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Familiarity Effects on Facial Emotion Processing – An ERP study

Ana Luísa Pereira Abreu

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Universidade do Porto
Faculdade de Psicologia e de Ciências da Educação

FAMILIARITY EFFECTS ON FACIAL EMOTION PROCESSING – AN ERP STUDY

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AVISOS LEGAIS

Table of contents

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This project, that has so much to do with familiarity, with proximity, and emotions, would have never been possible without my own loved ones. These words will not be enough to express the gratitude I feel for their support.

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Resumo

As faces são certamente dos estímulos sociais mais pertinentes para o ser humano desde o nascimento. Possibilitam a identificação de emoções e identidade, ambos processos fundamentais para a monitorização das nossas interações diárias. Investigações anteriores sugerem que o reconhecimento de uma face é potenciado pelo seu grau de familiaridade. Assim, o presente estudo visa explorar a forma como a familiaridade melhora o processamento facial e a identificação emocional. Colocámos a hipótese de que a resposta neuronal e as taxas de acerto serão maiores com o aumento da familiaridade das faces, o que pode ser explicado pela maior robustez das representações neuronais para estes estímulos. Esta representação aumentada pode induzir processos neuronais extra aos já motivados pela identificação facial, tais como processos afetivos e informação autobiográfica relacionada com o indivíduo reconhecido. Através de duas tarefas experimentais, analisámos as taxas de acerto e a morfologia dos potenciais cerebrais relacionados com eventos descritos como correlatos neuronais do processamento facial (P100, N170 e N250). Estes potenciais foram induzidos por faces invertidas e emocionais com diferentes graus de familiaridade. Na primeira tarefa, com vista ao estudo do processamento facial, foram apresentadas três categorias de estímulos faciais durante uma tarefa de deteção de um alvo: faces famosas; faces pessoalmente familiares; e faces desconhecidas. Para explorar o efeito de inversão de faces, de acordo com o nível de familiaridade, estes estímulos faciais foram também apresentados de forma invertida. Na segunda tarefa, para estudar o processamento emocional de faces, foi conduzida uma tarefa de identificação emocional de faces pessoalmente familiares e desconhecidas com diferentes expressões faciais de emoção. De acordo com a literatura, os resultados comportamentais obtidos nesta tarefa mostraram um desempenho melhorado na identificação de emoções expressas por faces familiares, em comparação a faces desconhecidas. Os resultados eletrofisiológicos mostraram uma resposta aumentada do N250 para faces pessoalmente familiares, em comparação com faces desconhecidas. Estes resultados são consistentes com um maior recrutamento neuronal para faces familiares, induzido por um processamento adicional de faces de entes queridos. Por fim, na primeira tarefa, faces invertidas induziram maiores amplitudes nos três componentes, independentemente do seu grau de familiaridade. Este resultado é consistente com resultados anteriores que sugerem que as faces invertidas, por serem mais difíceis de processar, levam a um maior recrutamento de recursos neurais.

Palavras chave: Familiaridade; Identificação emocional; Processamento facial; N170; N250;

Abstract

From the time we are born faces might surely be the most pertinent social stimuli, with a role in identifying emotions and identity, vital processes that monitor our daily interactions. Previous research suggests that face recognition is enhanced by their degree of familiarity. Thus, the present study aims to explore how familiarity improves face processing. We hypothesize that the neural response and accuracy rates will be higher with the increase of familiarity of each face. This can be explained by the greater robustness of the neural representations for these stimuli that can induce extra neural processes to the ones already prompted by facial identification (e.g., affective processes and autobiographical information related to the individual recognized). Through two experimental tasks, we analysed accuracy rates and the morphology of event-related brain potentials associated with face processing (P100, N170, and N250), elicited by inverted and emotional faces with different degrees of familiarity. In the first task, to study facial processing, three different categories of facial stimuli were presented during a target detection task: famous familiar faces; personally familiar faces; and unfamiliar faces. To explore the face inversion effect accordingly to each degree of familiarity, these facial stimuli were also presented upside down. In the second task, to study emotional face processing, an emotional recognition task on personally familiar and unfamiliar faces was conducted. The behavioural results showed an improved performance in the identification of facial expressions of emotion with the increase of facial familiarity, consistent with the previous literature. The electrophysiological results showed an enhanced response exclusive to N250 when personally familiar faces were presented in comparison to unfamiliar faces. The higher recruitment of neural resources for familiar faces was expected in relation to the further information elicited by our loved ones faces. Finally, a higher response of the three components when faces were presented upside down, independently of their degree of familiarity, was obtained. This result is in line with previous research suggesting that inverted faces are more difficult to process, leading to higher recruitment of neural resources.

Keywords: Familiarity; Emotion Identification; Face Processing; N170; N250;

Résumé

Les visages sont certainement l'un des stimuli sociaux les plus pertinents pour les êtres humains dès sa naissance. Ils permettent d'identifier les émotions et l'identité, deux processus fondamentaux pour le suivi de nos interactions quotidiennes. Des recherches antérieures suggèrent que le décodage neuronal des visages est amélioré par le degré de familiarité. Nous avons émis l'hypothèse que les taux de réponse neuronale et de réussite seront plus élevés avec les visages plus familiers, ce qui peut s'expliquer par la plus solidité des représentations neuronales pour ces stimuli. Cette représentation neuronale augmentée peut induire des processus neuronaux supplémentaires à ceux déjà motivés par l'identification du visage, tels que les processus affectifs et les informations autobiographiques liées à l'individu reconnu. À l'aide de deux tâches expérimentales, nous avons analysé les taux de réussite et la morphologie des potentiels cérébraux liés à des événements décrits comme des corrélats neuronaux du décodage des visages (P100, N170 et N250). Ces potentiels ont été induits par des visages inversés et émotionnels avec différents degrés de familiarité. Dans la première tâche, afin d'étudier le décodage des visages, trois catégories de stimuli de visages ont été présentées au cours d'une tâche de détection de cible: visages célèbres, visages personnellement familiers et visages inconnus. Pour explorer l'effet de l'inversion des visages, en fonction du niveau de familiarité, ces stimuli de visages ont également été présentés sous une forme inverse. Dans la deuxième tâche, pour étudier le décodage émotionnel des visages, une tâche d'identification émotionnelle de visages personnellement familiers et non familiers avec différentes expressions faciales d'émotion a été menée. Selon la littérature, les résultats comportementaux obtenus dans cette tâche ont montré une meilleure performance dans l'identification des émotions exprimées par des visages familiers par rapport aux visages non familiers. Les résultats électrophysiologiques ont montré une réponse augmentée uniquement à N250 pour les visages personnellement familiers par rapport aux visages non familiers. Ces résultats sont cohérents avec un recrutement neuronal augmenté des visages familiers, induit par un traitement supplémentaire des visages des personnes aimées. Finalement, dans la première tâche, les visages inversés ont induit des amplitudes plus élevées dans les trois potentiels, quel que soit leur degré de familiarité. Ce résultat est cohérent avec les résultats précédents suggérant que les visages inversés, étant plus difficiles à traiter, conduisent à un plus grand recrutement de ressources neuronales.

Mots clés: Familiarité; Identification émotionnelle; Décodage facial; N170; N250

Introduction

In order to function, both socially and independently, humans have to be able to recognize others by their faces (Schweinberger & Neumann, 2016). Faces might surely be the most pertinent social stimuli, and this holds true from birth. Through them, humans can extract a variety of information (e.g., related to identity, emotions, intentions) that guides the behaviour at every moment (George, 2013). Through facial expressions, the human face has become a major nonverbal communication channel for emotions, informing about other people's needs and intentions (e.g., escape from something, fight, have a friendly approach; George, 2013). Considering their social relevance, much work has been done to investigate our abilities of coding, learning, and recognize faces.

Although traditional models of face recognition have largely concentrated on cognitive processes, current models have included affective aspects into this matter, assuming that the cognitive and affective aspects fit into two distinct routes, as proposed by Bruce and Young (1986). According to their model, the initial stage of face processing corresponds to the structural encoding of the face, subsequently processed by several systems in charge of perceiving personal identity, expressions, and mouth movements related to speech. Following the establishment of the identity of the face, later systems act in the recovery of the name and personal information linked to the stimulus (Haxby et al., 2000).

In the continuity of this model, Haxby and colleagues (2000) claimed that the human neural system for face perception can be divided into a core system concerning the visual analysis of faces, and an extended system responsible for extracting the meaning behind faces by exploring the direction of attention, speech processing, personal knowledge, and emotional content. Thereby, the extended system would involve regions linked to the neural systems of other cognitive functions, such as the spatial attention system including regions of the intraparietal sulcus and frontal eye fields; the auditory-verbal comprehension systems correspondent to the superior temporal gyrus; systems related to biographical semantic knowledge enrolled in the retrieving of the information related to the face, which include the anterior temporal lobe; and systems for processing emotional content of expression, embracing regions in the amygdala and insula (Haxby et al., 2000). Although the original model has postulated that only the occipital face area, fusiform face area, and the posterior superior temporal sulcus made part of the core system (Haxby et al., 2000), further research has included other face areas of the anterior temporal and right inferior frontal cortices (Ramon & Gobbini, 2018).

Much of the literature on emotion has highlighted the neural substrates of facial expressions of emotion (FEE). For instance, studies of fear conditioning have shown the dominant role of the amygdala in processing fear (Haxby et al., 2000), as this structure of the limbic system showed greater activation in response to fearful than neutral and happy faces (George, 2013). Moreover, patients with lesions in this area showed impairments in the orientation to the face area where the best predictive information arises. This structure appears to use widened eyes as an indicator for the presence of a fearful face, and patients with lesions of the amygdala seem not to compute the immense amount of information that a fearful face contains. It was also discovered an increased response of this structure for angry expressions that, along with fear, act as a signal for the presence of threats learned across experience (Whalen et al., 2017).

In contrast with previous investigations that reduced the role of the amygdala to the perception of negative emotions as fear and anger, it was found that this structure is involved in the perception of disgusted, sad, surprised, and happy faces, in comparison to neutral ones. Furthermore, this structure also plays a role in the evaluation of these stimuli and their context (taking into account innate and acquired knowledge) and in the emotional reactions required (George, 2013).

In addition to the amygdala, the anterior insula has been found to be involved in the perception of facial expressions as disgust, fear, pain, anger, and happiness. Several lines of evidence suggest that this structure must be activated by the empathic processes elicited by the perception of emotions of others and their understanding, by the conscious experience of emotions, or, more generally, by the predictive significance of the events (George, 2013).

As pointed out by Rossion (2014) "the human face is a complex multidimensional visual pattern with which everyone is familiar" (p. 310). In addition to the emotional states and mood, a face conveys a large amount of information about an individual (e.g., age, identity, familiarity; Herzmann et al., 2004), that humans may extract without any training. Moreover, humans may detect a face soon after a hundred milliseconds, categorizing it as familiar with only one or two gaze fixations (Rossion, 2014). It has been previously observed, across behavioural and neuroimaging findings, that facial processing is optimized for personally familiar faces. This improvement can be perceived through several aspects: recognition throughout a range of image variations (i.e., changes in viewpoints, viewing distances, resolution, or natural changes such as lighting, angle, and expression), efficient retrieval of personal knowledge and emotional responses. Humans are experts in the detection and determination of the familiarity of a face, and this efficiency persists even if the stimuli are presented after substantial time periods (Ramon & Gobbini, 2018). In a study by Bruck and colleagues (1991), participants identified and provided correct names of 87% of their former classmates from yearbook images 24 to 26 years after graduate. Also, when asked to match these images with photographs taken 25 years later, participants gave 78% of correct responses for the category of the most familiar classmates, corresponding to the highest results.

Previous research has established that, as personally familiar faces are more regularly encountered throughout the experience of each human being and learned in more diverse and natural conditions, they can inevitably lead to more "robust" neural representations of a variety of semantic and affective traits. These representations facilitate their detection, the recognition of their identity, and the activation of their personal knowledge. As simple as this process may seem, to be able to recognize a face as familiar it is necessary to separate it from unfamiliar faces at the individual level and access past experience representations (Caharel & Rossion, 2021). Furthermore, when comparing these representations between different individuals, they should be sensitive to structural and textural differences. However, in the same person, they should be tolerant to any changes in appearance to which the person may be subject to (Andrews et al., 2017).

The optimization of the human face processing to relevant persons is highly improved by the experiences with these individuals and has the purpose to enhance social interactions. The viability of these interactions is under the precondition of the retrieval of personal knowledge about familiar individuals (e.g., biographical information, shared memories) determining our approach to each person (Ramon & Gobbini, 2018). The importance of exploring the familiarity effects on the neural processing and the behavioural identification of facial expressions of emotion – an equally relevant social ability – is undeniable.

This project aims to investigate the effect of familiarity on facial processing through electrophysiological techniques. Specifically, through electroencephalography (EEG), we will record voltages on the scalp, generated by synaptic activity in populations of synchronized cortical pyramidal neurons. From the EEG, we will extract event-related potentials (ERP), which are defined as waveforms of small voltages generated by the firing of cortical cells in response to a particular sensory, motor or cognitive event (Amodio et al., 2014). The sequence of ERP waves directly represents the flow of information as the world is processed, and the voltage represents the neural activity that occurs in the brain in that exact moment (Luck, 2014).

Through this technique and focusing on three ERP components that have been proposed as neural correlates of facial processing (P100, N170, and N250), we will investigate the effect of familiarity in the neural processing of faces and in the behavioural identification of FEE.

Moreover, we aimed to investigate the role of familiarity on an effect that typically disrupts facial identification: the Face inversion effect (FIE).

Inverting a face has been shown to cause a significant decrease of the activity of face-selective brain areas – among others, the fusiform face area (FFA) – and an increased response of other regions selective for nonface objects. When presented upside down, both objects and faces find their recognition disrupted, however there are stronger losses for facial stimuli rather than objects (Farah et al., 1995). This reduced performance in recognition for inverted faces (i.e., decreased recognition accuracy, increased reaction times and subjective reports of higher difficulty) is defined as the Face inversion effect (FIE; Latinus & Taylor, 2006). Several researchers have attempted to discover when the FIE takes place, being suggested that it occurs at the perceptual encoding stage, mainly due to the reduced ability to extract relational information from inverted faces (Rossion & Gauthier, 2002). As postulated by Rossion & Gauthier (2002), expertise can be a critical factor to determine a successful encoding of a face or object. Subsequently, FIE may result from a combination of constraints in the visual processing and in our extensive expertise for face recognition. Being true, the effect of familiarity should reduce FIE, and the high temporal resolution of the ERP may be an essential tool to unravel the time-course of the processing of upright and inverted faces.

Regarding the neural correlates of facial processing, the P100 is usually the first major visual component, with a peak latency at around 100 ms witnessed over posterior electrode sites (Luck, 2014). Previous studies, using mathematical modeling procedures, have suggested that the early part of this component originates from the extrastriate visual cortex, with the later portion arising from the fusiform gyrus (Di Russo et al., 2002). The P100 is well known for its high sensitivity to several low-level characteristics of visual stimuli (e.g., contrast; Rossion & Jacques, 2008). Evidence suggests that it may also be influenced by emotional content, increasing for emotion-relevant stimuli (Luck, 2014).

The N170 component corresponds to a negative deflection of large amplitude on the ERP, peaking approximately 170 ms following facial stimulus onset. This response appears predominantly on the occipito-temporal region of the scalp, showing a right lateralization. With an interindividual variability ranging between 130 and 200 ms, the N170 reflects two functions: recognition of a stimulus as a face, as shown by face-sensitivity effects emerging at the onset of this time window (i.e., 120-130 ms, see Rossion & Jacques, 2008), and recognition of the face familiarity as an individual, sustained by positive face familiarity effects observed at the peak of this component. There is evidence that these two functions regularly overlap in time.

Therefore, it is not yet determined if the familiarity effect of this component is associated with the perceptual awareness of a familiar face (Caharel & Rossion, 2021).

When evoked by faces in comparison to nonface familiar object shapes, N170 shows a more consistent lateralization, a larger amplitude, and earlier peak (Rossion, 2014). A considerable number of studies using personally familiar faces report larger N170 to these stimuli compared to unfamiliar faces. It should also be reinforced that this familiarity effect is usually discovered more frequently in personally familiar than famous faces or experimentally familiarized faces. This may be due to the greater robustness of the neural representations of personally familiar faces, but also to the discrepancy of knowledge of celebrities among the participants of each investigation (Caharel & Rossion, 2021).

Despite all these findings, recent research suggest that the familiarity effect reported in the N170 is too small and inconsistent throughout the studies to be utilized as an electrophysiological marker of face familiarity. Extensive research claims this effect as significant to report that long-term familiarity does not emerge during the time-window of this component, but only at later phases (Caharel & Rossion, 2021).

This function is usually better associated to N250, a negative deflection observed approximately between 200 and 300 ms across occipto-temporal scalp sites. Displaying a clear sensitivity to facial familiarity, this component is increasingly more negative for familiar faces – including experimentally learned, famous and personally known faces – compared to unfamiliar faces. Studies investigating face repetition support that N250 shows an increased negativity for repeated faces, reflecting the activation of an individual face representation that takes place when new facial identities are being learned (Wiese et al., 2019). In a study of this kind, Tanaka et al. (2006) reported that natural face learning originates robust representations across image transformations, sustaining that the individuals are able to recognize a person's identity even when the photographs were taken under different lighting conditions or viewpoints (Schweinberger & Neumann, 2016). In line with these results, when learned through experience, facial stimuli elicit enhanced negativity of the occipto-temporal N250 when compared to novel faces in the late time window of this component (i.e., 280-400 ms). This enhancement was also shown for famous faces in the earlier time range of N250 (i.e., 180-280 ms; Andrews et al., 2017).

As previously stated, multiple studies have been exploring face processing, along with the emotional content and familiarity of faces. However, there is a large field to explore in this area considering that the relationship between the neural response of emotional identification and the recognition of a face as familiar is not yet determined (Caharel & Rossion, 2021). This study aims to investigate the effect of familiarity in the modulation of the ERPs associated with face processing when a face is inverted and expressing an emotion. With this purpose, two experimental tasks were developed. Firstly, with the aim to study facial processing, facial stimuli of three different categories of familiarity were presented in a Face Processing Task: (1) personally familiar faces, to explore the effect of familiarity and affective proximity; (2) famous familiar faces, to investigate the effect of familiarity without the influence of affective connections; and (3) unfamiliar faces. To this end participants known and unknown to each other were recruited and their photos were identified as “personally familiar” and “unfamiliar”, faces of famous individuals were then used to the “famous familiar” category in conformity with the indication of each participant. With the purpose to explore the role of familiarity in the FIE, these stimuli were also presented in inverted form. Secondly, to study the effects of familiarity on emotion identification abilities, an Emotion Identification Task was conducted, composed of these personally familiar and unfamiliar faces displaying facial expressions of happiness, sadness, disgust, fear, anger, surprise, and neutral. Both tasks were performed during EEG recordings to allow the extraction of the neural correlates of face processing presented above.

Based on previous findings concerning the effects of familiarity on the recognition of social cues (e.g., Caharel & Rossion, 2021), a better performance in the identification of FEE with the increase of facial familiarity can be predicted (H1). We also expected that the amplitudes of the ERP components will be higher with the increase of familiarity of each face (H2). In other words, higher amplitudes of each ERP component are expected for personally familiar faces than for unfamiliar faces (H2.1), for famous than for unfamiliar faces (H2.2), and for personally familiar faces than famous faces (H2.3). This can be explained by the greater robustness of the neural representations for these stimuli, which may induce extra neural processes to the ones already prompted by facial identification (e.g., affective processes and autobiographical information related to the individual recognized; Caharel & Rossion, 2021; Wiese et al., 2019).

Evidence suggests that face inversion leads to a significant delay of the peak latency and an increase of the amplitude at the level of the N170 component. Despite being small (around 10 ms), this delay is highly robust and consistent across studies (Rossion & Gauthier, 2002). A similar effect has been found in P100 (see e.g., Bentin et al., 1996; Itier and Taylor, 2002, 2004; Rossion et al., 2000; Taylor et al., 2001). Rossion & Gauthier (2002) suggest that although these effects are typically measured at the N170 peak, they are likely to originate before 170 ms, initiating between the two components – P100 and N170. Stronger evidence appears to be needed to determine the effects of face inversion at the level of later components. Therefore, with the presentation of inverted faces, amplitude increases and a delay at the level of the components analysed in the present study can be expected (H3).

As far as we are concerned, to date, the usage of personally familiar faces during the presentation of upright and inverted faces has been scarce. Thus, the relationship between familiarity and the FIE is undoubtedly worth studying. Therefore, two different results will be explored regarding this issue: (1) it is possible that the FIE can persist through the different levels of familiarity as defended by the previous research highly advocating the FIE as independent of the familiarity of faces (see e.g., Collishaw & Hole, 2000; Yarmey, 1971); (2) or, in contrast, this effect can be less expressive as the familiarity of faces increases, which can be suggested through the evidence that familiarity improves the recognition of facial stimuli, even when the face is inverted.

Method

Participants

Eleven triads of participants with close relationships between them were recruited from the local university and community, composing a total sample of 33 healthy adults. Nonetheless, one participant dropped out the study before the second session, originating a final sample of 32 participants (25 female; age: *M* = 27.7 years, *SD* = 9.3). The current study was favourably appraised by the local Ethics Committee. The totality of the participants provided written informed consent to participate in the study, accordingly with the Declaration of Helsinki.

Procedures

Session 1

To avoid fatigue effects, participants were tested individually in two different sessions. The first session included the collection of demographic information, information regarding the inclusion/exclusion criteria, and self-report measures (described below). We included healthy participants between 20 and 65 years of age, both men and women, with more than four years of formal education. Participants would be excluded if they reported uncorrected visual impairments. The participants who meet the inclusion criteria were invited to the second session of data collection. The photographs of participants displaying FEE were also collected during the first session. For the personally familiar category we included the photographs of the members of each participants triad. For the unfamiliar category, photographs of the members of other triads were included, pseudo-randomly selected to have similar demographic characteristics to the triad of each participant. Moreover, to select the famous faces, each participant was asked to nominate "10 famous persons by order of familiarity" (i.e., beginning with the person with a face that is more familiar). Thus, the famous facial stimuli were retrieved from the internet accordingly to the most known celebrities reported by each participant that had similar demographic characteristics to their loved ones that participated in the study (i.e., age, sex, and ethnicity). Therefore, each participant was presented with facial stimuli of two different individuals of each category of familiarity with the same demographic characteristics between them (two personally familiar faces, two famous faces, and two unknown faces. The famous faces were only used in the Face Processing Task, described below).

Self-report measures. To assess the proximity between subjects of each triad, the participants were asked to classify the "type of relationship" (i.e., father, mother, best friend, spouse) they have with each of the loved ones with whom they participated in the study. With the same purpose, the Multidimensional Scale of Perceived Social Support (MSPSS; Zimet et al., 1988; Portuguese norms by Carvalho et al., 2011) was applied to each subject. This scale was developed to do a subjective evaluation of social support asking subjects for their perceived social support accordingly to 3 areas: *family*, *friends,* and *significant others*. The Portuguese version demonstrates a good internal consistency (Cronbach's α between .85 and .95), an adequate construct validity and test-retest stability (Carvalho et al., 2011). An additional adapted version of this scale was also included, in which participants filled the questionnaire according to the perceived social support specifically considering each of the loved ones who participated in the study.

In addition, The Toronto Alexithymia Scale (TAS-20; Taylor et al., 1992; Portuguese norms by Praceres et al., 2000) was used to detect the presence of alexithymia, controlling its effect on the neural processing of facial expressions of emotion. The structure of this scale is theoretically congruent with this construct and is based on the following factors: (1) *difficulty identifying and distinguishing between feelings and bodily sensations*; (2*) difficulty describing feelings*; and (*3) externally oriented thinking*. The results of the study for the Portuguese adaptation by Praceres et al. (2000) indicated an adequate internal consistency (Cronbach's α = .79) and test-retest precision. Moreover, the cut-off points tested in the Portuguese sample revealed that scores equal or above 61 indicate the presence of alexithymia. Subjects with results equal or below 51 are considered non-alexithymic and those who reveal results between 52 and 60 (inclusively) are in an intermediate zone between two categories and cannot be classified as alexithymic nor non-alexithymic (Taylor et al., 1997).

Finally, the Hospital Anxiety and Depression Scale (HADS; Snaith & Zigmond, 1994; Portuguese norms by Pais-Ribeiro et al., 2007) was used to evaluate anxiety and depression, controlling their effects on the neural processing of facial expressions of emotion. This 14-item scale, with a cut-off threshold of 11 for both depression and anxiety has a good internal consistency (with a Cronbach's α for anxiety of .76 and .81 for depression) and test-retest reliability (Pais-Ribeiro et al., 2007).

Session 2

In the second session, each participant sat inside an EEG chamber and completed two tasks while simultaneously undergoing an EEG recording. Participants were seated with ∼115 cm between them and a 17″ screen, where the task was displayed. These tasks were counterbalanced and delivered in E-Prime 2.0 (2011, Psychology Software Tools, Inc., Sharpsburg, PA, USA).

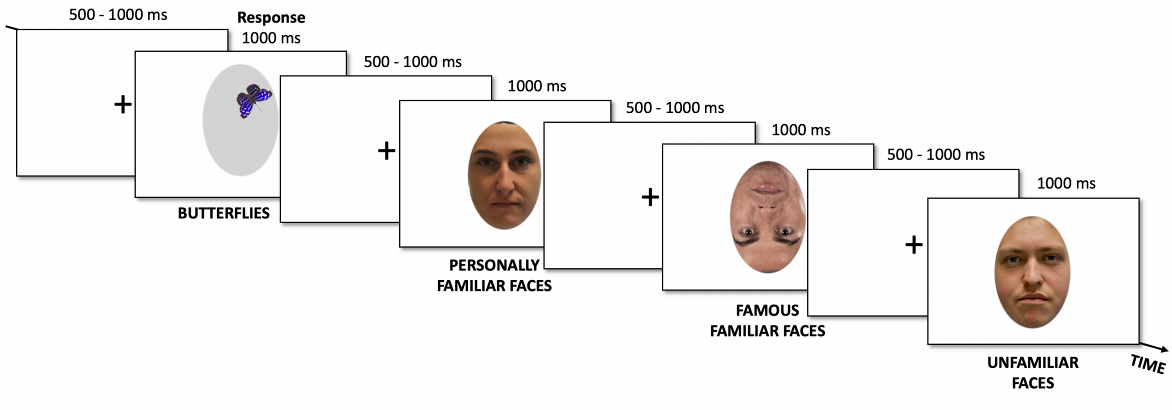
Task 1: Face Processing Task. In this task, neutral expressions of the three categories of familiarity (i.e., personally familiar faces, famous faces, and unfamiliar faces) were presented both in an upright and inverted way. To avoid making this a passive task and to ensure that the participant pays attention to every stimulus, participants were asked to press a button as quickly as possible to pictures of butterflies (these stimuli were randomly selected from an original dataset – Vagnoni et al., 2012 – to be used as targets). The behavioural and EEG data elicited by these stimuli were not analysed.

The stimuli collected during the first session and from the internet were resized in IrfanView Thumbnails (version 4.51; www.irfanview.com). Every picture was enclosed within an oval frame using GIMP (version 2.8; www.gimp.org) to eliminate hair and non-facial contours, also ensuring the same number of pixels per stimulus. In both tasks, each stimulus was presented at a visual angle of 6.89º x 9.86º.

This task was composed by 210 experimental trials: 180 neutral faces (60 photographs of loved ones, 60 famous faces, and 60 unfamiliar faces) and 30 butterflies. As each category of familiarity was composed by facial stimuli of two different individuals, each face was repeated 15 times. The task was organized in a practice block (8 practice trials: 4 butterflies and 4 faces randomly selected), and three experimental blocks (with 70 trials each) divided by unlimited pauses. The structure of four trials is depicted in Figure 1. Participants were instructed to pay attention to every stimulus and press a key of a response box when a butterfly appeared. This task had an approximate duration of 8 minutes.

Figure 1

Schematic representation of the Face Processing Task



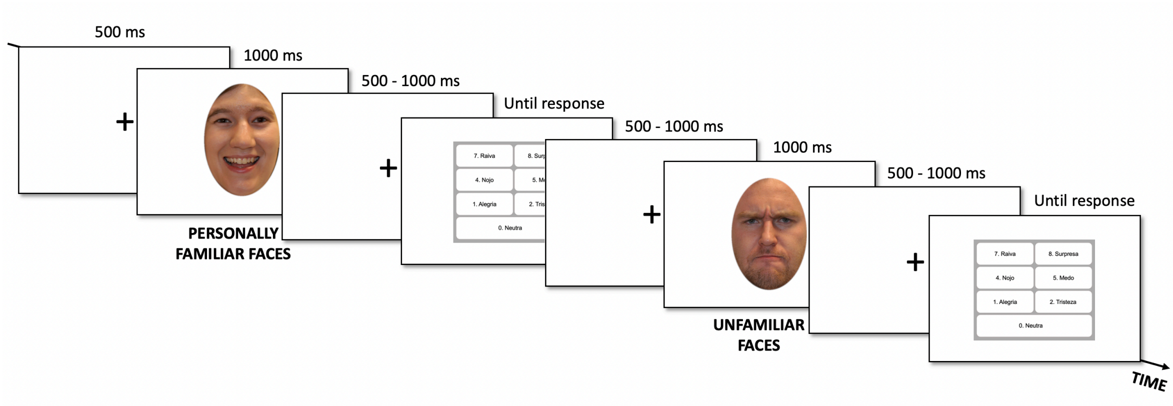
Note. The facial stimuli depicted in the figure are part of a set of facial stimuli (Conley et al., 2018) and have the purpose to illustrate the task.

Task 2: Emotion Identification Task. This task aimed to assess identification and neural processing of FEE from personally familiar (loved ones) and unfamiliar faces. Thereby, stimuli included different facial expressions (i.e., neutral, happiness, sadness, disgust, fear, anger, and surprise) taken in the first experimental session. Once again, for the personally familiar category of stimuli, each participant saw photographs of the members of their triad. For the unfamiliar category, participants were presented with photographs of the members of other triads pseudo-randomly selected to have similar demographic characteristics to the triad of each participant.

This task was composed by 420 experimental trials: 30 photographs of loved ones and 30 photographs of unfamiliar faces, displaying the seven emotional expressions. The organization of the task consisted in a practice block (3 trials), and three experimental blocks (with 140 trials each) divided by an unlimited pause. Participants were asked to categorise the emotions displayed by the facial stimuli on a response slide displaying labels of the seven emotions (1. Neutral, 2. Happiness, 3. Sadness, 4. Disgust, 5. Fear, 6. Anger, and 7. Surprise). Each participant was instructed to respond in the response slide, to ensure that artifacts of preparatory response potentials during the facial stimuli were avoided. This task had a duration of approximately 21 minutes. Figure 2 presents a scheme of two trials of this task.

Figure 2

Schematic representation of the Emotion Identification Task



Note. The facial stimuli depicted in the figure are part of a set of facial stimuli (Conley et al., 2018) and have the purpose to illustrate the task.

EEG recording and signal processing

The eletroencephalographic (EEG) data recorded from both tasks was recorded through the NetStation V4.5.2 software (2008, Electrical Geodesics Inc., Eugene, OR, USA – EGI), using a 128-electrode Hydrocel Geodesic Sensor Net connected to a Net Amps 300 amplifier (EGI). Impedances were kept below 50 kOhm for all electrodes (as this is a high impedance system). Data was recorded with a sampling rate of 500 Hz and the electrodes were referenced to the vertex (Cz). The pre-processing of the raw data was conducted through EEGLAB (version 2021.0; Delorme and Makeig, 2004) a toolbox of MATLAB (version 2017b, The Mathworks Inc., Natick, MA, USA). Firstly, the EEG signal was downsampled to 250 Hz, bandpass filtered (0.1-30Hz), and bad channels were removed (maximum of 10% of the electrodes). Then, data was decomposed in Independent Components Analysis (ICA) and artifacts (i.e., eye blinks, saccades, and heart rate) were corrected through the subtraction of the respective activity of these components from the data. Channels previously removed were subsequently interpolated, the signal was re-referenced offline to the average of all electrodes and segmented into epochs ranging from -200 to 800 ms time-locked to faces onset. Every segment was then visually inspected, and the remaining artifacts were manually rejected. All epochs were baseline corrected (200 ms pre-stimulus) and averaged by condition.

For peak scoring, two regions where peaks were most prominent (maximum positive/negative voltage) and consistent with the previous literature were chosen through the inspection of the topographical maps. The P100 was measured at O1/O2 cluster (O1: 65, 66, 70, 71; O2: 76, 83, 84, 90), while the N170 and N250 were measured at P7/P8 cluster (P7: 50, 57, 58, 63, 64; P8: 95, 96, 99, 100, 101). The peak amplitudes and latencies were measured in the time window of 100-200 ms after stimulus onset for the P100, 150-255 ms for the N170, and 250-360 ms for the N250 (Figure 3).

Statistical analysis

Behavioural Results. For Task 2, accuracy rates were computed for each participant, emotional condition (neutral, happiness, sadness, disgust, fear, and anger), and familiarity (personally familiar and unfamiliar faces). The results of Task 2 were analysed through rmANOVAs, with *familiarity* and *emotion* as within-participants factors.

Electrophysiological Results. For Task 1, rmANOVAs were computed to analyse the effects of *familiarity* (personally familiar faces, famous faces, unfamiliar faces), *orientation* (inverted, upright) and *hemisphere* (left, right) – all within-participants factors – on the amplitude and latency of the P100, N170, and N250. For Task 2, rmANOVAs were computed to analyse the effects of *familiarity* (personally familiar faces, famous faces, unfamiliar faces), *emotion* (neutral, happiness, sadness, disgust, fear, anger, and surprise) and *hemisphere* (left, right) – within-participants factors – on the amplitude and latency of the P100, N170, and N250.

Exploratory Analysis. Pearson's correlations were computed to examine the correlation between demographic/self-reported information and behavioural/neural results obtained in the two tasks we computed. Linear regression models were then carried out to explore significant correlations. Due to space constraints, these results are reported in the Annex.

The threshold for statistical significance was set at $\alpha = .05$ for all analyses. In case of a violation of sphericity, Greenhouse-Geisser corrected results were reported. Post-hoc pairwise comparisons were corrected to multiple comparisons using the Bonferroni correction. All statistical analyses were carried out using SPSS software, version 27 (IBM Corp., Armonk, NY, USA).

Results

Descriptive statistics of the demographic information and self-report measures can be found in the Annex (Table 1), along with the correlations between demographic/neuropsychological results and ERP amplitudes and behavioural results (Table 2). Descriptive statistics of ERP amplitudes obtained for both experimental tasks are available in the Annex (Tables 3 and 4, respectively).

Behavioural Results

No behavioural data was analysed in the Face Processing Task (Task 1).

Emotion Identification Task. A main effect of *familiarity* was found $F(1, 30) = 4.88$, $p = .035$, $\eta^2_p = .140$, revealing higher accuracy rates for familiar ($M = 79.9$, $SD = 2.1$) compared to unfamiliar faces ($M = 76.0$, $SD = 1.8$). A main effect of *emotion* was also found, $F(3.59, 107.62) = 43.94$, $p < .001$, $\eta^2_p = .594$, showing that happiness ($M = 98.1$, $SD = 0.9$) and neutral expressions ($M = 95.0$, $SD = 1.5$) were more accurately identified compared with the others (all *p*s < .001). The identification of fear ($M = 41.7$, $SD = 3.7$) was significantly less accurate than the other emotions (Anger: $M = 81.3$, $SD = 3.5$; Disgust: $M = 76.3$, $SD = 3.7$; Sadness: $M = 77.8$, $SD = 3.7$; Surprise: $M = 75.6$, $SD = 3.5$; all *p*s < .001). The familiarity*emotion interaction was also significant, $F(6, 180) = 3.40$, $p = .011$, $\eta^2_p = .102$, $\varepsilon = .685$, revealing that fear (Familiar: $M = 47.5$, $SD = 4.6$; Unfamiliar: $M = 35.8$, $SD = 4.5$; $p = .034$) and neutral expressions (Familiar: $M = 97.5$, $SD = 1.2$; Unfamiliar: $M = 92.5$, $SD = 2.3$; $p = .030$) were better recognized when expressed by familiar faces. However, the emotion of surprise was better recognized in unfamiliar faces (Familiar: $M = 69.2$, $SD = 4.3$; Unfamiliar: $M = 81.9$, $SD = 69.2$; $p = .002$).

Electrophysiological Results

Face Processing Task

P100. For the P100 peak amplitude, we did not find a main effect of *familiarity* ($p = .164$), but we found a main effect of *orientation,* $F(1, 31) = 48.35$, $p < .001$, $\eta^2_p = .609$, showing that inverted faces ($M = 6.0$, $SD = 0.7$) elicited higher amplitudes than upright faces ($M = 4.4$, $SD = 0.6$). The familiarity*orientation interaction was non-significant ($p = .240$), but the familiarity*orientation*hemisphere interaction was marginally significant, $F(2, 62) = 2.90$, $p = .086$, $\eta^2_p = .085$, $\varepsilon = .662$, showing that in the left hemisphere, when presented in an upright way, personally familiar faces ($M = 4.8$, $SD = 0.7$) elicited higher amplitudes in comparison to famous faces ($M = 3.0$, $SD = 0.6$). Regarding latencies, no main effects of *familiarity* were found ($p = .307$). However, a main effect of *orientation* was found, $F(1, 31) = 13.68$, $p < .001$, $\eta^2_p = .306$, revealing that inverted faces ($M = 153.5$, $SD = 2.0$) elicited higher latencies than upright faces ($M = 149.0$, $SD = 2.5$). The remaining main effects and interactions were non-significant for the P100 peak amplitude and latency (all *p*s > .113).

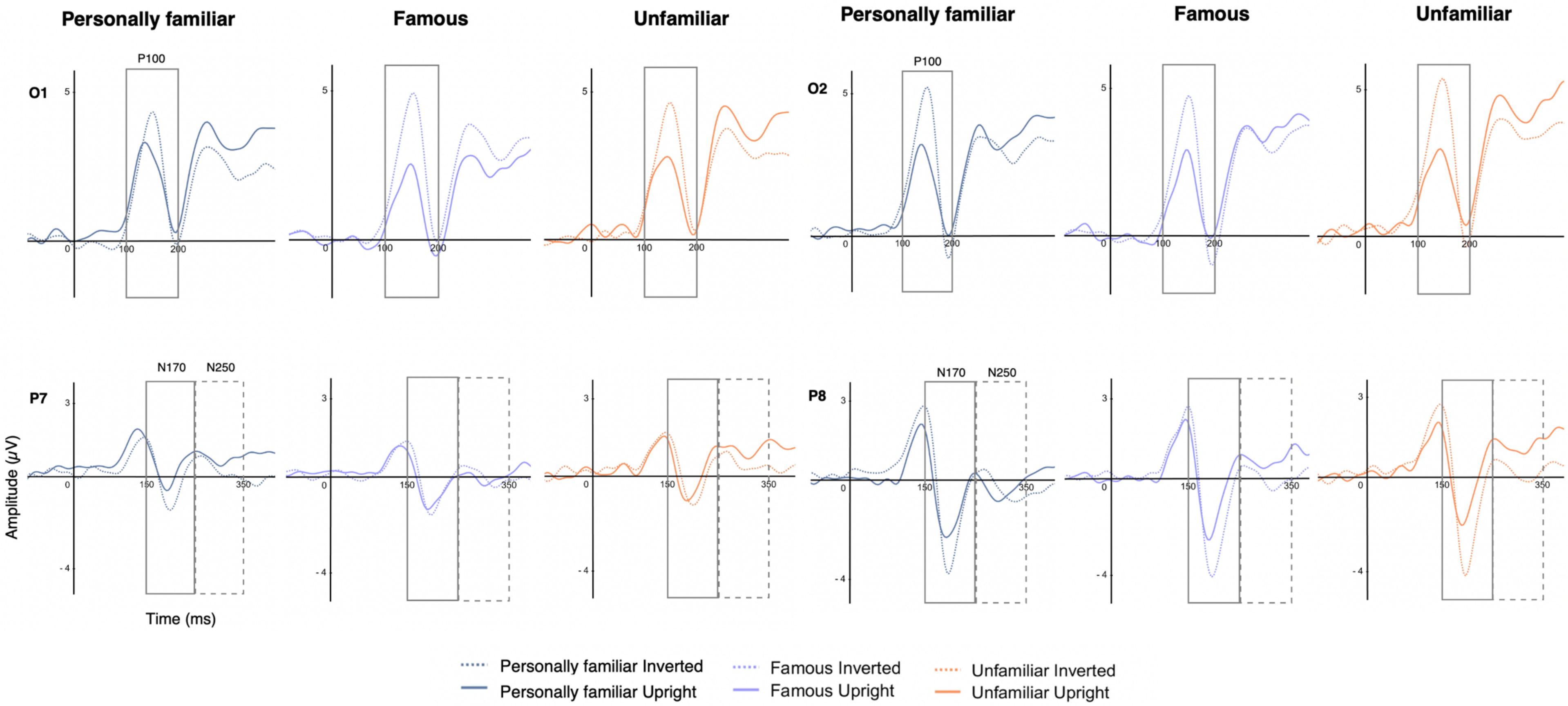
N170. For the N170 peak amplitude, we did not find a main effect of *familiarity* ($p = .438$). However, we found a main effect of *orientation,* $F(1, 31) = 23.20$, $p < .001$, $\eta^2_p = .428$, showing that inverted faces ($M = -3.7$, $SD = 0.6$) elicited higher N170 peak amplitudes than upright faces ($M = -2.6$, $SD = 0.5$). A main effect of *hemisphere,* $F(1, 31) = 28.60$, $p < .001$, $\eta^2_p = .480$, was also found, revealing significantly higher amplitudes in the right hemisphere ($M = -4.3$, $SD = 0.4$) compared to the left hemisphere ($M = -2.1$, $SD = 0.7$). We did not find a significant familiarity*orientation interaction ($p = .456$). However, the orientation*hemisphere interaction was significant, $F(1, 31) = 12.25$, $p < .001$, $\eta^2_p = .283$, showing that, in the right hemisphere, the N170 peak amplitude was significantly higher for inverted ($M = -5.1$, $SD = 0.8$) than upright faces ($M = -3.4$, $SD = 0.6$). The familiarity*orientation*hemisphere interaction was marginally significant, $F(2, 62) = 2.56$, $p = .085$, $\eta^2_p = .076$, showing that, in the right hemisphere, upright personally familiar faces ($M = -3.9$, $SD = 0.7$) elicited higher amplitudes than upright unfamiliar faces ($M = -2.9$, $SD = 0.5$). No other significant main effects or interactions emerged (all *p*s > .289).

Regarding latencies, we also did not find a significant effect of *familiarity* ($p = .404$). However a marginally significant effect of *orientation,* $F(1, 31) = 3.92$, $p = .057$, $\eta^2_p = .112$ was found. Although we did not find a significant orientation*familiarity interaction ($p = .097$), the familiarity*orientation*hemisphere interaction was significant, $F(2, 62) = 4.77$, $p = .023$, $\eta^2_p = .133$, $\varepsilon = .712$, showing that, in the left hemisphere, the upright unfamiliar faces ($M = 197.6$, $SD = 2.8$) elicited lower latencies than upright famous faces ($M = 206.4$, $SD = 2.9$), and higher latencies than the upright personally familiar faces ($M = 196.9$, $SD = 2.7$). The remaining main effects and interactions were non-significant (all *p*s > .404).

N250. For the N250 peak amplitudes, we found a main effect of *familiarity,* $F(1.64, 50.75) = 3.70$, $p = .040$, $\eta^2_p = .107$, revealing significantly higher N250 peak amplitudes for famous faces ($M = -1.0$, $SD = 0.4$) in comparison to unfamiliar faces ($M = -0.4$, $SD = 0.4$). However, the difference between personally familiar and unfamiliar or famous faces were non-significant (both *ps* > .076). We also found a main effect of *orientation,* $F(1, 31) = 6.91$, $p = .013$, $\eta^2_p = .182$, showing that inverted faces ($M = -1.1$, $SD = 0.4$) elicited higher amplitudes than upright faces ($M = -0.6$, $SD = 0.4$). No significant orientation*familiarity interaction was found ($p = .257$). However, we found a significant familiarity*hemisphere interaction, $F(2, 62) = 4.71$, $p = .012$, $\eta^2_p = .132$, showing that, in the left hemisphere, the amplitudes were significantly higher for famous faces ($M = -1.1$, $SD = 0.5$) than unfamiliar faces ($M = -0.3$, $SD = 0.5$). In the right hemisphere, the personally familiar faces ($M = -1.8$, $SD = 0.6$) elicited significantly higher amplitudes than unfamiliar faces ($M = -0.6$, $SD = 0.4$). Regarding latencies, we did not find a main effect of *familiarity* ($p = .147$). However, we found a main effect of *orientation,* $F(1, 31) = 5.78$, $p = .022$, $\eta^2_p = .157$, revealing higher latencies for inverted ($M = 311.4$, $SD = 1.9$) in comparison to upright faces ($M = 307.4$, $SD = 1.7$). The remaining main effects and interactions were non-significant (all *p*s > .130).

Figure 3

Grand averages of P100, N170, and N250 peak amplitudes when faces of the three categories of familiarity were presented (personally familiar, famous, unfamiliar) in an upright and inverted orientation.



Note: O1 = Cluster of the electrodes 65, 66, 70, and 71; O2 = Cluster of the electrodes 76, 83, 84, and 90; P7 = Cluster of the electrodes 50, 57, 58, 63, and 64; P8 = Cluster of the electrodes 95, 96, 99, 100, and 101.

Emotion Identification Task

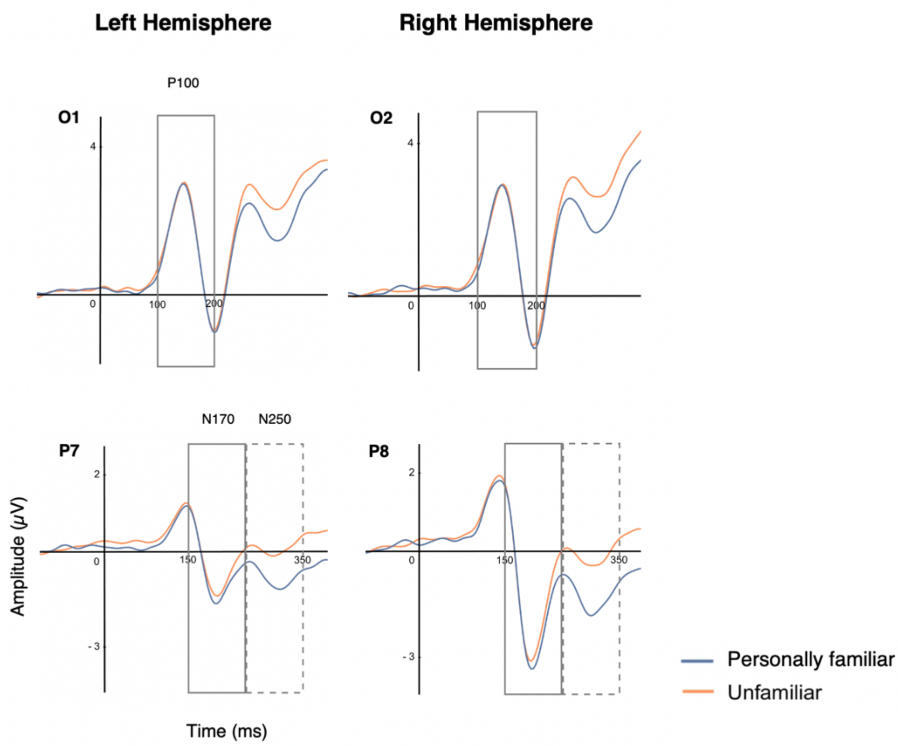
P100. We did not find a main effect of *familiarity* (p = .578) for the P100 peak amplitude. We found a main effect of *emotion,* $F(6, 180) = 2.81$, $p = .012$, $\eta^2_p = .086$. However, after correcting for multiple comparisons, the post-hoc tests did not reveal significant contrasts between emotional categories. No other significant main effects or interactions emerged for the P100 peak amplitude and latency (all ps > .203).

N170. For the N170 peak amplitude, we did not find a main effect of *familiarity* (p = .153), but we found a main effect of *hemisphere,* $F(1, 30) = 18.55$, $p < .001$, $\eta^2_p = .382$, showing that the right hemisphere (M = -4.3, SD = 0.6) had higher amplitudes compared to the left hemisphere (M = -2.2, SD = 0.4). We did not find a significant emotion*familiarity interaction, however a significant familiarity*emotion*hemisphere interaction was found, $F(6, 180) = 2.45$, $p = .026$, $\eta^2_p = .076$. According to this interaction, on the right hemisphere, anger familiar faces elicited significantly higher N170 peak amplitude (M = -5.0, SD = 0.7) than unfamiliar faces (M = -3.8, SD = 0.7). Regarding N170 latency, the main effect of *familiarity* was also not found (p = .281), and the main effect of *emotion* was marginally significant, $F(6, 180) = 1.93$, $p = .079$, $\eta^2_p = .060$. All the remaining main effects and interactions were non-significant (all ps > .147).

N250. A main effect of *familiarity* was found for the N250 peak amplitude, $F(1, 30) = 14.32$, $p < .001$, $\eta^2_p = .323$, revealing higher amplitudes for personally familiar (M = -2.3, SD = 0.5) than for unfamiliar faces (M = -1.3, SD = 0.4). Additionally, a main effect of *emotion* was also obtained, $F(3.85, 6.12) = 3.02$, $p = .022$, $\eta^2_p = .091$, but the post-hoc tests did not reveal significant contrasts between emotional categories. Regarding latencies, it was discovered a main effect of *familiarity,* $F(1, 30) = 7.45$, $p = .010$, $\eta^2_p = .199$, showing higher latencies for personally familiar faces (M = 308.0; SD = 1.7) than unfamiliar faces (M = 305.3; SD = 1.7). No other main effects and interactions were found (all ps > .101).

Figure 4

Grand averages of P100, N170, and N250 peak amplitudes when personally familiar versus unfamiliar faces were presented



Note: As no significant differences were found accordingly to emotion, the results for personally familiar faces and unfamiliar faces were concatenated; O1 = Cluster of the electrodes 65, 66, 70, and 71; O2 = Cluster of the electrodes 76, 83, 84, and 90; P7 = Cluster of the electrodes 50, 57, 58, 63, and 64; P8 = Cluster of the electrodes 95, 96, 99, 100, and 101.

Discussion

A strong relationship between familiarity and face processing has been reported in the literature advocating that this process is optimized in familiar faces – specially personally familiar faces (e.g., Bruck et al., 1991; Caharel & Rossion, 2021; Ramon & Gobbini, 2018; Rossion, 2014;). The present study aimed to explore this improvement by analysing the neural processes elicited by inverted and emotional faces with different degrees of familiarity. It was hypothesized that, with the increase of the facial familiarity, the participants would have a better performance in the identification of FEE (H1), along with higher ERP amplitudes (H2). Concerning the face inversion effect, we hypothesized increased amplitudes and latencies of the ERP components for inverted than upright faces (H3), but we also explored if the familiarity of the face maintained or attenuated the face inversion effect.

Face Processing Task

For the first task, only electrophysiological data was analysed. There were no main effects of familiarity for the amplitudes and latencies of the first two components, partially refuting our second hypothesis. However, marginally significant familiarity*orientation*hemisphere interactions suggest that, in the left hemisphere, upright personally familiar faces elicited higher P100 amplitudes than upright famous faces. Regarding the N170, in the right hemisphere, upright personally familiar faces elicited larger peak amplitude than upright unfamiliar faces. In line with these findings, in the left hemisphere, upright famous faces elicited larger N170 latency than upright unfamiliar faces.

Our hypothesis was based on evidence suggesting greater robustness of the neural representations for more familiar stimuli, which might induce extra neural processes (e.g., related to affective processes and autobiographical information from the individual recognized; Caharel & Rossion, 2021; Wiese et al., 2019). However, as we did not find a main effect of familiarity for the P100 and N170 amplitudes and latencies, our results do not support this hypothesis for the temporal windows of these components. However, the significant familiarity*orientation*hemisphere interactions found for these components further suggests punctual increased amplitudes and latencies for familiar faces compared to unfamiliar faces, as well as for famous faces compared to unfamiliar faces.

In contrast, for the N250 component, the results concerning familiarity are partially consistent with our expectations. We found a higher N250 peak amplitude for famous than for unfamiliar faces, despite the difference between personal familiar and famous or unfamiliar faces be non-significant. Additionally, we obtained a significantly larger N250 peak amplitude for famous than unfamiliar faces in the left hemisphere, as well as for personally familiar than unfamiliar faces in the right hemisphere. Higher neural responses following increased familiarity are strongly supported in the literature and appear to occur as a result of the robustness of the neural representations prompted by familiar faces. These faces not only induce neural processes regarding facial identification, but also affective processes related to memories and autobiographical information (Caharel & Rossion, 2021).

It is interesting to note that the P100 component, as the major visual component (Luck, 2014), seems to translate a basic visual processing of information. The results for the N170 component, in turn, appear to be explained by the detection of information related to the face in the visual field (i.e., processing of different components of the face) that allows the distinction of the face from any other object. Our results suggest that both processes may be similar for both familiar and unfamiliar faces. Since the N250 component may translate the comparison of sensorial inputs with the ones already stored in memory, its increased amplitude for famous and personally familiar faces, in comparison with unfamiliar faces, may be explained by the increased amount of information stored in memory for the former categories of stimuli.

We obtained larger peak amplitudes of the P100, N170, and N250 for inverted faces in comparison to upright faces. This is in agreement with our last hypothesis and the literature concerning the Face Inversion Effect (see e.g., Bentin et al., 1996; Itier and Taylor, 2002, 2004; Jacques & Rossion, 2007; Rossion et al., 2000; Rossion & Gauthier, 2002; Taylor et al., 2001). A delayed latency was found at the level of the P100 and N250. Surprisingly, in the time window of the N170 the differences were only marginally significant. This component is typically delayed in face inversion, an event that also happens when face features are displaced, removed, or masked, or even when isolated features are presented. This demonstrates that the inversion of a face causes a disruption of our expert use of local relational information between parts of the faces (Rossion & Gauthier, 2002). This latency effect can reflect a delayed activation of face representations or a slower enrolment of neural activity when the faces are displayed in these unusual views (Jacques & Rossion, 2007). A particularly striking aspect of this lack of latency results is that, as speculated by Jacques and Rossion (2007), the phenomenon that may explain the amplitude effect expected for inverted faces may be the same for the latency effect.

The absence of a significant orientation*familiarity interaction at this level is worth mentioning. As supported by previous studies, this may suggest that the FIE is independent of the degree of face familiarity. In other words, it is believed to persist through the different levels of familiarity (see e.g., Collishaw & Hole, 2000; Yarmey, 1971). This is inconsistent with the familiarity effect, as it should enhance the recognition of faces and therefore could make the FIE less expressive with the increase of familiarity. However, a possible explanation for these results may be the lack of statistical power in this task to turn possible the observation of the familiarity effect. This limitation can also explain the lack of ambiguity regarding the second hypothesis, through the results of this first task, more specifically from the N170 component outcomes.

Emotion Identification Task

At a behavioural level, we found that the participants had better results in the identification of emotions displayed in personally familiar than unfamiliar faces. This result supports our first hypothesis and previous findings systematically advocating that there is an optimization in terms of performance as the familiarity of faces increases (e.g., Caharel & Rossion, 2021; Ramon & Gobbini, 2018). There is no doubt of the crucial social purpose of this improvement: to enrich social interactions with relevant persons (Ramon & Gobbini, 2018).

We also found that fearful and the neutral expressions were better recognized when displayed in personally familiar than unfamiliar faces, but the same did not happen with the expression of surprise, better recognized when expressed by unfamiliar faces. A possible explanation for this inconsistency may be related to the well-known trade-off between the control of the stimuli and ecological validity (Ferreira-Santos, 2015). In favour of the ecological validity of the study, the photographs were taken without asking participants to remove any visible accessories (e.g., glasses), and kept in the original colours. Nevertheless, multiple steps to ensure the control of the stimuli were also taken (i.e., the effort to take all the photographs in the same conditions, the preparation of standard instructions for the training of each FEE with the participants, the edition of changes in luminance/contrast, and the inclusion of an oval mask). The efforts to reduce the variability of the stimuli is a plausible factor of the lack of consistency and effects throughout the different emotions. For example, the usage of standard instructions may possibly have led the participants to fake their expression of the emotions, while a more "open" instruction, (e.g., example of a situation) could have elicited more genuine expressions that would facilitate their detection by their loved ones.

At a neural level, the results of this task were consistent with the results of our Face Processing Task. In the P100 and N170 time-windows, there were no main effects found for amplitudes and latencies, but personally familiar anger faces elicited higher N170 amplitudes than unfamiliar anger faces in the right hemisphere.

Regarding the N250 component, it was found a larger amplitude and latency for personally familiar than unfamiliar faces, allowing a more robust confirmation of our hypothesis for the neural processing occurring on this time-window. As this task has more trials per familiar conditions than the previous one, it has increased statistical power. Moreover, the lack of significant emotion*familiarity interaction, may suggest that the effect of familiarity on this ERP component is related to the identification of the identity of the face, independently of the emotion expressed.

To explore the predictive roles of demographic characteristics and self-report data in the behavioural and neural results, we conducted an exploratory analysis that is reported in the Annex. We found that age and years of formal education were significant predictors of the accuracy in the identification of the most emotional categories displayed in both familiar and unfamiliar faces. The results regarding age are in line with a previous study (Gonçalves et al., 2018) that suggests that aging can impair our abilities of identifying emotions, and these age-related changes seem to take place progressively through the lifespan. Thereby, a natural progression of this work could be the analysis of the familiarity effects through the lifetime, with a sample of different age groups.

Additionally, the MSPSS was a significant predictor of accuracy rates for personally familiar faces expressing fear. At a neural level, we also found that the mean of the results of the MSPSS reported for the loved ones was a predictor of both N170 and N250 peak amplitudes elicited by unfamiliar faces expressing anger. This suggests that the degree of perceived social support can predict a better performance in the identification of emotions of fear expressed by loved ones, but also an increased neural response to emotions of anger expressed by unfamiliar individuals. These findings are consistent with the previous literature demonstrating the adaptative value of recognizing expressions of fear and anger. For instance, the increased response of the amygdala for fear and anger expressions serves as a signal for the presence of threats learned across experience. In other words, fearful and anger expressions allow the questioning about what is making the person afraid or angry, directly modulating the viewer's emotional state accordingly this perception (Whalen et al., 2017). This outcome suggests that this ability may be influenced by the perceived social support that we have from our social peers.

Through our regression analysis, we also discovered that the TAS-20 was a significant predictor of the N170 peak amplitude elicited by personally familiar faces expressing happiness. The subscale related to the difficulty in identifying feelings was also found to be a significant predictor of the N250 peak amplitude when unfamiliar faces expressing sadness were presented. This result reflects the relevance of controlling for the presence of alexithymia (i.e., the ability to identify emotions) in studies that rely on facial emotion processing.

Similarly, we found that, for both tasks, the depression subscale of the HADS was a significant predictor of increased N170 and N250 peak amplitudes obtained for most of the conditions. This result is in conformity with a qualitative review supporting that depression is characterized by a higher activation of the amygdala in response to FEE (Swartz et al., 2017). Therefore, it shows the importance of controlling for the effects of trait and state depression and/or the use of psychotropic medication by the participants included. In the present study, we did not exclude participants with depression and/or use of psychotropic medication to increase the proximity of our results to those expected in the "real" population, where these effects have a high incidence and prevalence. However, these effects may also affect the conditions that are being compared in this study. Thus, future studies, conducted with larger samples, should focus on searching for a better control of the effects of these variables.

Conclusion

The most obvious finding to emerge from this study is that facial familiarity improves the identification of facial expressions of emotion, as systematically reported across the literature. Additionally, we found a higher N250 response for personally familiar faces in comparison to unfamiliar ones. This result supports the reasoning that the facial familiarity increases the neural activity during the N250 time-window, which may be explained by the processing of additional information prompted by the viewing of our loved ones faces, in contrast to what happens with unfamiliar individuals. The absence of familiarity results concerning the P100 and N170 reflects the immediate nature of these components in facial processing, previous to the awareness of the identity of the face, giving us insights about the timing of facial familiarity recognition.

Lastly, the present study has revealed a general enhanced response of the P100, N170, and N250 for inverted faces in comparison to upright faces. However, the facial familiarity does not seem to reduce the face inversion effect, as suggested by the lack of a significant interaction between face inversion and familiarity.

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Annex

Table 1

Means (and standard deviations) obtained in the demographic information and self-report measures.

Measures	M(SD)
Age	27.69 (9.26)
Education	16.03 (3.29)
MSPSS	74.16 (7.96)
MSPSS (LO)	67.48 (11.20)
TAS-20	52.72 (12.08)
TAS-20 (DIF)	19.34 (6.04)
HADS (Anxiety)	8.12 (3.07)
HADS (Depression)	4.28 (2.72)

Note: MSPSS = Multidimensional Scale of Perceived Social Support; MSPSS (LO) = Mean of the results of the MSPSS in relation to each loved one of each participant; TAS-20 = Toronto Alexithymia Scale; TAS (DIF) = Difficulty in identifying feelings, a subscale from TAS-20; HADS = Hospital Anxiety and Depression Scale.

Table 2

Correlations between demographic/neuropsychological results and ERP amplitudes (µV) and behavioural results.

				Age	Education	MSPSS	MSPSS (LO)	TAS-20	TAS (DIF)	HADS (Anxiety)	HADS (Depression)
Task 1: Face Processing Task											
P100	O1 Cluster	Unfamiliar	Inverted	.004	-.209	-.120	.081	.097	.181	.077	-.010
			Upright	.034	-.123	.054	.202	-.048	-.022	-.056	-.169
		Famous	Inverted	-.123	-.133	-.018	.146	-.059	.027	-.057	-.240
			Upright	-.042	-.155	-.088	.142	.009	.091	.015	-.099
		Personally Familiar	Inverted	.053	-.270	.006	.100	-.023	-.023	.028	-.097
			Upright	-.038	-.090	-.054	.091	-.024	.081	.007	-.072
	O2 Cluster	Unfamiliar	Inverted	-.027	-.142	-.051	.180	-.053	.074	-.005	-.148
			Upright	-.004	-.151	.085	.169	.018	-.023	-.022	-.221
		Famous	Inverted	-.100	-.132	.000	.137	-.051	.009	-.073	-.193
			Upright	-.027	-.060	-.023	.149	-.056	.001	-.030	-.110
		Personally Familiar	Inverted	.025	-.165	.088	.222	-.143	-.088	-.048	-.203
			Upright	-.034	-.275	-.069	.217	.053	.077	.138	-.020

N170	P7 Cluster	Unfamiliar	Inverted	-.173	-.013	-.048	.067	-.074	-.060	.023	**-.363***
			Upright	-.130	.057	.161	.302	-.291	-.115	-.212	**-.500****
		Famous	Inverted	-.163	-.111	.081	.053	-.099	-.075	-.117	**-.478****
			Upright	-.013	-.173	.016	-.153	.002	-.115	-.065	-.337
		Personally	Inverted	.091	-.122	-.038	-.034	.001	-.146	-.077	-.216
		Familiar	Upright	-.080	.032	.017	-.080	-.235	-.143	-.234	**-.382***
	P8 Cluster	Unfamiliar	Inverted	.125	.083	-.007	.229	-.039	-.125	-.197	-.318
			Upright	.058	.162	.043	.088	-.074	-.222	-.203	**-.417***
		Famous	Inverted	.032	-.012	.000	.285	-.041	-.121	-.170	**-.442***
			Upright	-.041	.177	-.076	.185	-.022	-.116	-.096	-.252
		Personally	Inverted	.096	-.056	.035	.275	.087	-.114	.011	-.253
		Familiar	Upright	.220	-.044	-.040	.073	-.031	-.234	-.115	-.237
N250	P7 Cluster	Unfamiliar	Inverted	.032	.038	.019	.056	-.001	-.051	.039	-.249
			Upright	.062	.212	.155	.205	**-.360***	-.198	-.319	**-.428***
		Famous	Inverted	-.008	.122	.137	-.018	-.192	-.162	-.338	**-.481****
			Upright	.165	.082	.106	-.127	-.133	-.191	-.241	-.325
		Personally	Inverted	.305	-.004	-.057	-.194	-.025	-.173	-.133	-.003
		Familiar	Upright	.155	.167	.093	-.153	-.219	-.157	-.316	-.270
	P8 Cluster	Unfamiliar	Inverted	.101	.166	-.090	.045	-.246	-.097	-.243	-.164
			Upright	.055	.126	-.179	-.337	-.170	-.089	-.020	-.157
		Famous	Inverted	-.042	.006	-.225	.062	-.044	.089	-.055	-.152

		Upright	-.146	.221	-.237	-.218	-.056	-.034	.090	.055
	Personally Familiar	Inverted	.156	-.101	-.127	-.025	.090	.028	.207	.039
		Upright	.054	-.063	-.161	-.070	-.138	-.131	.127	.000
Task 2: Emotion Identification Task										
Accuracy (%)	Unfamiliar	ANG	**-.529****	.205	-.240	-.238	.243	.146	-.120	-.119
		DIS	-.201	.231	.056	.065	-.038	-.050	.112	-.055
		FEA	**-.365***	**.392***	.031	-.084	-.011	.038	-.050	-.254
		HAP	**-.659****	**.538****	.091	-.113	-.311	-.203	-.229	-.342
		NEU	-.133	.248	.071	-.080	.148	.170	.240	.060
		SAD	-.354	.265	-.063	-.177	-.215	-.124	-.230	-.208
		SUR	-.288	.139	.120	.251	-.187	-.136	-.259	-.191
	Personally Familiar	ANG	-.311	**.370***	.159	.011	.059	.127	.115	-.109
		DIS	**-.499****	**.682****	-.030	-.193	-.127	-.007	-.013	-.046
		FEA	-.202	**.437***	**.508****	.186	-.078	-.137	-.036	-.222
		HAP	**-.864****	**.565****	.117	.077	-.278	-.137	-.184	**-.436***
		NEU	**-.435***	**.414***	.213	.211	.045	.181	-.067	-.217
		SAD	-.113	**.433***	.230	-.031	-.121	-.026	-.071	-.166
		SUR	-.158	-.259	.142	.004	-.033	-.017	-.031	.063

P100	O1 Cluster	Unfamiliar	ANG	-.004	-.164	-.132	.033	-.002	.021	.018	.046
			DIS	-.020	-.179	-.033	.005	-.063	.037	.028	.008
			FEA	-.001	-.053	.030	.244	.123	.092	.055	.079
			HAP	.061	-.216	-.008	.222	.165	.055	.101	-.002
			NEU	-.058	-.087	-.114	.056	.119	.050	.076	.058
			SAD	-.005	-.122	-.018	-.094	-.027	.002	-.027	.014
			SUR	-.075	-.218	.017	.183	.035	.078	.029	-.103
		Personally Familiar	ANG	.091	-.079	.024	-.084	-.084	-.074	-.033	-.022
			DIS	-.247	-.078	.031	.136	.010	.025	-.012	-.102
			FEA	-.068	-.267	.064	-.014	.118	.122	.086	-.003
			HAP	-.033	-.186	.020	-.030	-.088	-.032	-.059	-.026
			NEU	.032	-.172	-.066	-.090	-.094	-.070	-.059	.036
			SAD	-.050	-.082	.070	-.075	.015	-.019	-.033	-.085
			SUR	.045	-.264	.050	.028	.087	.102	.133	.028
	O2 Cluster	Unfamiliar	ANG	.065	-.110	-.132	.031	-.079	-.144	-.146	-.087
			DIS	.010	-.198	.004	.125	-.081	.013	.039	.013
			FEA	.012	-.179	.051	.254	.082	.077	.088	.006
			HAP	.063	-.208	-.083	.223	-.070	-.092	-.012	-.077
			NEU	-.047	-.137	.075	.197	-.045	-.102	.020	-.124
			SAD	.018	-.123	.031	.189	-.061	-.080	-.057	-.071
			SUR	.006	-.168	.116	.248	-.099	-.073	-.014	-.161

		Personally Familiar	ANG	.012	-.179	.051	.254	.082	.077	.088	.006
			DIS	-.138	-.207	-.021	.266	-.055	-.081	.078	-.093
			FEA	.112	-.146	.146	.127	-.093	-.118	-.012	.068
			HAP	.044	-.232	.110	.206	-.092	-.052	.005	-.103
			NEU	.033	-.212	.035	.169	-.079	-.087	-.103	-.040
			SAD	.028	-.139	.127	.091	-.127	-.151	-.077	-.170
			SUR	.072	-.298	.075	.251	.051	.062	.128	-.015
N170	P7 Cluster	Unfamiliar	ANG	-.012	.115	-.116	**-.463****	-.294	-.143	-.118	-.175
			DIS	-.302	.159	.083	-.138	-.022	.038	-.125	**-.449***
			FEA	-.120	.256	-.080	-.233	-.338	-.136	-.331	-.333
			HAP	-.264	-.055	.186	-.191	-.171	-.166	-.205	**-.569****
			NEU	-.252	.195	.023	-.318	-.319	-.193	-.202	**-.470****
			SAD	-.121	.145	.020	-.245	**-.405***	-.256	-.319	**-.491****
			SUR	-.090	.149	-.103	-.133	**-.427***	-.229	-.297	**-.386***
		Personally Familiar	ANG	-.061	**.368***	.099	-.216	**-.453***	-.264	**-.387***	**-.494****
			DIS	-.232	.109	.203	.003	-.214	-.235	-.221	**-.531****
			FEA	-.132	.167	-.025	.140	-.020	.014	-.084	-.210
			HAP	-.217	.185	.038	.010	**-.378***	-.244	-.203	-.339
			NEU	-.127	.234	.140	-.185	-.193	-.212	-.215	-.315
			SAD	-.272	.237	-.049	.078	-.169	.003	-.082	-.310
			SUR	-.197	.110	-.082	-.052	-.168	-.096	-.127	**-.395***

	P8 Cluster	Unfamiliar	ANG	.164	.131	-.049	-.016	-.092	-.303	-.308	**-.379***
			DIS	.163	-.058	-.035	-.050	-.029	-.203	-.112	-.318
			FEA	.120	.032	.017	-.086	-.011	-.227	-.149	-.340
			HAP	.242	.050	.008	.069	-.226	**-.440***	**-.380***	**-.396***
			NEU	.167	.056	.058	.039	-.065	-.279	-.140	**-.402***
			SAD	.248	.124	.137	.032	-.190	**-.444***	-.342	**-.373***
			SUR	.098	-.019	.201	-.052	-.127	-.298	-.121	**-.413***
		Personally Familiar	ANG	.202	.166	.039	-.089	-.168	-.328	-.147	-.284
			DIS	.057	.251	.143	.078	-.198	**-.485****	-.288	**-.502****
			FEA	.257	.041	.086	-.048	-.197	**-.447***	-.271	**-.361***
			HAP	.266	.022	.138	.041	-.219	-.349	-.291	**-.382***
			NEU	.219	.173	.051	.090	-.159	**-.367***	-.316	**-.444***
			SAD	.140	.119	.045	.000	-.109	-.239	-.253	**-.462****
			SUR	.210	.086	.027	.110	-.166	-.349	-.245	**-.370***
N250	P7 Cluster	Unfamiliar	ANG	.176	.169	.017	**-.408***	-.321	-.235	-.291	-.240
			DIS	-.034	.194	.032	-.326	-.132	-.056	-.285	**-.384***
			FEA	.105	.197	-.111	-.261	-.307	-.167	**-.432***	-.337
			HAP	-.157	.059	.236	-.266	-.117	-.152	-.285	**-.534****
			NEU	-.019	.199	.093	-.251	**-.360***	-.212	-.325	**-.483****
			SAD	.043	.136	.041	-.274	-.336	-.172	-.279	**-.415***
			SUR	.091	.212	-.090	-.159	-.318	-.172	**-.375***	-.351

	Personally Familiar	ANG	.118	.302	.021	-.219	-.331	-.221	**-.385***	**-.421***
		DIS	.018	.170	-.047	-.050	-.122	-.087	-.271	**-.404***
		FEA	.102	.190	-.172	-.073	-.124	-.035	-.258	-.131
		HAP	-.016	.190	-.062	-.103	-.294	-.116	-.218	-.190
		NEU	.032	.251	.046	-.296	-.174	-.147	-.307	**-.373***
		SAD	.046	.283	-.029	.038	-.158	-.049	-.191	-.263
		SUR	.099	.123	-.147	-.170	-.128	-.084	-.182	-.277
P8 Cluster	Unfamiliar	ANG	.139	.214	-.149	-.010	-.228	-.266	-.231	-.217
		DIS	.219	-.148	-.073	-.188	-.179	-.194	.040	-.026
		FEA	.172	-.020	.065	-.134	.038	-.100	.026	-.216
		HAP	.325	.130	-.008	.053	**-.360***	**-.427***	-.143	-.159
		NEU	.212	-.067	-.079	-.108	.022	-.144	.007	-.197
		SAD	**.368***	.062	.147	-.155	-.336	**-.493****	-.316	-.202
		SUR	.184	-.054	.155	-.285	-.198	-.230	.078	-.045
	Personally Familiar	ANG	.294	.086	-.007	-.159	-.168	-.241	.013	-.116
		DIS	.204	.160	.090	-.110	-.217	-.330	-.115	-.264
		FEA	.244	-.040	.125	-.160	-.139	-.269	.016	-.176
		HAP	.236	.067	.029	-.015	-.233	-.167	-.036	-.098
		NEU	.277	.045	.016	.090	-.077	-.204	-.058	-.211
		SAD	.210	.064	.093	-.028	-.080	-.165	-.095	-.342
		SUR	.292	.109	.033	.032	-.112	-.183	-.033	-.159

Note: ***p* < .05; ****p* < .01.** Correlations in boldface were explored through Linear Regression Models (Tables 6-10). MSPSS = Multidimensional Scale of Perceived Social Support; MSPSS (LO) = Mean of the results of the MSPSS in relation to each loved one of each participant; TAS-20 = Toronto Alexithymia Scale; TAS (DIF) = Difficulty in identifying feelings, a subscale from TAS-20; HADS = Hospital Anxiety and Depression Scale; ANG = Anger; DIS = Disgust; FEA = Fear; HAP = Happiness; NEU = Neutral; SAD = Sadness; SUR = Surprise.

Table 3

Means (standard deviations) for P100, N170 and N250 amplitudes (µV) and latencies (ms) evoked per condition of the Face Processing Task.

		P100				N170				N250			
		Amplitude		Latency		Amplitude		Latency		Amplitude		Latency	
		O1	O2	O1	O2	P7	P8	P7	P8	P7	P8	P7	P8
Unfamiliar	Upright	4.45	4.67	149.75	147.78	-1.75	-2.90	197.58	200.38	0.02	0.04	306.64	303.10
		(4.14)	(3.56)	(18.59)	(17.75)	(3.18)	(3.08)	(15.96)	(17.50)	(3.69)	(2.62)	(20.32)	(17.57)
	Inverted	5.65	6.62	154.16	151.81	-2.24	-5.20	204.20	203.55	-0.63	-1.17	308.13	316.16
		(3.24)	(4.12)	(16.43)	(14.73)	(3.59)	(4.94)	(15.07)	(15.40)	(2.61)	(3.07)	(19.84)	(22.46)
Famous	Upright	3.80	4.20	152.16	150.21	-2.38	-3.48	206.41	199.38	-1.11	-0.58	310.60	312.38
		(3.20)	(3.49)	(14.39)	(16.30)	(2.54)	(3.30)	(16.56)	(16.70)	(2.90)	(3.07)	(17.78)	(20.65)
	Inverted	5.92	6.05	155.81	152.01	-2.30	-5.10	201.13	205.03	-1.07	-1.16	310.95	311.90
		(4.38)	(4.59)	(14.35)	(14.41)	(3.35)	(4.72)	(16.77)	(14.15)	(3.11)	(3.64)	(18.32)	(16.16)
Personally Familiar	Upright	4.77	4.63	147.29	146.62	-1.40	-3.87	196.94	203.96	-0.36	-1.88	304.41	306.73
		(3.96)	(3.50)	(16.22)	(16.44)	(3.53)	(4.06)	(15.02)	(16.28)	(3.67)	(3.24)	(17.87)	(20.22)
	Inverted	5.36	6.36	153.49	153.69	-2.29	-5.02	203.05	204.20	-0.69	-1.72	308.08	313.05
		(3.80)	(5.43)	(15.89)	(12.58)	(3.08)	(4.88)	(15.06)	(17.30)	(3.20)	(4.01)	(18.35)	(20.14)

Table 4

Means (standard deviations) for P100, N170 and N250 amplitudes (µV) and latencies (ms) evoked per condition of the Emotion Identification Task.

		P100				N170				N250				
		Amplitude		Latency		Amplitude		Latency		Amplitude		Latency		Accuracy (%)
		O1	O2	O1	O2	P7	P8	P7	P8	P7	P8	P7	P8	
Unfamiliar	Anger	4.22 (3.23)	4.42 (3.44)	154.06 (14.79)	149.89 (17.80)	-2.50 (2.58)	-3.83 (3.64)	205.63 (13.83)	205.41 (16.31)	-1.57 (3.11)	-1.36 (2.66)	305.18 (15.64)	303.96 (21.53)	78.28 (25.44)
	Disgust	5.04 (3.33)	5.04 (3.80)	152.19 (12.77)	148.60 (16.72)	-1.96 (2.55)	-4.44 (3.54)	208.72 (16.36)	204.71 (14.38)	-1.30 (3.04)	-1.55 (2.79)	306.16 (19.05)	305.34 (18.51)	72.58 (26.97)
	Fear	3.74 (3.98)	4.04 (3.97)	151.28 (17.10)	153.10 (17.23)	-2.47 (2.55)	-4.11 (3.57)	208.45 (13.66)	207.72 (15.18)	-1.73 (3.69)	-1.63 (3.22)	306.17 (22.52)	304.86 (18.61)	35.81 (25.25)
	Happiness	4.44 (3.30)	4.76 (3.70)	150.81 (14.85)	148.10 (16.19)	-1.44 (3.77)	-4.45 (3.59)	206.05 (14.03)	204.81 (18.59)	-0.26 (3.71)	-1.70 (2.68)	306.74 (18.70)	303.74 (19.79)	97.96 (4.92)
	Neutral	4.01 (3.49)	4.49 (3.76)	151.66 (15.81)	151.52 (16.83)	-2.08 (2.96)	-4.07 (4.21)	206.59 (16.89)	206.44 (15.37)	-0.51 (3.35)	-1.36 (3.51)	306.88 (22.88)	312.21 (16.35)	92.47 (12.82)
	Sadness	4.16 (3.24)	4.17 (3.69)	152.52 (16.16)	151.87 (17.19)	-1.70 (2.95)	-4.40 (3.71)	208.45 (17.79)	203.25 (15.22)	-0.68 (3.57)	-1.55 (3.01)	300.64 (20.91)	306.22 (17.23)	73.23 (22.29)
	Surprise	4.27 (3.63)	3.98 (3.93)	153.44 (12.95)	150.84 (15.82)	-2.58 (2.58)	-3.73 (2.97)	208.45 (17.79)	203.25 (15.22)	-1.59 (3.16)	-0.78 (3.06)	305.36 (16.75)	300.21 (17.38)	81.94 (19.73)

Personally Familiar	Anger	4.27	4.04	148.32	149.10	-2.30	-5.01	206.26	207.30	-2.42	-3.33	309.24	309.54	84.30
		(2.91)	(3.97)	(13.27)	(15.38)	(3.12)	(4.07)	(18.05)	(16.61)	(4.11)	(4.70)	(17.61)	(19.30)	(20.32)
	Disgust	4.34	4.98	150.52	152.74	-2.41	-4.39	209.35	206.01	-2.31	-2.76	304.12	307.76	80.11
		(3.15)	(4.05)	(15.96)	(15.98)	(2.48)	(3.03)	(16.03)	(18.31)	(3.70)	(3.52)	(17.00)	(17.18)	(24.86)
	Fear	4.22	4.04	152.84	149.81	-2.39	-4.59	205.48	203.98	-2.08	-3.00	312.52	304.85	47.53
		(3.13)	(3.44)	(16.39)	(16.74)	(3.10)	(3.82)	(17.52)	(15.20)	(4.14)	(3.46)	(20.15)	(21.62)	(25.65)
	Happiness	4.20	4.27	152.06	147.56	-2.64	-4.17	206.28	203.33	-1.68	-2.39	310.49	310.68	98.28
		(3.33)	(3.65)	(13.48)	(16.09)	(2.73)	(3.34)	(17.32)	(13.96)	(3.56)	(3.34)	(17.91)	(18.37)	(5.64)
	Neutral	4.06	4.29	152.67	151.29	1.96	-4.06	207.76	202.74	-1.46	-2.26	303.94	313.92	97.53
		(3.04)	(3.25)	(15.99)	(18.31)	(2.85)	(3.95)	(15.34)	(17.79)	(3.66)	(3.90)	(18.89)	(16.63)	(6.72)
	Sadness	3.96	4.14	150.13	149.87	-2.26	-4.58	200.03	204.27	-1.63	-2.79	305.56	304.32	82.37
		(3.42)	(3.83)	(13.84)	(16.21)	(2.62)	(4.42)	(15.63)	(16.06)	(3.61)	(4.28)	(17.30)	(17.54)	(30.69)
	Surprise	4.29	4.52	151.23	149.26	-2.33	-4.16	203.73	203.09	-1.28	-2.68	307.21	307.97	69.25
		(2.79)	(3.29)	(13.36)	(16.30)	(2.50)	(3.93)	(16.10)	(14.09)	(3.19)	(3.75)	(17.03)	(21.77)	(24.06)

Linear Regression Models

We computed Pearson's *r* to examine possible correlations between demographic/neurocognitive information and behavioural and neural results of both tasks (See Table 2). Linear regression models were also carried out to explore significant correlations.

Face Processing Task

N170 (P7 Cluster). Statistically significant regression equations were found for the models that included the N170 peak amplitudes at P7 for unfamiliar upright ($F(2,29) = 4.86$, $p = .015$), and unfamiliar inverted faces ($F(1,30) = 4.56$, $p = .041$), as well as for famous inverted faces ($F(1,30) = 8.90$, $p = .006$), and personally familiar upright faces ($F(1,30) = 5.14$, $p = .031$), as outcome variables, with adjusted R2's of .199, .103, .203, and .118, respectively (Table 5). The depression subscale of the HADS was the only significant predictor of these models (unfamiliar upright faces: $\beta = -.478$, $p = .017$; unfamiliar inverted faces: $\beta = -.363$, $p = .041$; famous inverted faces: $\beta = -.478$, $p = .006$; personally familiar upright faces: $\beta = -.382$, $p = .031$).

N170 (P8 Cluster). The model that included N170 peak amplitudes at P8 for unfamiliar upright faces ($F(1,30) = 6.33$, $p = .017$), and famous inverted faces ($F(1,30) = 7.28$, $p = .011$), as outcome variables, was significant, with adjusted R2's of .147 and .168, respectively (Table 6). The depression subscale of the HADS was the only significant predictor of these models (unfamiliar upright faces: $\beta = -.417$, $p = .017$; famous inverted faces: $\beta = -.442$, $p = .011$).

N250 (P7 Cluster). The model that included N250 peak amplitudes at P7 for unfamiliar upright faces ($F(1,30) = 4.47$, $p = .043$) as the outcome variable, was significant, with an adjusted R2 of .101 (Table 7). The TAS-20 was the only significant predictor of this model ($\beta = -.360$, $p = .043$).

Emotion Identification Task

Behavioural Results (see Table 9)

Unfamiliar faces displaying anger. Statistically significant regression equations were found for the models with accuracy identifying unfamiliar faces expressing anger as the outcome variable, $F(1,29) = 11.28$, $p = .002$, with an adjusted R2 of .255. Age was the only significant predictor ($\beta = -.529$, $p = .002$).

Unfamiliar faces displaying happiness. Statistically significant regression equations were found for the models with accuracy identifying unfamiliar faces expressing happiness as the outcome variable, $F(2,27) = 17.69$, $p < .001$, with an adjusted R2 of .535. Age ($\beta = -.553$, $p < .001$) and education ($\beta = .371$, $p = .009$) were the only significant predictors.

Personally familiar faces displaying anger. Statistically significant regression equations were found for the models with accuracy identifying personally faces expressing anger as the outcome variable, $F(1,28) = 4.45$, $p = .044$, with an adjusted R2 of .106. Education ($\beta = -.370$, $p = .044$) was the only significant predictor.

Personally familiar faces displaying disgust. Statistically significant regression equations were found for the models with accuracy identifying personally faces expressing disgust as the outcome variable, $F(2,27) = 17.79$, $p < .001$), with an adjusted R2 of .537. Education ($\beta = -.337$, $p = .017$) was the only significant predictor.

Personally familiar faces displaying fear. Statistically significant regression equations were found for the models with accuracy identifying personally faces expressing fear as the outcome variable, $F(2,27) = 7.69$, $p = .002$, with an adjusted R2 of .316. Education ($\beta = -.329$, $p = .048$) and the MSPSS ($\beta = -.428$, $p = .012$) were the only significant predictors.

Personally familiar faces displaying happiness. Statistically significant regression equations were found for the models with accuracy identifying personally faces expressing happiness as the outcome variable, $F(3,26) = 58.21$, $p < .001$, with an adjusted R2 of .855. Age ($\beta = -.745$, $p < .001$) and the education ($\beta = .290$, $p = .001$) were the only significant predictors.

Personally familiar faces displaying sadness. Statistically significant regression equations were found for the models with accuracy identifying personally faces expressing sadness as the outcome variable, $F(1,28) = 6.46$, $p = .017$), with an adjusted R2 of .158. Education ($\beta = -.433$, $p = .017$) was the only significant predictor.

Electrophysiological Results

N170 (P7 Cluster). Statistically significant regression equations were found for the models that included the N170 (P7 cluster) peak amplitudes for unfamiliar faces expressing anger ($F(1,29) = 7.89$, $p = .009$), disgust ($F(1,29) = 7.33$, $p = .011$), happiness ($F(1,29) = 13.87$, $p < .001$), neutral ($F(1,29) = 8.22$, $p < .008$), sadness ($F(2,28) = 5.26$, $p = .011$), and surprise ($F(2,28) = 3.96$, $p = .031$), as outcome variables, with adjusted R2's of .187, .174, .300, .194, 221, and .165 respectively (Table 10). For anger, the MSPSS related to the loved ones was the only significant predictor of N170 peak amplitude ($\beta = -.463$, $p = .009$). The depression subscale of HADS was a significant predictor of N170 peak amplitude in the remaining models (disgust: $\beta = -.449$, $p = .011$; happiness: $\beta = -.569$, $p < .001$; neutral: $\beta = -.470$, $p = .008$).

Statistically significant regression equations were also found for the models that included the N170 peak amplitudes at P7 for personally faces expressing disgust ($F(1,29) = 11.41$, $p = .002$), happiness ($F(1,29) = 4.84$, $p = .036$), and surprise ($F(1,29) = 5.36$, $p = .028$), as outcome variables, with adjusted R2's of .258, .114, and .127, respectively (Table 10). The subscale of depression of the HADS was the only significant predictor of N170 peak amplitude for personally familiar faces expressing disgust ($\beta = -.531$, $p = .002$) and surprise ($\beta = -.395$, $p = .028$). The TAS-20 was the only significant predictor for happiness ($\beta = -.378$, $p = .036$).

N170 (P8 Cluster). Statistically significant regression equations were found for the models that included the N170 (P8 cluster) peak amplitudes for unfamiliar faces expressing anger ($F(1,29) = 8.67$, $p = .035$), neutral ($F(1,29) = 5.61$, $p = .025$), surprise ($F(1,29) = 5,95$, $p = .021$), personally familiar faces expressing happiness ($F(1,29) = 4.96$, p = .034), sadness ($F(1,29) = 7.89$, $p = .009$), and surprise ($F(2,70) = 4.59$, $p = .041$), as outcome variables, with adjusted R2's of .114, .133, .142, .116, .187, and .107, respectively (Table 11). The HADS depression subscale was the only significant predictor of N170 peak amplitude (anger displayed by unfamiliar faces: $\beta = -.379$, $p = .035$; neutral displayed by unfamiliar faces: $\beta = -.402$, $p = .025$; surprise displayed by unfamiliar faces: $\beta = -.413$, $p = .021$; happiness displayed by personally familiar faces: $\beta = -.382$, $p = .034$; sadness displayed by personally familiar faces: $\beta = -.462$, $p = .009$; surprise displayed by personally faces: $\beta = -.370$, $p = .041$).

N250 (P7 Cluster). Statistically significant regression equations were found for the models that included the N250 (P7 cluster) peak amplitudes for unfamiliar faces expressing anger ($F(1,29) = 5.80$, $p = .023$), disgust ($F(1,29) = 5.01$, $p = .033$), fear ($F(1,29) = 6.67$, $p = .015$), happiness ($F(1,29) = 11.59$, $p = .002$), neutral ($F(2,28) = 4.69$, $p = .018$), sadness ($F(1,29) = 6.05$, $p = .020$), and surprise ($F(1,29) = 4.76$, $p = .037$), as outcome variables, with adjusted R2's of .138, .118, .159, .261, .197, .144 and .111, respectively (Table 12). For anger, the MSPSS related to the loved ones was the only significant predictor of N250 peak amplitude ($\beta = -.408$, $p = .023$). The depression subscale of HADS was a significant predictor of N250 peak amplitude for the unfamiliar faces expressing disgust, ($\beta = -.384$, $p = .033$), happiness ($\beta = -.534$, $p = .002$), neutral ($\beta = -.405$, $p = .042$), and sadness ($\beta = -.415$, $p = .020$). The anxiety subscale of HADS was also significant predictor of N250 peak amplitude for the unfamiliar faces expressing fear, ($\beta = -.432$, $p = .015$), and surprise ($\beta = -.375$, $p = .037$).

Statistically significant regression equations were also found for the models that included the N250 peak amplitudes at P7 for personally faces expressing disgust ($F(1,29) = 5.64$, $p = .024$), and for the neutral expression ($F(1,29) = 4.69$, $p = .039$), as outcome variables, with adjusted R2's of .134, and .109 respectively (Table 12). The subscale of depression of the HADS was the only significant predictor of N250 peak amplitude for these models (disgust: $\beta = -.404$, $p = .024$; neutral: $\beta = -.373$, $p = .039$).

N250 (P8 Cluster). Statistically significant regression equations were also found for the models that included the N250 peak amplitudes at P8 for unfamiliar faces expressing sadness ($F(2,28) = 6.51$, $p = .005$) as an outcome variable, with an adjusted R2 of .269 (Table 13). The subscale related to the difficulty in identifying feelings of TAS-20 was the only significant predictor of N250 peak amplitude for this model ($\beta = -.436$, $p = .011$).

Table 5

Multiple Linear Regression Models with N170 peak amplitudes elicited at P7 cluster in the Face Processing Task as the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	p	β	p
Unfamiliar upright Faces	$4.86_{(2,29)}$	.199	.015*		
TAS-20				-.041	.829
HADS - Depression				-.478	.017*
Unfamiliar inverted Faces	$4.56_{(1,30)}$	.103	.041*		
HADS - Depression				-.363	.041*
Famous inverted Faces	$8.90_{(1,30)}$	.203	.006*		
HADS - Depression				-.478	.006*
Personally familiar upright Faces	$5.14_{(1,30)}$	.118	.031*		
HADS - Depression				-.382	.031*

Table 6

Multiple Linear Regression Models with N170 peak amplitudes elicited at P8 cluster in the Face Processing Task as the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	p	β	p
Unfamiliar upright Faces	$6.33_{(1,30)}$	.147	.017*		
HADS - Depression				-.417	.017*
Famous inverted Faces	$7.28_{(1,30)}$	.168	.011*		
HADS - Depression				-.442	.011*

Table 7

Multiple Linear Regression Models with N250 peak amplitudes elicited at P7 cluster in the Face Processing Task as the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	p	β	p
Unfamiliar upright Faces	$4.47_{(1,30)}$	.101	.043*		
TAS-20				-.360	.043*

Table 8

Multiple Linear Regression Models with N250 peak amplitudes elicited at P8 cluster in the Face Processing Task as the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	p	β	p
Unfamiliar upright Faces	$0.76_{(1,30)}$	-.008	.391		
HADS - Depression				-.157	.391
Famous inverted Faces	$0.07_{(1,30)}$	-.031	.790		
HADS - Depression				-.049	.790

Table 9

Multiple Linear Regression Models with accuracy (%) in the Emotion Identification Task the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	*p*	*β*	*p*
Unfamiliar Faces - Anger	$11.28_{(1,29)}$	.255	.002*		
Age				-.529	.002*
Unfamiliar Faces - Fear	$3.81_{(2,27)}$	.162	.035*		
Age				-.270	.141
Education				.311	.093
Unfamiliar Faces - Happiness	$17.69_{(2,27)}$	.535	<.001*		
Age				-.553	<.001*
Education				.371	.009*
Personally Familiar Faces - Anger	$4.45_{(1,28)}$	.106	.044*		
Education				-.370	.044*
Personally Familiar Faces - Disgust	$17.79_{(2,27)}$	.537	<.001*		
Age				-.337	.017*
Education				.581	.983
Personally Familiar Faces - Fear	$7.69_{(2,27)}$	.316	.002*		
Education				.329	.048*
MSPSS				.428	.012*
Personally Familiar Faces - Happiness	$58.21_{(3,26)}$	.855	<.001*		
Age				-.745	<.001*
Education				.290	.001*
HADS - Depression				-.130	.108
Personally Familiar Faces - Neutral	$5.26_{(2,27)}$	.227	.012*		
Age				-.347	.053
Education				.309	.082
Personally Familiar Faces - Sadness	$6.46_{(1,28)}$	.158	.017*		
Education				.433	.017*

Table 10

Multiple Linear Regression Models with N170 peak amplitudes elicited at P7 cluster in the Emotion Identification Task as the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	p	β	p
Unfamiliar Faces - Anger	$7.89_{(1,29)}$	.187	.009*		
MSPSS - LO				-.463	.009*
Unfamiliar Faces - Disgust	$7.33_{(1,29)}$	.174	.011*		
HADS - Depression				-.449	.011*
Unfamiliar Faces - Happiness	$13.87_{(1,29)}$	.300	<.001*		
HADS - Depression				-.569	<.001*
Unfamiliar Faces - Neutral	$8.22_{(1,29)}$	.194	.008*		
HADS - Depression				-.470	.008*
Unfamiliar Faces - Sadness	$5.26_{(2,28)}$	.221	.011*		
TAS-20				-.209	.274
HADS - Depression				-.384	.050
Unfamiliar Faces - Surprise	$3.96_{(2,28)}$	.165	.031*		
TAS-20				-.311	.120
HADS - Depression				-.227	.252
Personally Familiar Faces - Anger	$5.86_{(4,25)}$	.402	.002*		
Education				.030	.860
TAS-20				-.387	.054
HADS - Anxiety				-.294	.177
HADS - Depression				-.095	.622
Personally Familiar Faces - Disgust	$11.41_{(1,29)}$	.258	.002*		
HADS - Depression				-.531	.002*
Personally Familiar Faces - Happiness	$4.84_{(1,29)}$	.114	.036*		
TAS-20				-.378	.036*
Personally Familiar Faces - Surprise	$5.36_{(1,29)}$	.127	.028*		
HADS - Depression				-.395	.028*

Table 11

Multiple Linear Regression Models with N170 peak amplitudes elicited at P8 cluster in the Emotion Identification Task as the outcome variable

OUTCOME	$F_{(\text{df})}$	$AdjR^2$	p	β	p
Unfamiliar Faces - Anger	$4.87_{(1,29)}$	.114	.035*		
HADS - Depression				-.379	.035*
Unfamiliar Faces - Happiness	$2.76_{(3,27)}$	.150	.061		
TAS-20 - DIF				-.286	.215
HADS - Anxiety				-.075	.755
HADS - Depression				-.203	.352
Unfamiliar Faces - Neutral	$5.61_{(1,29)}$	.133	.025*		
HADS - Depression				-.402	.025*
Unfamiliar Faces - Sadness	$4.07_{(2,28)}$	.170	.028*		
TAS-20 - DIF				-.343	.088
HADS - Depression				-.195	.324
Unfamiliar Faces - Surprise	$5.95_{(1,29)}$	.142	.021*		
HADS - Depression				-.413	.021*
Personally Familiar Faces - Disgust	$6.62_{(2,28)}$	.273	.004*		
TAS-20 - DIF				-.308	.102
HADS - Depression				-.342	.070
Personally Familiar Faces - Fear	$4.02_{(2,28)}$	.168	.029*		
TAS-20 - DIF				-.355	.078
HADS - Depression				-.178	.369
Personally Familiar Faces - Happiness	$4.96_{(1,29)}$	.116	.034*		
HADS - Depression				-.382	.034*
Personally Familiar Faces - Neutral	$4.01_{(2,28)}$	.167	.029*		
TAS-20 - DIF				-.188	.342
HADS - Depression				-.347	.086
Personally Familiar Faces - Sadness	$7.89_{(1,29)}$	.187	.009*		
HADS - Depression				-.462	.009*
Personally Familiar Faces - Surprise	$4.59_{(2,70)}$	.107	.041*		
HADS - Depression				-.370	.041*

Table 12

Multiple Linear Regression Models with N250 peak amplitudes elicited at P7 cluster in the Emotion Identification Task as the outcome variable

OUTCOME and Predictors	$F_{(\mathrm{df})}$	$AdjR^2$	p	β	p
Unfamiliar Faces - Anger	$5.80_{(1,29)}$	.138	.023*		
MSPSS - LO				-.408	.023*
Unfamiliar Faces - Disgust	$5.01_{(1,29)}$	.118	.033*		
HADS - Depression				-.384	.033*
Unfamiliar Faces - Fear	$6.67_{(1,29)}$	.159	.015*		
HADS - Anxiety				-.432	.015*
Unfamiliar Faces - Happiness	$11.59_{(1,29)}$	.261	.002*		
HADS - Depression				-.534	.002*
Unfamiliar Faces - Neutral	$4.69_{(2,28)}$	.197	.018*		
TAS-20 HADS - Depression				-.152 -.405	.430 .042*
Unfamiliar Faces - Sadness	$6.05_{(1,29)}$	.144	.020*		
HADS - Depression				-.415	.020*
Unfamiliar Faces - Surprise	$4.76_{(1,29)}$	.111	.037*		
HADS - Anxiety				-.375	.037*
Personally Familiar Faces - Anger	$3.61_{(2,28)}$	.148	.040*		
HADS - Anxiety HADS - Depression				-.209 -.297	.327 .167
Personally Familiar Faces - Disgust	$5.64_{(1,29)}$	.134	.024*		
HADS - Depression				-.404	.024*
Personally Familiar Faces - Neutral	$4.69_{(1,29)}$	.109	.039*		
HADS - Depression				-.373	.039*

Table 13

Multiple Linear Regression Models with N250 peak amplitudes elicited at P8 cluster in the Emotion Identification Task as the outcome variable

OUTCOME and Predictors	$F_{(df)}$	$AdjR^2$	p	β	p
Unfamiliar Faces - Happiness	$3.14_{(2,28)}$	.125	.059		
TAS-20				-.054	.851
TAS-20 - DIF				-.384	.187
Unfamiliar Faces - Sadness	$6.51_{(2,28)}$	.269	.005*		
Age				.279	.091
TAS-20 - DIF				-.436	.011*