the AQ total score. Also, for each design, ANCOVAs were conducted with each AQ subscale as covariates.

The threshold for statistical significance in all analyses was set at $\alpha = .05$. To account for violations of sphericity, the Greenhouse-Geisser correction was applied. Significant results were further analyzed using Sidak-corrected post-hoc comparisons.

Results

Descriptive statistics for the amplitudes and latencies of the components across conditions are presented in Table 2. Time-course plots of the ERP for each condition are provided below for the analyzed components.

Table 2

Mean Amplitudes and Latencies (SD in Parenthesis) of ERP Components in the Left and Right Hemisphere by Condition

Hemisphere	Measure	Conditions							
		Anger low	Anger high	Happiness low	Happiness high	Calm pleasant	Calm unpleasant	Surprise pleasant	Surprise unpleasant
Left	Amplitude (μV)								
	P1	1.55 (1.76)	1.42 (1.68)	1.36 (1.68)	1.15 (1.57)	1.88 (1.73)	1.69 (1.76)	1.18 (1.84)	1.46 (1.81)
	N170	1.00 (1.37)	0.86 (1.54)	0.91 (1.34)	0.82 (1.34)	1.23 (1.44)	1.14 (1.61)	0.68 (1.71)	0.91 (1.50)
	Latency (ms)								
	P1	140.67 (23.08)	138.22 (19.75)	140.97 (22.52)	139.15 (21.65)	140.24 (21.92)	145.64 (23.47)	140.88 (22.69)	137.50 (21.07)
	N170	175.56 (19.47)	178.18 (17.28)	176.33 (17.57)	176.52 (18.46)	174.13 (20.49)	173.62 (16.80)	175.15 (18.86)	174.45 (18.52)
Right	Amplitude (μV)								
	P1	1.90 (1.85)	1.73 (2.08)	1.73 (1.85)	1.44 (1.89)	2.08 (2.02)	2.03 (2.16)	1.78 (2.01)	1.83 (1.94)
	N170	1.71 (1.93)	1.59 (1.92)	1.76 (1.80)	1.58 (1.82)	1.90 (2.12)	1.98 (1.87)	1.80 (1.95)	1.70 (1.90)
	Latency (ms)								
	P1	141.86 (19,98)	134.71 (14.74)	139.62 (19.64)	138.27 (21.10)	141.01 (21.37)	142.51 (19.52)	139.16 (18.75)	135.75 (17.53)
	N170	175.41 (15.76)	181.86 (13.24)	174.89 (17.13)	175.57 (14.93)	174.62 (17.29)	173.45 (16.86)	173.96 (15.85)	174.87 (16.42)

ANCOVA with the AQ Total Score as Covariate

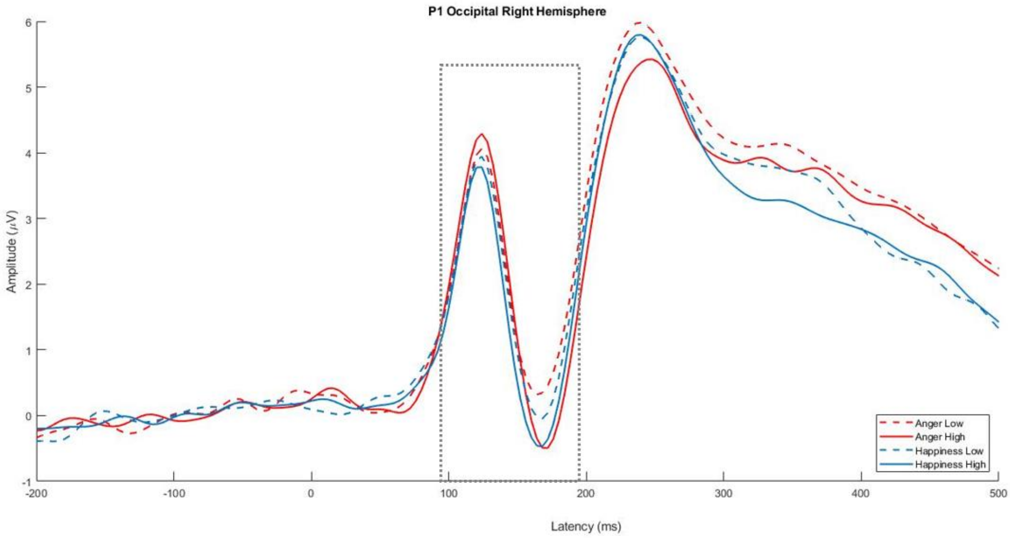
P1 mean amplitude. There were no significant effects regarding the Arousal Design or the Valence Design.

P1 peak latency. For the Arousal Design, there was a significant main effect of Arousal, $F(1,72) = 4.54$, $p = .04$, $\eta^2_p = .06$. Specifically, low arousal ($M = 140.78$, $SE = 1.99$) elicited longer response latencies compared to high arousal ($M = 137.59$, $SE = 1.74$), with this difference reaching statistical significance ($p = .01$). However, no further significant effects were found.

Conversely, no significant effects were identified for the Valence Design.

Figure 2

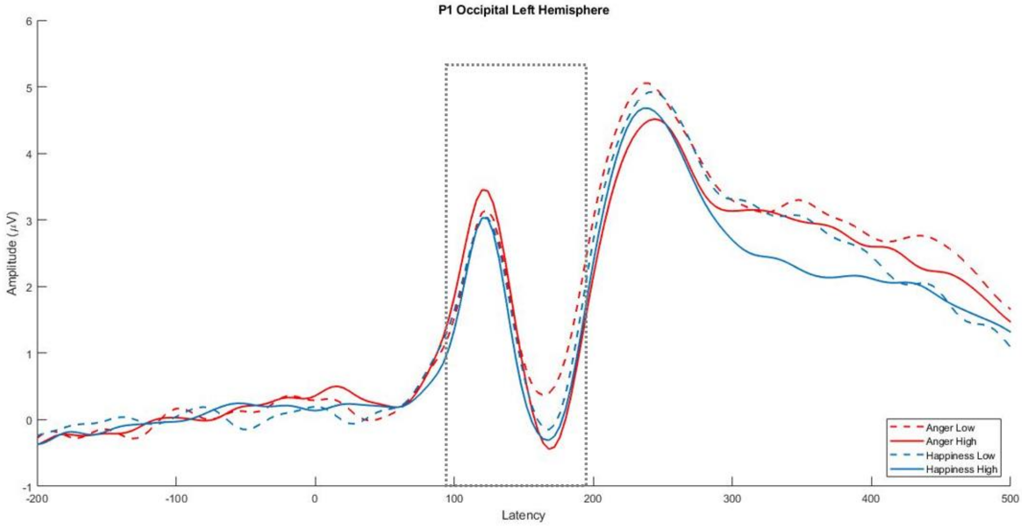
ERP grand averages at P1 occipital electrode locations for Anger/Happiness in the Right Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

Figure 3

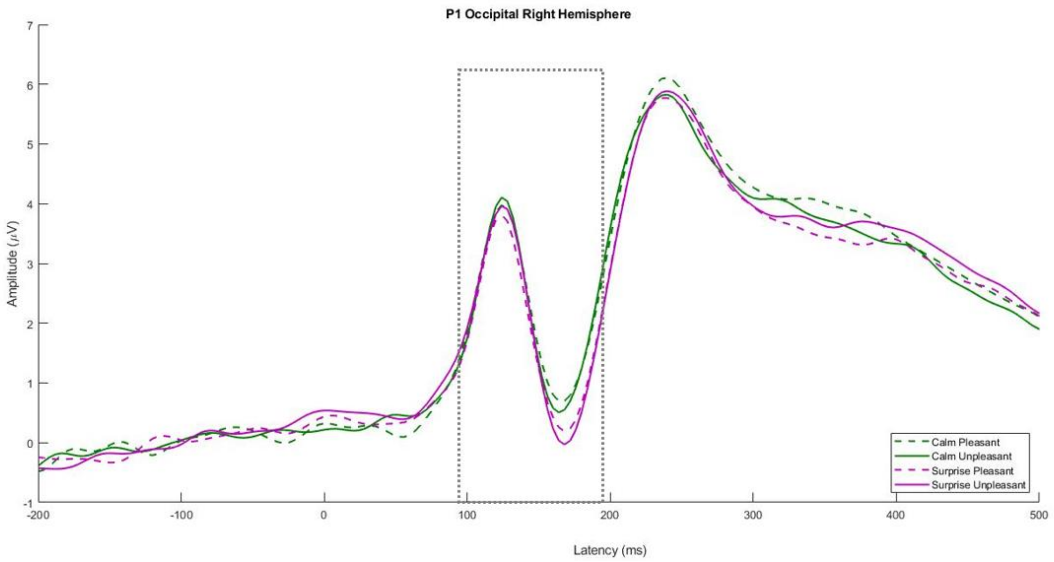
ERP grand averages at P1 occipital electrode locations for Anger/Happiness in the Left Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

Figure 4

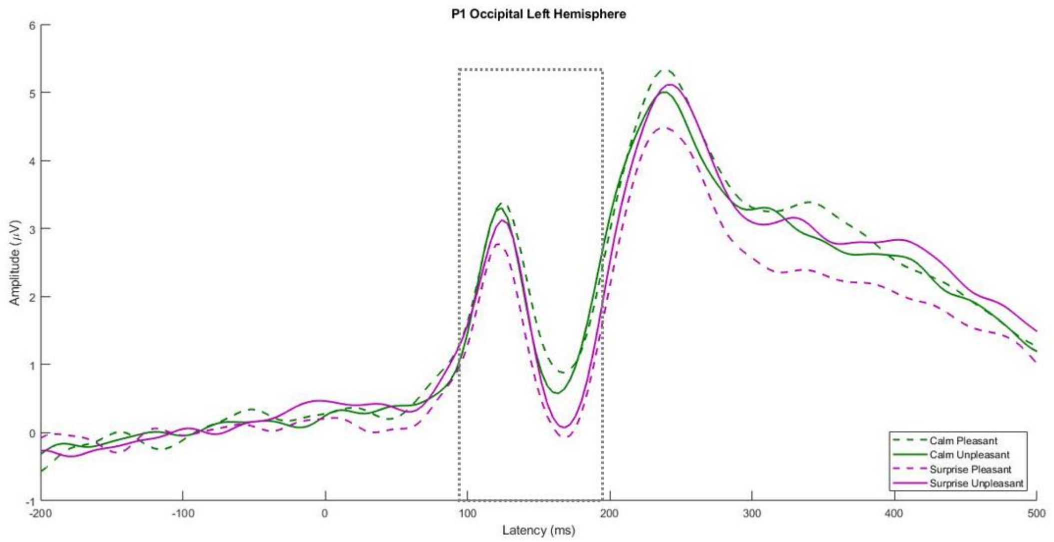
ERP grand averages at P1 occipital electrode locations for Calm/Surprise in the Right Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

Figure 5

ERP grand averages at P1 occipital electrode locations for Calm/Surprise in the Left Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

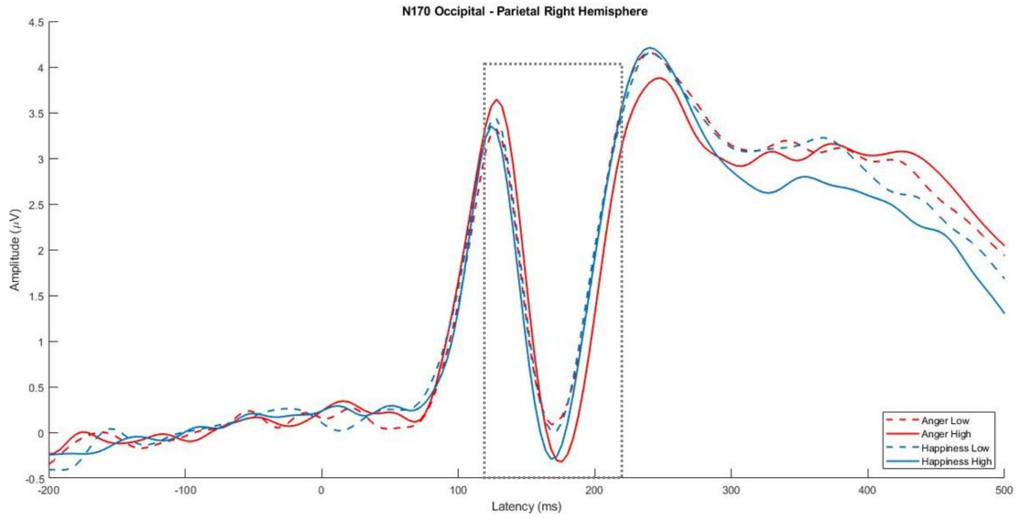
N170 mean amplitude. No significant effects were observed for the Arousal Design and the Valence Design.

N170 peak latency. A significant interaction of the Hemisphere by Arousal regarding the Arousal Design was reported, $F(1,72) = 5.64$, $p = .02$, $\eta^2_p = .07$. Decomposing this interaction for each Hemisphere, in the Right Hemisphere, we found two main effects: Emotion, $F(1,73) = 11.53$, $p = .001$, $\eta^2_p = .14$, with anger ($M = 178.63$, $SE = 1.49$) elicited longer latencies compared to happiness ($M = 175.23$, $SE = 1.75$) ($p = .001$); and Arousal, $F(1,73) = 10.94$, $p = .001$, $\eta^2_p = .13$, with high arousal ($M = 178.71$, $SE = 1.46$) elicited longer latencies compared to low arousal ($M = 175.15$, $SE = 1.81$) ($p = .001$). There was also a significant interaction between Emotion and Arousal in the Right Hemisphere, $F(1,73) = 8.81$, $p = .004$, $\eta^2_p = .11$. Decomposing this interaction by each emotion, we found a main effect of arousal in anger, $F(1,73) = 16.34$, $p < .001$, $\eta^2_p = .18$, with high arousal ($M = 181.86$, $SE = 1.54$) elicited longer latencies compared to low arousal ($M = 175.41$, $SE = 1.83$) ($p < .001$). No effects of arousal for happiness in the Right Hemisphere were observed. Also, no significant effects were observed for the left Hemisphere. Additionally, the interaction between Hemisphere x Arousal x AQ total score was also significant, $F(1,72) = 4.41$, $p = .04$, $\eta^2_p = .06$. When decomposing the emotion by arousal and considering the AQ covariate separately for each Hemisphere, a main effect of Arousal was found in the Right Hemisphere, $F(1,72) = 5.98$, $p = .02$, $\eta^2_p = .08$. Specifically, high arousal ($M = 178.71$, $SE = 1.46$) elicited longer latencies compared to low arousal ($M = 175.15$, $SE = 1.78$) ($p = .001$). No significant effects were found in the left hemisphere. Also, no other significant effects were detected regarding the Arousal Design.

For the Valence Design, the Emotion by Valence interaction was significant, $F(1,72) = 4.03$, $p = .05$, $\eta^2_p = .05$. Decomposing this interaction for each emotion, neither the calm nor the surprise condition revealed significant effects regardless of the hemisphere or the valence. The Emotion x Valence x AQ total score was also significant, $F(1,72) = 5.26$, $p = .03$, $\eta^2_p = .07$. No significant effects were found in the surprise condition when decomposing the interaction between Emotion x Valence x AQ scores. In contrast, in the calm condition, a significant interaction was observed between Valence x AQ total score, $F(1,72) = 4.30$, $p = .04$, $\eta^2_p = .06$. When decomposing the Valence of Calm considering the AQ covariate for each valence, no significant effects were found in the pleasant and unpleasant calm. There were no other effects regarding the Valence Design.

Figure 6

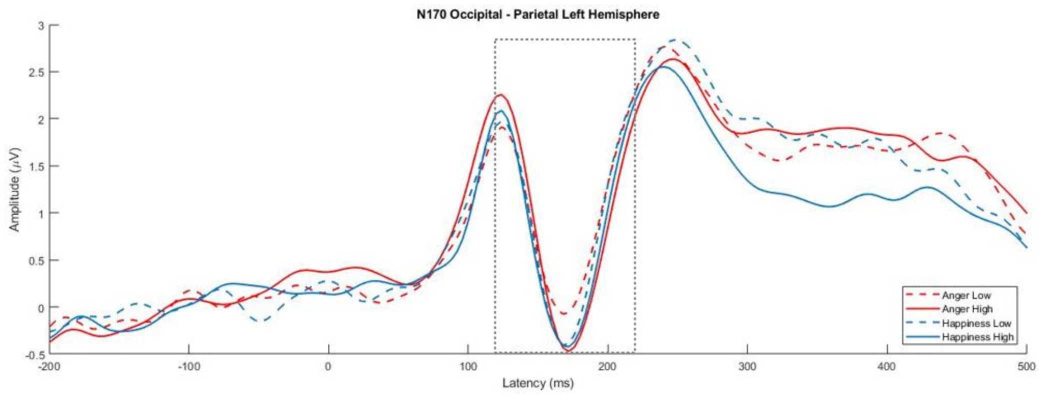
ERP grand averages at N170 occipital-parietal electrode locations for Anger/Happiness in the Right Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

Figure 7

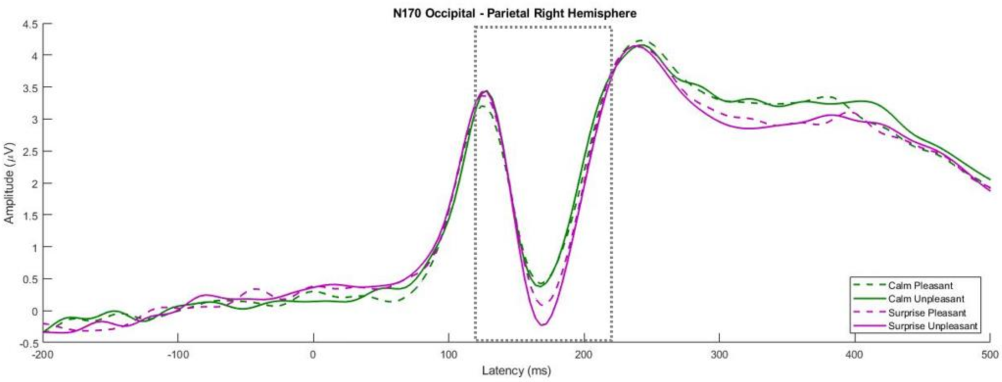
ERP grand averages at N170 occipital-parietal electrode locations for Anger/Happiness in the Left Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

Figure 8

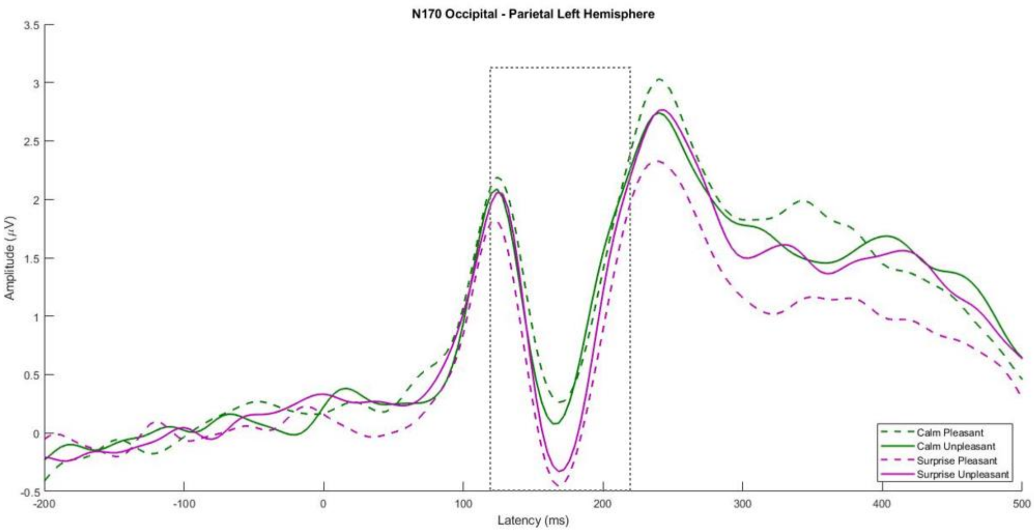
ERP grand averages at N170 occipital-parietal electrode locations for Calm/Surprise in the Right Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

Figure 9

ERP grand averages at N170 occipital-parietal electrode locations for Calm/Surprise in the Left Hemisphere



Note. The dotted area indicates the latency windows where the component was measured.

ANCOVA with the Communication Subscale as a Covariate

P1 mean amplitude. For the Arousal Design, there was a significant main effect of Emotion, $F(1,72) = 4.25$, $p = .04$, $\eta^2_p = .06$. Specifically, the anger condition ($M = 1.65$, $SE = 0.18$) elicited larger amplitudes compared to the happiness condition ($M = 1.42$, $SE = 0.18$), with this difference reaching statistical significance ($p = .01$). No other significant effects were detected regarding the Arousal Design.

A significant main effect of Emotion was reported in the Valence Design, $F(1,72) = 7.75$, $p = .01$, $\eta^2_p = .10$. The calm condition ($M = 1.92$, $SE = 0.20$) elicited larger amplitudes compared to the surprise condition ($M = 1.56$, $SE = 0.19$) ($p < .001$). No other effects were found for the Valence Design.

P1 peak latency. For the Arousal Design, we found a main effect of Arousal, $F(1,72) = 9.09$, $p = .004$, $\eta^2_p = .11$, with low arousal ($M = 140.78$, $SE = 1.98$) eliciting longer latencies than high arousal ($M = 137.59$, $SE = 1.75$) ($p = .01$). Additionally, a significant interaction of the Hemisphere, Emotion, and Arousal was reported, $F(1,72) = 4.40$, $p = .04$, $\eta^2_p = .06$. When decomposing the Emotion and Arousal for each hemisphere, a main effect of Arousal was found in the right hemisphere, $F(1,73) = 6.21$, $p = .02$, $\eta^2_p = .08$. Specifically, low arousal ($M = 140.74$, $SE = 2.09$) elicited longer latencies compared to high arousal ($M = 136.49$, $SE = 1.73$) ($p = .02$). No significant effects were found in the left hemisphere. Also, no other significant effects were detected regarding the Arousal Design.

For the Valence Design, there was a significant main effect of Emotion, $F(1,72) = 5.26$, $p = .03$, $\eta^2_p = .07$, with the calm category ($M = 142.35$, $SE = 2.00$) eliciting longer latencies than the surprise category ($M = 138.32$, $SE = 1.76$) ($p = .004$). There was also a significant interaction between Emotion and Valence, $F(1,72) = 4.63$, $p = .04$, $\eta^2_p = .06$, and between Hemisphere and Emotion, $F(1,72) = 7.14$, $p = .01$, $\eta^2_p = .09$. Decomposing the interaction Emotion and Valence by emotion, in the calm condition, a main effect of Valence was significant, $F(1,73) = 3.99$, $p = .05$, $\eta^2_p = .05$, with calm unpleasant ($M = 144.08$, $SE = 2.22$) eliciting longer latencies than calm pleasant ($M = 140.62$, $SE = 2.12$) ($p = .05$). No others effects were found for the calm condition. Also, no significant effects were detected for the surprise condition. Decomposing the interaction Hemisphere and Emotion by each hemisphere, in the right hemisphere, a main effect of Emotion was significant, $F(1,73) = 7.37$, $p = .008$, $\eta^2_p = .09$, with calm ($M = 141.76$, $SE = 2.14$) eliciting longer latencies than surprise ($M = 137.45$, $SE = 1.80$) ($p = .008$). In the left hemisphere, a main effect of Emotion was significative, $F(1,73) = 5.92$,

p = .02, η^2_p = .08, with calm (M = 142.94, SE = 2.42) eliciting longer latencies than surprise (M = 139.19, SE = 2.27) (p = .02). The Hemisphere x Emotion x Communication scores interaction was also significant, F(1,72) = 10.97, p = .001, η^2_p = .13. When decomposing the Emotion x Valence x Communication scores separately for each hemisphere, we found a significant main effect of Emotion in the right hemisphere, F(1,72) = 10.87, p = .002, η^2_p = .13, with the calm category (M = 141.76, SE = 2.14) eliciting longer latencies than the surprise category (M = 137.45, SE = 1.82) (p = .007). In the left hemisphere, no significative effects were found.

N170 mean amplitude. For the Arousal Design, there was a significant main effect of Hemisphere, F(1,72) = 9.19, p = .003, η^2_p = .11. Specifically, the right hemisphere (M = 1.66, SE = 0.20) elicited larger amplitudes compared to the left hemisphere (M = 0.90, SE = 0.13), with this difference reaching statistical significance (p = .001). Also, a significant interaction effect between Hemisphere x Emotion x Arousal x Communication scores was observed, F(1,72) = 4.88, p = .03, η^2_p = .06. When decomposing this interaction separately for each hemisphere, no significant effects were found in the right hemisphere and the left hemisphere.

For the Valence Design, a main effect of Hemisphere was found, F(1,72) = 5.99, p = .02, η^2_p = .08, with the right hemisphere (M = 1.85, SE = 0.21) eliciting larger amplitudes than the left hemisphere (M = 0.99, SE = 0.17) (p < .001). Also, a main effect of Emotion was found, F(1,72) = 7.77, p = .01, η^2_p = .10, with calm (M = 1.56, SE = 0.15) eliciting larger amplitudes than surprise (M = 1.28, SE = 0.15) (p < .001).

N170 peak latency. For the Arousal Design, there was a significant main effect of Emotion, F(1,72) = 12.84, p < .001, η^2_p = .15, with anger (M = 177.75, SE = 1.43) elicited longer latencies compared to happiness (M = 175.83, SE = 1.49) (p = .01). There was also a significative interaction effect between Emotion x Communication, F(1,72) = 5.49, p = .02, η^2_p = .07. Decomposing this interaction separately for each emotion using the MEMORE procedure to estimate mediation and moderation models, the results confirm the significance of the tested model, with the set of predictors explaining approximately 7% of the variance in communication, R^2 = 0.071, F(1,72) = 5.49, p = .02. The communication subscale is positively associated with the emotion variables. Higher communication values correspond to a greater difference between happiness and anger, indicating that the effect evolves in a positive direction. Thus, despite communication initially starting with a negative value, it transforms into a positive one over time.

No significant effects were observed for the Valence Design.

ANCOVA with the RIDO Subscale as a Covariate

P1 mean amplitude. For the Arousal Design, there was a significant main effect of Hemisphere, $F(1,72) = 6.34$, $p = .01$, $\eta^2_p = .08$, with the Right Hemisphere ($M = 1.70$, $SE = 0.20$) eliciting larger amplitudes than the Left Hemisphere ($M = 1.37$, $SE = 0.18$) ($p = .03$).

Similarly, a main effect of Hemisphere was found in the Valence Design, $F(1,72) = 4.55$, $p = .04$, $\eta^2_p = .06$. The Right Hemisphere ($M = 1.93$, $SE = 0.21$) elicited larger amplitudes compared to the Left Hemisphere ($M = 1.55$, $SE = 0.19$) ($p = .01$). Also, a main effect of Emotion was found, $F(1,72) = 9.25$, $p = .003$, $\eta^2_p = .11$, with the calm ($M = 1.92$, $SE = 0.20$) elicited larger amplitudes compared to surprise ($M = 1.56$, $SE = 0.19$) ($p < .001$).

P1 peak latency. For the Arousal Design, a main effect of Arousal was found, $F(1,72) = 8.58$, $p = .005$, $\eta^2_p = .11$, with low arousal ($M = 140.78$, $SE = 1.95$) eliciting longer latencies than high arousal ($M = 137.59$, $SE = 1.74$) ($p = .01$).

There were no significant effects regarding the Valence Design.

N170 mean amplitude. For the Arousal Design, a main effect of Hemisphere was found, $F(1,72) = 10.35$, $p = .002$, $\eta^2_p = .13$, with Right Hemisphere ($M = 1.66$, $SE = 0.20$) eliciting larger amplitudes than the Left Hemisphere ($M = 0.90$, $SE = 0.13$) ($p = .001$). Also, a main effect of Arousal was found, $F(1,72) = 6.08$, $p = .02$, $\eta^2_p = .08$, with low arousal ($M = 1.34$, $SE = 0.13$) eliciting larger amplitudes than high arousal ($M = 1.21$, $SE = 0.12$) ($p = .03$).

For the Valence Design, a main effect of Hemisphere was found, $F(1,72) = 9.38$, $p = .003$, $\eta^2_p = .12$, with Right Hemisphere ($M = 1.85$, $SE = 0.21$) eliciting larger amplitudes than the Left Hemisphere ($M = 0.99$, $SE = 0.17$) ($p < .001$). Also, a main effect of Emotion was found, $F(1,72) = 8.60$, $p = .005$, $\eta^2_p = .11$, with calm ($M = 1.56$, $SE = 0.15$) eliciting larger amplitudes than surprise ($M = 1.28$, $SE = 0.15$) ($p < .001$).

N170 peak latency. For the Arousal Design, a main effect of Emotion was found, $F(1,72) = 9.52$, $p = .003$, $\eta^2_p = .12$, with anger ($M = 177.75$, $SE = 1.40$) eliciting longer latencies than happiness ($M = 175.83$, $SE = 1.43$) ($p = .01$). The RIDO subscale was also significant, $F(1,72) = 5.31$, $p = .02$, $\eta^2_p = .07$. To analyze the covariation between the variables RIDO and the N170 latencies of Arousal Design, the Pearson correlation coefficient was estimated. The results indicated a significant correlation between the two variables, characterized by a positive relationship ($r(74) = .26$, $p = .02$).

For the Valence Design, there was only a significant result of the RIDO subscale, $F(1,72) = 5.42$, $p = .02$, $\eta^2_p = .07$. To analyze the covariation between the variables RIDO and the N170 latencies of Valence Design, the Pearson correlation coefficient was estimated. The results indicated a significant correlation between the two variables, characterized by a positive relationship ($r(74) = .19$, $p = .03$).

ANCOVA with the Social Skills Subscale as a Covariate

P1 mean amplitude. There were no significant effects regarding the Arousal Design.

For the Valence Design, there was a significant main effect of Emotion, $F(1,72) = 5.95$, $p = .02$, $\eta^2_p = .08$. Specifically, the calm category ($M = 1.92$, $SE = 0.20$) elicited larger amplitudes compared to the surprise category ($M = 1.56$, $SE = 0.19$) ($p < .001$). Additionally, a significant interaction between Hemisphere, Emotion, and Valence was found, $F(1,72) = 6.05$, $p = .02$, $\eta^2_p = .08$. When decomposing this interaction by Hemisphere, the right one had no significative effects. In the Left Hemisphere, a main effect of Emotion was found, $F(1,73) = 20.75$, $p < .001$, $\eta^2_p = .22$, with the calm category ($M = 1.78$, $SE = 0.19$) elicited larger amplitudes compared to the surprise category ($M = 1.32$, $SE = 0.20$) ($p < .001$). Also in the Left Hemisphere, the interaction between Emotion and Valence was significant, $F(1,73) = 5.09$, $p = .03$, $\eta^2_p = .07$. Decomposing this interaction by Valence for each emotion, the calm condition did not reveal any significant effects. In contrast, the surprise condition exhibited a significant main effect of Valence, $F(1,73) = 5.07$, $p = .03$, $\eta^2_p = .07$, with unpleasant surprise ($M = 1.46$, $SE = 0.21$) elicited larger amplitudes compared to pleasant surprise ($M = 1.18$, $SE = 0.21$) ($p = .03$).

P1 peak latency. For the Arousal Design, a main effect of Arousal was found, $F(1,72) = 7.34$, $p = .008$, $\eta^2_p = .09$, with low arousal ($M = 140.78$, $SE = 1.99$) eliciting longer latencies than high arousal ($M = 137.59$, $SE = 1.74$) ($p = .01$).

Conversely, no significant effects were identified for the Valence Design.

N170 mean amplitude. For the Arousal Design, a main effect of Hemisphere was found, $F(1,72) = 5.32$, $p = .02$, $\eta^2_p = .07$, with Right Hemisphere ($M = 1.66$, $SE = 0.20$) eliciting larger amplitudes than the Left Hemisphere ($M = 0.90$, $SE = 0.13$) ($p = .001$).

Similarly, only a main effect of Hemisphere was found in the Valence Design, $F(1,72) = 5.79$, $p = .02$, $\eta^2_p = .07$. The right hemisphere ($M = 1.85$, $SE = 0.21$) elicited larger amplitudes compared to the left hemisphere ($M = 0.99$, $SE = 0.17$) ($p < .001$).

N170 peak latency. For the Arousal Design, a main effect of Arousal was found, $F(1,72) = 8.62$, $p = .004$, $\eta^2_p = .12$, with high arousal ($M = 178.03$, $SE = 1.39$) eliciting longer latencies than low arousal ($M = 175.55$, $SE = 1.56$) ($p = .004$).

For the Valence Design, there was a significant interaction between Emotion xValence x Social Skills, $F(1,72) = 5.28$, $p = .02$, $\eta^2_p = .07$. When decomposing the Emotion by Valence and considering the Social Skills covariate separately for each emotion, no significant effects were found in the calm and surprise categories.

Discussion

The present pre-registered study aimed to evaluate the influence of varying levels of autism traits in adults from a non-clinical population on the modulation of P1 and N170 amplitude and latency during the perception of facial expressions of emotion, considering the affective dimensions of valence and arousal. In line with the structure of the results, the discussion will be organized by addressing each ERP component in relation to the AQ Total Score, followed by an analysis of the three subscales separately (Communication, RIDO, and Social Skills). Finally, the discussion will conclude with a brief consideration of the study's limitations and suggestions for future research directions.

AQ Total Score

On the neural level, the results revealed that only arousal significantly affected P1 latencies, with facial expressions of anger and happiness with low arousal taking longer to be processed than those with high arousal. This aligns with recent studies showing that arousal significantly impacts P1 latency, reflecting increased neural engagement with more intense stimuli, regardless of valence (Droit-Volet & Berthon, 2017). However, contrary to our initial hypothesis (H1), which predicted that higher autistic traits in adults would be associated with longer P1 latencies, the results did not show significant differences in P1 latencies based on total autistic traits. This finding diverges from previous literature, which reported delayed P1 responses in individuals with higher autistic traits, suggesting a generalized inefficiency in early-stage perceptual processing (Stavropoulos et al., 2018).

As the modulation of the P1 response is influenced by various factors, including individual developmental trajectories and task characteristics (Hileman et al., 2011), one possible explanation for this discrepancy is the non-clinical nature of our sample. While clinical ASD populations often demonstrate clearer neural processing differences, individuals with subclinical levels of autistic traits may not exhibit the same degree of neural inefficiency. Autistic traits are distributed across a continuum, and these individuals may use compensatory strategies (Happé & Frith, 2020), which could mitigate any delays in early sensory processing. Moreover, our viewing task may not have demanded sufficient cognitive engagement to reveal processing delays, as more attention and active tasks, such as emotion categorization, tend to elicit stronger and more prolonged neural responses (McPartland et al., 2004).

Similarly, the mean amplitude of the P1 component did not show a significant association with AQ Total Scores, contradicting our hypothesis (H3), which posited a positive relationship between autistic traits and larger P1 amplitudes (Higher autistic traits in adults are related to larger P1 amplitudes). This hypothesis was grounded in prior research that indicated heightened perceptual sensitivity in individuals with higher levels of autistic traits. Several studies have demonstrated that individuals with higher autistic traits often exhibit larger P1 amplitudes during early visual processing, which has been interpreted as increased sensitivity to sensory stimuli, particularly facial stimuli (Cygan et al., 2014), and associated with a greater allocation of attentional resources.

This absence of an effect could reflect a more complex interaction between sensory sensitivity and autistic traits, where heightened sensitivity might not uniformly affect all aspects of sensory processing. In our study, the facial stimuli spanned multiple emotional categories, potentially diluting the effect of heightened sensitivity in individuals with higher autistic traits because differences in P1 amplitude are often more pronounced in response to specific types of stimuli (Faja et al., 2016). Additionally, this would align with the work of Webb et al. (2012), who found that neural markers of face processing can normalize over time in individuals with subclinical autistic traits due to compensation and adaptation mechanisms.

Regarding the N170 component, we hypothesized (H2) that higher AQ Total Scores would be associated with longer N170 latencies, reflecting delays in face-specific processing. However, our findings did not support this hypothesis, which might be attributed to individual variability in face processing within non-clinical populations, diluting the expected effects. Several studies have demonstrated that N170 latencies are often delayed in clinical ASD populations (Hileman et al., 2011; Xiong et al., 2019), particularly in response to ambiguous faces (McPartland et al., 2004).

Additionally, emotional content and arousal levels of the stimuli may play a significant role in modulating N170 responses. Previous research has demonstrated that high-arousal emotions (e.g., anger and surprise) can prolong N170 latencies, especially in individuals with face processing difficulties (Almeida et al., 2016). However, in our study, while arousal significantly affected N170 latency, AQ scores did not interact with arousal to modulate neural responses. This suggests that while emotional intensity impacts face processing, the relationship between autistic traits and N170 latency may be more nuanced and contingent on the nature of the task and stimuli.

Finally, we did not observe significant associations between AQ scores and N170 amplitude, which goes in accordance with some prior studies (Churches et al., 2010; Kang et al., 2018; McPartland et al., 2004; Stavropoulos et al., 2018). The lack of significant findings in this study could be attributed to several factors. First, N170 amplitude is known to be sensitive to the emotional content and familiarity of the face stimuli, as well as task demands. Additionally, the emotional categories may have elicited varied neural responses across participants, obscuring any consistent relationship with autistic traits. For example, facial expressions of happiness are generally processed more efficiently, potentially minimizing the impact of autistic traits on N170 amplitude (Nomi & Uddin, 2015).

In summary, although our pre-registered hypotheses regarding the relationship between AQ Total Scores and the modulation of P1 and N170 components were not supported, the findings provide valuable insights into how autistic traits may influence the early stages of face perception. These results suggest that the interaction between autistic traits and neural responses during face processing is more complex than initially anticipated, likely shaped by factors such as task demands, the emotional content of stimuli, and individual variability in sensory processing.

Beyond our pre-registered hypotheses and analyses described above, we also explored whether specific AQ subscales influenced neural ERP responses.

Communication Subscale

The Communication subscale of the AQ assesses challenges in social communication, such as interpreting social cues, engaging in conversations, and understanding non-verbal communication (Baron-Cohen et al., 2001). Given the well-established link between social communication impairments and neurocognitive deficits in ASD, we aimed to conduct an exploratory analysis to examine whether this association persists in adults with autistic traits, using the P1 and N170 components as neural markers. In general, the results revealed significant effects of both emotion and arousal, with further distinctions across hemispheres.

Regarding P1 amplitudes, anger elicited larger P1 amplitudes than happiness, which aligns with previous findings showing that negative emotions, particularly those linked to threat or increased vigilance, enhance early perceptual processing (Wieser & Brosch, 2012). These results may reflect the brain's adaptive mechanism to allocate greater attentional resources to this type of stimulus. The calm stimuli evoked larger amplitudes than surprise, suggesting that low-arousal emotions may engage more sustained attentional processes due to their potential for evoking reflective or restful states, as opposed to the more transient response elicited by surprise, despite being less dynamic (Zhang et al., 2014). These results highlight the importance of considering the specific emotional context when interpreting early sensory responses.

Our results showed no significant association between Communication scores and P1 latency. However, low-arousal stimuli were processed more slowly than high-arousal ones, suggesting that lower-arousal emotional stimuli may require more time to be processed at the early stages of visual perception (Zhang & Jiang, 2022). These occur especially in the right hemisphere, consistent with theories highlighting the role of the right hemisphere in processing emotionally salient stimuli (Davidson, 2004). The calm stimuli had longer latencies than the surprise, which may reflect the additional time required to process less dynamic or more neutral emotional stimuli. Notably, interactions between hemisphere and emotion were observed, further supporting the notion of lateralized emotional processing, particularly in the context of valence (Killgore & Yurgelun-Todd, 2007).

Regarding the N170 component, the significant hemisphere effect found in both designs, with larger amplitudes in the right hemisphere, supports the notion that the right hemisphere is more involved in the processing of emotional faces (Rossion & Jacques, 2012). Moreover, calm stimuli elicited larger N170 amplitudes than surprise, suggesting that even emotionally less intense stimuli can still demand significant neural responses when they engage in deeper cognitive processing.

Anger elicited longer N170 latencies than happiness, likely reflecting the increased cognitive effort associated with processing negative emotions, which tend to evoke more sustained neural activity (Schupp et al., 2004). Additionally, the interaction between emotion and communication scores in the N170 latency results is particularly noteworthy, suggesting that communication abilities may moderate the neural response to emotions. Specifically, individuals with higher communication scores showed a greater distinction between happiness and anger, further emphasizing the role of individual differences in emotional processing. These findings align with recent studies suggesting that individual differences, such as social communication abilities, can modulate neural responses to emotional faces (Herbert et al., 2013).

RIDO Subscale

In line with previous research, our results demonstrated a significant main effect of the hemisphere on P1 amplitude in both the Arousal and Valence designs, with the right hemisphere exhibiting larger amplitudes than the left. This hemispheric asymmetry aligns with theories suggesting that the right hemisphere is preferentially involved in the processing of emotional stimuli and recognizing affective cues (Bradley & Lang, 1999). Moreover, calm stimuli elicited larger amplitudes than surprise. This finding supports the notion that emotional arousal plays a critical role in modulating early visual processing (Schupp et al., 2004).

Low arousal conditions elicited longer P1 latencies compared to high arousal conditions, which posits that increased arousal levels enhance attentional focus and perceptual processing efficiency, as mentioned in the Arousal Theory (Bradley & Lang, 1999).

The N170 component also revealed significant hemispheric effects, with larger amplitudes observed in the right hemisphere for both designs. As mentioned previously, this finding further corroborates the hypothesis of lateralization in emotional processing, explicitly highlighting the right hemisphere's role in face and emotion recognition. Additionally, low arousal conditions elicited larger amplitudes compared to high arousal conditions, suggesting that more emotionally charged stimuli capture attention more effectively (Schupp et al., 2004). The enhanced processing of low-arousal stimuli might indicate that less emotionally intense stimuli still hold relevance and warrant significant cognitive resources.

For the N170 latency, anger elicited longer latencies compared to happiness. This finding supports the notion that negative emotions may demand more cognitive resources for processing (Streit et al., 2000), which may explain the increased latency observed. Furthermore, the significant correlation between the RIDO subscale and N170 latencies in both designs indicates that individuals with higher RIDO scores experience a differential response to emotional stimuli, suggesting a potential link between emotion regulation and neural processing of emotions.

Social Skills Subscale

Regarding the P1 amplitude, the calm category elicits larger amplitudes than the surprise category, suggesting that emotionally low arousal stimuli are processed more efficiently than emotionally ambiguous or surprising stimuli. Furthermore, the significant interaction between Hemisphere, Emotion, and Valence indicated that the left hemisphere is particularly responsive to the emotions of the valence design, reflecting a possible lateralization in emotional processing. The significant interaction between Emotion and Valence in the left hemisphere further supports this notion, particularly in the context of unpleasant versus pleasant surprise. The observation that unpleasant surprise elicited larger amplitudes compared to pleasant surprise may indicate an adaptive mechanism where negative or threatening stimuli demand more cognitive resources for processing, as suggested by the attentional bias towards negative information (Yiend, 2010).

The P1 latency results indicated that lower arousal conditions resulted in longer latencies than high arousal conditions. This finding suggests that lower arousal stimuli may require more prolonged processing, potentially due to increased attentional demands or cognitive load associated with these stimuli.

For the N170 component, a main effect of the hemisphere was observed in both the arousal and valence designs, with larger amplitudes recorded in the right hemisphere. This finding indicates that the right hemisphere is preferentially engaged in processing emotional and facial stimuli. The right hemisphere’s dominant role in emotion processing may be attributed to its involvement in recognizing emotional expressions and integrating affective information (Gainotti, 2019).

Finally, the N170 latency results indicated high arousal conditions eliciting longer latencies. This suggests that stimuli with higher emotional arousal may engage more cognitive resources, potentially leading to delayed processing times. In contrast, a significant interaction involving Emotion, Valence, and Social Skills was found, although no significant effects were identified for calm and surprise categories. This lack of significant findings may indicate that the interplay between emotional processing and social skills is more nuanced.

Limitations and Future Directions

One key limitation of the current study is the relatively small sample size, which may limit the generalizability of the findings. While we carefully selected participants to avoid confounding factors such as neurological or psychiatric conditions, the final sample size of 74 participants may not fully capture the variability in autistic traits and neural processing across the general adult population. Additionally, the study focused on a non-clinical adult population, which may not exhibit the same degree of face-processing deficits as individuals with a clinical diagnosis of ASD. Furthermore, despite having elevated autistic traits, it is plausible that throughout their lives, these adults have acquired compensatory social strategies, which could mitigate the observable deficits in social and emotional processing.

Another limitation pertains to the viewing task employed in this study. While this task is widely used in ERP research, it may not sufficiently engage participants in emotional face processing, potentially limiting the detection of differences between groups. Active tasks, such as emotion categorization or forced-choice tasks, may elicit stronger neural responses, particularly in non-clinical populations with autistic traits, as they require greater cognitive engagement and attention. Future research should expand the range of stimuli to include more complex social interactions, such as dynamic facial expressions or multimodal stimuli, which may yield a more comprehensive understanding of how autistic traits influence emotional perception.

Regarding the P1 and N170 components, a limitation we encountered was the exclusive analysis of mean amplitude, without considering the peak amplitude. The peak amplitudes of these components appear to suggest the presence of effects that were not captured through mean amplitude analysis. Additionally, the latency window used (as observed in the time-course plots) would have been more appropriate for measuring the peak amplitude of the components. This is because the window for calculating mean amplitude was too broad, leading, for instance, to the inclusion of significant portions of the P1 component in the mean amplitude of N170. Moreover, the study used only two ERP components (P1 and N170) as markers of early-stage face processing. While these components provide valuable information about perceptual processes, they do not capture the full spectrum of neural activity involved in emotion recognition. Future research could benefit from including additional components, such as the late positive potential (LPP), to investigate the later stages of emotional processing.

Future studies should investigate the role of individual differences in cognitive and emotional abilities and could further elucidate how these factors interact with autistic traits to modulate neural responses to emotional faces. This could also inform the development of targeted interventions to enhance emotion recognition and social functioning in individuals with higher autistic traits. These future research directions could contribute to a more nuanced understanding of the neurocognitive processes involved in face perception and emotion recognition.

Finally, this study demonstrates the utility of event-related potentials (ERPs) in exploring autistic traits and their associations with emotional processing. Despite the limitations previously mentioned, the findings offer valuable insights into the nuances of neural processing in adults with autistic traits. The combination of arousal and valence measures provided a more detailed understanding of how different levels of emotional intensity influence the timing and magnitude of neural responses. The study also highlights the importance of considering factors like social skills when developing interventions to enhance emotion recognition in individuals with higher levels of autistic traits. Additionally, the inclusion of a non-clinical adult population with a wide range of autistic traits is a notable strength. By focusing on subclinical levels of autistic traits, this study addresses an important gap in the literature, offering insights into how these traits manifest in the general population beyond clinical diagnoses. This approach contributes to the growing body of research on the broader autism phenotype, highlighting the continuum of autistic traits and their impact on cognitive and neural processes.

Conclusion

This study offers a deeper understanding of how autistic traits modulate neural responses, specifically the P1 and N170 components, during the perception of facial emotional expressions. Using a non-clinical sample of adults, the findings suggest that the processing of emotional stimuli is influenced by both valence and arousal dimensions, revealing a complex relationship with autistic traits.

Although our main pre-registered hypotheses regarding autistic traits were not supported, several significant results emerged regarding the modulation of the P1 and N170 components across different affective dimensions, and these may be the basis for future confirmatory research. Findings on P1 latency indicate that low-arousal stimuli resulted in longer latencies, suggesting that these stimuli require more processing time. In contrast, P1 amplitude was modulated by emotion, with calm stimuli eliciting greater amplitudes than surprise. For the N170 component, a significant hemisphere effect was observed, with the right hemisphere displaying larger amplitudes in both the arousal and valence designs. These findings further support the idea of lateralization in emotional and facial processing, with the right hemisphere playing a predominant role in recognizing emotions. Additionally, significant interactions between emotion, valence, and social skills suggest that social competence may modulate neural responses during emotional recognition, underlining the importance of social abilities in emotional processing even in non-clinical populations.

In conclusion, this work contributes significantly to the field of social neuroscience by offering a foundation for future research that may investigate interventions aimed at improving social and emotional functioning in individuals with elevated autistic traits.

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Appendix 1

Table 3

NimStim Stimuli Used per Condition in the Anger/Happiness Set and Relevant Descriptive Statistics (from Ferreira Santos, 2013).

Affective condition	Emotional categories							
	Anger				Hapiness			
	Stimulus/statistic	V	**A**	Recog.	Stimulus/statistic	V	**A**	Recog.
Low A	03F-NA-C	3.100	**3.825**	0.82	01F-HA-O	5.875	**4.475**	0.99
	07F-AN-C	2.575	**4.700**	0.94	03F-HA-O	5.800	**4.700**	1.00
	08F-AN-C	2.775	**4.500**	0.96	11F-HA-O	5.925	**4.475**	0.99
	09F-AN-C	2.625	**4.625**	0.99	13F-HA-O	5.700	**4.625**	0.99
	16F-AN-C	2.650	**4.725**	0.89	14F-HA-O	5.775	**4.650**	0.99
	19F-AN-C	2.550	**4.250**	0.88	18F-HA-O	5.775	**4.650**	1.00
	20M-AN-C	2.675	**4.575**	0.99	24M-HA-X	5.725	**4.675**	1.00
	31M-AN-C	2.625	**4.275**	0.98	29M-HA-O	5.900	**4.675**	0.98
	32M-AN-C	2.900	**3.950**	0.90	36M-HA-O	5.750	**4.375**	1.00
	36M-AN-C	2.475	**4.675**	1.00	43M-HA-O	5.875	**4.300**	0.95
	M	2.695	**4.410**	0.935	*M*	5.810	**4.560**	0.989
	SD	0.185	**0.322**	0.060	*SD*	0.078	**0.142**	0.015
High A	01F-AN-O	1.925	**6.325**	0.96	02F-HA-X	6.200	**5.750**	0.80
	07F-AN-O	2.075	**5.775**	0.96	08F-HA-X	6.075	**5.775**	0.95
	12F-AN-O	1.900	**6.000**	0.90	09F-HA-X	6.350	**6.225**	0.85
	17F-AN-O	1.900	**6.175**	0.99	10F-HA-O	6.300	**5.750**	0.99
	24M-AN-O	2.175	**5.900**	0.88	19F-HA-X	6.250	**6.150**	0.86
	25M-AN-O	2.125	**5.925**	0.99	22M-HA-X	6.300	**6.000**	0.85
	29M-AN-O	1.925	**6.225**	0.94	27M-HA-X	5.825	**5.925**	0.88
	36M-AN-O	1.850	**6.175**	0.99	31M-HA-X	6.075	**5.875**	0.76
	39M-AN-O	2.400	**5.775**	0.93	40M-HA-X	6.175	**6.125**	0.93
	43M-AN-O	2.075	**6.050**	0.96	45M-HA-X	6.200	**6.075**	0.85
	M	2.035	**6.033**	0.950	*M*	6.175	**5.965**	0.872
	SD	0.170	**0.190**	0.038	*SD*	0.153	**0.176**	0.069

Note. V = valence; A = arousal; Recog. = recognition of emotional category. Values in bold emphasize the manipulated affective dimension.

Table 4

NimStim Stimuli Used per Condition in the Calm/Surprise Set and Relevant Descriptive Statistics (from Ferreira Santos, 2013)

Affective condition	Emotional categories							
	Calm				Surprise			
	Stimulus/statistic	**V**	**A**	Recog.	Stimulus/statistic	**V**	**A**	Recog.
Pleasant	03F-CA-C	**4.475**	2.375	0.79	02F-SP-O	**4.025**	5.175	0.98
	11F-CA-C	**4.450**	2.375	0.88	05F-SP-O	**5.025**	5.125	0.91
	17F-CA-C	**4.275**	2.050	0.97	10F-SP-O	**4.650**	5.250	0.96
	18F-CA-C	**4.525**	2.225	0.93	17F-SP-O	**3.950**	5.150	0.90
	22M-CA-C	**4.400**	2.575	0.78	21M-SP-O	**5.000**	5.150	0.94
	23M-CA-C	**4.275**	2.100	0.90	22M-SP-O	**5.075**	4.900	0.90
	24M-CA-O	**4.525**	2.375	0.81	27M-SP-O	**4.425**	5.075	0.91
	28M-CA-C	**4.425**	1.950	0.94	34M-SP-O	**4.100**	4.825	0.95
	41M-CA-C	**4.275**	2.150	0.89	37M-SP-O	**4.675**	5.100	0.94
	45M-CA-C	**4.350**	2.525	0.79	40M-SP-O	**3.950**	5.325	0.90
	M	**4.398**	2.270	0.868	*M*	**4.488**	5.108	0.929
	SD	**0.100**	0.207	0.070	*SD*	**0.460**	0.149	0.029
Unpleas.	02F_CA_C	**3.425**	2.000	0.84	01F_SP_O	**3.175**	5.525	0.80
	05F_CA_C	**3.425**	2.275	0.80	06F_SP_O	**3.175**	4.900	0.75
	05F_CA_O	**3.450**	2.175	0.85	09F_SP_O	**3.275**	5.225	0.79
	09F_CA_O	**3.175**	2.650	0.78	14F_SP_O	**3.325**	5.200	0.91
	12F_CA_C	**3.500**	2.275	0.91	30M_SP_O	**3.225**	5.800	0.88
	19F_CA_O	**3.275**	2.300	0.80	31M_SP_O	**3.275**	4.975	0.80
	21M_CA_O	**3.500**	2.400	0.79	32M_SP_O	**3.275**	5.875	0.89
	32M_CA_O	**3.125**	2.500	0.79	42M_SP_O	**3.225**	5.200	0.79
	33M_CA_O	**3.275**	2.625	0.79	43M_SP_O	**3.475**	4.875	0.86
	35M_CA_C	**3.225**	2.325	0.78	45M_SP_O	**3.325**	5.700	0.76
	M	**3.338**	2.353	0.813	*M*	**3.275**	5.328	0.823
	SD	**0.139**	0.199	0.042	*SD*	**0.088**	0.374	0.057

Note. V = valence; A = arousal; Recog. = recognition of emotional category; Unpleas. = unpleasant. Values in bold emphasize the manipulated affective dimension.

Appendix 2

Script with the parameter settings used to run HAPPE+ER during the data preprocessing phase.

Density: high (> 30 channels)

Resting state or task: task

- task onset tags: an10, an20, ha30, ha40, ca50, ca60, su70, su80
- conditions: na
- erp analysis: yes

Data file format: .raw (netstation simple binary)

Acquisition layout: 128 channel egi hydrocel geodesic sensor net

Channels: all

Line noise frequency: 50 hz

Line noise reduction method: cleanline - default

Resample: off

Filter:

- lowpass cutoff: 30
- highpass cutoff: 0.1
- type: eeglab's fir

Bad channel detection: on

- bad channel detection order: before wavelet thresholding

Ecgone: off

Wavelet thresholding: default

- threshold rule: hard

Muscil: off

Segmentation: on

- starting parameter for stimulus: -0.2 seconds
- ending parameter for stimulus: 0.8 seconds
- task offset: 0 milliseconds
- baseline correction: on
    - baseline correction start: -200 milliseconds
    - baseline correction end: 0 milliseconds

Interpolation: off

Segment rejection: on

- segment rejection method: both amplitude and similarity criteria
    - minimum segment rejection threshold: -150
    - maximum segment rejection threshold: 150
    - segment rejection based on all channels or roi: all

Re-referencing: on

- re-reference method: average

Visualizations: off

Save format: .txt file

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