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Facemasks selectively impair the recognition of facial expressions that stimulate empathy: An ERP study

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Abstract

Previous research suggests that masks disrupt expression recognition, but the neurophysiological implications of this phenomenon are poorly understood. In this study, 26 participants underwent EEG/ERP recording during the recognition of six masked/unmasked facial expressions. An emotion/word congruence paradigm was used. Face-specific N170 was significantly larger to masked than unmasked faces. The N400 component was larger for incongruent faces, but differences were more substantial for positive emotions (especially happiness). Anterior P300 (reflecting workload) was larger to masked than unmasked faces, while posterior P300 (reflecting categorization certainty) was larger to unmasked than masked faces, and to angry faces. Face masking was more detrimental to sadness, fear, and disgust than positive emotions, such as happiness. In addition, mask covering did not impair the recognition of angry faces, as the wrinkled forehead and frowning eyebrows remained visible. Overall, facial masking polarized nonverbal communication toward the happiness/anger dimension, while minimizing emotions that stimulate an empathic response.

KEYWORDS

EEG/ERPs, emotions, face processing, recognition, visual perception

1 | INTRODUCTION

The aim of the study was to investigate the impact of surgical masks on people's ability to accurately perceive emotional expressions. A previous behavioral study (Proverbio & Cerri, 2022) showed that masking heavily affected emotion recognition with a 31% decay in recognizability of facial expressions. These findings agree with previous recent literature showing how facemasks reduce emotion recognition accuracy (Calbi et al., 2021; Carbon, 2020; Grundmann et al., 2021; Marini et al., 2021; Roberson et al., 2012; Ruba & Pollak, 2020) and reduces interpersonal distance (Cartaud et al., 2020). In Proverbio and Cerri's study (2022), face masking was more detrimental to sadness and especially disgust detection, than positive emotions such as happiness. This pattern of results is consistent with previous evidence offered, for example, by Marini et al. (2021), showing how sadness was the most affected emotion, and happiness the least affected, by face masking. However, it was also found that mask coverage did not influence the recognition of angry faces, which replicates some evidence obtained with nondigital masks by Noyes and co-authors (Noyes et al., 2021). After all, the primacy of anger among the biologically relevant emotions is not unknown (e.g., Mancini et al., 2020). In general, as concluded by Pavlova and Sokolov's recent review

(Pavlova & Sokolov, 2021), there is no doubt that wearing masks hampers facial affect recognition, and it might be particularly challenging for individuals with neuropsychiatric or neurodevelopmental conditions. Here we wondered if the masks could distort social communication by favoring the expression of anger, while demeaning facial expressions that more frequently stimulate empathy in the observer, such as the expressions of sadness or fear (but also of disgust or surprise).

In this investigation, in order to study the neural underpinnings of facial expression comprehension, and how face masking possibly affected the various stages of neural processing, behavioral and electrophysiological data were collected during a word/face emotional congruence task. To observe the early configural face processing, N170 response of ERPs was analyzed. N170 is a negative occipito/temporal response, mostly reflecting the activity of the 'fusiform face area' (Gao et al., 2019), which is considered a marker for the structural encoding of faces, being also affected by face familiarity, orientation, race, and facial expression (Eimer, 2011; Rossion & Jacques, 2011). We assumed that, if face masking impaired the recognition of facial expressions at an early perceptual level, this would result in a modulation of N170 amplitude, and possibly an enhancement in its amplitude, similarly to what was found for inverted faces (e.g., Sadeh & Yovel, 2010). The word/face emotional congruence task was used as a tool for directly measuring the degree of comprehension of the masked versus unmasked facial expressions. If masking did affect the recognition of the facial emotional content we would have observed not only a modulation of perceptual and cognitive components of ERPs elicited by faces (i.e., N170 and P300) but also a difference in brain responses to congruent versus incongruent word/face pairs (typically the N400/P300 complex). N170 response was found to be sensitive to facial expressions, but the literature reported a heterogeneous pattern of results, with larger amplitudes to anger, fear, and happy faces in different ERP studies (in this regard, see the meta-analysis by Hinojosa et al., 2015). We expected that N170 showed discriminative responses for higher valence emotions (e.g., happiness), but not for more subtle emotions such as sadness.

As for the effect of prime/face congruence, based on literature, N400 response of ERPs is strongly sensitive to the incongruence between an item and its previous context, being much larger to unexpected, unprimed, incorrect, unpredictable, or incongruent information (Kutas & Federmeier, 2011; Lau et al., 2008). However, N400 amplitude is reduced if the incoming information is poorly understood or processed with difficulty because it is degraded, incomplete, or too unfamiliar (Daltrozzo et al., 2012; Proverbio et al., 2004). For example, in an ERP study in which participants had to assess the congruence/incongruence between a bodily sign language and a verbal description of it (e.g., "High five!" or "I'm freezing cold"), the N400 to incongruent pairs was smaller if the images were stripped of facial information, via face blurring (Proverbio et al., 2018). Therefore, we expected that N400 to incongruent faces was smaller for masked versus unmasked faces in this study. On the other hand, P300 would generally reflect working memory and cognitive updating processes (Rac-Lubashevsky & Kessler, 2019). More in detail, mid-parietal P300 would likely reflect the certainty of stimulus representation (Alday & Kretzschmar, 2019; Kopp et al., 2016), while anterior P300 component would index the workload and encoding effort (Azizian & Polich, 2007; Karis et al., 1984; Polich, 2007; Wang et al., 2015). We, therefore, hypothesized that, in this study, face covering might enhance the amplitude of ERP amplitudes reflecting enhanced (or more extended) neural processing, especially at N170 and anterior P300 level.

We expected that the lack of information of the masked faces combined with the need to make decisions on the incomplete material, activated more extensively the anterior brain regions (thus resulting in higher amplitudes of the anterior P300) for the greater cognitive effort required. At the same time, we hypothesized that word-face congruence, and the validity of semantic priming, reduced uncertainty and facilitated recognition of facial expressions, resulting in greater posterior P300 amplitudes.

Six emotional facial expressions were compared in this study to investigate if face masking would generally impair the whole spectrum of emotional cues, or would preserve some emotions in favor of others—as previously shown, for example, by Noyes et al. (2021) or Proverbio and Cerri (2022)—thus possibly distorting social interactions. If the advantage for high valence emotions such as happiness and anger, and in particular the primacy of anger under masking conditions, had also emerged from the electrophysiological data, thanks to the ERP technique it would have been possible to enucleate whether it was a perceptual advantage (with effects visible on the amplitude of the N170) or was the result of a more analytical and higher order analysis, emerging only at the level of the P300.

2 | MATERIALS AND METHODS

2.1 | Participants

Twenty-six right-handed individuals (13 women and 13 men) aged about 22.35 years (*SD* = 2.6) took part in this study as unpaid volunteers. They were University students and earned 0.6 academic credits for their participation. All the subjects were right-handed, as determined by

Edinburgh Inventory Questionnaire (mean score = 0.831). All the participants had a normal or correct-to-normal vision with no history of neurological or psychiatric diseases, or drug abuse, and they all provided their written and informed consent. The experiment was conducted in accordance with international ethical standards (Helsinki, 1964), and with the approval of the local Ethical Committee. The project, entitled "Perception of facial expressions under masking conditions" was pre-approved by the Research Assessment Committee of the Department of Psychology (CRIP) for minimal risk projects, under the aegis of the Ethical committee of University of Milano-Bicocca, on April 9th, 2021, protocol (n: RM-2021-401). The current sample size was tested for power analysis (Boudewyn et al., 2018) with alpha level = 0.05. The data were recorded during COVID pandemics (from June 2021 to November 2021).

2.2 | Stimulus and material

Stimulus images represented frontal close-ups of faces of 5 females and 5 males of approximately 23 years of age (*SD* = 1.333). For each actor/actress, pictures of 6 spontaneous emotional expressions (joy, surprise, sadness, fear, disgust, anger), in masked and unmasked conditions, were taken. Two extra actors (1 M, 1F) provided pictures to be used only in the training sessions. Faces were makeup-free. Actors wore no paraphernalia whatsoever (such as earrings, glasses, hairpins, pliers, any type of hair embellishments, mustaches, beard). Everyone wore a black t-shirt and had their hair pulled back behind their heads. The photos were self-taken (during COVID lockdown) with a cell phone about 40 cm away in controlled light conditions while standing against a white wall. A masked version of the faces was created by having the actors wear real surgical masks, and not digitally overlaying a picture, for a more realistic effect. In this way, it was possible to observe the air suction, or the opening/widening of the mouth under the mask, which slightly deform the mask in reality. The images were equiluminant as assessed by subjecting their luminance values to analysis of variance. Photos were in color, had the same size (3.37 × 5 cm; 199 × 295 pixels) and were presented in the same position at the center of the screen. Unmasked face stimuli were validated on a group of 50 students (25 females, 24 males and 1 gender fluid) aged about 23.7 years. Participants were shown (randomly mixed and once at a time), 56 pictures relative to the 7 facial expressions acted by 8 female and male actors. Subjects were required to rapidly observe each picture and decide which one of the seven emotion words typed below (e.g., "surprise") was more appropriate to describe the viewed facial expression, by clicking a check mark. Overall performance for correctly identifying facial emotions in unmasked faces was remarkably high = 87.35%. In more details, accuracy was 98.47% for joy, 86.73% for surprise, 80.1% for sadness, 89.29% for anger, 72.70% for fear, 85.97% for disgust, and 98.21% for neutrality (Proverbio & Cerri, 2022). Stimulus set was also evaluated for facial attractiveness by a further group of 12 students (7 females and 5 males) aged 18–25 years. Judges were requested to evaluate the attractiveness of neutral unmasked pictures of all identities, by using a 3-point Likert scale, where 1 stood for "not attractive," 2 for "average," and 3 for "attractive." The results showed a perfect balance across the two sexes and indicated an "average" degree of attractiveness for the facial stimuli (Females = 1.83; *SD* = 0.78; Males = 1.82; *SD* = 0.76). This characteristic of stimuli promotes the generalizability of results to the normally looking population. Masked and unmasked faces underwent a further validation through the behavioral study by Proverbio and Cerri (2022) performed on a group of 220 undergraduate students. Subjects were presented with 112 pictures displaying the faces of the 8 actors wearing or not wearing facemasks, and expressing 7 emotional states (neutrality, surprise, happiness, sadness, disgust, anger, and fear). The task consisted in categorizing facial expressions while indicating their recognizability on a 3-point Likert scale. Scores underwent repeated measures ANOVAs. Overall, face masking reduced emotion recognition by 31%. All emotions were affected by mask covering except for anger. Face covering was most detrimental to sadness and disgust, both relying on mouth and nose expressiveness.

2.3 | Procedure

Stimuli were randomly presented in 14 experimental sequences (runs), preceded by two training sequences. Each sequence lasted approximately 2 min, for a total duration of ~35 min. Each run comprised the presentation of 62 trials structured as follows: an emotional word (either 'happiness', 'sadness', 'surprise', 'fear', 'anger', or 'disgust') was presented for 200 ms at the center of the screen (see Figure 1). After an Inter-stimulus Interval (ISI) ranging from 400 to 600 ms, a face was shown that lasted 800 ms. The face expressed 1 out of 6 emotions and was either uncovered or wearing a mask (50% of probability). The intertrial interval (ITI) was 700–900 ms. Participants pressed one of two keys on a joystick with index (for indicating congruence) and middle finger (for indicating incongruence), which was operated in alternating runs with the right and left hand. Run order was randomized across participants. Overall, 864 face stimuli were administered. Each emotional expression was presented 144 times

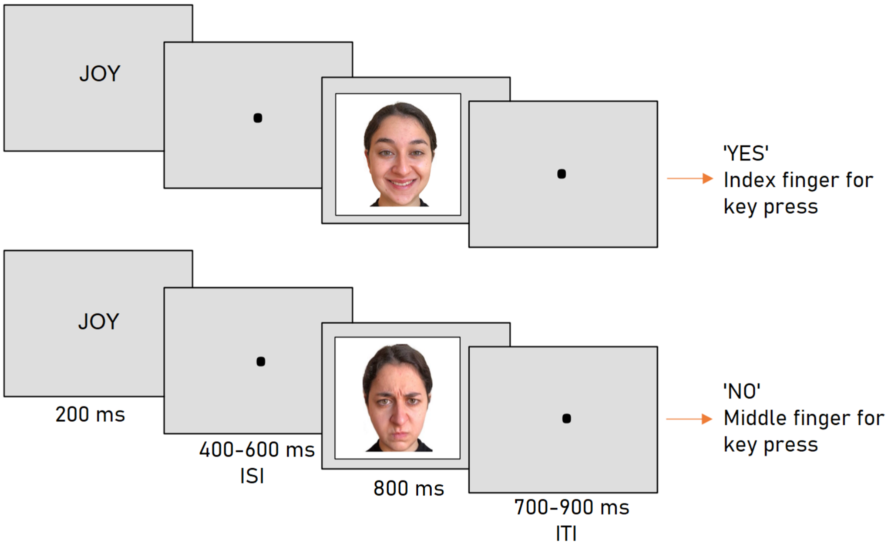

FIGURE 1 Time sketch of the experimental procedure.

during the experiment. Half the time it was congruent with the prime word (72 trials × average) and the other times it was incongruent (72 trials × average). Each emotional expression was presented masked half of the time (72 trials × average) and unmasked the remaining (72 trials × average). Stimuli were equiprobable across runs and categories. To avoid that participants might guess facial expressions by simply counting their occurrence within each run, the number of expressions varied minimally across runs. Face identities were perfectly balanced across conditions (12 actors × 12 face pictures = 144 face stimuli).

2.4 | EEG recording

The EEG was continuously recorded from 128 scalp sites at a sampling rate of 512 Hz and according to the 10/5% system (Oostenveld & Praamstra, 2001). Horizontal and vertical eye movements were recorded. Averaged ears (earlobes) served as the reference lead. The EEG and electro-oculogram (EOG) were amplified with a half-amplitude band pass of 0.016–70 Hz. Electrode impedance was maintained below 5 kΩ. The EEG was recorded and analyzed using ANT *EEProbe* software. Stimuli presentation and triggering was performed using ANT *Eevoke* Software. EEG epochs were synchronized with the onset of face presentation. A computerized artifact rejection criterion was applied before averaging to discard epochs in which eye movements, blinks, excessive muscle potentials, or amplifier blocking occurred. The artifact rejection criterion was a peak-to-peak amplitude exceeding 50 μv (±25 μv) and the rejection rate was below 5% (min = 0/72; max = 11/72 rejected trials). All trials were checked for eye and muscle activity related artifacts. To detect eye movements and blinks, the EOG signals were combined to derive bipolar vertical and horizontal channels that were passed through a set of artifact detection steps. Any trials containing amplitude change larger than ±25 μV in the vertical or horizontal bipolar EOG channels were removed to avoid any contamination of data by eye blinks or muscle movements. Additionally, any trials with potential eye-movement activity were rejected.

The ERPs were averaged off-line from −100 ms before to 800 ms after face onset. ERP components were identified and measured with reference to the average baseline voltage over the interval of −100 to 0 ms at the sites and latencies at which they reached their maximum amplitudes. The electrode clusters and time windows for measuring and quantifying ERP components of interest were based both on previous literature (e.g., Duval et al., 2013; Eimer & Holmes, 2007; Hinojosa et al., 2015; Ku et al., 2020; Proverbio et al., 2022) and on the observed timing and topographic distribution of ERP responses. Precise criteria were as follows: a pair of homologous left and right electrodes were selected where the electrical potentials reached their maximum amplitude. The time window for measuring ERP responses was centered on the peak of maximum negative or positive voltage (i.e., the inflection point on the curve), ± a time range depending on the duration of the ERP response. This interval ranged from a 40-ms window for the highly synchronized N170 responses (~ ±20 ms from the deflection point), to the 150-ms window for the large N400 deflection, extended to the 200-ms window for the slowest and largest positive deflection (~ ±100 ms from deflection point, or the plateau midpoint, plus 150 ms for the descending phase, for both N400 and P300 components).

ERP waves were filtered offline with a bandpass filter of 0.016/30 Hz for illustration purposes. The mean area amplitude of the N170 response (peak latency: 166 ms) was measured at posterior occipital sites (PPO9h, PPO10h) in the 150–190-ms temporal window. The mean area amplitude of the N400 component (peak latency: 373 ms) was measured from anterior-frontal sites (AFF1, AFF2) in the

300–450-ms temporal window The mean area amplitude of the P300 component (peak latency: 563 ms) was measured in the 450–650-ms temporal window. P300 was quantified at dorsolateral frontal sites (F3, F4) for the *anterior* P300, and at parietal sites (PO3, PO4) for the *posterior* P300.

2.5 | Data analysis

The mean area amplitude values of the ERP components of interest were subjected to 4-way repeated-measure ANOVAs. Factors of variability were: *emotion*, with 6 levels (happiness, surprise, sadness, anger, fear, and disgust); *congruence*, with 2 levels (congruent and incongruent); *masking*, with 2 levels (natural and masked), and *hemisphere*, with 2 levels (left, right). Tukey's (HSD) post hoc comparisons ($p < .01$) were used for contrasting means. ERP data were preprocessed both by (i) by considering all EEG trials, and (ii) only those associated with correct emotion categorizations. Due to the largely uneven error rate across conditions (ranging from 3.22 to 55.66%) ERP comparisons were made on equiprobable averages including correct and incorrect (artifact rejected) trials. It should be noted that, otherwise, ERPs uniquely based on correct categorizations mostly contained signals reflecting the processing of more easily recognizable faces (e.g., happy unmasked faces), as shown in Figure 2. The whole set of the data (with/without rejection of incorrect trials) can be accessed at this link doi: https://doi.org/10.17632/kpcgv763kc.1.

Behavioral data (error rates and response times) were subjected to 4-way repeated-measure ANOVAs whose factors of variability were: *emotion*, with 6 levels (happiness, surprise, sadness, anger, fear, and disgust); *congruence*, with 2 levels (congruent and incongruent); *masking*, with 2 levels (natural and masked), *response hand*, with 2 levels (left hand and right hand). The Greenhouse–Geisser correction was also applied to compensate for possible violations of the sphericity assumption associated with factors which had more than two levels. In this case, the degrees of freedom accordingly modified are reported together with the epsilon (ε) and the corrected probability level. The effect size for the statistically significant factors was estimated using partial eta squared (η_p^2) values.

3 | RESULTS

3.1 | Behavioral data

3.1.1 | Reactions times

The ANOVA performed on reaction times showed the significance of *emotion* factor [$F(5, 125) = 39.2$; $p < .001$, $\varepsilon = .798$; adj $p < .001$, $\eta_p^2 = 0.61$]. Post hoc comparisons showed faster RTs to happy faces (619 ms, $SE = 18.5$) than other expressions, and slower RTs to sad faces (690, $SE = 21.3$). Angry faces were responded faster than other negative expressions (Figure 3a). The *congruence* factor was also significant [$F(1, 25) = 11.40$; $p < .05$; $\varepsilon = 1$, $\eta_p^2 = 0.31$], with faster RTs to congruent (652 ms, $SE = 20.1$) than incongruent faces (672, $SE = 19.7$). Furthermore, the *masking* factor was significant [$F(1, 25) = 37.31$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.60$], with shorter RTs to unmasked (651.310, $SE = 20.4$) than masked faces (673 ms, $SE = 19.1$). The interaction between *emotion* × *congruence* was strongly significant [$F(5, 125) = 11.76$; $p < .001$; $\varepsilon = .795$; adj. $p < .001$, $\eta_p^2 = 0.32$] suggesting a marked difference in the speed of response to the different emotions for the two conditions of congruence and incongruence. RTs to happy congruent faces were faster (587 ms; $SE = 18.7$) than to all other stimuli ($p < .001$). On the contrary, sadness in the incongruence condition received the slowest responses (701 ms, $SE = 20.7$). Masked sad faces and fearful and disgusted masked and unmasked faces did not show any congruence effect, indicating that they were difficult to recognize. The *emotion* × *masking* interaction was also statistically significant [$F(5, 125) = 4.88$; $p < 001$; $\varepsilon = .722$, adj. $p < 001$, $\eta_p^2 = 0.16$], thus suggesting differences in the ability to recognize masked versus unmasked facial expressions. In particular, shorter RTs were found, once again, for unmasked happy faces (601, $SE = 19.6$) compared to other stimuli. Post hoc comparisons also showed a cost for all masked faces except for anger and fear, as visible in Figure 3a,b (Happiness: Masked = 636.5 ms ($SE = 17.7$) vs. Unmasked = 601.5 ms ($SE = 19.6$): $p = .0000001$; Surprise: Masked = 699 ms ($SE = 19.2$) vs. Unmasked = 646 ms ($SE = 19.7$): $p = .000000$; Sadness: Masked = 699 ms ($SE = 20.1$) vs. Unmasked = 680 ms ($SE = 23$): $p = .001$; Anger: Masked = 654 ms ($SE = 20.1$) vs. Unmasked = 648 ms ($SE = 22.1$): $p =$ n.s. (.29); Fear: Masked = 678.5 ms ($SE = 20.3$) vs. Unmasked = 670 ms ($SE = 21$): $p =$ n.s. (.129); Disgust – Masked = 692 ms ($SE = 20.1$) vs. Unmasked = 663 ms ($SE = 20.1$): $p = .00001$). Finally, the interaction of *emotion* × *congruence* × *masking* was also found strongly significant [$F(5, 125) = 5.97$, $p < .001$; $\varepsilon = .73$; adj. $p < .001$, $\eta_p^2 = 0.19$]. Post hoc comparisons showed faster responses to happy unmasked faces, and slowest responses to sad masked faces. Masked surprised, masked or unmasked sad, masked or unmasked disgusted faces failed to show a congruence effect.

3.1.2 | Error rates

The ANOVA performed on the percentage of errors yielded the significance of *emotion* factor [$F(5, 125) = 49.75$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.67$], with fewer errors ($p < .001$) associated with happy faces (9.71%, $SE = 1.2$). Surprised

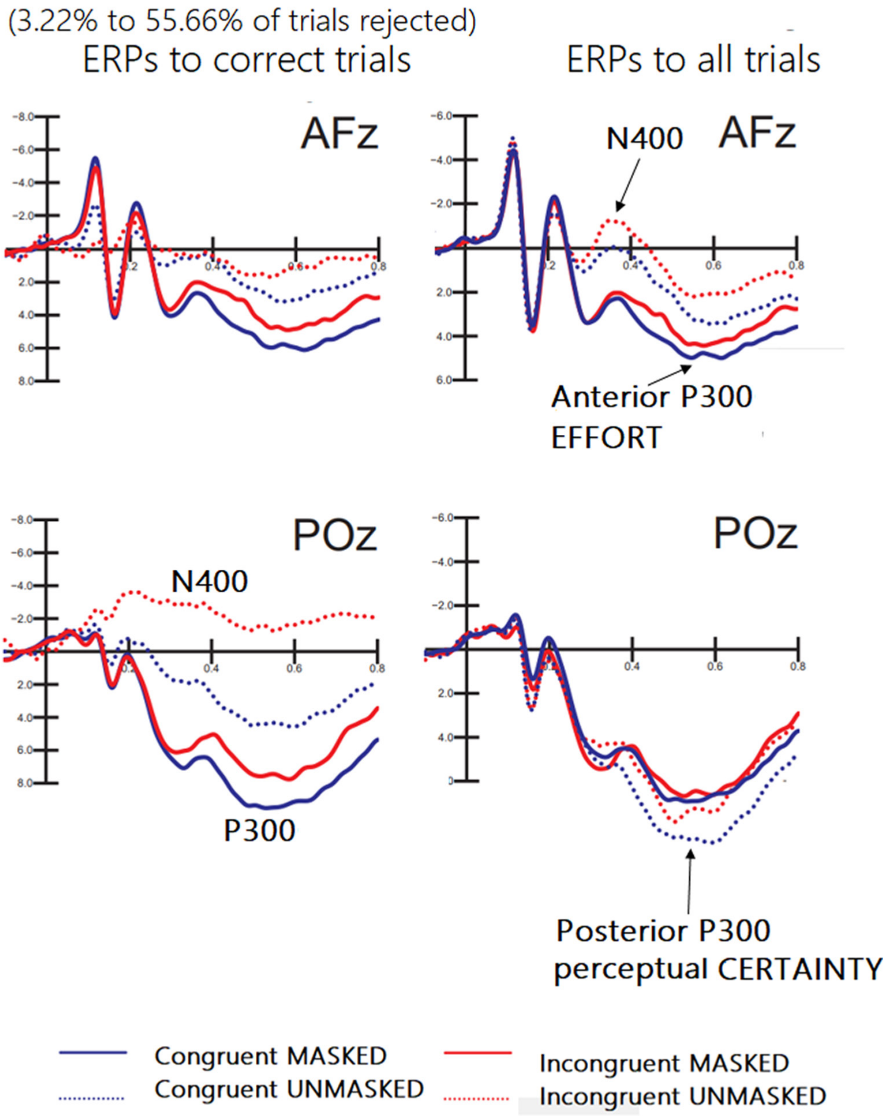

FIGURE 2 Comparison between ERP averages obtained by excluding incorrect responses (left), therefore, based on an uneven number of trials (e.g., reflecting only the processing of unambiguous facial expressions) versus (right) ERP averages based on all trials (reflecting the processing of all faces). While at anterior electrodes there was not much difference between the two types of signals (upper part of the figure), posterior signals were quite different. Masked faces that succeeded in being correctly recognized (left) were associated with larger P300 responses, likely reflecting enhanced processing, while masked faces that did not succeed or succeeded in being correctly recognized (right) were associated with smaller P300 responses than unmasked faces at mid-parietal sites. Overall, masked faces (as in the face picture) elicited an enhanced anterior P300 reflecting effort, while unmasked faces (as in the corresponding face picture) elicited an enhanced posterior P300 reflecting perceptual certainty.

(18.3%, $SE = 1.35$) and angry faces (17.3%, $SE = 1.36$) then followed, whose error rate did not differ. However, sad faces were associated with the highest error rate (27.9, $SE = 1.7$), followed by fear (26.9%, $SE = 1.5$) and disgust (26.13%, $SE = 1.37$), the latter values not being statistically different from each other (see Figure 3a).

The main effect of *masking* was also highly significant [$F(1, 25) = 146.81$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.85$], with lower error rates for unmasked (17.57, $SE = 1.16$) than masked faces (24.5%, $SE = 1.08$). The interaction of *emotion* × *masking*, [$F(5, 125) = 31.85$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.85$], and relative post hoc comparisons, showed that the lowest error rate was found in response to unmasked happy faces (7.08%, $SE = 1.28$). The largest error rate was found for masked disgusted and sad faces. Masking negatively affected the recognition of all emotions except for fear ($p = .22$) as visible in Figure 3a,b).

The interaction of *emotion* × *congruence* was significant [$F(5, 125) = 5.93$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.19$]. Happy incongruent faces were associated with the lowest error rate, followed by angry and surprised expressions. The significant interaction of *congruence* × *masking* was also significant [$F(1, 25) = 19.41$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.44$]. Post hoc showed a higher error rate for congruent masked faces (27.67%, $SE = 2.1$) than unmasked congruent or incongruent faces (congruent unmasked = 17.3%, $SE = 1.8$; incongruent masked = 21.37 &, $SE = 1.6$; incongruent unmasked = 17.8%, $SE = 1.35$). The triple interaction *emotion* × *congruence* × *masking* ([$F(5, 125) = 14.62$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.37$], showed that the expressions associated with the largest error rate (in the congruent masked condition) were disgust and sadness ($p < .00001$), while anger was relatively unaffected by face masking.

3.2 | Electrophysiological data

3.2.1 | N170 response

The ANOVA performed on the N170 amplitudes recorded over the posterior occipital electrodes (PO9, PO10) revealed the significance of *emotion* [$F(5, 125) = 4.21$; $p < .001$; $\varepsilon = .75$, adj. $p < .005$, $\eta_p^2 = 0.14$]. Post hoc tests showed that N170 amplitude was larger for faces expressing happiness (−3.1. μV, *SE* = 1.13) and surprise (−2.97 μV, *SE* = 0.45), and smallest for faces expressing disgust (−2.55 μV, *SE* = 1.17), anger (−2.68 μV, *SE* = 1.12), and sadness (−2.78 μV, *SE* = 1.22). The *masking* factor was statistically significant [$F(1, 25) = 26$; $p < .0001$, $\varepsilon = 1$, $\eta_p^2 = 0.51$], with larger N170s to masked (−3.34 μV, *SE* = 1.98) than unmasked faces (−2.27 μV, *SE* = 2.16), as can be observed in Figures 4 and 5. The ANOVA also showed the significance of *emotion* × *hemisphere* interaction [$F(5, 125) = 2.6$; $p < .002$; $\varepsilon = .73$; adj. $p < .04$, $\eta_p^2 = 0.10$], with smaller N170 responses over left hemispheric sites to all expressions, except for disgust and fear.

3.2.2 | N400 response

The ANOVA performed on the N400 amplitude recorded over anterior-frontal sites (AFF1, AFF2, AFp3h, Afp4h) in the 300–450-ms temporal window yielded the significance of *congruence* [$F(1, 25) = 19.9$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.36$], with much greater N400 amplitudes to incongruent (−1.67 μV, *SE* = 0.67) than congruent faces (−1.0 μV, *SE* = 0.68), as visible in Figure 6. The *masking* factor was highly significant [$F(1, 25) = 126$; $p < .001$, $\varepsilon = 1$, $\eta_p^2 = 0.84$], with larger N400 amplitudes to unmasked (−2.78 μV, *SE* = 0.74) than masked faces (0.1 μV, *SE* = 0.63). The significant interaction between *congruence* and *emotion* factors [$F(5, 125) = 2.86$; $p < .017$, $\varepsilon = .67$, adj. $p < .036$, $\eta_p^2 = 0.10$], and relative post hoc comparisons, showed significantly larger N400 to incongruent than congruent faces for all emotions (especially happiness), but not for surprise ($p = .06$) and anger (0.125). The smallest effect was found for sadness. Moreover, the interaction between *congruence* and *masking* was found significant [$F(1, 25) = 8.7$; $p < .007$, $\varepsilon = 1$, $\eta_p^2 = 0.26$]. Specifically, the N400 elicited by incongruent unmasked faces (−3.36 μV, *SE* = 0.73) showed the largest amplitude, followed by the N400 elicited by congruent unmasked faces (−2.19 μV, *SE* = 0.76), in turn followed by incongruent masked faces (0.02 μV, *SE* = 0.66), each differing significantly from the others ($p < .05$). Finally, the smallest N400 amplitude was elicited in response to congruent masked faces (0.18 μV, *SE* = 0.62). Also significant was the *hemisphere* factor [$F(1, 25) = 4.22$; $p < .05$; $\varepsilon = 1$, $\eta_p^2 = 0.15$], showing greater N400 amplitudes over the left (−1.42 μV, *SE* = 0.67) than right anterior sites (−1.26 μV, *SE* = 0.68).

3.2.3 | Anterior P300

The ANOVA performed on the anterior P300 amplitude recorded over the frontal electrodes (F3, F4) revealed the significance of *emotion* factor [$F(5, 125) = 5.5$; $p < .001$, $\varepsilon = .74$, adj. $p < .0001$, $\eta_p^2 = 0.18$]. In particular, post hoc tests showed the greatest P300 amplitude for faces expressing anger (4.23 μV5, *SE* = 0.67), and the smallest amplitude for faces expressing fear (3.2 μV, *SE* = 0.57) (Figure 7). The main effect of *congruence* was also statistically significant [$F(1, 25) = 16.5$; $p < .0001$, $\varepsilon = 1$, $\eta_p^2 = 0.40$], with a greater P300 for congruent (4.0 μV, *SE* = 0.56) than incongruent faces (3.1 μV, *SE* = 0.58). The further interaction of *emotion* × *congruence* [$F(5, 125) = 7.02$; $p < .0001$, $\varepsilon = .837$, adj. $p < .001$, $\eta_p^2 = 0.22$], showed larger P300 amplitudes to angry and happy congruent faces than all other faces (see Figure 8). Again, the main effect of *masking* was found significant [$F(1, 25) = 44.16$; $p < .001$, $\varepsilon = 1$, $\eta_p^2 = 0.64$], with larger P300 amplitudes in response to masked (4.28 μV, *SE* = 0.53) than unmasked faces (2.87 μV, *SE* = 0.62), as shown in Figure 8. The significant

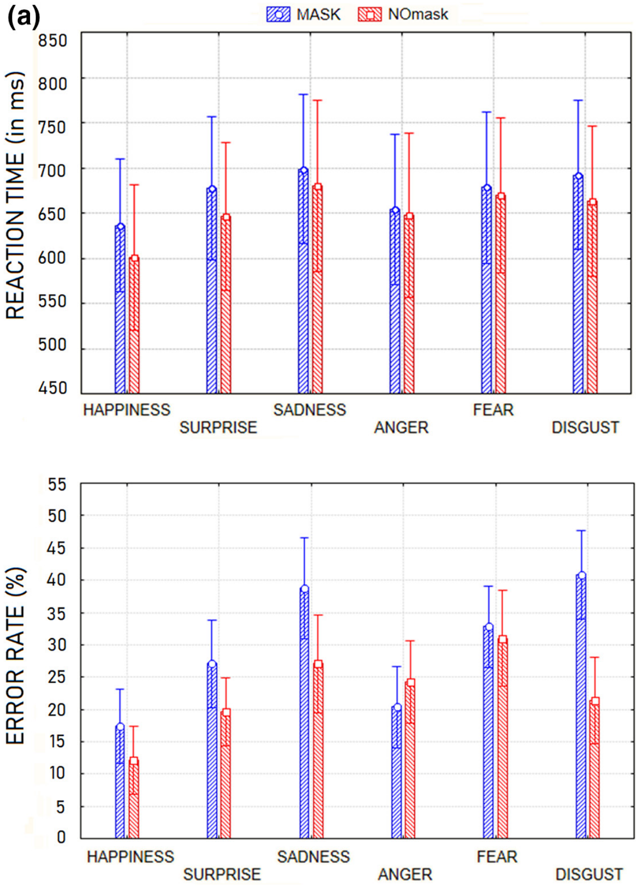

FIGURE 3 (a) Response times and percentages of correct responses (with standard errors) recorded as a function of the face emotional content and masking conditions. (b) Response times and percentages of correct responses recorded as a function of the face emotional content, masking condition, and stimulus congruence.

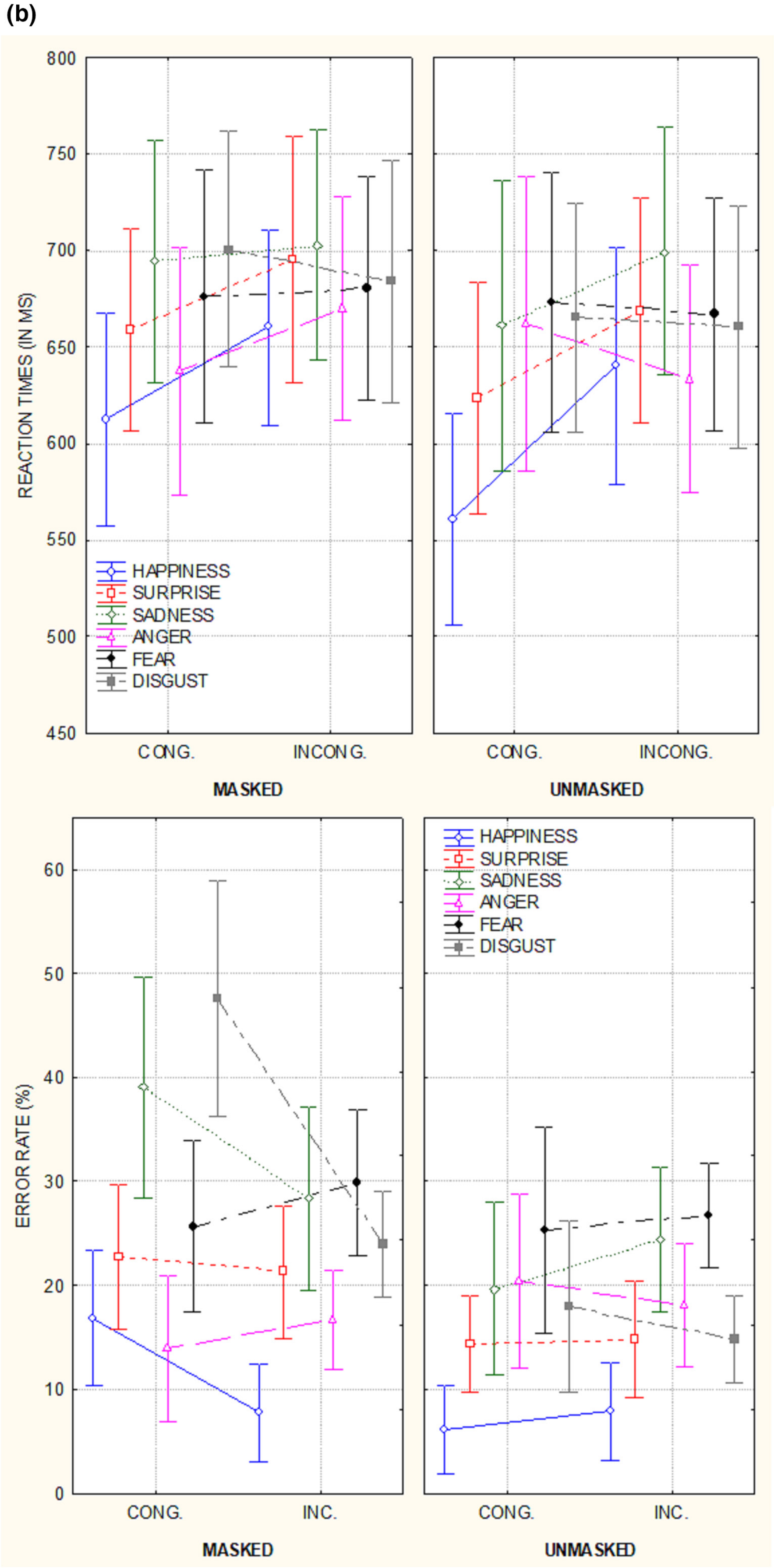

FIGURE 3 Continues

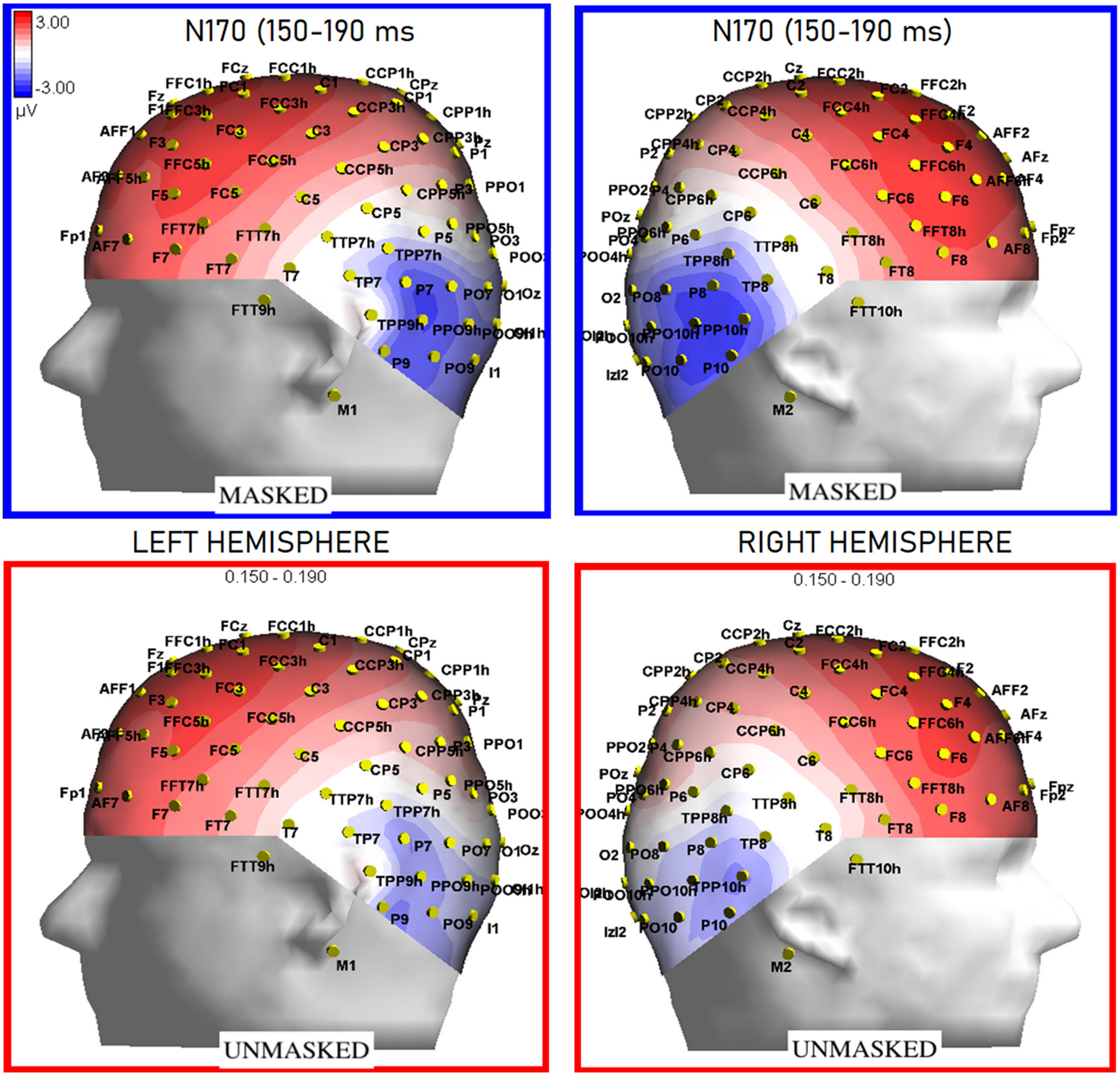

FIGURE 4 Isocolor topographical maps of N170 voltage recorded in the 150–190-ms time window in response to masked and unmasked faces. On the left and right are displayed the left and right cerebral hemispheres. Blue shades indicate negative potentials (N170 amplitude).

interaction of *masking* × *emotion* [$F(5, 125) = 4.74$; $p < .001$, $\varepsilon = .84$, adj. $p < .0001$, $\eta_p^2 = 0.16$], and relative post hoc comparisons, showed larger P300 responses to angry and happy masked faces than other expressions, and especially fearful expressions. P300 amplitudes were larger to all masked than unmasked facial expressions.

3.2.4 | Posterior P300

The ANOVA performed on the P300 amplitude recorded over the parieto/occipital sites (PO3, PO4 electrodes), revealed a significant effect of *emotion* [$F(5, 125) = 11$; $p < .001$; $\varepsilon = .71$, adj. $p < .001$, $\eta_p^2 = 0.30$]. Post hoc tests showed that P300 amplitude was larger to happy (9.35 μV, $SE = 0.87$) and angry (9.04 μV, $SE = 0.88$) faces and smallest to faces expressing sadness (7.77 μV, $SE = 0.77$). The main effect of *congruence* was also significant [$F(1, 25) = 11.94$; $p < .001$; $\varepsilon = 1$, $\eta_p^2 = 0.32$], with a greater P300 response to congruent (8.77 μV, $SE = 0.80$) than incongruent faces (8.03 μV, $SE = 0.74$). The *emotion* × *congruence* interaction was significant [$F(5, 125) = 25.14$; $p < .001$; $\varepsilon = .54$, adj. $p < .001$, $\eta_p^2 = 0.50$], with P300 responses being larger to all congruent than incongruent

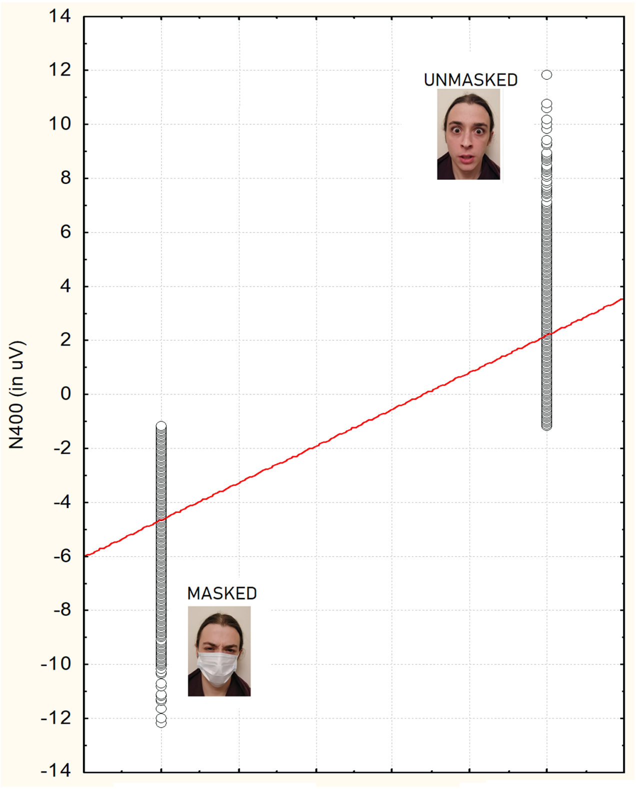

FIGURE 5 Scatterplot of individual mean area amplitudes values of N170 response recorded to masked and unmasked faces (2496 data points).

faces, except for surprise. The *masking* factor was highly significant [$F(1, 25) = 32.9$; $p < .001$, $\varepsilon = 1$, $\eta_p^2 = 0.57$], with a much wider P300 to unmasked (9.05 μV, $SE = 0.83$) than masked faces (7.75 μV, $SE = 0.83$), as shown in Figure 9. There was also a highly significant interaction between *masking* and *emotion* factors [$F(5, 125) = 9.34$; $p < .001$; $\varepsilon = .76$, adj. $p < .001$, $\eta_p^2 = 0.27$]. Post hoc comparisons (displayed in Figure 10) showed that P300 amplitude was significantly reduced by face masking, especially for negative emotions, but also surprise. The least affected expressions were happiness, but especially anger, for which P300 did not show a significant reduction in amplitude. The smallest posterior P300 amplitudes were recorded in response to fearful, disgusted, and surprised masked faces. The interaction between *congruence* and *masking* proved significant [$F(1, 25) = 4.91$; $p < .03$, $\varepsilon = 1$, $\eta_p^2 = 0.17$]. Post hoc comparisons showed that the posterior P300 was significantly reduced by face masking, both in the congruent and incongruent conditions. The P300 response reached its largest amplitude in response to congruent and unmasked faces (9.53 μV, $SE = 0.86$), followed by the incongruent unmasked faces (8.57 μV, $SE = 0.81$), congruent masked faces (8.00 μV, $SE = 0.76$), and incongruent masked faces (7.50 μV, $SE = 0.69$).

4 | DISCUSSION

In this study, ERPs were recorded in a group of healthy male and female students engaged in a facial expression categorization task involving six emotions, and masked versus unmasked faces. Faces were preceded by the visual presentation of emotional prime words that were congruent or incongruent with the facial expression.

4.1 | Behavioral data

Overall response times were slower in the incongruent than congruent condition, for an emotional priming effect. Indeed previous studies have found that the time needed to evaluate a target (e.g., a face) "angry" or "happy" is shorter when prime and targets are affectively congruent (e.g., "HAPPY" followed by an happy face) than when they are affectively incongruent (e.g., Frings & Wentura, 2008; Klauer et al., 1997; Vermeulen et al., 2006). This phenomenon is referred to as the affective priming effect. In this study, face masking was quite detrimental to emotion recognition, especially for negative emotions (disgust, sadness, and fear). Happy and angry faces were recognized faster and more accurately. Happy faces were responded to in the shortest time, and somewhat resisted masking. Interestingly, stimulus validation also showed that, especially in the natural (maskless) conditions, positive emotions (happiness, neutrality, positive surprise) were recognized more accurately than negative emotions such as fear, sadness, or disgust. The primacy of happy expressions was also showed in previous investigations (e.g., Kirita & Endo, 1995). Here, angry faces did not show any cost for masking in terms of both accuracy and response times. This pattern of results resembles the behavioral evaluations reported in Proverbio and Cerri (2022) showing how anger facial expressions were relatively unaffected by masking. Indeed, the corrugated forehead and frowning eyebrows, the typical facial cues of an angry attitude, remain clearly visible outside facemasks. Sad, fearful, and disgusted masked faces were not recognized more quickly when preceded by congruent primes, indicating that they were more difficult to recognize. Indeed the effect of emotional word priming (i.e., faster responses to items semantically congruent with primes) would reflect access to target semantic comprehension. Affective priming occurs when responses to a target are facilitated when it is preceded by a prime congruent in emotional meaning (e.g., Ferrè & Sánchez-Casas, 2014). Therefore, a lack of benefit for congruent emotional displays would indicate a poor semantic comprehension for these types of facial expressions. This piece of results fits with previous literature reporting stronger detrimental effects of masking for sad

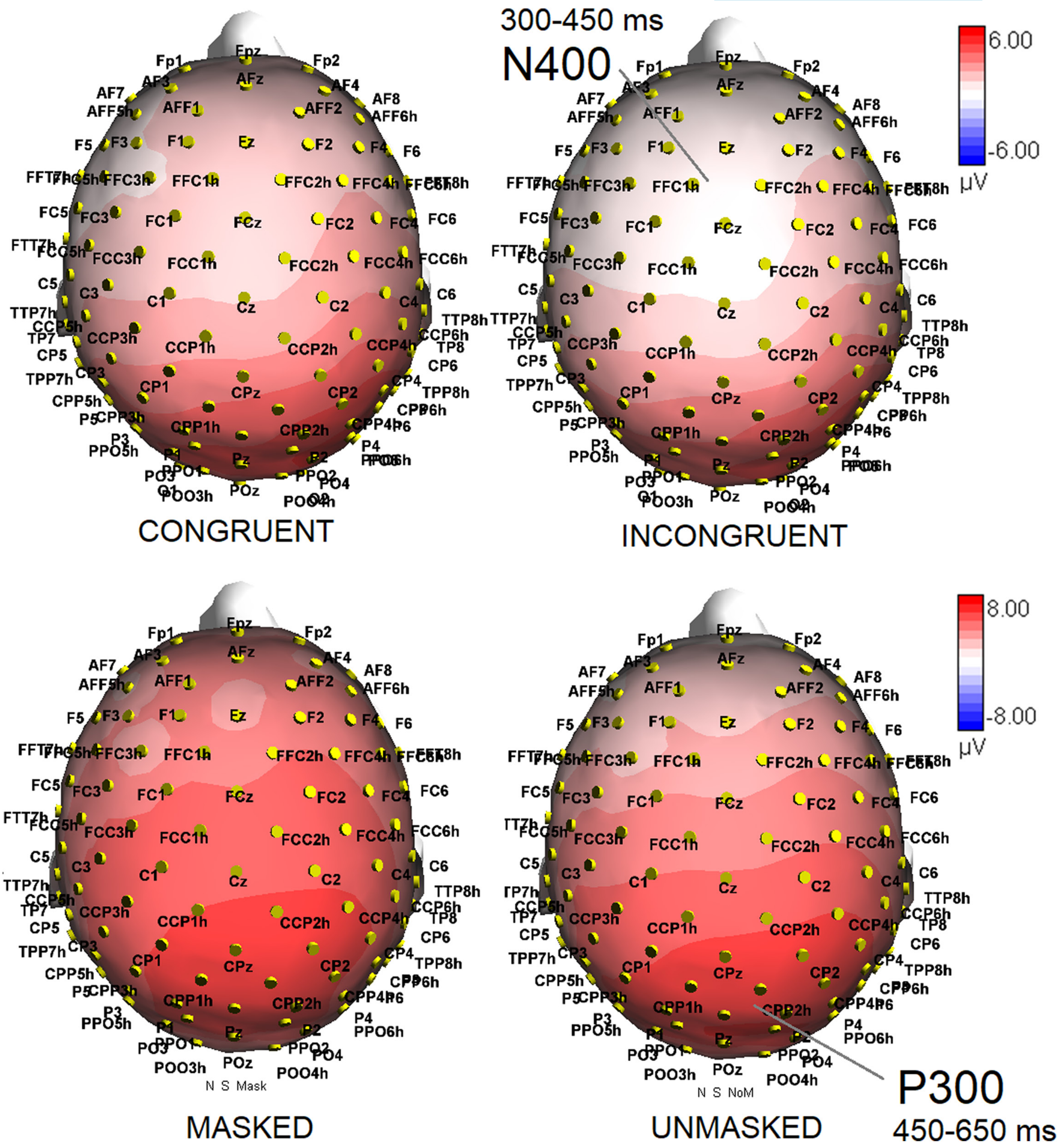

FIGURE 6 (Top). Isocolor topographical maps of N400 voltage recorded in the 300–450-ms time window in response to congruent and incongruent faces. (Bottom). Isocolor topographical maps of P300 voltage recorded in the 450–650-ms time window in response to masked and unmasked faces.

(Marini et al., 2021), fearful and disgusted faces (Noyes et al., 2021; Proverbio & Cerri, 2022).

Apart from anger, we found that facemasks affected emotion recognition in terms of accuracy and speed. This seems a consolidated evidence reported in the recent literature (Calbi et al., 2021; Carbon, 2020; Grundmann et al., 2021; Marini et al., 2021; Pavlova & Sokolov, 2021; Roberson et al., 2012; Ruba & Pollak, 2020). Proverbio and Cerri (2022) found that face masking was associated with a 31% decay in the ability to categorize emotional facial expressions. In that study, as well as in the present one, face masking was most detrimental to sadness, disgust, and fear. This finding fits with the evidence reported by Marini and coauthor (Marini et al., 2021),

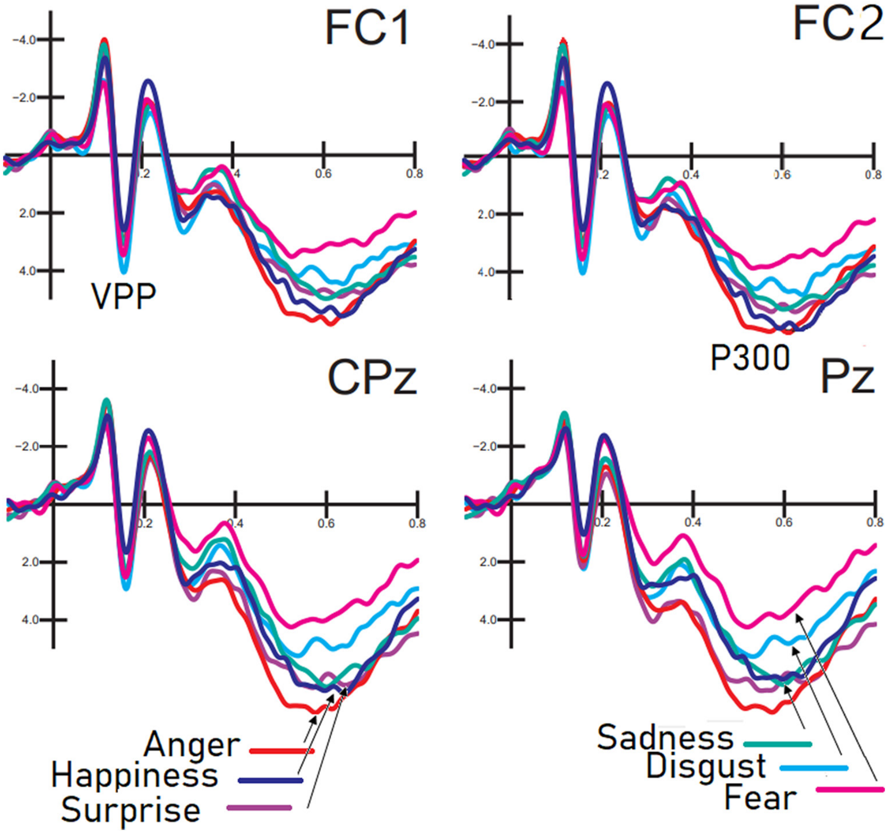

FIGURE 7 Grand-average ERPs recorded at left and right fronto/central, and midline centroparietal sites as a function of facial expression.

who only compared happiness, fear, and sadness recognition, according to which sadness would be the most affected expression, and happiness the least affected, by face masking. However, in this and Proverbio and Cerri (2022)'s study (investigating seven facial expressions including neutrality), disgust recognition was severely affected by face masking, which is consistent with what reported by Noyes and coworkers (2021). Indeed, the disgusted face is made recognizable by facial cues (i.e., nasolabial lifting and grimacing and/or nose wrinkling) that are concentrated in the mouth/nose area that is completely covered by facemasks. The finding that masking did not affect the recognition of angry faces, replicates those by Noyes and coauthors (2021), obtained with non-digital masks. Following the previous line of reasoning, this effect can be due to the fact that the markers of anger are mostly distributed over the disclosed face area (the wrinkled eyebrows and frowning eyes) (see also Ponari et al., 2012; Yitzhak et al., 2020).

4.2 | Electrophysiological data

EEG/ERP studies on emotional processing of masked faces are not many in the available literature. There are evidence of costs in the recognition of body language of stimuli when they are deprived from facial information through pixelling or blurring (Hadjikhani & de Gelder, 2003; Proverbio et al., 2018). Overall, behavioral and electrophysiological data (e.g., N170 and posterior P300 amplitudes) demonstrated how happy expressions were the easiest to recognize among facial expressions. However, facial masking did affect recognition of joy (as the smile remains hidden by the mask), but to a lesser extent than other negative emotions (or surprise). Again, the reason may lie in the fact that the main other indicator of a genuine happy attitude, that is, the joyful eyes (Smith et al., 2005) still remain outside the mask. Here we found enhanced amplitudes of face-specific N170 components during processing of masked than unmasked faces. This may be interpreted as reflecting an increased or more extended neural processing of faces, due to the lower amount of facial information available. A similar effect was reported for inverted faces (Sadeh & Yovel, 2010), as well as for other-race (ORE) faces (Caharel et al., 2011; Stahl et al., 2010), both characterized by disrupted or unfamiliar facial configurations. Indeed, it is likely that masked faces, blurred, inverted, and ORE faces would require extra processing (and/or the recruitment of additional neural mechanisms), due to the difficulty that these stimuli impose. As noted by our reviewer, N170 was enhanced both by a clearly recognizable expression, and by masked faces. It is possible that both factors (emotional poignancy, Hinojosa et al., 2015) and lack of familiarity arousal or emotional poignancy (Hinojosa et al., 2015) and lack of familiarity (e.g., Caharel et al., 2011) might

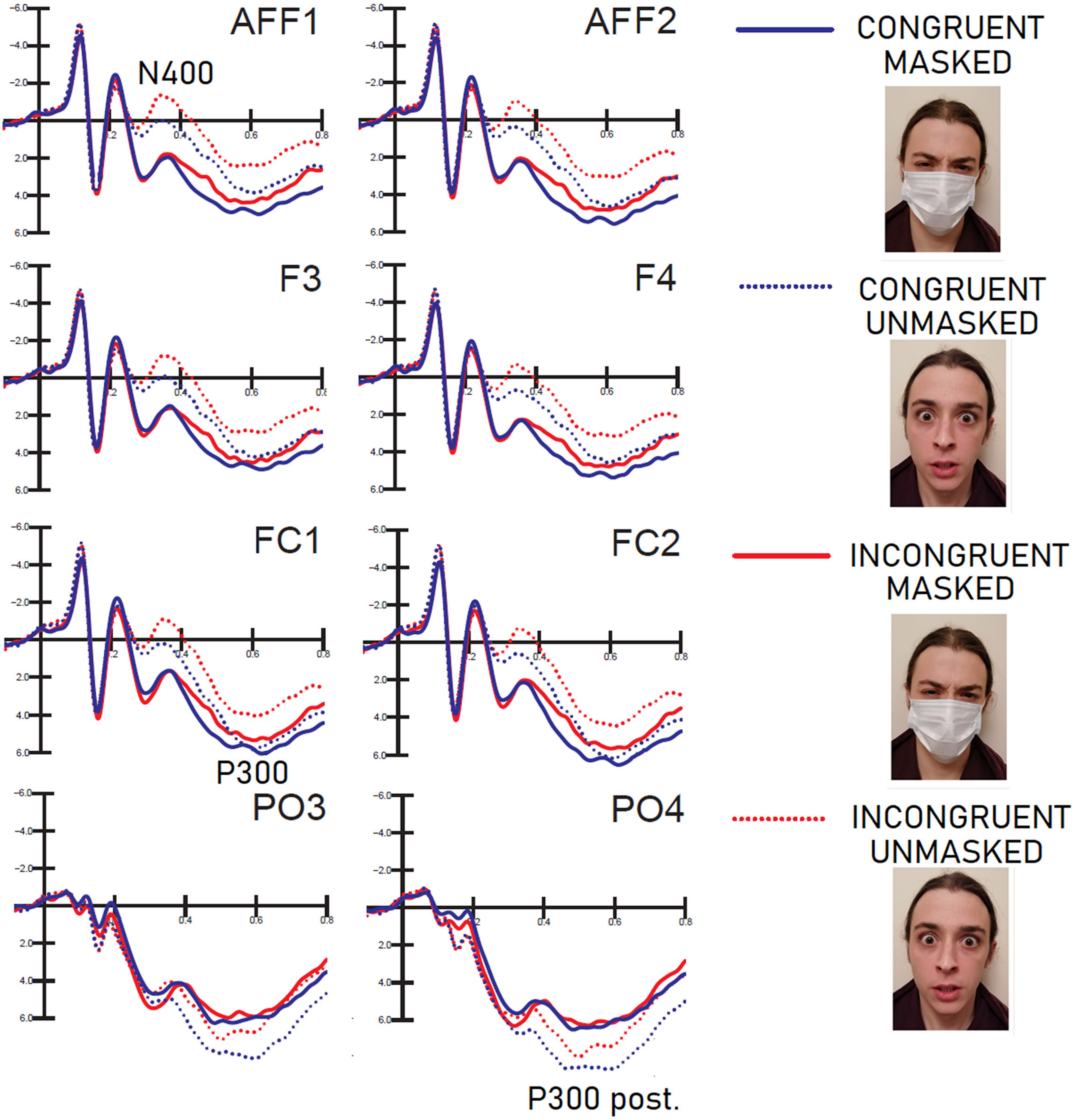

FIGURE 8 Grand-average ERPs recorded at left and right anterior frontal, dorsal frontal, fronto/central, and occipito/parietal sites as a function of face congruence and masking condition.

enhance N170 response. These factors might be mutually interacting with each other.

Anterior N400 was much larger to incongruent and unmasked faces, while posterior P300 was larger to congruent and unmasked faces. The larger N400/P300 complex to unmasked faces, might possibly indicate easier categorization and decision making processes for facial expressions not deprived by any coverage, resulting in a better performance. In agreement with this hypothesis, other studies investigating face or body comprehension have reported how congruent prime/face or prime/body displays elicited larger P300 responses than incongruent items (Gunter & Bach, 2004; Proverbio et al., 2014: Proverbio et al., 2018). Conversely, the finding of larger N400 amplitudes to incongruent word/face pairs is commonly observed in the literature where targets are anomalous

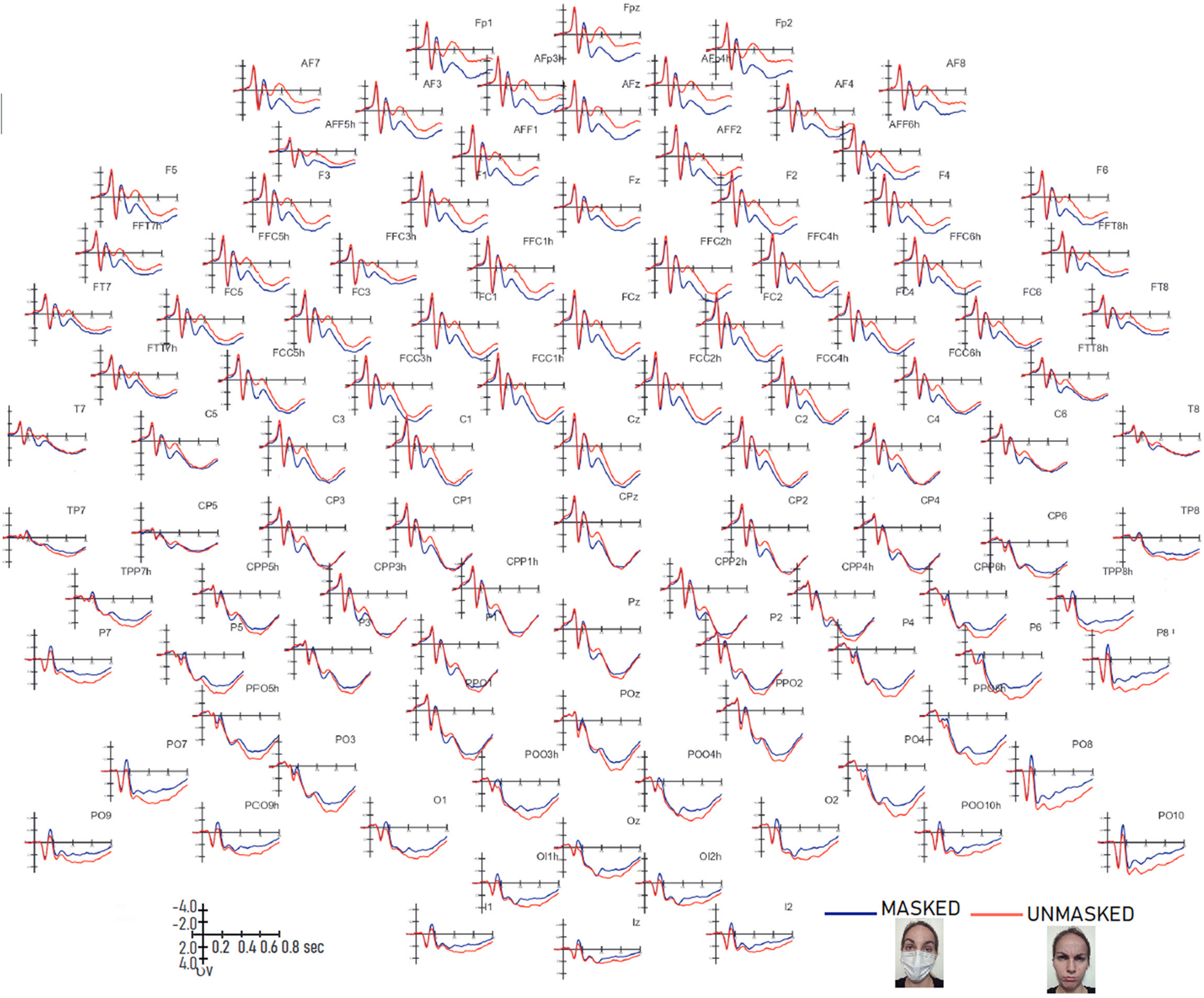

FIGURE 9 Grand-average ERPs recorded from anterior and posterior sites in response to masked and unmasked faces, regardless of their emotional content and congruence.

and semantically incongruent with previous context (Lau et al., 2008: Proverbio et al., 2020). Congruent emotional primes might have facilitated the access to the correct information. However, incongruent primes would not have provided any possibility of guessing the hidden expression. Since the masking effect was obtained by considered both congruent and incongruent conditions averaged together, we can hypothesize that congruence, in addition to providing an excellent methodological expedient to implicitly assess whether subjects understood the emotional content of facial expressions, did not alter the process of masked face comprehension. Indeed P300 was significantly reduced by face masking, both in the congruent and incongruent conditions.

On a different vein, it is thought that the posterior P300 (also named mid-parietal P3b, Polich, 2007) would reflect the certainty and clarity of mental representation (Alday & Kretzschmar, 2019). Accordingly, P300 would be linked to evidence accumulation for categorization, that is, its amplitude would be enhanced the more evidence from stimulus properties has been accumulated in order to make a decision on the stimulus category. Our data showed that parietal P300 was larger to unmasked than masked faces, clearly being more problematic to categorize due to the loss of the lower half. More anteriorly, frontal P300 response (also named anterior P3a, Dell'Acqua et al., 2016; Polich, 2007) was much larger in amplitude to masked (and congruent) than unmasked faces. This may be interpreted in the light of the literature reporting how anterior P300 would index enhanced attention, working memory, workload and encoding effort (Azizian & Polich, 2007; Karis et al., 1984; Polich, 2007; Wang et al., 2015). Again, in our study, masked faces probably required enhanced neural processing due to the incomplete facial information.

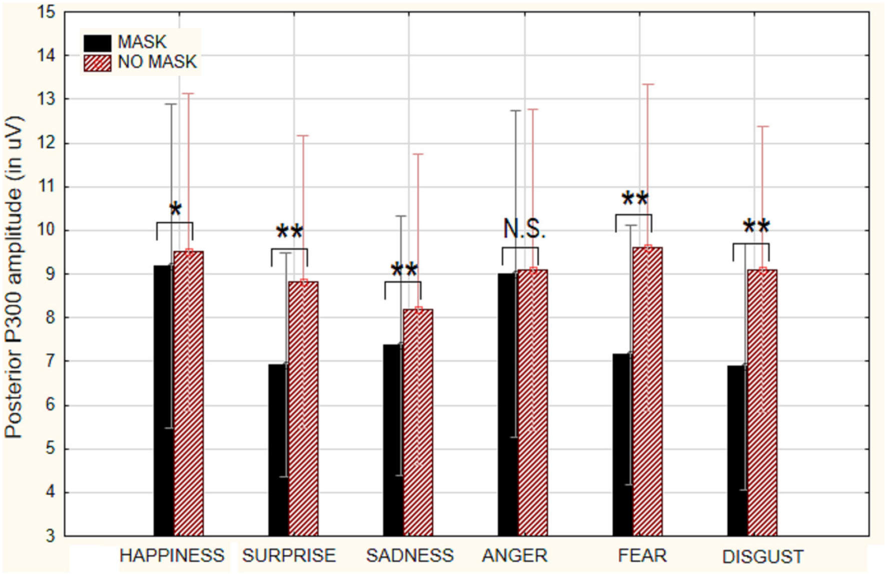

FIGURE 10 Mean area values of the posterior P300 component recorded as a function of facial expressions and masking condition. Significances were $*p < .02$; $**p < .0001$; n.s. = $p = .08$.

4.3 | Cost for face masking

In our knowledge, this is one the firsts published electrophysiological study where ERP responses were recorded to masked and unmasked emotional faces. The data provided evidence of an increased neural processing at perceptual (N170) and cognitive (anterior P300) level for masked than unmasked faces. The occipito/temporal cortex would increase its activation between 150–190 ms during processing of masked faces, regardless of emotion or congruence. This would be followed by an enhancement of activity over the dorsolateral frontal cortex to provide enhanced attention and more efficient stimulus encoding (Polich, 2007). The finding of enhanced N170 and P300 (300–600 ms) in response to masked than unmasked masked faces is fully consistent with another electrophysiological evidence (Żochowska et al., 2022). According to the authors, enhanced P300 for covered versus uncovered faces may reflect amplified attentional processing of faces with surgical-like masks, the fusiform gyrus being one of the strongest generators.

Notwithstanding the increased processing, facemask would impair emotion comprehension, as shown by the subjects' poor performance. The recognition of facial expression was considerably more delayed and inaccurate, because the eye and mouth areas are fundamental for the recognition of surprise, sadness, disgust, and partly fear. The impact of masks on interpersonal affective communication seems automatic and unavoidable; in no way observers can control at least part of their detrimental effects by increasing attentional level, because of the incomplete visual input and disruption of gestalt facial information. One possible way to address this problem would be to use transparent masks in which the often-occluded parts of the face are entirely visible. As recently found, (Yi et al., 2021) transparent masks increase speech intelligibility as compared to traditional face masks, and reduce the costs linked to inefficient lips reading (Fitousi et al., 2021).

4.4 | The happiness/anger dichotomy

One interesting piece of result was the primacy of anger among other negative emotions, also reported by Proverbio and Cerri (2022). In the present ERP study, while happy faces were recognized faster in unmasked conditions, and elicited larger N170 responses, angry faces showed a lack of costs related to face coverage, both in terms of speed and accuracy of response. In addition, angry faces elicited larger parietal P300 responses (likely indexing perceptual certainty) with no difference across masking conditions. Overall, face masking was strongly detrimental to the comprehension of emotional markers, especially of non-aggressive negative states (such as sadness, disgust and fear) but also surprise. The only expression, whose recognition was not impaired by masking, since the main facial cues are displayed over the eyes area, was indeed anger.

The primacy of anger among other more subtle emotions (such as sadness) has been reported in previous other studies (Esteves et al., 1994; Fox et al., 2000; Öhman, 1993), who found increased psychophysiological responding to masked angry faces relative to masked happy faces. The data showed how face masking was able to polarize emotion comprehension toward the negative/positive opposite dimensions (happiness/anger or approach/withdrawal), while causing a deficit in social interaction and communication of softer emotions that usually trigger an empathic resonance in the observer (sadness, fear, surprise). The limited recognition of distress people's emotions might lead to a reduction of personal concern and empathic response (Israelashvili et al., 2020).

In conclusion, notwithstanding happiness was recognized more quickly and higher accuracy than most emotions, and elicited a larger N170 (thus showing a perceptual advantage), angry faces elicited larger P300 responses and were unaffected by face masking. This suggests that the anger primacy might be a cognitive effect, being strictly dependent on a late latency, analytic processing of uncovered face details.

4.5 | Study limits and future research

One possible limitation of the current investigation is that ERPs were averaged by considering both correct and incorrect behavioral trials. In fact, due to the largely uneven error rate across conditions it would have been inappropriate to compare the resulting ERP averages (e.g., masked vs. unmasked faces). As well known, the amplitude of ERPs is inversely related to the number of composing trials, since, as the number of trials decreases, ERPs become more and more similar to large-amplitude EEG signals. The advantage of the selected method is that it enables one to closely observe the modulation of ERP components as a function of subjects' decision certainty, which would have been impossible if we had considered only correct trials. Anyway, all the data (ERPs to correct/incorrect trials) are visible at this repository:v1. https://doi.org/10.17632/kpcgv763kc repository Bicocca Open Archive Research Data.

One of the merits of this study is that we used real and not digital masks. Indeed, digitally applying a mask or headscarf over the face images, in order to create identically expressive faces, across the masked or unmasked conditions, might be problematic. While this procedure could ensure an optimal match between masked expressions and unmasked expressions, it nevertheless lacks verisimilitude and ecological value. In fact, digitally applied masks are not deformed by facial expressions, thus reducing verisimilitude. Furthermore, they deprive the visual image of details that are present in the real masked face, such as mask sucking or bending. In reality, surgical masks are, for example, deformed by the vertical opening of the mouth in expressions such as surprise or laughter, or during verbal speech; similarly, they are stretched horizontally to smile. Indeed the masks fit and reveal underlying muscular movements, which can be caught by an observer. To maintain visibility of mask bending and stretching due to underlying facial expressions, in this study, the actors wore real surgical masks during filming. Several repetitions and much effort were devoted to the perfect match between expressions produced with and without masks. Notwithstanding that, it cannot be excluded that facial expressions might still minimally vary (with and without facemasks). To overcome this potential problem, 10 different identities were used to generate face stimuli.

AUTHOR CONTRIBUTIONS

Alice Mado Proverbio: Conceptualization; formal analysis; methodology; project administration; resources; supervision; writing – original draft; writing – review and editing. **Alice Cerri:** Data curation; investigation; methodology; validation; visualization. **Cristina Gallotta:** Data curation; formal analysis; investigation; methodology.

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CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data sets analyzed for this study can be found in the Proverbio et al. (2022), "Data related to article" Facemasks impair the recognition of facial expressions that stimulate empathy (sadness, fear, and disgust): an ERP study, Mendeley Data, v1. https://doi.org/10.17632/kpcgv763kc repository Bicocca Open Archive Research Data.

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