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DISTORTED FACE PERCEPTION: AN ERP STUDY OF EMOTIONAL EXPRESSION PROCESSING

Background. ***Reading the emotional cues from the faces of people around us is considered to be the crucial element of successful social interaction. However, at the moment there is no single point of view on the basic principles of the organization of neuromechanisms corresponding to face perception, which determines the relevance of this work. Therefore, we focused primarily on the effective neuronal networks formed during the processing of emotional visual stimuli – human faces, in their natural form and under the conditions of configurational changes' introduction. Current study aimed at highlighting more subtle elements of face perception and decoding mechanisms.***

Methods. ***For the purpose of the study, blurred facial expressions were presented amongst the natural face images of different emotional valence. During the exposition, the electroencephalogram was recorded, which then formed the basis for event-related potentials' grand average calculation. Further analysis involved comparing the grand average ERP curves recorded from the precentral cortical regions in two gender-based groups. The findings showed that female participants were more engaged in detecting and deciphering emotional expressions even from the minute hints included in the blurred photos. On the other hand, the male group also showed more significant decoding and recall processes, when presented with blurred neutral stimuli.***

Results. ***The findings showed that female participants were more engaged in detecting and deciphering emotional expressions even from the minute hints included in the blurred photos. On the other hand, the male group also showed more significant decoding and recall processes, when presented with blurred neutral stimuli.***

Conclusions. ***These results are consistent with current evidence on the emotional sensitivity hypothesis and gender-specific variations in face perception strategies, which reveal that men and women appear to perceive neutral faces with varying degrees of accuracy, and women are more likely to perform better when processing emotional expressions.***

Keywords: ***electroencephalography; event-related potentials; emotions; face perception.***

Background

Successful social interaction is said to depend heavily on one's ability to perceive nonverbal cues, such as facial expressions. Intuitive reading of mimic cues occurs automatically since it is seamlessly incorporated into our daily social interactions. There is no consensus on how the human brain interprets facial traits, though, as of yet. The perception of the face as a whole and as a single image is described by one competing idea, while the other emphasizes the significance of isolating particular structural components of the face with subsequent progressive processing. This ambiguity makes the problem of choosing the most important elements in emotional irradiation, which may be studied using warped images. The human face is perceived holistically, and information concerning the "centering" of the face is located in both the right and left hemispheres of the human brain cortex, according to recently discovered data (Almeida et al., 2020).

According to the concept of a holistic (configurational) face perception strategy, these visual stimuli are perceived atomically, as an inseparable object, at all stages of cognitive processing, and each subsequent presentation of a stimulus from this category is correlated by the brain with a previously formed template. Holism is a basic premise of Gestalt theory, which states that gestalts are "sensory wholes" that are qualitatively different from the sum of their individual parts or components and possess new traits (Almeida, 2020), that is, emergent properties. In the field of face perception, terms such as "configurational," "relational," and "holistic" are used to explain the emergent attributes of a face that emerge only when two or more of its elementary features (such as the eyes, nose, or mouth) are processed simultaneously at the same point in time.

The recognition process begins with the stage of visual analysis, which leads to the construction of a detailed perceptual image of the face being presented. For the reason that faces constitute a visually homogeneous category with a high level of structural similarity seen among individual exemplars, successful discrimination at the individual level requires detailed holistic/configural processing that integrates multiple parts of a face into a unified perceptual image, taking into account subtle differences in the spatial relations between its components (Rossion, 2014). Thus, under normal circumstances, the activation of a face memory representation is accompanied by the search for multimodal information about the degree of familiarity of a person, which is a diverse collection of relevant biographical/semantic facts (e. g., profession, name, and personality traits), autobiographical/episodic details (e.g., memories of specific personal meetings) and an emotional reaction that reflects the personal significance of a person.

Thanks to the numerous works that exist at the moment, it has been proven that the perception of such a stimulus category as a face occurs thanks to an extensive cortical network that connects topographically separated areas of the cortex and some of the subcortical structures. Currently, it is customary to divide the elements of the face perception network into two distinct large networks: the central system, which specializes in processing the characteristics of the stimulus, according to the modality inherent in the face itself, and the extended system, which is responsible for storing a memory trace of the face, and is also able to generate an emotional response. The key components of the central system responsible for face recognition include three well-defined areas of the visual cortex located along the posterior-anterior axis of the ventral occipito-temporal cortex (VOTC) – these are face-specific areas of the occipital cortex (occipital face area, OFA), the fusiform face area (FFA), and anterior temporal face area (ATFA) (Kessler et al., 2021).

Core components of the extended face recognition system regions within the anterior temporal lobe (ATL), namely ventrolateral and medial structures including the hippocampus and perirhinal/entorhinal cortex. They are involved in the storage and updating of semantic and episodic memory. The extended network also includes the amygdala and other elements of the limbic system (insula, ventral striatum, cingulate cortex, orbitofrontal cortex), which are involved in evaluating the emotional significance and personal significance of faces. Finally, it was found that the activation of the ventrolateral prefrontal cortex (PFC) during the processing of a familiar face was associated with the involvement of top-down monitoring functions and executive control mechanisms for face perception operations performed by the temporal cortex and memory network (Willinger et al., 2019).

For the purposes of the study, the event-related potential (ERP) technique was chosen due to its ability to detect fine aspects of input information perception and processing. In this study we focused on the nuances of cognitive processing, therefore only several cortical regions, all of precentral nature (frontal, central, and parietal) were selected for further inquiry, as they are known for their role in information analysis and integration. Several components of the grand average ERP curve demonstrate high specificity for face detection and analysis both at the early and late stages of processing, i.e., P100, N170, N400, LPP, etc. While the N170 peak (a negative peak, which arises at 150–200 msec after stimulus onset) is considered to be the major marker of face detection (Feurriegel et al., 2015), an increasing amount of evidence is currently being accumulated regarding the sensitivity of such ERP components as N400 (a negative component, which occurs around 400 msec after stimulus onset and indicates attention modulation during face processing (Neumann, Schweinberger, 2008)) and late positive potential (LPP, a positive peak at 800–1000 msec latency after stimulus onset). According to recent data (Gao et al., 2022), the LPP is considered to be the major ERP component conveying the face context effect. That is, the early-stage processing mainly reflects the emotion-valence based effects of face perception, while the late positive potentials correlate with specific contextual emotion-based effects.

The aim of this study was to uncover subtle neuromechanisms of face perception, "coding", and emotional impact processing by using functionally misconstrued ("blurred") faces.

Methods

20 healthy volunteers of ESC "Institute of Biology and Medicine", Taras Shevchenko National University of Kyiv (n = 20, n_{fem} = 11) aged 18 to 24 (M = 21, SD = 1.76) were involved in the study. The participants were informed about the content of the stimulation, and written informed consent was obtained from each subject under the World Medical Association (WMA) Declaration of Helsinki–ethical principles for the medical research involving human subjects (Helsinki, Finland, June 1964), the Declaration of Principles on Tolerance (28th session of the General Conference of UNESCO, Paris, November 16, 1995), the Convention for the protection of Human Rights and Dignity of the Human Being about the Application of Biology and Medicine: Convention on Human Rights and Biomedicine (Oviedo, April 04, 1997).

The experimental structure consisted of the consequential oddball presentation of four stimulation series (10 min long each), with simultaneous EEG data recording. Each series of images was preceded by a resting EEG recording with eyes closed (3 min) and eyes open (3 min).

Stimulation material was obtained from the International Affective Pictures System (International Affective Pictures System) (Bradley, Lang, 2007), with further blur filter application. In the stimulation program, faces with neutral emotional valence were chosen as frequent stimuli (M = 4.22, SD = 1.64, n = 100, n_{fem} = 50 to M = 5.84, SD = 1.62, n = 100, n_{fem}=50). Rare stimuli were identified as positive (mean values of emotional valence: M = 6.94, SD = 1.42, n = 100, n_{fem} = 50 to M = 8.03, SD = 1.13, n = 100, n_{fem} = 50) and negative (mean values of emotional valence M = 2.1, SD = 1.63, n = 100, n_{fem} =50 to M = 4.21, SD = 1.62, n = 100, n_{fem} = 50) faces, which were blurred. Rare stimuli (positive and negative in valence, respectively) were presented according to a randomized pattern with rare stimuli' appearance probability at a 30 % rate. The total number of rare stimuli reached 100, and each stimulus was onset for 500 msec with a follow-up period of 3 sec ± 30 %.

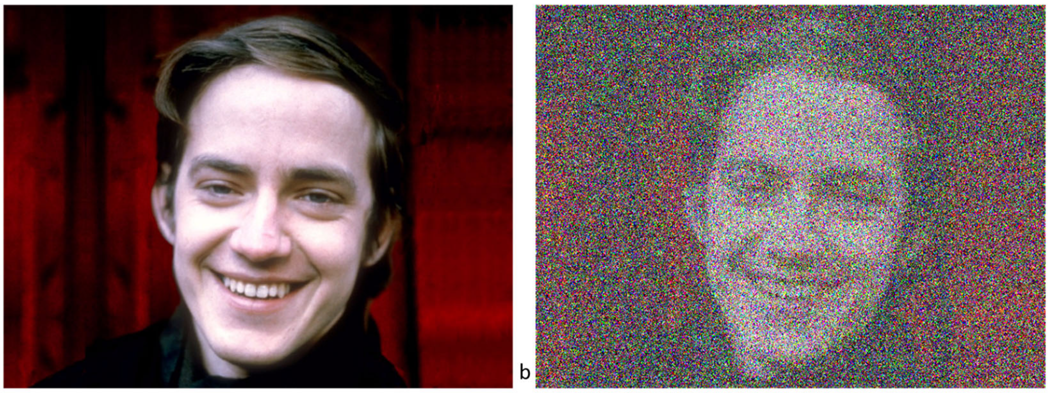

Fig. 1. Example of stimulation material – positive facial expression (a); blurred positive facial expression (b)

Further preprocessing and analysis of the obtained data were carried out using the EEGLAB tool based on the MATLAB engineering package (Delorne, Makeig, 2004). In the above-mentioned software components, preprocessing of the primary data – filtering and ICA analysis – was carried out in order to remove the present artifactual components (oculomotor, neck muscle artifacts, etc.). The subjects were divided into two gender-based groups. With the use of total EEG recordings, several averaged ERP curves were created, reflecting the cognitive processes associated with the brain's response to visual stimulation – event-related potentials.

The following assumptions form the basis of the ERP derivation from the original EEG signal: in a situation of multiple repetition of the event (stimulus presentation) the EEG signal that is registered is the sum of two сошmponents: spontaneous EEG and event-related potential (i). The component of spontaneous EEG is distributed accidentally across a series of consecutive event repetitions (ii). The component of the potential associated with the event is constant for all repetitions of the event (iii). Accidental "noise" from the raw EEG-data is removed by smoothing.

As a result of the accumulation of the EEG segments associated with certain events, their preprocessing (filtration, smoothing, artifactual components removal) and averaging, the ERPs are obtained, which can be described as a sequence of amplitude values or as a sequence of oscillations (waves).

ERP morphology is usually described in terms of waves, oscillations, deflections and shifts – directly observed changes in potential, and components – components of ERPs that do not necessarily coincide with a certain wave or oscillation and can determine the shape of several consecutive waves (synthetic component).

To identify a wave or component, the following parameters were used: amplitude characteristics – polarity (positive or negative deviations denoted as P and N, respectively), duration, latent period from the beginning of the deflection or its peak with respect to the moment of stimulus appearance (i); scalp distribution topography (ii); relation to the events, its characteristics (iii); task dependence (iv).

The major intergroup trends in the mechanisms underlying the response generation were revealed using the permutation statistical approach ($p < 0.05$), with further application of the Bonferroni correction in order to eliminate statistical inexactness if any.

Results

The results obtained during the subjects' exposition to the blurred neutral faces presented amongst negative facial expressions demonstrated regions of statistically significant differences both in the early and late ERP components. The female group demonstrated larger ERP amplitudes in the frontal cortical area around both at 200 msec (Δ = 2.1 µV, $p < 0.05$) and in the range of 800–1000 msec (Δ = 4.2 µV, $p < 0.05$) after stimulus onset (Fig. 2). At the same time, the male group was characterized by a significantly more pronounced negative ERP component, emerging at 200 msec latency.

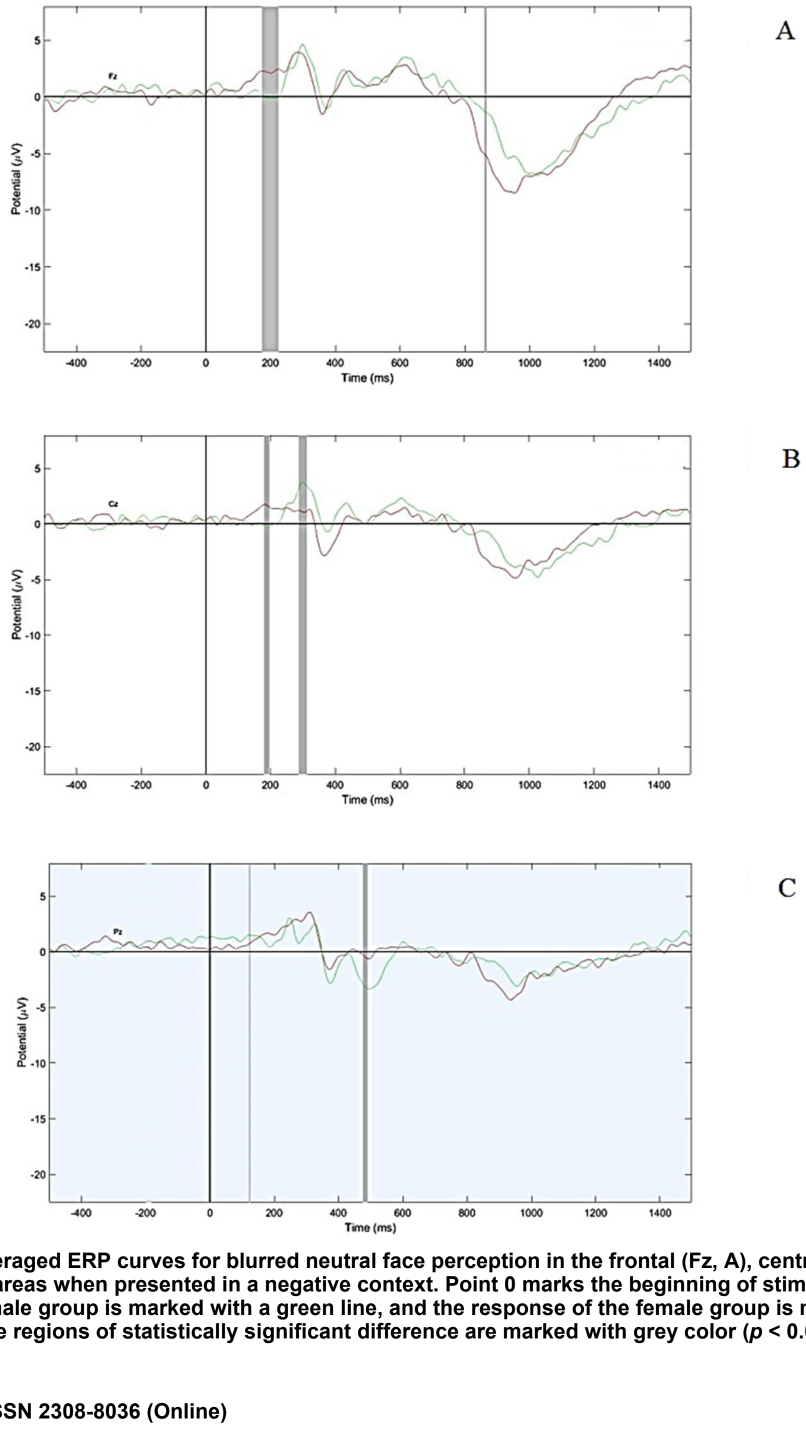

Fig. 2. Averaged ERP curves for blurred neutral face perception in the frontal (Fz, A), central (Cz, B), and parietal (Pz, C) areas when presented in a negative context. Point 0 marks the beginning of stimulus demonstration. The response of the male group is marked with a green line, and the response of the female group is marked with a red line. The regions of statistically significant difference are marked with grey color (p < 0.05)

A similar early-component trend was observed in the central cortical areas for the early 200 msec-ERP component (Δ = 1.4 μV, $p < 0.05$). Apart from that, the male group appeared to have a larger amplitude of the P300 ERP component (Δ = 1.9 μV, $p < 0.05$). Lastly, in the central parietal cortical area, the male group demonstrated a statistically significant increase of ERP components amplitude both in the range of 100–150 msec (Δ = 0.7 μV, $p < 0.05$) and 400–600 msec (Δ = 3.1 μV, $p < 0.05$), correspondingly.

In the case of blurred facial expression presentation on the background of positive emotional context, a slightly different picture was observed. That is, within the frontal region of the cortex the latencies of statistically significant difference included 300 msec (Δ = 0.6 μV, $p < 0.05$) and 800–1000 msec (Δ = 2.0 μV, $p < 0.05$) after rare stimulus was onset (Fig. 3). Notably, the female group demonstrated enhanced amplitude of the P300 component and delayed development of positive slow-wave (800–1200 msec). At the same time, the ERP data obtained from the parietal EEG-lead was characterized by the regions of statistically significant differences at the latencies of 200 msec (Δ = 1.1 μV, $p < 0.05$) and 800–1000 msec (Δ = 2.6 μV, $p < 0.05$), and the female group showed larger ERP amplitudes in both cases. Alongside with this evidence, the parietal grand average ERP obtained from the male group demonstrated enhanced amplitude at 200 msec and decreased amplitudes at the latency of 400–600 msec (Δ = 2.3 μV, $p < 0.05$) compared to the female group.

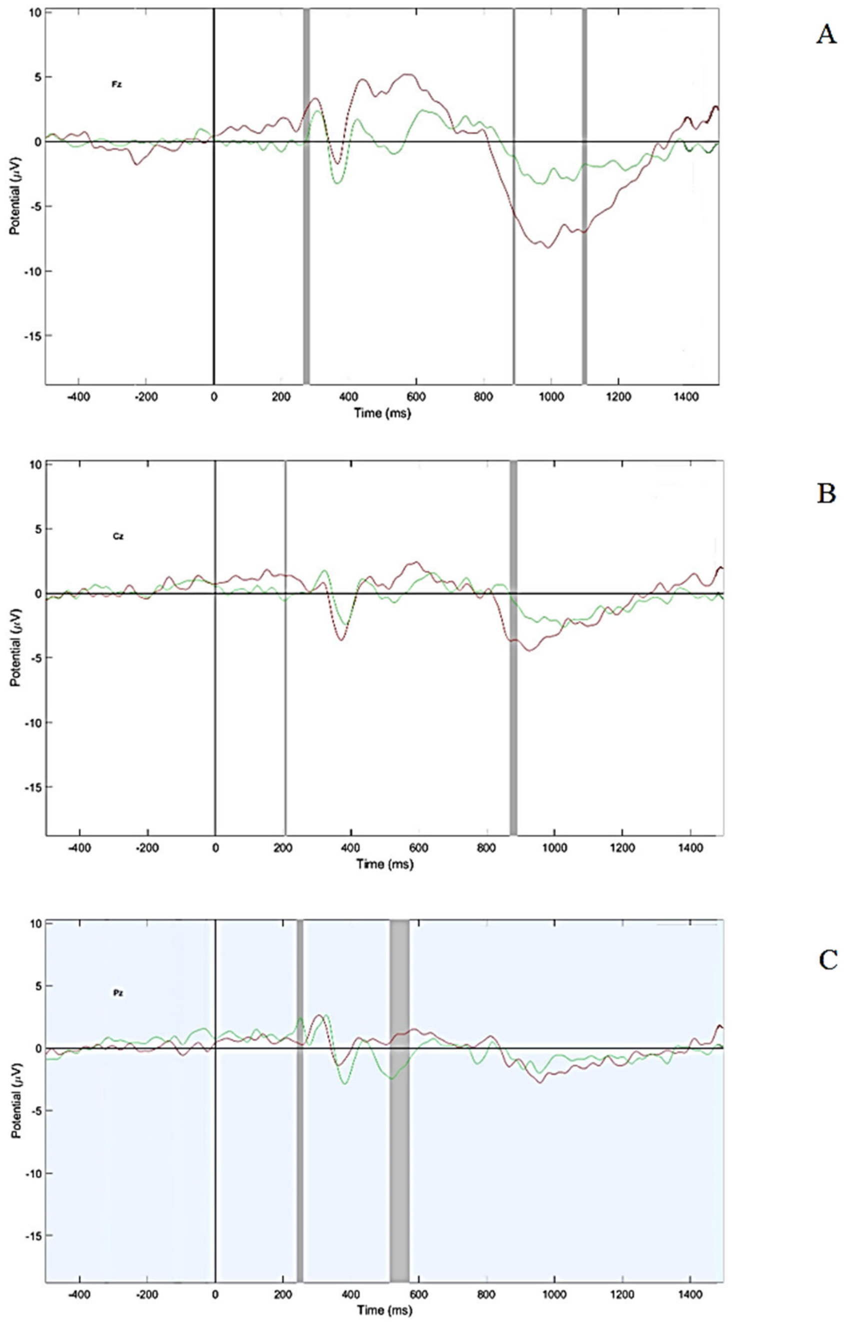

Fig. 3. Averaged ERP curves for blurred neutral face perception in the frontal (Fz, A), central (Cz, B), and parietal (Pz, C) areas, when presented in a positive context. Point 0 marks the beginning of stimulus demonstration. The response of the male group is marked with a green line, and the response of the female group is marked with a red line. The regions of statistically significant difference are marked with grey color ($p < 0.05$)

The ERP data obtained during the exposition to negative blurred faces presented among neutral images demonstrated the areas of statistically significant amplitude increase for the negative component around 800–1000 msec of latency, localized in the frontal and central cortical regions (Δ = 5.1 μV, $p < 0.05$ and Δ = 5.5 μV, $p < 0.05$, correspondingly) (Fig. 4).

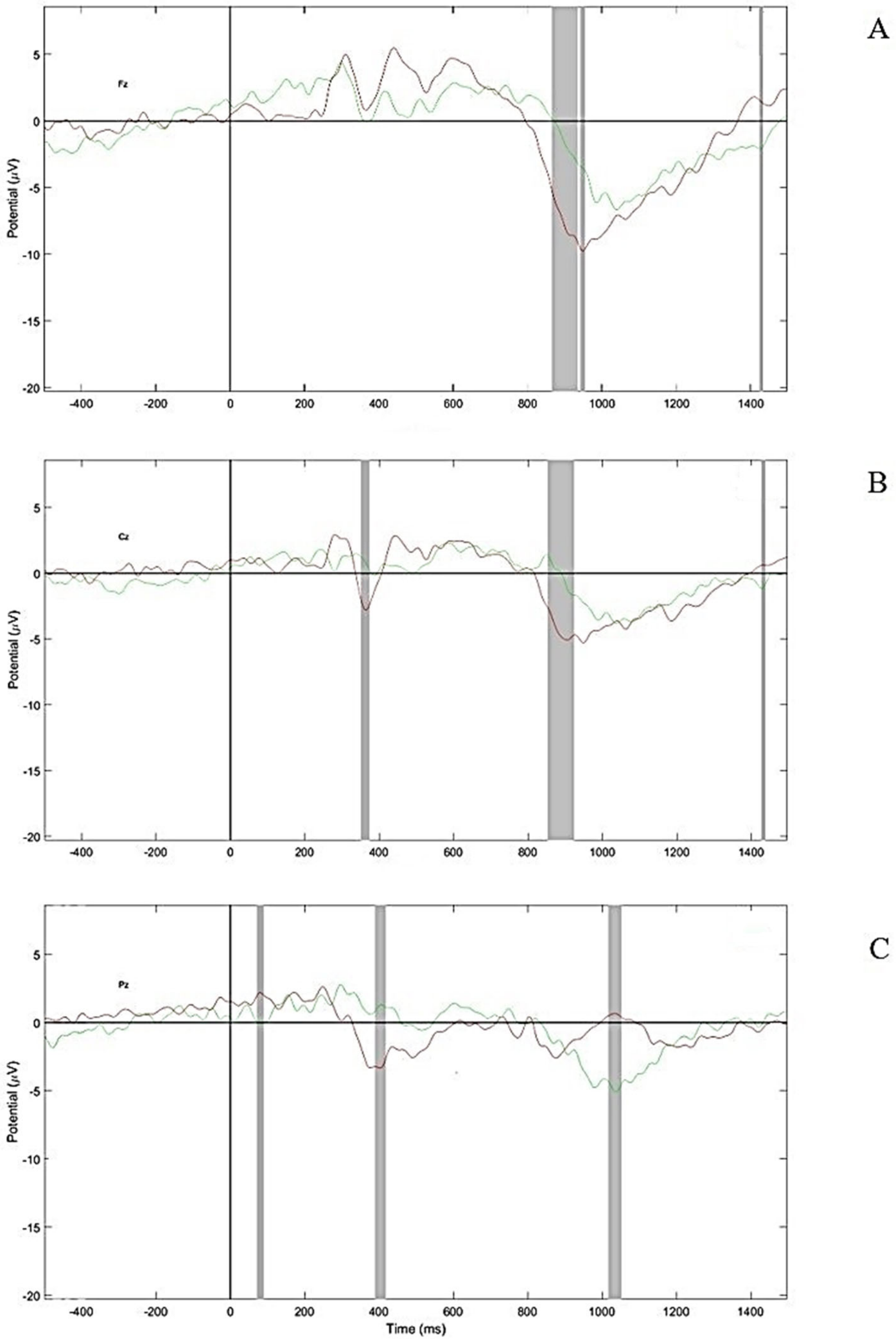

Fig. 4. Averaged ERP curves for blurred negative face perception in the frontal (Fz, A), central (Cz, B), and parietal (Pz, C) areas, when presented in a neutral context. Point 0 marks the beginning of stimulus demonstration. The response of the male group is marked with a green line, and the response of the female group is marked with a red line. The regions of statistically significant difference are marked with grey color ($p < 0.05$)

Furthermore, in the case of the blurred negative face presentation, the female group demonstrated larger amplitudes of N-400 negativity, located in the central and parietal regions of the cortex (Δ = 1.7 μV, $p < 0.05$ and Δ = 3.1 μV, $p < 0.05$, correspondingly) (Fig. 4). Also, the N-400 assumption might be further supported by the difference observed at early latencies (around 100 msec), located within the parietal cortical region (Δ = 0.9 μV, $p < 0.05$).

Lastly, it is important to note that this phenomenon was not observed when the rare stimuli consisted of positive blurred faces (Fig. 5). The only areas of the statistically significant differences were observed in the centro-parietal areas of the cortex within 600–800 msec after stimulus onset (LPP), with female group demonstrating larger amplitudes (Δ = 4.2 μV, $p < 0.05$).

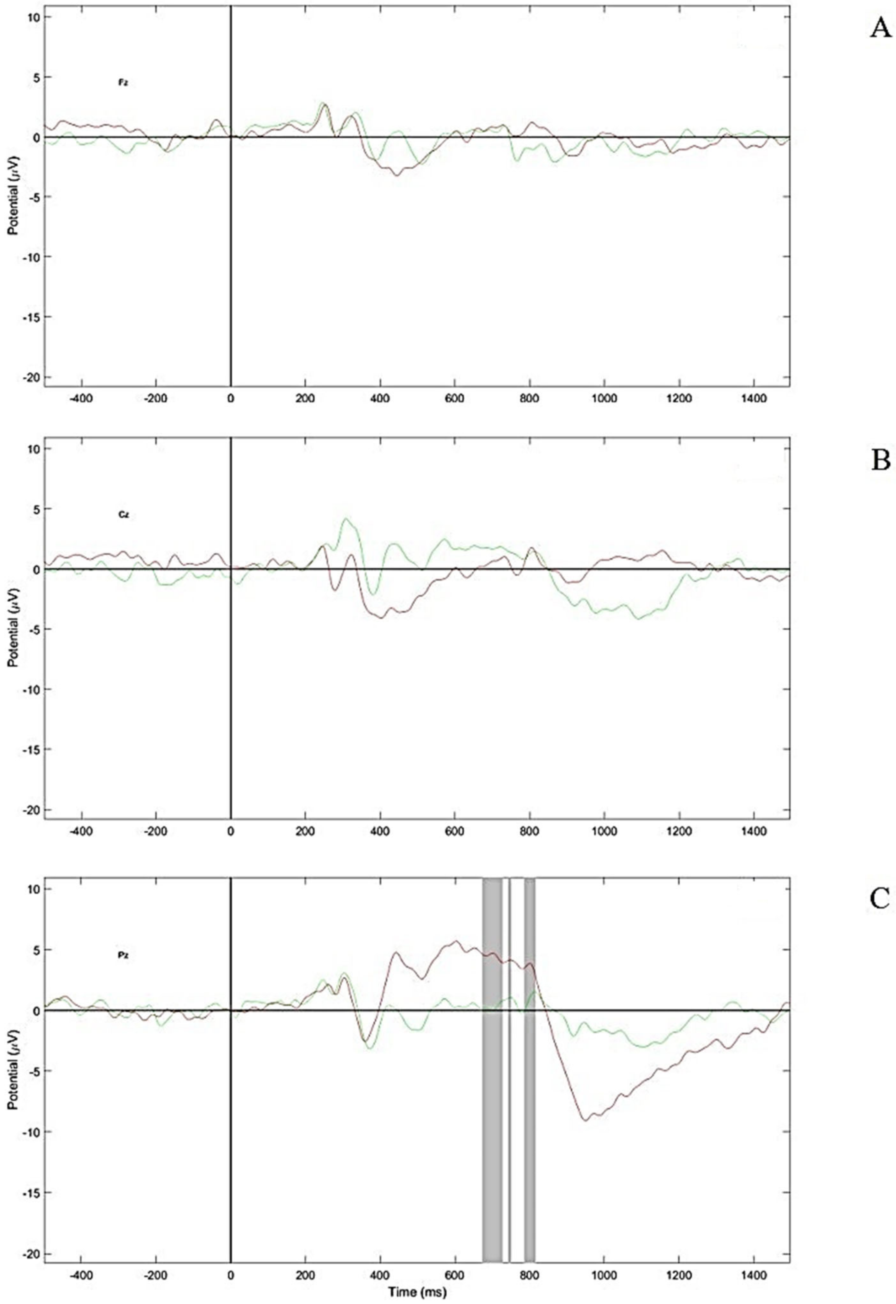

Fig. 5. Averaged ERP curves for blurred positive face perception in the frontal (Fz, A), central (Cz, B), and parietal (Pz, C) areas, when presented in a neutral context. Point 0 marks the beginning of stimulus demonstration. The response of the male group is marked with a green line, and the response of the female group is marked with a red line. The regions of statistically significant difference are marked with grey color (*p* < 0.05)

Discussion and conclusions

First and foremost, we would like to point out the results of blurred neutral face perception, when primed with negative natural images, both in terms of early and late ERP components (Fig. 2). Speaking of the frontal cortical areas, generally, the time window between 100 and 200 msec is now seen as a transitional period between low- and high-level vision (Caharel et al., 2013). According to the current data, the negative ERP peak emerging at the latency of 200 msec, corresponds to the development of internal visual representation of the face (Rossion, 2014), which was more pronounced for the male group. We can also assume, that the difference observed in terms of the late positive potential (800–1000 msec), might reflect better emotion regulation for the female group, as effective emotional reestimation and intended shift of attention focus reduce the amplitude of the LPP (Schienle, Unger, Schwab, 2022). As for the central cortical regions, larger P300 component amplitudes, observed in the male group, might depict the allocation of enhanced attention processes driven by rare stimuli (Marhöfer, Bach, Heinrich, 2015). Lastly, we have to mention the trend observed in the central parietal regions of the cortex within the male group, which is expressed in amplitude increase both at the early and medium latencies after the rare stimus was onset.The ERP positive peak between 100 msec and 150 msec (P1) is often seen as a neuronal marker of stimulus detection, traits' assembling, and discrimination (Bublatzky, Schupp, 2011) when the increased

N400 amplitude might reflect larger perception fluency and recollection (Stróżak, Leynes, Wojtasiński, 2021).

The general ERP pattern, obtained during the blurred neutral stimuli presentation in the positive medium (Fig. 3), displayed the trends observed during negative context-mediated perception analysis. However, more regions of statistically significant differences were observed for the late components of the grand average ERP, all of them demonstrating the difficulties of rare stimuli discrimination and recollection, alongside enhanced emotional regulation characteristics for the female group (Stróżak, Leynes, Wojtasiński, 2021).

As for the reverse mode of presentation, when the blurred negative faces were presented as rare amongst the frequent neutral images, the enhanced amplitude of late negative component within the fronto-central cortical region (Fig. 4) might reflect that the female group was more inclined to retrodiction (i. e., infer which emotional expression the subject was viewing (Kang et al., 2018)).

Lastly, the late positive potential (LPP, 600–800 msec after stimulus onset) demonstrated the enhanced memory retrieval processes and perceptual knowledge consolidation in the female group, when blurred positive faces were onset (Fig. 4) (Taylor, Shehzad, MacCarthy, 2016). Furthermore, in the case of the blurred negative face presentation, the female group demonstrated larger amplitudes of N-400 negativity, located in the central and parietal regions of the cortex (Fig. 4). This evidence correlates with the modern view of the N-400 component, which was first discovered as a marker of linguistic processing, but is currently associated with morphed face emotion detection and decoding (Balconi, Pozzoli, 2005). In this case, the N-400 assumption might be further supported by the difference observed at early latencies (around 100 msec), located within the parietal cortical region, which depicts the enhanced external attention functioning at early stages of morphed negative stimuli processing in the female group (Hermann et al., 2004). Notably, no such tendency was observed when the rare stimuli group consisted of the blurred positive facial expressions (Fig. 5), which once again emphasizes the vital importance of accurate threat-reading directly from the facial cues (Bublatzky, Schupp, 2011).

In sum, we might assume, that participants from the female group were more prone to decoding and perceiving the emotion even from the subtle cues, present in the blurred images. At the same time, the male group demonstrated more pronounced decoding and recollection processes, when presented with blurred neutral stimuli. These findings fall in line with to-date data regarding the gender-specific differences in face perception strategies and emotional sensitivity hypothesis (Hoffmann et al., 2010), as women tend to perform better when processing emotional expressions, whilst men appear to show more accuracy in perceiving neutral faces (Skolnick, Bascom, Wilson, 2013).

Consequently, the female group generally tended to decoding and recollection mechanisms' enhancement when both positive and negative blurred stimuli were presented in the neutral context. Additionally, the female group was characterized by the increase of retrodiction mechanisms' function, when presented with morphed negative faces. The male group, on the other hand, demonstrated enhancement of processes, related to discrimination and recollection, with accompanying attentional resources involvement and greater cortical activation at the later stages of stimuli processing, when blurred neutral stimuli were presented amongst emotional face expressions. However, no specific difference was observed in regards to context valence (positive or negative), when the participants were presented with blurred neutral images. This falls in line with to-date data on the gender-based differences in emotion perception strategies, as females tend to decode emotion-related cues, whilst men tend to focus more on neutral stimuli. Thus, the described regularity might indicate the differences in neurobiological mechanisms of behavior formation characteristic for men and women.

Authors' contribution: Mariia Chernykh – conceptualization, methodology, software, data curation, validation, formal analysis, writing – original draft preparation; Ihor Zyma – conceptualization, writing – review and editing, supervision.

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СПРИЙНЯТТЯ ВИДОЗМІНЕНИХ ОБЛИЧ: ДОСЛІДЖЕННЯ ПОТЕНЦІАЛІВ, ПОВ'ЯЗАНИХ З ПОДІЄЮ, ПІД ЧАС ОБРОБКИ ЕМОЦІЙНОГО ВИРАЗУ

В с т у п . ***Зчитування емоційних сигналів з облич оточуючих людей вважається ключовим елементом успішної соціальної взаємодії. Утім, на сьогодні не існує єдиного погляду на базові принципи організації нейромеханізмів, відповідальних за сприйняття обличчя, що й обумовлює актуальність роботи. Метою дослідження було виділення більш тонких аспектів сприйняття облич, а також механізмів їхньої обробки та декодування.***

М е т о д и . ***Об'єктом дослідження виступили ефективні нейрональні мережі, що формуються під час обробки емоціогенних візуальних стимулів – людських облич, у їхньому природному вигляді та за умов внесення конфігураційних змін. У процесі дослідження розмиті вирази обличчя були представлені серед природних зображень обличчя різної емоційної валентності. Під час експозиції була записана електроенцефалограма, яка потім стала основою для розрахунку повних усереднених кривих потенціалів, пов'язаних з подією, зареєстрованих у прецентральних областях кори головного мозку у двох групах, виділених за статтю.***

Р е з у л ь т а т и . ***Показано, що учасники із жіночої групи були більш схильні до декодування та сприйняття емоцій, навіть із тонких ознак, наявних у розмитих зображеннях. У той же час чоловіча група продемонструвала більш виражені процеси декодування та пригадування, коли їм пред'являли розмиті нейтральні стимули.***

В и с н о в к и . ***Отримані результати узгоджуються з сучасними даними щодо гендерних відмінностей у стратегіях сприйняття обличчя та гіпотези емоційної чутливості, оскільки жінки зазвичай демонструють більшу успішність під час обробки емоційних виразів, тоді як чоловіки виявляють підвищену точність у сприйнятті нейтральних облич.***

К л ю ч о в і   с л о в а : ***електроенцефалографія, потенціали, пов'язані з подією, емоції, сприйняття обличчя.***

Автори заявляють про відсутність конфлікту інтересів. Спонсори не брали участі в розробленні дослідження; у зборі, аналізі чи інтерпретації даних; у написанні рукопису; в рішенні про публікацію результатів.

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