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A neural signature of exposure to masked faces after 18 months of COVID-19

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ABSTRACT

In the last two years, face-to-face interactions have drastically changed worldwide, because of the COVID-19 pandemic: the persistent use of masks has had the advantage of reducing viral transmission, but it has also had the cost of impacting on the perception and recognition of social information from faces, especially emotions. To assess the cerebral counterpart to this condition, we carried out an EEG experiment, extracting Event-Related Potentials (ERPs) evoked by emotional faces with and without surgical masks. Besides the expected impairment in emotion recognition in both accuracy and response times, also the classical face-related ERPs (N170 and P2) are altered by the presence of surgical masks. Importantly, the effect is stronger in individuals with a lower daily exposure to masks, suggesting that the brain must adapt to an extra constraint in decoding social input, due to masks hiding crucial facial information.

1. Introduction

Since the end of 2019, face-to-face interactions have drastically changed for most of the human population, because of the COVID-19 pandemic. Along with other restrictions on daily life and mobility, in March 2020 the Italian Government made the use of surgical masks in social situations compulsory, in the attempt to contain the spread of the virus. The same measure was taken also in most other countries, leading people to interact with 'masked persons' in many everyday circumstances (Martinelli et al., 2020). The widespread and persistent use of masks has many advantages in terms of reducing viral transmission (Howard et al., 2021; Leech et al., 2022), thus limiting even stricter preventive measures (e.g., quarantine) and their social and psychological effects (Prete et al., 2020), but it has the cost of impacting on the perception and recognition of social information from faces (Cannito et al., 2021), including emotions (Pavlova and Sokolov, 2022). After more than two years, the COVID-19 pandemic has not yet been defeated, and we have got used to interacting with each other using masks. In this scenario, a growing number of studies have documented the negative effects of masks both on face perception, showing an impairment in recognizing the different information conveyed by faces - such as identity and emotions (Carbon, 2020; Grundmann et al., 2021) - and on facial learning and recognition (Freud et al., 2020). As expected, face occlusion involves a difficulty in encoding facial information, but the effect also depends on the specific portion of the face that is occluded: it has been shown that when compared to covering the upper part of the face (i.e., with sunglasses), covering the lower part (i.e., with face mask) has a stronger negative effect on both emotion processing and familiar faces matching (Noyes et al., 2021). Besides previous evidence suggesting that eyes would act as emotional intensifiers for expressions mainly expressed by the mouth (Kontsevich and Tyler, 2004), it has been proposed that the weaker effect of sunglasses with respect to face mask can be due to a greater familiarity with this type of occlusion, an explanation that calls into question the frequency of exposure to a given type of facial concealment. In the same domain, another recent evidence seems to further support an effect of exposure on facial encoding (Kret et al., 2021): samples from two countries that differ in the salience and frequency of exposure to Islamic garments (the Netherlands and UAE) were asked to label the emotions conveyed by female faces in three conditions: i) fully visible (uncovered faces), ii) clothing occlusion (faces wearing a niqāb, the veil covering the entire face but the eyes), and iii) physical occlusion (faces occluded by a black rectangle from the nose down). Moreover, after each trial, participants were asked how they would evaluate future interactions with the perceived woman and to what extent they would feel at ease while talking to her: the responses to these questions were considered an index of anxiety. The authors found a worse performance in emotion recognition in the occlusion with the niqāb for both positive and negative emotions, compared to both the

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uncovered face and, importantly, to the face occluded by the black rectangle, revealing an influence of exposure to culture-related face covering on emotion processing. Furthermore, higher anxiety related to the task was found in the sample less exposed to Islamic garments, revealing higher anxiety level in Western participants when Islamic garments were shown, confirming an effect of familiarity with the type of facial occlusion in an emotion recognition task.

Starting from these premises and considering the persistence of social constraints imposed by the ongoing pandemic, we considered it relevant to test whether the described perceptual impairment in recognizing emotions from faces wearing surgical masks has a specific neural substrate. Due to the fundamental importance they have in everyday interactions, in fact, faces are 'special stimuli' for our brain (Kanwisher and Yovel, 2006), and a number of cortical networks, characterized in particular by the Fusiform Face Area (Kanwisher et al., 1997), are crucially involved in processing this special category of stimuli. As a result of the activity of these networks, face-specific ERPs can be extracted from EEG recordings, as time-locked bioelectrical signatures, immediately after seeing a face (Eimer and Holmes, 2007): especially over temporal sites, a negative voltage component recorded at around 170 ms from stimulus onset (N170) is specifically related to face encoding, and two positive peaks, at around 100 ms and 200 ms (P1 and P2), are related respectively to faster processing (low level; e.g., face shape) and to slower processing (high level; e.g., emotions) of facial features. Numerous studies have documented the sensitivity of these cortical signals to face manipulation: changes in the N170 have been described as a consequence of both violations of the canonical facial schema, such as face inversion (Colombatto and McCarthy, 2017), scrambling (Civile et al., 2018), and occlusion (Chu et al., 2007; Kloth et al., 2013), and of social expectancies, such as ingroup vs outgroup categorization (Caharel et al., 2011; Ofan et al., 2011) and emotional expressions (Qiu et al., 2017), and similar changes have been also reported in some studies for P1 and for P2 (Prete et al., 2015; Stahl et al., 2010). Importantly, in the only previous study in which faces were presented as uncovered and covered by a surgical mask during EEG recordings, and the participants' attention was focused on the identity of the stimuli, the amplitude of both early (P1) and late (P3 and Late Positive Potential) attention-related ERPs were higher for masked than for unmasked stimuli, whereas N170 did not differ between the two conditions (Żochowska et al., 2022). It must be underlined, however, that in such a study all faces were presented as neutral, and participants were asked to categorize each face according to its familiarity level – thus no previous evidence exists on ERP modulations for emotional faces presented with or without surgical masks.

1.1. The present study

To assess the possible effect of surgical masks on the face-related ERPs in accordance with an emotional coding, from September to November 2021 we recorded EEG signals from healthy participants during the presentation of angry and happy faces, shown either with a surgical mask covering the face from nose to chin, or without mask. Moreover, to also explore the possible effect of the personal exposure to surgical masks, participants were required to report the time spent daily using a mask and the time spent daily in the presence of people wearing masks. We hypothesized i) a worse performance in emotion recognition for masked compared to unmasked faces, ii) a modulation of the face-related ERP components due to the presence of a mask, with slower (higher latency) and larger (higher amplitude) N170 and P2 for masked than for unmasked faces (no difference were expected in the P1 component, which would be related to a low-level analysis of the image), and iii) an effect of the daily exposure to masks, with a stronger ERP modulation for participants reporting a lower exposure to masks.

2. Method

2.1. Participants

Twenty healthy adult volunteers (mean age and standard error: 25.95 ± 3.67 years old; 10 females) with no previous psychiatric or neurological history took part in the study. Their vision was normal or corrected-to-normal. Sample size was calculated using the G*POWER software version 3.1.9.2 for F test (repeated measures ANOVA, within-between interaction), using 0.67 as the effect size of F, an error probability of 0.05, correlation among repeated measures of 0.5, and non-sphericity correction of 1. Effect size was taken from the N170 latency results described in a EEG study carried out on 16 heathy participants who were presented with either whole faces or occluded faces (without mouth/eyes; (Kloth et al., 2013). The sample size calculated by the software was 8 for each subgroup (low vs high daily exposure to masks), but considering a potential dropout and the impossibility to a priori divided the sample into two groups according to their mask exposure (see Data acquisition and analysis), the final sample size was increased to 20 participants.

Participants were invited to take part in an EEG study and after having completed the task they received a link to an online form created by means of Qualtrics XM (https://www.qualtrics.com/it/?rid=langMatch&prevsite=en&newsite=it&geo=IT&geomatch=): after demographical information (sex and age), they were asked: i) to fill out the Italian version of the Edinburgh Handedness Inventory (EHI; (Salmaso and Longoni, 1985), ii) to fill out the COVID-19 Peritraumatic Distress Index (CPDI; (Costantini and Mazzotti, 2020), iii) to answer two questions about their routines in the use of surgical masks in daily life. Results of the EHI showed that a participant was left-handed and the remaining were right-handed, with a mean handedness score of 76.01 (±11.36), in a scale from −100 (complete left preference) to +100 (complete right preference). The mean score of the sample in the CPDI was 23.8 (±3.67), with a range from 1.04 to 52.08, in a scale from 0 (no COVID-19 related distress) to 100 (highest peritraumatic COVID-19 related distress). In the last two questions, participants were asked to use a Likert scale from 0 (never) to 6 (always) to report a) how many hours a day they wear a mask, and b) how many hours a day they are exposed to people wearing a mask (0 = never, 1 = up to an hour/day, 2 = from 1 to 2 h/day, 3 = from 2 to 5 h/day, 4 = from 5 to 8 h/day, 5 = from 8 to 12 h/day, 6 = always, from when I wake up until I go to bed).

Written informed consent was obtained from all participants prior to testing. The whole procedure was carried out in accordance with the principles of the Declaration of Helsinki and it was approved by the Institutional Review Board of Psychology of the Department of Psychological, Health and Territorial Sciences – University "G. d'Annunzio" of Chieti-Pescara (protocol number: IRBP/21019). The EEG experiment lasted about 90 min and the online form required about 10 min.

2.2. Stimuli

Stimuli were created starting from photographs of the Karolinska Directed Emotional Faces (Lundqvist et al., 1998): photographs in frontal view of 16 female and 16 male faces in happy and angry poses were selected and modified to measure 7.9° × 10.4° (400 × 530 pixels), seen at a distance of 72 cm. Each stimulus was then further modified by overlapping a white surgical mask which covered the face from the nose to the chin (see Fig. 1). The final set of 128 stimuli, comprising 16 females and 16 males in happy and angry pose, with the mask and without the mask, was converted into gray-scale images.

2.3. Procedure

Participants comfortably sat in a dark room, at a distance of about 72 cm from the computer screen (1024 × 768 pixels), and they were tested individually. Written instructions were presented before the start of the

Fig. 1. Example of unmasked and masked happy and angry faces.

task, in which the participants were asked to focus on the emotional expression of each face. They were also informed that in 1/7 of the trials they had to categorize the face as happy or angry, by pressing the "n" or "m" key of the keyboard with the index and the middle finger of the right hand, respectively (these trials were excluded from ERP analyses and the responses were used only for the behavioural analyses). Participants were invited to reduce movements as much as possible, maintaining the gaze at the fixation in the centre of the screen for the whole duration of task. Prior to the beginning of the experimental sessions, six trials were carried out, allowing participants to familiarize with the task.

In all trials, a black fixation cross was presented in the centre of the white screen for 500 ms, and it was followed by the presentation of a stimulus (an emotional face), lasting 150 ms. Then, during the inter-stimulus interval (ISI), a fixation cross was presented in the center of the screen. Participants were instructed that only in the 128 trials in which the cross after the face would become red, they had to categorize the emotional expression of the face as happy or angry; in the remaining 768 trials no response was required. The ISI lasted 2000 ms in the trials in which a response was required, and it was randomized between 1300 ms and 1700 ms (step: 100 ms) in the remaining trials.

The set of 128 stimuli was repeated 6 times without active task (768 ERP trials) and a further time in which the emotional categorization was required (128 behavioural trials, not included in ERP analyses), for a final set of 896 trials, divided into 4 sessions (224 trials each). Between sessions participants were allowed to take a break. The presentation order of the stimuli was randomized within and across participants. The paradigm was administrated by means of E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA), and it lasted about 30 min. During the task both accuracy and response times (RTs) were recorded, in addition to EEG signals.

2.4. Data acquisition and analysis

EEG data were recorded by means of a 64 electrodes net (BePlus EB-Neuro), placed according to the 10–20 system. Skin/electrode impedance was measured before the recording and kept below 5 KΩ. EEG data were sampled at 512 Hz and processed off-line by using NPXLab software (Bianchi, 2018). For the analysis, data were filtered between 0.1 and 40 Hz. The acquisition time for all data was set from −0.5 to +1 s after the stimulus. One hundred ninety-two EEG trials were collected for each of the 4 experimental conditions (i.e., each combination of facial expression and face mask), for each participant. Trials contaminated by eye movement, blinking, or involuntary motor acts (e.g., mouth, head, trunk or arm movements) were rejected off-line. The EEG epochs with ocular and other types of artifacts were preliminarily identified by a computerized automatic procedure and excluded.

Statistical analyses were carried out on T5 and T6 sites, for the ERP components N170, P1 and P2 (see, for instance, Prete et al., 2018). Specifically, for each condition, N170, P1 and P2 amplitudes and latencies were automatically extracted at peak-maximum electrodes T5/T6 (time windows = P1: 50–150 ms; N170: 120–220 ms; P2: 200–300 ms). All peaks were confirmed by visual inspection. Amplitude (microvolts) and latency (milliseconds) for each peak were subjected to a repeated-measure analysis of variance (ANOVA) with Hemisphere (Left, Right), Emotion (Angry, Happy) and Face (Masked, Unmasked) as within-subject factors. Moreover, the sample was divided into two subsamples according to the responses given to the questions on daily mask use: the scores obtained in the Likert scale on the time spent in a day using a mask and the time spent in a day with other people wearing masks were averaged. The mean score of the sample was 2.68 and the sample was then divided into a subsample with a score lower than the mean (low mask exposure, N = 9, corresponding approximately to 1.5 h a day) and a subsample with a score higher than the mean (high mask exposure, N = 11, corresponding approximately to 5 h a day). Mask exposure was used as between-subject factor in all analyses. ANOVAs were also computed on the proportion of correct responses (accuracy; range: 0–1) in categorizing the emotional expressions and on the Response Times (RTs) in milliseconds. The latter were considered only for correct responses and only when they were comprised between 150 and 1500 ms. In the behavioural analyses, Emotion (Angry, Happy) and Face (Masked, Unmasked) were used as within-subject factors, and Exposure (Low, High) was used as between-subject factor.

All statistical analyses were computed by means of Statistica8.0 software (StatSoft. Inc., Tulsa, USA) and, when needed, Duncan test was used for post-hoc comparisons ($p < 0.05$).

3. Results

3.1. Behavioural results

As regards accuracy (proportion of correct responses: prop), the main effect of Face was significant ($F_{(1, 18)} = 20.05$, $MSE = 0.004$, $p < 0.001$, $\eta_p^2 = 0.53$), showing a higher accuracy for Unmasked (0.96 ± 0.01 prop) than for Masked faces (0.89 ± 0.02 prop; Fig. 2A). Exposure verged on significance ($F_{(1, 18)} = 4.05$, $MSE = 0.17$, $p = 0.059$, $\eta_p^2 = 0.06$), suggesting that participants with Low exposure (0.95 ± 0.01 prop) were more accurate in emotion categorization with respect to participants with High exposure (0.91 ± 0.02 prop).

Concerning RTs, the main effect of Face was significant ($F_{(1, 18)} = 18.82$, $MSE = 1764$, $p < 0.001$, $\eta_p^2 = 0.51$), with higher RTs for Masked (884.41 ± 20.71 ms) than for Unmasked faces (842.27 ± 19.94 ms; Fig. 2B). Exposure reached statistical significance ($F_{(1, 18)} = 5.15$, $MSE = 49368$, $p = 0.036$, $\eta_p^2 = 0.22$): participants with Low exposure (800.99 ± 14.74 ms) were faster in emotion categorization with respect to participants with High exposure (914.35 ± 20.43 ms). Moreover, the interaction between Exposure and Emotion was significant ($F_{(1, 18)} = 6.1$, $MSE = 2074$, $p = 0.024$, $\eta_p^2 = 0.25$) and post-hoc comparisons revealed that participants with High exposure were slower in categorizing the Happy compared to the Angry expression ($p = 0.023$), and that participants with Low exposure were faster than participants with High exposure in categorizing the Angry expression ($p = 0.02$), whereas the same comparison did not reach significance for the Happy expression (p

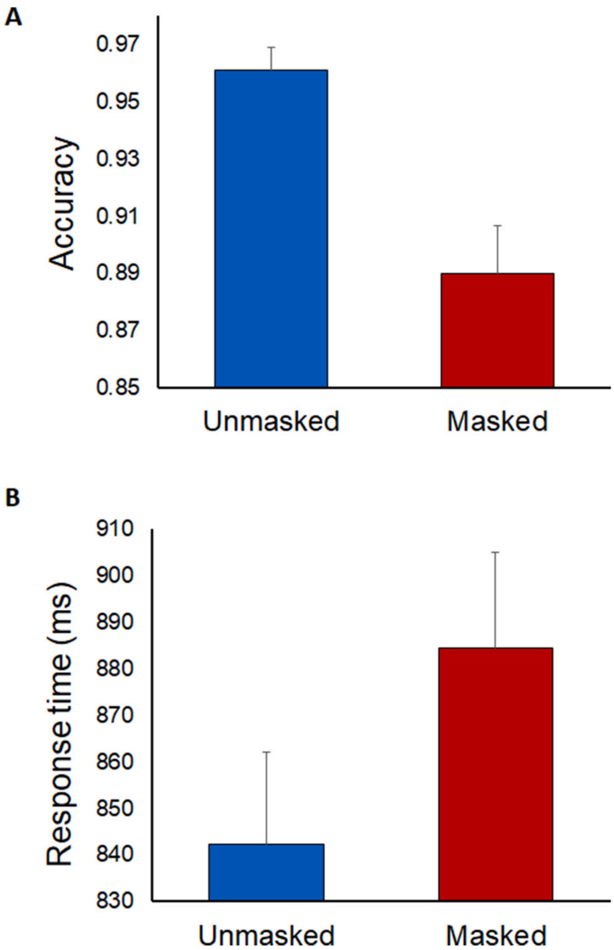

Fig. 2. (A) Accuracy in the categorization of emotional expression of Unmasked and Masked faces. (B) Response times for the correctly categorized trials of Unmasked and Masked faces.

$= 0.099$). Finally, also the interaction between Face and Emotion was significant ($F_{(1, 18)} = 16.19$, $MSE = 750$, $p < 0.001$, $\eta_p^2 = 0.47$), revealing that for Unmasked faces, the Happy expression was categorized faster than the Angry expression ($p < 0.001$), and that the Happy expression was categorized faster for Unmasked than for Masked faces ($p < 0.001$), whereas for the Angry expression this comparison did not reach the significance ($p = 0.06$).

3.2. ERP results

Fig. 3 shows the temporal evolution of the topographic maps over the whole scalp for the voltage difference between Unmasked and Masked faces. The time interval comprised between 50 ms and 300 ms post-stimulus was chosen, verifying that before 50 ms no reliable responses were present. Topographic maps confirmed activation in posterior sites, corresponding to the latencies of the ERP peaks P1, N170 and P2. Fig. 4 shows the grand average waveform for Unmasked and Masked faces recorded at T5/T6 sites, and the mean whole-scalp topographic maps for Unmasked and Masked faces at N170 latency.

3.2.1. N170 amplitude and latency

In the ANOVA carried out on N170 amplitude, the main effect of Face was almost significant ($F_{(1, 18)} = 4.32$, $MSE = 3.19$, $p = 0.052$, $\eta_p^2 = 0.19$), with larger amplitude for Masked (-4.14 ± 0.81 μV) than for Unmasked (-3.61 ± 0.79 μV) faces. The other main effects and interactions were not significant.

The ANOVA on N170 latency showed a significant main effect of Face ($F_{(1, 18)} = 8.93$, $MSE = 103$, $p = 0.008$, $\eta_p^2 = 0.33$), with shorter latency for Unmasked (172.86 ± 3.23 ms) than for Masked (177.72 ± 3.09 ms) faces. The interaction between Emotion and Hemisphere was significant ($F_{(1, 18)} = 4.62$, $MSE = 31$, $p = 0.046$, $\eta_p^2 = 0.20$), and post-hoc comparisons showed that for the Happy expression the N170 peak latency was shorter in the Right (173.34 ± 1.90 ms) than in the Left (176.88 ± 2.53 ms) hemisphere.

3.2.2. P1 amplitude and latency

No significant results emerged for P1 amplitude, whereas in the ANOVA carried out on P1 latency the interaction between Emotion and Exposure was significant ($F_{(1, 18)} = 5.75$, $MSE = 92$, $p = 0.028$, $\eta_p^2 = 0.24$), even if no post-hoc comparisons reached statistical significance.

3.2.3. P2 amplitude and latency

In the ANOVA carried out on P2 amplitude, a smaller amplitude emerged for Masked (6.66 ± 1.26 μV) than for Unmasked (7.19 ± 1.23 μV) faces, even if the main effect of Face did not reach statistical significance ($F_{(1, 18)} = 3.98$, $MSE = 3.621$, $p = 0.061$, $\eta_p^2 = 0.18$). Face significantly interacted with Exposure ($F_{(1, 18)} = 19.49$, $MSE = 3.621$, $p = 0.032$, $\eta_p^2 = 0.23$; Fig. 5), and post-hoc comparisons showed that only in participants with Low exposure, the amplitude of P2 was smaller for Masked than for Unmasked faces ($p = 0.007$).

The interaction between Face and Hemisphere was significant ($F_{(1, 18)} = 5.93$, $MSE = 0.46$, $p = 0.026$, $\eta_p^2 = 0.25$) and post-hoc comparisons confirmed that for both Masked and Unmasked faces, P2 amplitude was larger in the Right than in the Left hemisphere ($p < 0.001$ for both comparisons), and that the smaller amplitude for Masked than for Unmasked faces reached statistical significance only in the Right hemisphere ($p < 0.001$).

In the ANOVA on P2 latency, the significant main effect of Face ($F_{(1, 18)} = 11.09$, $MSE = 240$, $p = 0.004$, $\eta_p^2 = 0.38$) revealed a shorter latency for Masked (261.98 ± 4.08 ms) than for Unmasked (269.73 ± 4.49 ms) faces. All of the other main effects and interactions did not reach statistical significance.

4. Discussion

In line with previous evidence, our behavioural results confirm an impairment in decoding emotional expressions when we look at a masked face (Carbon, 2020; Grundmann et al., 2021; Noyes et al., 2021). In particular for the happy expression RTs were slower for masked than for unmasked faces, showing that the expected facilitation in recognizing the positive expression disappears in the masked condition, and confirming previous evidence of a greater importance of the lower portion of the face for happiness recognition with respect to other emotions (Eisenbarth and Alpers, 2011). Moreover, participants with high mask exposure were slower than those with low mask exposure in categorizing emotional expressions, a result which seems in contrast with the suggested stronger impairment in emotion recognition due to a low familiarity with the specific facial manipulation (Noyes et al., 2021). We speculate in this regard that persons with higher experience with masked faces could have learned from their previous experience that an occluded face is less informative than a whole face, and thus they took longer to interpret the emotional expressions. Importantly, for the first time, we documented that the cortical response evoked by the 'transformed' stimulus is different than that recorded for the 'canonical' stimulus: both the N170 and the P2 components are modulated by the presence of surgical masks on emotional faces. In particular, the N170 was larger and slower for masked than for unmasked faces, and this result can be viewed as in line with previous evidence concerning other structural manipulations of the face (Civile et al., 2018; Colombatto and McCarthy, 2017; Prete et al., 2015), but also with an impact of the social context on the cortical signals (Ofan et al., 2011; Stahl et al., 2010). Importantly, this result differs from that described in a previous EEG study in which no difference emerged on the N170 component between

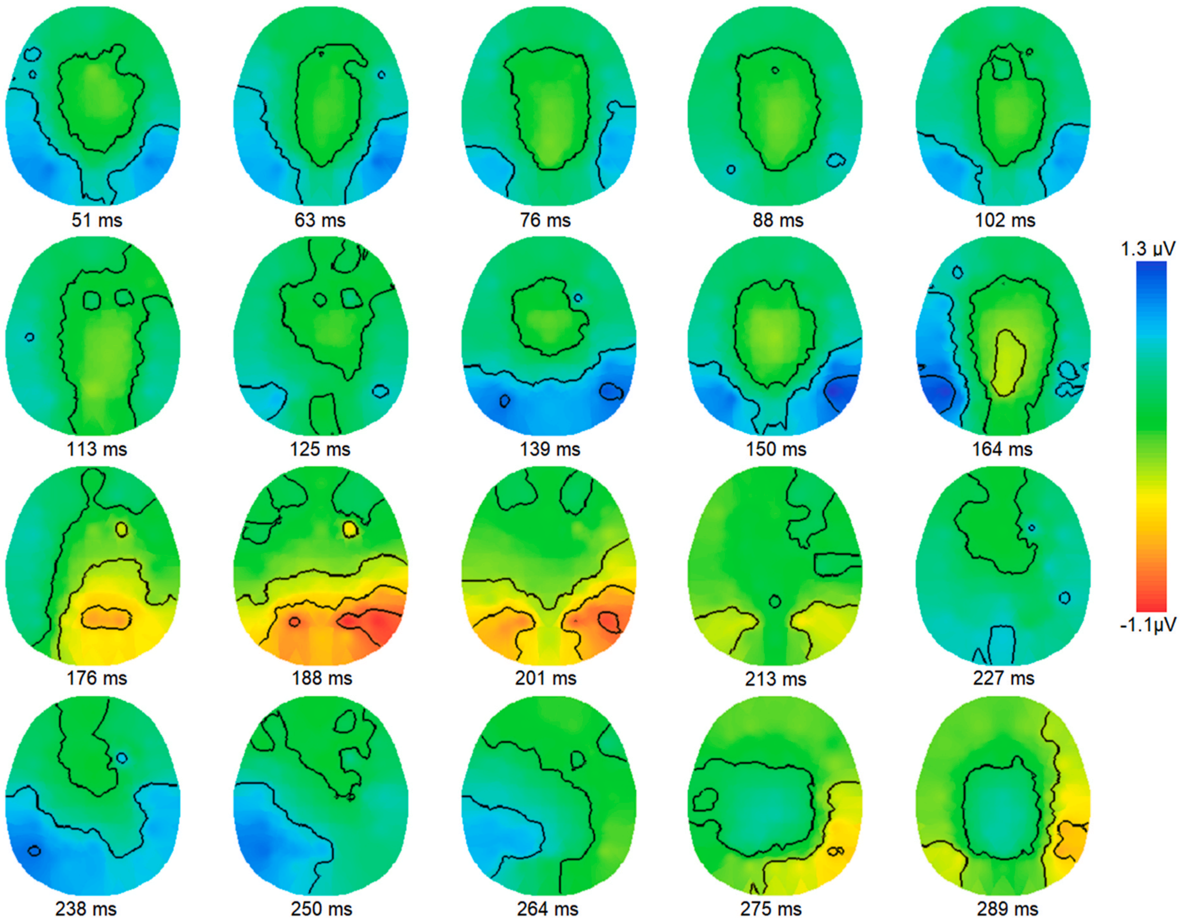

Fig. 3. Temporal evolution of the topographic maps over the whole scalp, for the difference between masked and unmasked faces.

masked and unmasked faces (Żochowska et al., 2022). It has to be highlighted that in that study all stimuli were neutral and participants were asked to categorize each stimulus as either self-face, close-other's face, or unknown face. This could confirm that the N170 is sensible to the emotional expression (but not to the identity) of the stimuli, and it is not just related to low-level facial detection per se (Qiu et al., 2017). Our results also revealed a shorter P2 latency for masked compared to unmasked faces and, interestingly, a smaller P2 amplitude for masked than for unmasked faces, mainly in the right hemisphere, that was significant only in participants with a low exposure to masks. This latter result confirms the effect of personal exposure (i.e., familiarity) on the face-related ERP, further supporting a different cortical response not only concerning the physical features of the stimuli, but also concerning inter-individual differences and habits. Such an inter-individual difference is not evident in the N170, maybe because the N170 is related to the stimulus features – or to the automatic judgment related to these features – more than to personal habits: in fact, previous studies described changes in the N170 amplitude according to the same-race vs other-race categorization of facial stimuli (Caharel et al., 2011; Ofan et al., 2011), suggesting that pre-existing racial attitudes affect early face processing. We speculate that this N170 amplitude change is thus related to a social prejudice, instead of being related to the simple familiarity level, so that the personal exposure to masked faces, as measured in the present task, is not suitable to elicit an N170 modulation, but it does affect the slower P2 component.

We conclude that the daily exposure to masks has added a constraint in the way in which our brain processes the social stimuli we are most accustomed to, namely our conspecifics' faces. Considering that the pandemic is still ongoing, we argue that further studies should focus on adaptations and long-term consequences on the brain induced by the restrictions impacting on social life in the general population. The fact that both behavioural (RTs) and ERP (P2) results do show a group difference in accordance with the mask exposure score also allows us to hypothesize a direct effect of the daily amount of exposure to masked faces on facial emotion processing. We speculate that perceiving a masked face can represent a potential anxiety-inducing signal, which hinders the correct and rapid detection of others' emotions, and which elicits a larger face-related N170, but also a reduced P2, which is a higher-order component strictly related to inter-individual psychological differences. Indeed, according to this speculation, modulation of the P2 component could be intended as a warning signal when compared to previous evidence of P2 changes during face perception in patients suffering from disorders in the affective domain, such as social anxiety (Eldar et al., 2010; van Peer et al., 2010; Yuan et al., 2014), but also from other clinical conditions such as schizophrenia (Müller et al., 2014; Ramos-Loyo et al., 2009). Further studies are needed to verify this possible link, but the present results constitute the first evidence that our brain is called to dynamically adapt to the pandemic world, modifying its cortical activity in response to the visual perception of the most frequent social stimulus we are exposed to. This conclusion is in line with the speculation proposed by Ferrari et al. (2021), who argued that, by excluding the lower half of the face, wearing masks consistently reduces the amount of information reaching cerebral areas specialized in face processing. The authors proposed that such mismatch with respect to the canonical stimulus would impair long-term functional and structural plasticity, both at a cellular level, in which Long Term Potential induction would be facilitated and Long Term Depression would be impaired, and at a system level, with a loss of synaptic connection among the different nodes of "face areas", due to the partial deprivation of visual inputs caused by wearing face masks (Ferrari et al., 2021). A

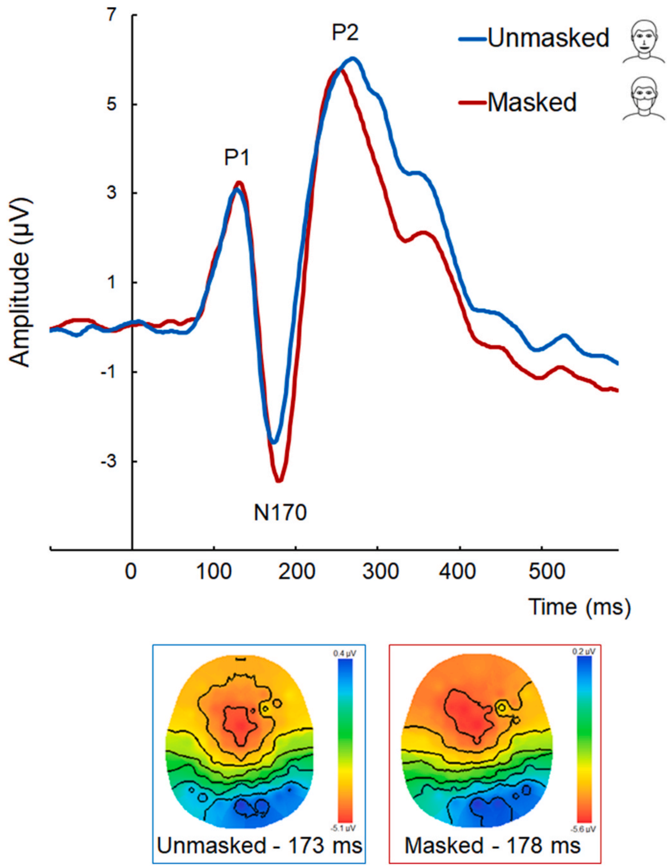

Fig. 4. (Top) Grand average of ERP waveforms for Unmasked and Masked faces at T5 and T6 sites in the time window from 100 ms before to 600 ms after face presentation. (Bottom) Mean whole-scalp topographic maps for Unmasked and Masked faces at N170 latency.

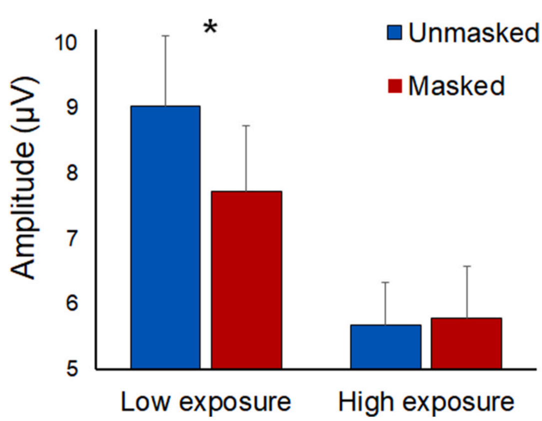

Fig. 5. Interaction between presence of the face mask and participant's mask exposure for the P2 amplitude. Error bars represent standard errors; asterisk shows the significant difference.

final remark should be made on the fact that this pattern of results has been collected in adults, whom brain is already specialized, with specific networks devoted to the fast processing of facial stimuli. We know that faces constitute a special stimulus also for newborns (Simion et al., 2007) and even before birth (Reid et al., 2017), thus it would be important to assess whether and to what extent the developing brain is affected by the 'deprivation' of information represented by mask occlusion.

Author contributions

Conceptualization, G.P, A.D., L.T.; Methodology, G.P., A.D.; Investigation, G.P., A.D.; Writing – Original Draft, G.P., A.D.; Writing – Review & Editing, L.T.; Software, A.D., G.P.; Visualization, A.D.; Funding Acquisition, L.T.; Supervision, L.T.

Data availability

The experiment reported in this article was not formally preregistered. Data have not been made available on a permanent third-party archive; requests for the data can be sent via email to the lead author at luca.tommasi@unich.it.

Declaration of competing interest

The authors declare no competing interests.

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