Neural dynamics of pride and shame in social context: An approach with Event-Related brain electrical Potentials

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Abstract

The neural underpinnings of social emotions such as pride and shame are largely unknown. The present study aims to add evidence by exploiting the advantage of Event-Related brain electrical Potentials (ERP) to examine the neural processes as they unfold over time. For this purpose, a dot-estimation task was adapted to explore these emotions as elicited in a simulated social context. Pride prompted an early negativity seemingly originated in medial parietal regions (precuneus) and possibly reflecting social comparison processes in successful trials. This was followed by a late positivity originated in medial frontal regions, probably reflecting the verification of singularly successful trials. Shame, in turn, elicited an early negativity apparently originated in the cuneus, probably related to mental imagery of the social situation. It was followed by a late positivity mainly originated in the same regions as the early negativity for pride, then conceivably reflecting social comparison processes, in this occasion in unsuccessful trials. None of these fluctuations correlated with self-reported feelings of either emotion, suggesting that they instead relate to social cognitive computations necessary to achieve them. The present results provide a dynamic depiction of neural mechanisms underlying these social emotions, probing the necessity to study them using an integrated approach with different techniques.

Keywords. ERP, pride, shame, social emotions, medial frontal areas, cuneus, precuneus.

Introduction

Social emotions, such as pride, shame, guilt or envy, play a critical role to establish social behavior and human moral, being considered of the highest relevance for people´s adherence to social norms (Beer & Keltner, 2004; Tangney et al., 2007). They regulate and motivate human thoughts, feelings, and behavior, encouraging us to achieve actions in order to attain a valued social position (Tracy & Robins, 2007). On the other hand, social emotions are cognitively complex. They require self-awareness (Abe & Izard, 1999; Lewis, 2000), as well as the ability of mentalizing, as they imply concerns about others (Haidt, 2003; Tangney and Dearing, 2003). Despite their centrality to understand the distinctiveness of human mind and its evolution (Flinn et al., 2005), the neural underpinnings of social emotions have been scarcely studied. The present paper aims at contributing to this field by focusing on two of these emotions: pride and shame.

Pride is a pleasant emotion which is experienced when an individual improves in social status by achievement and effort (Tracy and Robins, 2007). Shame, by contrast, is an unpleasant emotion that evokes pain and aversive feelings arising from situations driven by failure to one or others’ ideal standards (Tangney et al., 2007) or from an inappropriate social behavior (Menesini & Camodeca, 2008). It implies a damaged global self, leading to anger, hostility, or resentment (Tangney et al., 1996), and even anxiety or depression (Gilbert, 2000; Tangney et al., 1992). According to recent adaptationist theories, pride and shame are distinct components of a culturally universal status management system in which pride tracks status gains while shame differentially tracks status losses (Durkee et al. 2019). In this regard, pride would have evolved to guide decisions that are relevant to pursue actions that may enhance valuation and respect for the self in the minds of others, prompting the individual to take advantage of the enhanced social status (Sznycer et al. 2017a, 2018b). Shame, on the other hand, would reflect the degree to which others would devalue the individual based on a potential action to be done and weigh its direct payoff, the aversive intensity of shame encoding this social cost (Sznycer et al. 2018a). Given their functional dissimilarities, distinct computational structures may underlie pride and shame, and therefore it appears admissible that they could be neurally dissociated. (Durkee et al. 2019; Sznycer et al. 2017b)

Though the identification of a distinct neurobiological basis is critical for the characterization and definition of any basic emotion (Tracy & Randles, 2011), this has been highly elusive regarding social emotions. Overall, these emotions seem to involve basic emotional processing brain structures, typically located subcortically -such as the amygdala-, together with others related to self-reference and mentalizing and mostly placed in cortical areas (Bastin et al., 2016). Indeed, the latter seem to better characterize the neural underpinnings of social emotions. Yet, the depiction of distinct patterns singularizing social emotions like shame and pride within these self-reference and mentalizing regions is far from available.

Recent neuroimaging evidence reveals the special relevance of medial prefrontal and posterior regions belonging to self-referential and mentalizing circuits during both shame (Michl et al., 2014; Gilead et al., 2016; Roth et al., 2014; Zhu et al., 2019) and pride (Zahn et al., 2009, 2014; Simon-Thomas et al., 2012; Roth et al., 2014). Besides, other studies have also reported the involvement of the anterior temporal lobes in shame (Bastin et al., 2016), and the ventrolateral and dorsolateral prefrontal cortex or the superior, middle and inferior temporal regions in pride (Hong et al., 2019; Takahasi et al., 2008). Remarkably, however, Roth et al. (2014) studied pride and shame concurrently and found them indistinguishable in terms of brain activated areas: both emotions engaged the same basic emotion-related (amygdala, insula and ventral striatum) and self-referential (dorsomedial prefrontal and posterior cingulate cortex) regions. Only a larger activation of the basic emotion-processing areas by pride could distinguish these emotions, interpreted as due to an intrinsic hedonic value of pride as a positive emotion. If we pursue the identification of distinct underpinnings to better characterize and dissociate pride and shame at the neural level, the current situation appears restraining. The reduced number of studies is one determining factor. The present study aimed to expand current knowledge on the neural mechanisms by dissociating pride and shame in two remarkable ways that we explain below.

On the one hand, Event-Related brain electrical Potentials (ERP), at variance with other neuroimaging techniques, permit to study the neural temporal dynamics in milliseconds, which could, by itself, unveil noticeable differences between shame and pride. Moreover, ERP can also provide an approach to structural information by means of source-estimating algorithms (Awan et al., 2009). Zhu et al. (2017) used ERP to disentangle shame and guilt: both emotions were distinguished about 200 ms after the presentation of the stimulus prompting either emotion, since a significant increase of the

P2 component occurred in the shame condition. As the P2 relates to early selective attention (it is actually originated in visual association areas; see Luck & Hillyard, 1984), the finding was interpreted as an index of the self-relevance of the visual information eliciting shame. To our knowledge, while no other study has approached shame by means of ERP, none has been done in relation to pride. The present study records ERP fluctuations to stimuli presumably eliciting pride and shame in the same experimental session.

A second way in which the present work contributes to the literature is through the development of an experimental paradigm seemingly prompting genuine feelings of pride and shame, in controlled social context in the lab. With the exception of the Zhu et al., 2019 (studying shame), most of the neuroimaging literature on pride and shame elicited these emotions through cue recalling or visual imagination (e.g., reading a sentence or viewing a related picture). With these procedures, memory and imagination neural processes may interfere with the target emotions processes, while social context and evaluations, which are critical factors in shame and pride, might be absent. (Robertson et al., 2018). This caveat can be overcome by implementing interpersonal games in the lab. This approach has been used in studies on shame (using ERP -Leng et al. 2016; Zhu et al., 2017; Sánchez-García et al. 2019- and fMRI -Zhu et al., 2019-), but it has never been applied to study pride.

The present study used an innovative paradigm, endorsing the direct study of both emotions at the neural level in the same experiment. In the paradigm developed here, the participant played online against three other people in a dot-estimation task. After every trial, the participant received feedback on proper and others' correctness or failure. Eight different conditions were created, depending on the feedback pattern. In 4 of them, the participant was right, and the performance of the other three participants could be: a) they all were right, b) two of the others were right, c) one of the others was right, or d) none was right. This was repeated in the 4 conditions in which the participant was wrong. What is distinctive about this paradigm is that emotions of pride and shame can be elicited in the same session, as a function of the comparison between proper and others' performance. *Pride* would be maximal when the participant is right and all the other players are wrong. The corresponding control trial for this condition would be when both the participant and the other three players are right. In turn, *shame* would be maximal when the participant is wrong and all the other players are right, and the corresponding control trial would be when both the participant and all the other three players are wrong.

According to previous findings on ERP with social emotions (namely, guilt and shame) (Leng et al. 2016; Zhu et al, 2017; Sánchez-García et al. 2019) we expect a dual-time processing pattern, i.e., early and late components related to pride and shame, possibly reflecting different processing steps contributing to achieve these social emotions. Although the ERP technique is relatively unsuitable to explore activity from subcortical emotion-processing areas such as the amygdala, it is in turn highly sensible to cortical activations, including the medial areas (Luck, 2014). By means of source-estimating techniques, we expect to find the involvement of self-reference and mentalizing areas in both the medial and lateral cortices, presumably differing in their dynamic involvement when comparing pride and shame.

2. Materials and methods

2.1. Participants

Thirty-six undergraduate students participated in the experiment. Four were discarded due to excessive artifacts in their recordings. The remaining sample was composed of

16 females and 16 males. Their age varied between 18 and 28 years (M = 19.7 years; SD = 1.87). All participants were right-handed, with scores ranging from 50 to 100 (M=86.66%) according to the Edinburgh Handedness Inventory (Oldfield, 1971). Participants reported no history of psychiatric or neurological illness and provided written informed consent before the experiment. The study was performed in accordance with the Declaration of Helsinki and approved by the ethics committee of the Hospital Clínico San Carlos (Madrid). Participants received 15€ for taking part in the experiment.

2.2. Procedure

Before the ERP experiment, the participant was instructed in the experimental procedures. The goal was to play a dot-estimation task online with three other students from different universities, other than the host institution. Actually, before the task, experimenters showed a simulated conference video call where the three other students were being set up their EEG caps in their respective labs to enhance a social context setting (Figure 1). The participant was unaware of this pretending manipulation, since conference video call was pre-recorded, in a way that appeared realistic to the ongoing situation. The aim of the video was to make feasible and reliable the social setting of the experiment. In order to balance the gender composition in the social context, the video call was different depending on the gender of the participant: for female participants, the other 3 participants were two males and one female; for male participants, two females and one male. The participant was told that she/he was participating in a competition between different universities in Spain on the visuospatial abilities of their students, therefore promoting a social comparison situation.

Figure 1. Simulated pre-experiment ‘conference video call´, where the three other pretended participants are shown to the actual participant

The task consisted in a dot-estimation task, in which the participant received feedback on proper and others’ correctness or failure after every trial. Each feedback consisted in a composition with the pictures of the four persons presumably performing the task, the one of the participant located at the bottom center of the image, together with a hit or an error mark below each person’s picture (Figure 2). As depicted in Figure 2, there were 16 possible feedbacks, as a function of the combination of the correctness of the answer of the participant and of each of the 3 opponents.

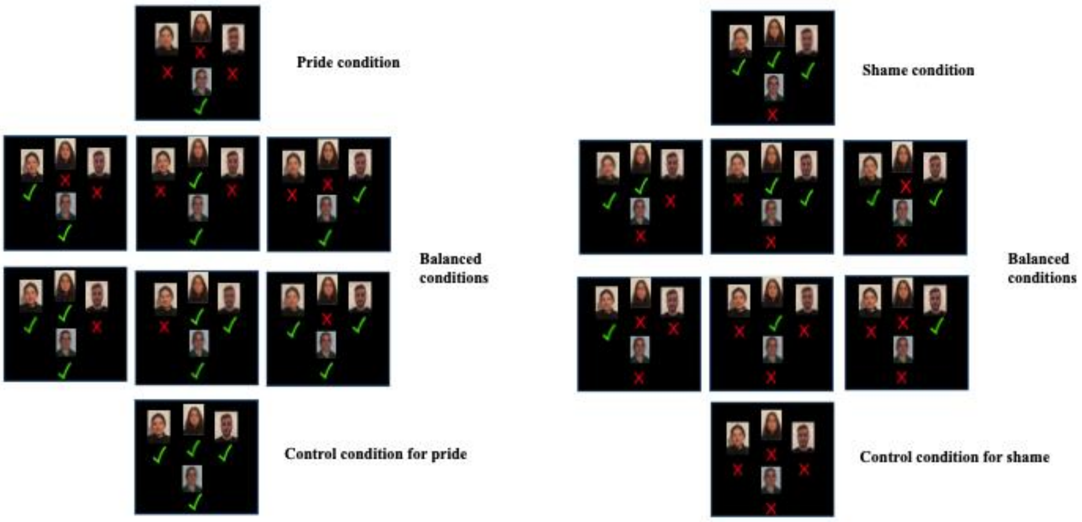


Figure 2. The 16 possible feedbacks displayed after every trial in the dot-estimation task.

The participant was seated on a comfortable chair while the stimuli were presented on an LCD screen located at 65 cm distance from her/his eyes. Each trial began with a fixation cross appearing at the center of the screen for 500 ms (Figure 3), followed by a black screen with twenty white dots (dot size = 3x3 pixels), randomly displayed, in a 300x300 pixels frame around the center of the monitor (x=0, y=0) to minimize ocular movements. The participant was instructed to estimate the number of dots on the screen. The dot stimuli were displayed for up to 1500 ms. After the dots disappeared, a blank screen appeared for 800, 1000 or 1200 ms depending on the trial (randomly chosen to avoid habituation), followed by a number (19, 20 or 21, randomly chosen) for 1500 ms, during which the participant pressed a button, the response being relative to whether the number of just-appearing dots was higher of lower than the preceding number. The response hand was counterbalanced across participants. After the presentation of a blank screen for 800, 1000 or 1200 ms, depending on the trial, the feedback about the performance of the 4 players was presented for 2 s, followed by a 1s black screen.

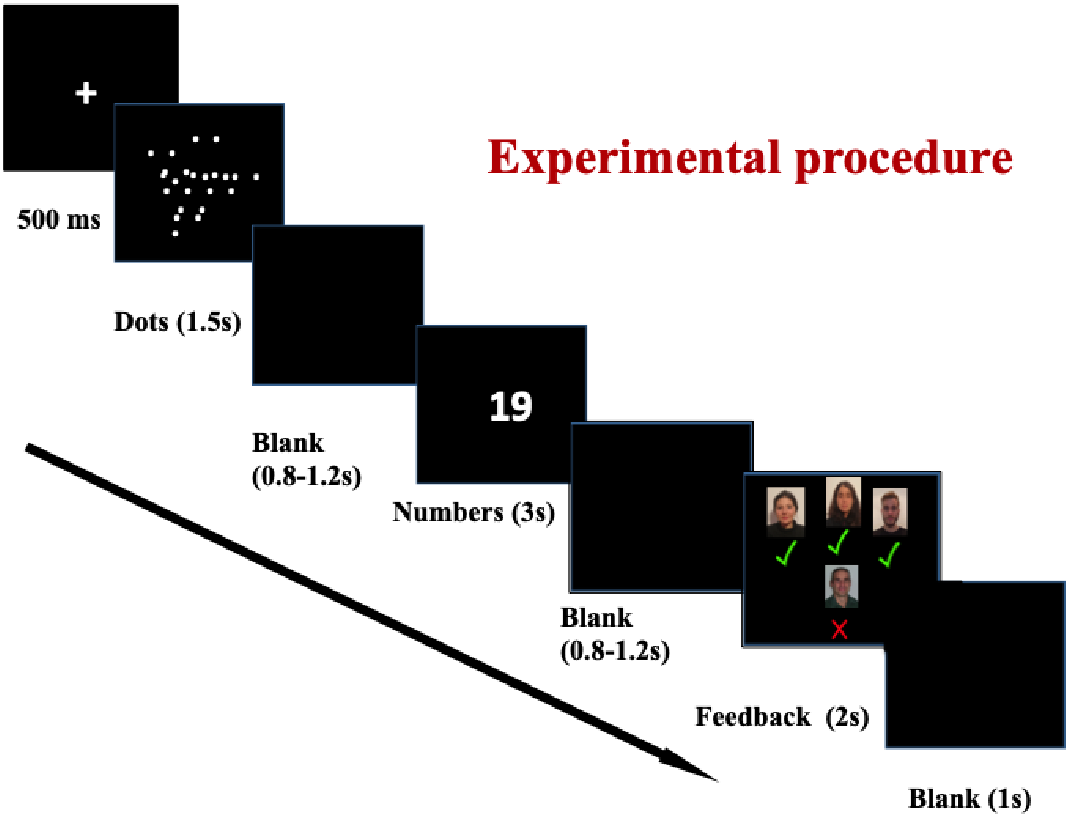


Figure 3. Schematic representation of the experimental procedure.

All performance feedbacks were predetermined by the experimenters, the participant being unaware of this circumstance, and they were randomly distributed in a realistic manner, as follows. There were a total of 480 trials. In half of them, the participant was right, and wrong in the other half. Within the 240 right trials, the distribution was: in 35, the other three participants were wrong (pride condition); in 55, all the other three participants were also right (control for pride condition); in 75, two of the other participants were also right, and in 75, one of the other participants was also right. Correspondingly, within the 240 wrong trials, the distribution was: in 35, the other three participants were right (shame condition); in 55, all the other three participants were also wrong (control for shame condition); in 75, two of the other participants were also wrong, and in 75, one of the other participants was also wrong. A brief training of 12 trials preceded the experiment. Overall, the whole experiment lasted about 90 min, divided into two blocks with a brief pause in between.

At the end of the recording session, the participant completed a survey on self-reported emotions to each different feedback, in order to check the validity of our assumptions relative to the emotions elicited. To each of the 16 different possible feedbacks a 7-point Likert scale was used to assess five different feelings: pride, joy, shame, anger and sadness.

2.3. Electrophysiological recording and analysis

EEG was recorded from 59 scalp electrodes mounted in an electrode cap (EasyCap), following the 10/20 International System. Bipolar vertical and horizontal EOGs were recorded to monitor blinks and horizontal eye movements. All scalp electrodes as well as one electrode at the left mastoid were originally referenced to one electrode at the right mastoid during recording, and offline re-referenced to the average of the right and left mastoids. The impedance of all electrodes was kept below 5 kΩ. The EEG data was analyzed with Brain Vision Analyzer® software. Raw data were filtered on-line with a band-pass from 0.01 to 100 Hz and sampled at 250 Hz; they were digitally filtered offline to a 0.1-30 Hz band-pass.

The continuous EEG was segmented into 1200-ms epochs, starting with a baseline of 200 ms before the feedback screen onset. Eye-movements were corrected using Independent Component Analysis (ICA, Makeig et al., 2000) as implemented in BrainVision Analyzer®. Remaining artifacts were further removed by a semi-automatic rejection, eliminating epochs exceeding ± 100 μV in any of the channels and manually removing drifts or muscular artifacts. The minimum percentage of accepted epochs per condition was always 80%, with a mean of 85,55%.

Statistical analyses were computed separately for pride and shame, as a) these emotions elicited activations with dissimilar time windows and b) their conditions, as well as their corresponding controls differed in other than the emotions of interest, such as joy, sadness and anger (see below). The comparisons comprised the ERP time-locked to pride and shame conditions feedbacks and those to their corresponding control condition. Considering the advantages and disadvantages of different types of analyses, two approaches for data analyses were applied: a) factorial cluster-based permutation analyses (Fields and Kuperberg, 2019; Groppe et al., 2011a,b), and b) time windows analyses based on visual inspection and guided by consideration of the results of the cluster analyses.

Cluster-based permutation analyses were calculated using the Factorial Mass Univariate Matlab® Toolbox. In agreement with the dual-time processing pattern observed in the ERP, and guided by previous literature (e.g., Brusini et al., 2017; Jiménez-Ortega et al. 2020), we considered early (0-500 ms) and late (500-900 ms) time segments for these analyses. Subsequently, two (one per time segment) factorial cluster-based permutation analyses were calculated separately for each emotion (pride, shame), each with 10,000 iterations and alpha level of .05 involving the factor Emotion (Emotion –i.e., pride or shame- vs the corresponding Control condition). For the time windows analyses, repeated-measures analyses of variance (ANOVAs) with the SPSS 22® software were performed. Guided by both visual inspections and cluster analyses, two scalp regions of interest (ROIs) and time-windows were used per emotion. For pride, one ROI comprised the electrodes F1, Fz, F2, FC1, FCz, FC2, C1, Cz, C2, CP1, CPz and CP2, and was analyzed in the 250-350 ms window; the other ROI for pride comprised the electrodes F1, Fz, F2, FC1, FCz and FC2, and was analyzed in the 600-800 ms window. For shame, one ROI comprised the electrodes AF3, AF4, F1, Fz, F2, FC1, FCz, and FC2, analyzed in the 330-410 ms window; the second ROI for shame comprised the electrodes FC1, FCz, FC2, C1, Cz, C2, CP1, CPz and CP2, and was analyzed in the 715-875 ms window. The main ANOVA used the mean voltage values of the electrodes grouped within each ROI, and involved the factor Emotion, in the same terms as in the cluster-based analyses. Violations of the sphericity assumption were corrected when necessary by the Greenhouse-Geisser method.

LORETA software, an algorithm based on inverse problem solution that offers brain activated areas from EEG neural activity (Pascual-Marqui et al., 2002), was used to locate the sources of the ERP fluctuations that could be estimated as specific of pride and shame. Only the activity that could be considered as specific of these emotions, in consonance with ERP analyses, was used in these computations. These were made at selected time windows and based on the contrast values between pride or shame and the corresponding control condition.

3. Results

3.1. Self-reported emotions ratings

The ratings obtained immediately after the experiment (Table 1) showed the largest emotions of pride in the condition in which the participant was right and the 3 opponents were wrong (pride condition), compared to the corresponding control condition (both the participant and the opponents were right). This difference was significant (t (31) = 6.45, p < .001) [all *ps* are Bonferroni-corrected]. Emotions of shame, sadness and anger were similarly low in both conditions, with no significant difference between them (1.74 < ts (31) < 2.41, all ps > .1). Joy, in turn, was similarly high in both conditions, but it was not statistically significant (t(31)= 1.76, p>0.1).

	PRIDE	SHAME	JOY	SADNESS	ANGER
Pride condition	6.22 (1.34)	1.41 (0.89)	5.84 (1.6)	1.34 (0.81)	1.089 (0.52)
Control for Pride	4.69 (1.74)	1.03 (0.17)	5.34 (1.42)	1.12 (0.33)	1.25 (0.61)
Shame condition	1.28 (0.94)	4.15 (2.08)	1.19 (0.55)	3.22 (1.71)	3.94 (1.95)
Control for shame	1.78 (1.24)	2.22 (1.47)	2.15 (1.54)	2.28 (1.44)	3.09 (1.84)

Table 1: Ratings in a 7-point Likert scale (Mean, SD) regarding the feelings in different emotions as a function of feedback received

Regarding the wrong trials, the ratings showed larger feelings of shame in the condition in which the participant was wrong and the 3 opponents right (shame condition), compared with the corresponding control condition (both the participant and the opponents were wrong). This contrast was significant (t(31)= 7.42, p<.001). Feelings of pride and joy were similarly low in both conditions; however, even if slightly, they were significantly larger in the control condition (t(31)= 3, p=.05 for pride; t(31)= 9.87, p<.001 for joy). The values for sadness were relatively moderate in the two conditions, but significantly larger in the shame condition (t(31)= 3.11, p<0.05). Both conditions also exhibited moderate values in anger, not differing significantly (t(31)= 2.46, p>.1).

3.2. Electrophysiological data: Pride

Main results corresponding to pride are summarized in Figures 4-6. As can be seen in Fig. 4, the pride condition exhibited a fronto-central negativity around 300 ms and a long-lasting frontal positivity from around 500 to 900 ms. It can be appreciated that the earlier negativity exhibited a progressive amplitude increase, from the control to the pride condition, as an inverse function of the number of opponents being right. The late positivity, in turn, appeared as an all-or-none process, only present in the pride condition. The cluster-based permutation analyses (Fig. 5) in the early time window (0–500 ms) revealed a significant cluster between 250 and 350 ms, involving up to 44 electrodes, showing the largest F values around frontocentral and centroparietal electrodes. In a later time window (500–900 ms), the cluster-based permutation analysis revealed a significant cluster between around 600 and 900 ms involving virtually all electrodes**,** showing the largest F values around the frontal and frontocentral electrodes

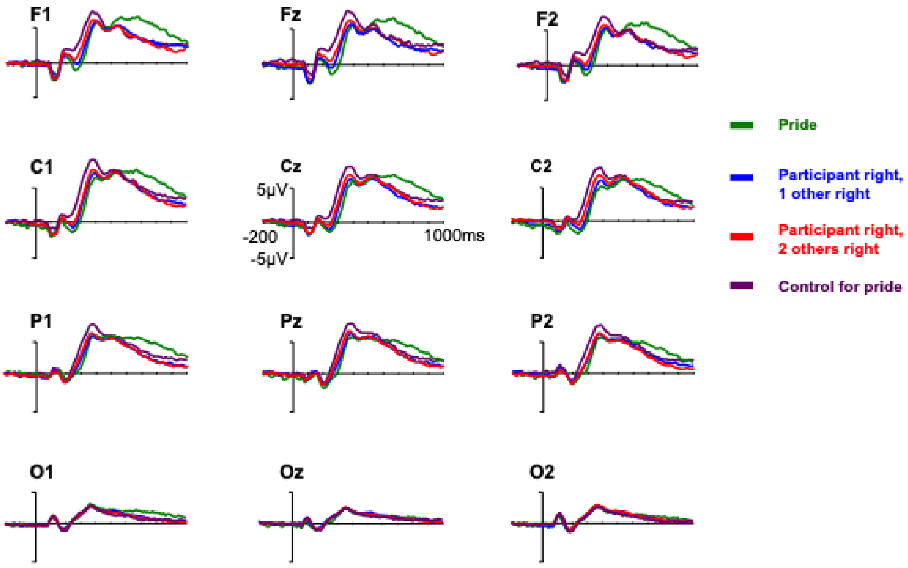


Figure 4. Mean average ERP fluctuations for pride conditions in a sample of electrodes.

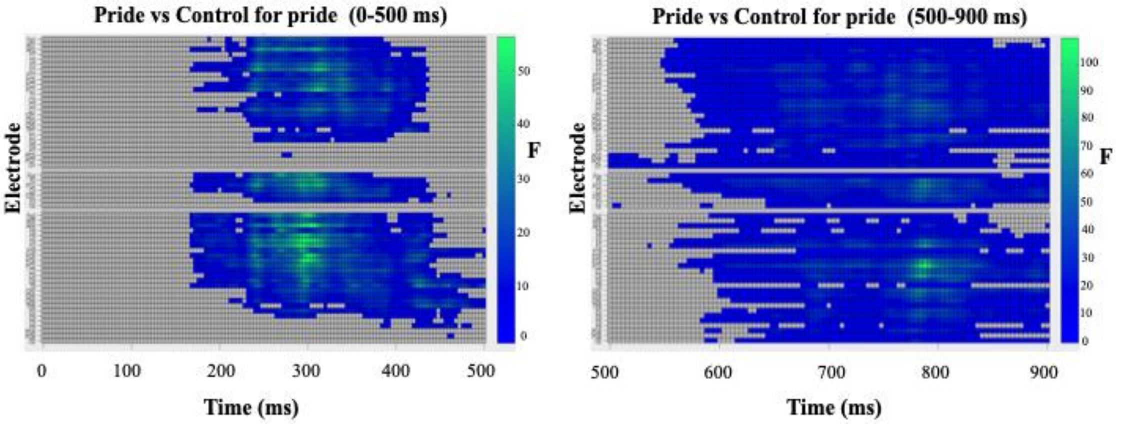


Figure 5. Results of cluster analyses for pride in the 0-500 (left) and 500-900 (right) time intervals for the comparison between the pride condition and its corresponding control condition. From top to bottom, electrodes are displayed orderly for the left hemisphere, midline and the right-hemisphere.

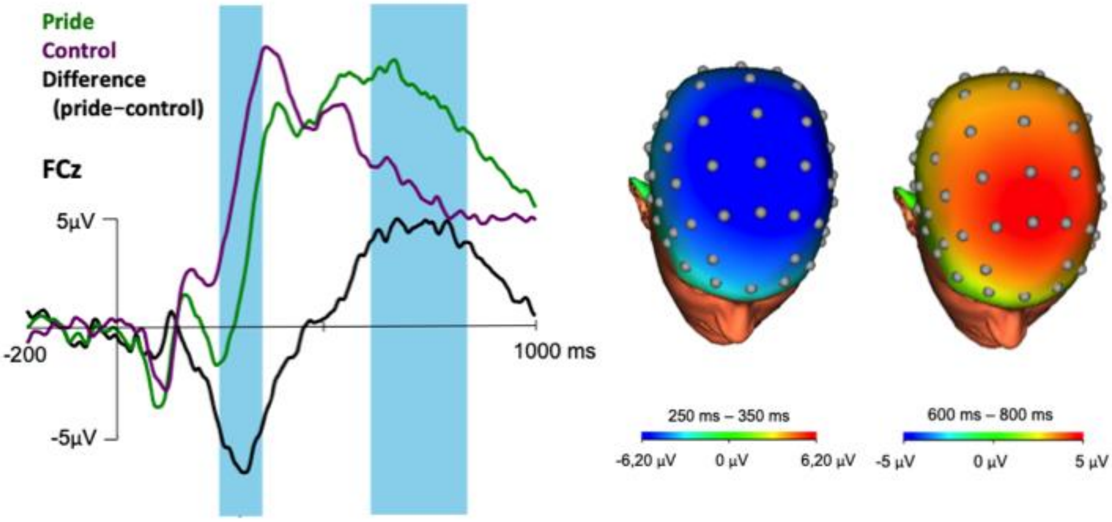
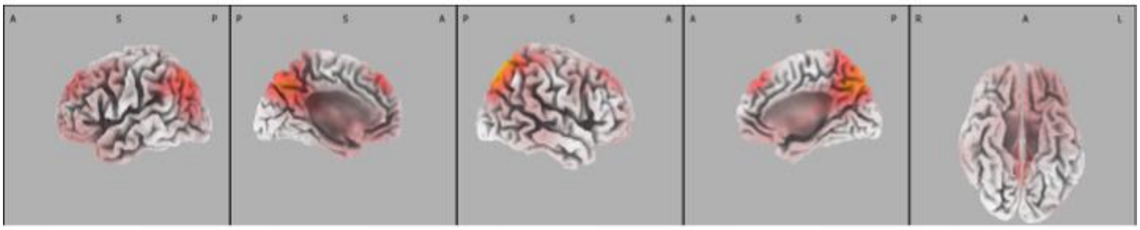


Figure 6. Main results of the comparison between the pride condition and its corresponding control condition. Left, ERP and difference wave resulting from this comparison at FCz electrode. Center and Right, topographic maps of the two main fluctuations related to pride.

The cluster-based permutation analyses complement the data in Fig. 6, where the topographies of the early negativity and the late positivity are represented, substantiating the ROIs and time-windows employed in the ANOVA analyses. These revealed significant differences between the pride and its corresponding control condition, both in the early negativity [$F(1,31) = 62.9$; $p<.0001$; $\eta p^2 = .67$] as well as in the late positivity [$F(1,31) = 53.4$; $p<.0001$; $\eta p^2 = .633$]. The progressive amplitude increase of the early negativity across the four conditions in which the participant was right seemed to justify an ANOVA analysis of this component comprising all these conditions. The results revealed main significant differences between conditions [$F(3,93) = 43.819$; $p<0.001$; $\eta p^2 = 0.586$], all post-hoc pair-wise Bonferroni-corrected comparisons being significant (-7.93 < ts (31) < 8.18, all ps < .001). Finally, neither the early negativity nor the late positivity correlated with the self-reported degree of pride felt in this condition (Spearman's R=0.14 and -0.13, respectively; p>0.1).

To estimate the neural source of the early negativity and late positivity related to pride, LORETA analyses were performed for the difference pride vs control around their corresponding peaks (250-350 and 600-800 ms time windows, respectively). The solution for the early negativity consisted of an involvement of the precuneus and the superior parietal regions and, with the best match at MNI coordinates X=20, y=-70, z=55 (Fig. 7, top). The solution for the late positivity involved the superior frontal and cingulate gyri, also apparently embracing the supplementary motor area (SMA), the best match being at MNI coordinates X=20, y=0, z=70 (Fig. 7, bottom). The solution also seemed to visibly involve right temporal regions.

Pride: Early component



Pride: Late component

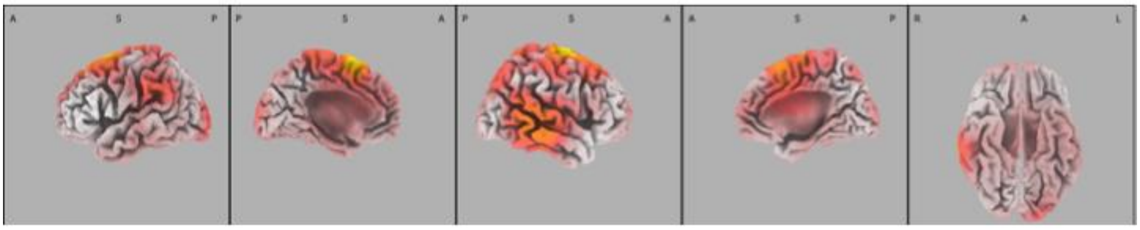


Fig. 7. Neural generators proposed by LORETA for the early negativity (top) and the

late positivity (bottom) obtained in the pride condition.

3.3. Electrophysiological data: Shame

Main results corresponding to shame are summarized in Figures 8-11. Fig. 8 shows that the shame condition exhibited, when compared to the corresponding control condition, a frontal negativity around 370 ms and a long-lasing central positivity from around 600 to 1000 ms. The earlier negativity did not exhibit a progressive amplitude increase from the control to the pride condition across other conditions. Although not so remarkably as in pride, the late positivity appeared again as an all-or-none process, mainly present in the shame condition. The cluster-based permutation analyses during the early time segment (0–500 ms) revealed no significant cluster. Possibly, this originates in the tendency of this method to miss narrowly distributed effects occurring across a limited number of time points and electrodes (Groppe et al., 2011a); indeed, as will be noticed below, the ANOVA analysis was able to find significant effects within this period. During the late time segment (500–900 ms), the cluster-based permutation analyses (Fig. 9) revealed a significant cluster apparent mainly between around 700 and 900 ms involving up to 42 electrodes**,** with largest F values around frontocentral and centroparietal electrodes in both hemispheres, with a slight right tendency.

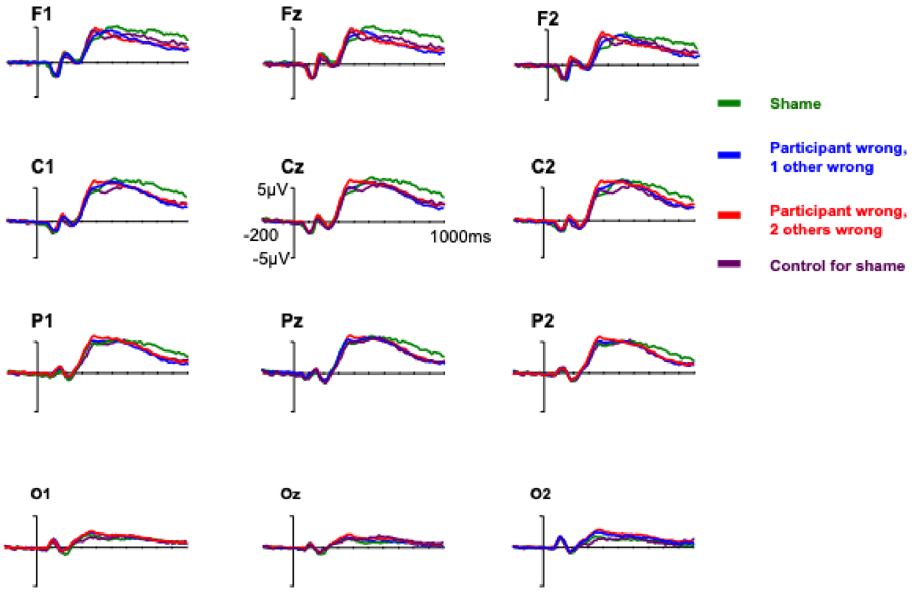


Figure 8. Mean average ERP fluctuations for shame conditions in a sample of electrodes.

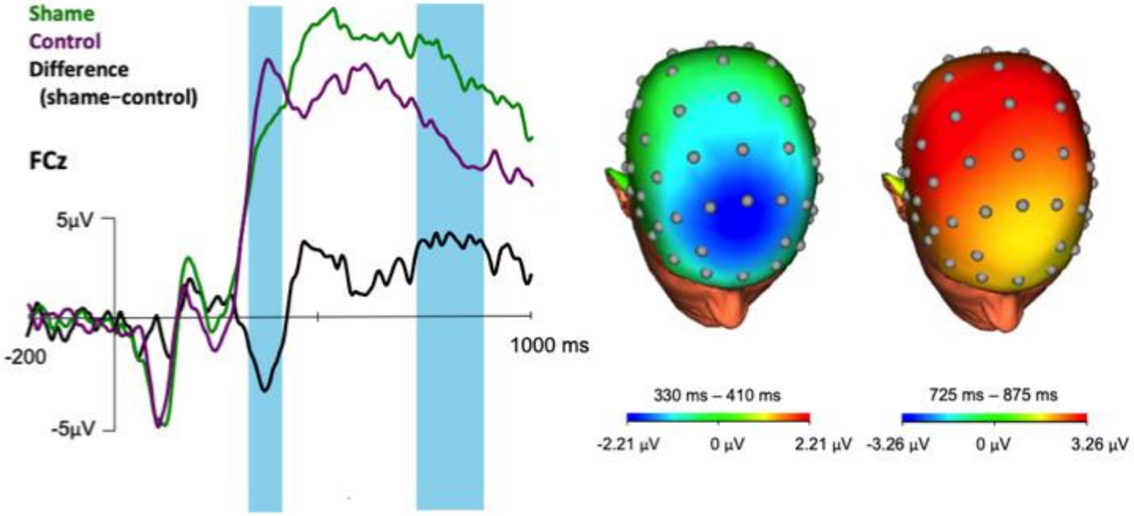


Figure 9. Main results of the comparison between the shame condition and its corresponding control condition. Left, ERP and difference wave resulting from this comparison at FCz electrode. Center and Right, topographic maps of the two main fluctuations related to shame.

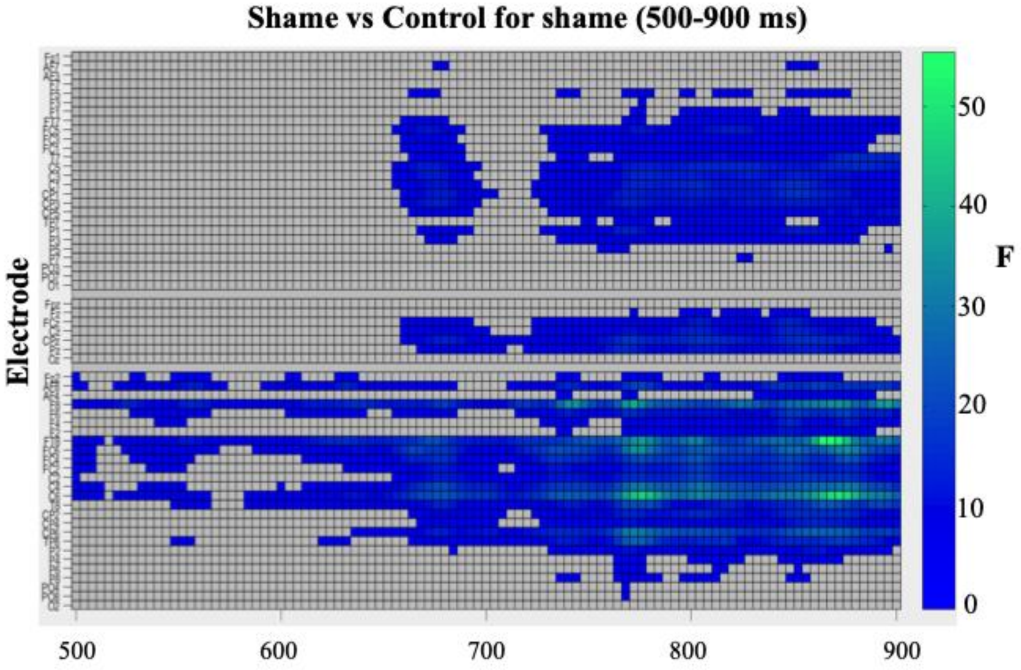
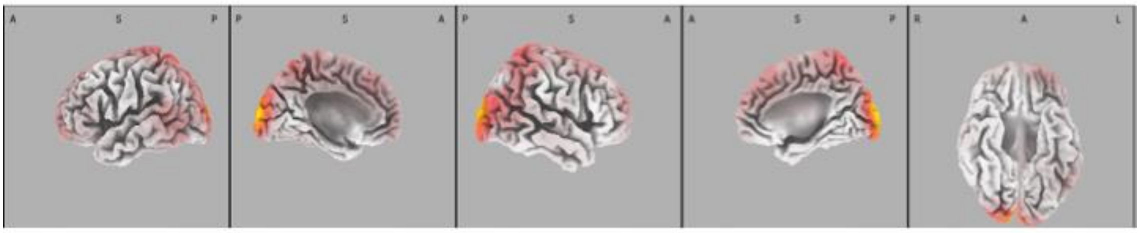


Figure 10. Results of cluster analyses for shame in the 0-500 (left) and 500-900 (right) time intervals for the comparison between the shame condition and its corresponding control condition. From top to bottom, electrodes are displayed orderly for the left hemisphere, midline and the right-hemisphere.

The data in Fig. 10, where the topographies of the early negativity and the late positivity are represented, are complemented by the cluster-based permutation analyses only for the late positivity, verifying the ROI and time-window employed in the ANOVA analyses for this component. The ROI and time-window used for the early negativity, in turn, was established solely by visual observation of the data. These analyses revealed significant differences between the shame and its corresponding control condition, both in the early negativity [$F(1,31) = 6.74$; $p<.014$; $\eta p^2 = .179$] as well as in the late positivity [$F(1,31) = 8.29$; $p<.007$; $\eta p^2 = .211$]. Neither the early negativity nor the late positivity correlated with the self-reported degree of shame (Spearman’s R=-0.03 and -0.23, respectively; p>0.1).

The neural sources of the early negativity and the late positivity related to shame were estimated using LORETA analysis for the difference shame vs control around its peaks -i.e., 330-410 and 715-875 ms windows, respectively-. The solution for the early negativity involved the superior cuneus, with the best match at MNI coordinates X=15, y=-100, z=15 (Fig. 11, top). The solution for the late positivity involved the superior parietal lobe and precuneus, with the best match at MNI coordinates X=5, y=-70, z=55 (Fig. 11, bottom), though it seemed to extend to the cuneus. A possible secondary solution for this positivity involved left inferior regions, extending to frontopolar cortex.

Shame: Early component



Shame: Late component

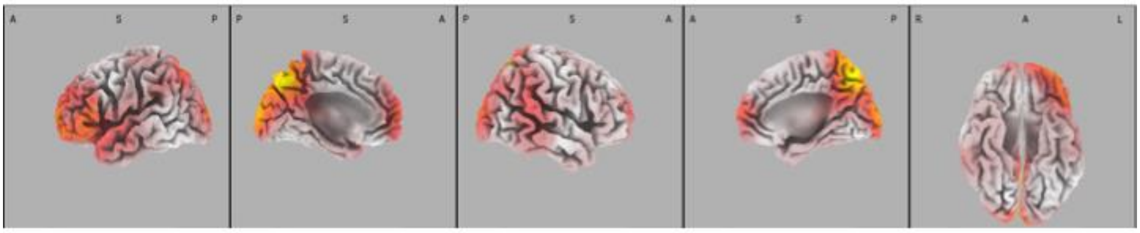


Fig. 11. Neural generators proposed by LORETA for the early negativity (top) and the late positivity (bottom) obtained in the shame condition.

4. Discussion

Brain electrical activity was recorded while participants performed a task in social context, with situations seemingly prompting feelings of pride and shame. The ERP technique used here permits a dynamic approach to the neural processes as these unfold over time, contributing therefore to better describe the neural underpinnings of these scarcely studied social emotions.

4.1. Prompting pride and shame in experimental environments

A main contribution of the present study is the setting of a procedure that permits studying pride and shame simultaneously and in experimental environments. The adaptation of a task previously used to prompt social emotions such as guilt or shame (Leng et al. 2016; Zhu et al, 2017; Sánchez-García et al. 2019), has allowed the elicitation of pride and shame within the same participants and session, endorsing direct study and comparison of these emotions at the neural level in the same experiment. The feelings reported by the participants seem to indicate that the procedure was successful. The largest feelings of pride were reported in the pride condition, significantly larger than in the corresponding control condition. Other emotions (shame, sadness and anger) were low in either the pride or its control condition, with the exception of joy, which was equivalent in both conditions. In turn, the feelings exhibiting the largest values in the shame condition corresponded to shame, and although anger was also relatively high, the latter did not differ with the control condition. Sadness, which appeared also moderately present in the shame condition, was less rated than shame (this comparison was tested: $t(31)= 3.1$, $p<0.05$ after Bonferroni correction). Finally, even if shame and the corresponding control condition differed in pride and joy, all these values were always low. Overall, the comparison between shame and its control condition could yield relatively valid results, even if some cautions could be needed.

It is noticeable that the amplitude of none of the brain fluctuations obtained under these manipulations correlated with the self-reported feelings of either pride or shame. This would suggest that although our electrophysiological findings probably relate to processes essential to endorse these emotions, they are seemingly not reflecting the neural underpinnings of their hedonic component. This feature is of relevance for the interpretation of our results.

4.2. Neural Mechanisms involved in pride

The brain activity related to pride exhibited the expected dual-time pattern, consisting of an early negativity and a late positivity. The former, occurring around 300 ms after the presentation of the feedback, appeared to originate in medial parietal regions, mainly the precuneus. The late positivity emerged along a larger time interval, being visible between 600 and 900 ms and seemingly originated in medial frontal areas, seemingly involving the supplementary motor area (SMA) and the anterior cingulate. There is also a possible contribution of right temporal regions to this activity. These results harmonize well with previous research using neuroimaging (fMRI), in the sense of underscoring the involvement of medial prefrontal and posterior regions in situations of pride (Zahn et al., 2009; Simon-Thomas et al., 2012; Roth et al., 2014). The present findings also provide evidence on the differential involvement of anterior and posterior medial areas underlying pride across time. The first and early involvement of the medial parietal cortex appeared relevant to bear evaluative processes on the degree of individual success, as compared to the other 3 opponents. The amplitude of the early negativity to trials in which the participant was right increased stepwise as a function of the number of opponents being wrong. Among other processes, the medial parietal cortex and the precuneus have been traditionally linked to self-referential processing, particularly in situations in which one is compared to other people (e.g., Northoff et al., 2006; Qin & Northoff, 2011; Davey et al., 2016; Lou et al., 2004). It appears plausible, therefore, that this fluctuation is reflecting social comparison processes determining the degree of exceptionality of own performance in successful trials.

As a consequence of the computations reflected in the early negativity, the late positivity would emerge uniquely in conditions in which the outcome implied that oneself is the only right in the group. This situation was self-reported as maximally granting feelings of pride. The areas presumably contributing to this effect -medial frontal and right temporal regions- have all been involved in pride (Roth et al., 2014; Hong et al., 2019) and appear related to appraisals of social meaning and theory of mind (Takahasi, 2008; Schurz et al., 2014). This is compatible with the possibility that the late positivity reflects at least part of the processes underlying the emotion of pride. This interpretation, however, seems not straightforward, considering that a) pride was also appreciable in the control condition, even if with lower values than in the pride condition, while the late positivity was an all-or-none process, and b) its amplitude did not correlate with the reported feelings of pride, as commented above. It might be, accordingly, that the later modulation is rather reflecting the verification of the singularity of a successful trial. The fact that the SMA, which appeared to contribute to this effect, has been proposed as critical in the evaluation of the outcomes of proper actions (Bonini et al. 2014) seems consistent with this possibility. Further, considering that other brain regions associated with theory of mind and social meaning also importantly contributed to this late positivity, this verification would be in social terms. Finally, it appears plausible that thereafter, and as an outcome of these processes, other, more basic emotion-related subcortical regions -such as the amygdala or the ventral striatum- become involved, this underlying the feelings of pride. However, these regions are not accessible through the ERP technique used here.

4.3. Neural mechanisms involved in shame

A dual-time pattern consisting of an early negativity and a late positivity was also found for shame. The early negativity was not supported by the cluster-based permutation analysis, though standard ANOVA analyses yielded significant results. This fluctuation occurred around 370 ms after feedback presentation, and seemed originated in the cuneus. Interestingly, Zahn et al. (2014) reported that individuals with reduced volumes of the cuneus and the precuneus are more pride-prone, probably in consonance with the fact that shame and pride are categorically opposed emotions. The cuneus has been involved in mental imagery in social situations, as compared to when the same situations are imagined as occurring alone (Mochizuki et al., 2014). Overall, our results suggest that mental imagery of the social situation might be a critical process emerging soon in conditions engendering shame.

The late positivity related to shame was again a long-lasting activity, starting about 700 ms and visible until the end of the epoch. This fluctuation was apparently originated in the superior parietal lobe and the precuneus, also involving the cuneus and, secondarily, left inferior frontal regions, including the frontopolar cortex. Interestingly, the main involved regions were those seemingly originating the early positivity linked to pride. It is tempting to reason, given its opposite electrical polarity, that it might be reflecting contrary processes to those reflected in the early negativity for pride, i.e., operations determining the degree of exceptionality of own performance, in this case in wrong trials, necessary to achieve feelings of shame. Though conceivable, this interpretation is nevertheless not clear-cut, since an ERP positivity is not necessarily the opposite of a negativity (Luck, 2005; Lopes da Silva & Niedermeyer, 2005). Moreover, this late positivity for shame and the early negativity for pride also differ in timing, duration and voltage topography. Actually, the late positivity for shame also seemed to engage the cuneus, already involved alongside the earlier component, while a secondary contribution appeared in the left inferior frontal regions, which have been related to emotion recognition in social perception (Keuken et al., 2011), as well as the frontopolar cortex , which appears involved in social scenarios linked to guilt, pity, embarrassment and empathy (Moll et al., 2005, 2007; Whittle et al, 2016) and in inferring the emotional states of others (Amodio and Frith, 2006). Considering that its amplitude did not correlate with the reported feelings of shame, it can be speculated that this fluctuation might reflect late assessment processes of the social episode presumably necessary for triggering feelings of shame, the latter probably involving subcortical neural structures not accessible through the ERP technique.

4.4. Limitations of the present study

The main limitations of the present study are intrinsic to the ERP technique. On the one hand, some portions of the brain, particularly those subcortically situated and possibly underlying primary basic emotional areas, are not accessible to this methodology. Our results, therefore, outline only part of the brain structures involved in pride and shame, and must be considered as complementing data obtained with other neuroimaging technologies. On the other hand, the areas defined here have to be approached as most plausible candidates, i.e., the result of computations based on algorithms that attempt to overcome the inverse problem (Pascual-Marqui et al., 2002). Nonetheless, the areas defined here largely harmonize with extant literature on pride and shame using methodologies with better spatial resolution, while the present data provide outstanding temporal resolution.

Other limitation relates to the data concerning shame. According to self-reports, the comparison between shame and its corresponding control condition implies outstanding differences in shame, but other emotions can also be present, even if to a reduced degree. This contrasts with the more straightforward results for pride. Moreover, the early negativity for shame was not supported by the more conservative cluster-based permutation analysis. Further research is needed to elucidate the validity of our inferences and conclusions on this emotion. Alternatively, it is possible that a larger sample than the used here (n=32) could have aided in clarifying these points. Nevertheless, our sample size can be considered relative large and comparable to most of the literature in the topic, while all of our results in the ANOVA comparisons were robust enough as to yield large –some of them exceptionally large- effect sizes (ηp2), according to Cohen's (1988) guidelines. Effect size is a way of quantifying the difference between two means, emphasizing the size of the difference without confounding it with sample size (Lakens, 2013).

Finally, a larger sample could have also turned into significant some of the correlations between the reported feelings of pride and shame and their corresponding ERP fluctuations, which yielded R values between 0.03 and 0.23. However, even if reaching statistical significance, these values would still remain weak or poor according to most standard criteria (e.g., Dancey & Reidy, 2007). Indeed, the amount of shared variance would always be below 6%, in line with our assumptions that our ERP modulations seem to mainly relate to cognitive processes essential to endorse these emotions rather than to their hedonic component.

4.5. Concluding remarks

Our results exhibit similarities and differences with previous literature. Some of the discrepancies are the consequence of using the ERP technique, while some others probably derive from prompting genuine feelings in laboratory conditions, at variance with less realistic procedures used previously. Overall, the available literature is notably scarce, and more research is granted. The brain regions seemingly involved in our data appear concerned in computations related to social cognition and, consequently, would be essential for the emergence of emotions that are directly defined by the position of the self in relation to others. In line with Roth et al. (2014) it appears plausible that the hedonic facets of pride and shame actually depend on primary basic emotional areas (e.g., amygdala, ventral striatum), the joint work of areas involved in social cognition being yet essential to establish and define these emotions. The present work suggests that the dynamic description of structures underlying social cognition can help to clarify their differential involvement in pride and shame, occasionally indistinguishable when more static neuroimaging techniques have been used. In conclusion, in pursuit of more accurate neural models of social emotions, more research is needed, and this should proceed integrating different available techniques.

References

Abe, J. A. A., & Izard, C. E. (1999). The developmental functions of emotions: An analysis in terms of differential emotions theory. *Cognition & emotion*, *13*(5), 523–549. https://psycnet.apa.org/doi/10.1080/026999399379177

Amodio, D. M., & Frith, C. D. (2006). Meeting of minds: the medial frontal cortex and social cognition. *Nature reviews neuroscience*, *7*(4), 268-277.

Awan, F. G.; Saleem, O. & Kiran, A. (2019). Recent trends and advances in solving the inverse problem for EEG source localization. *Inverse problems in science and engineering, 27,* 1521–1536. https://doi.org/10.1080/17415977.2018.1490279

Bastin, C., Harrison, B. J., Davey, C. G., Moll, J., & Whittle, S. (2016). Feelings of shame, embarrassment and guilt and their neural correlates: A systematic review. *Neuroscience & biobehavioral reviews*, *71*, 455–471. https://doi.org/10.1016/j.neubiorev.2016.09.019

Beer, J. S., & Keltner, D. (2004). What is unique about self-conscious emotions?. *Psychological inquiry*, *15*(2), 126–129. http://www.jstor.org/stable/20447214

Bonini, F., Burle, B., Liégeois-Chauvel, C., Régis, J., Chauvel, P., & Vidal, F. (2014). Action monitoring and medial frontal cortex: leading role of supplementary motor area. *Science*, *343*(6173), 888-891.

Brusini, P., Dehaene-Lambertz, G., van Heugten, M., de Carvalho, A., Goffinet, F., Fievet, A. C., & Christophe, A., (2017). Ambiguous function words do not prevent 18-month-olds from building accurate syntactic category expectations: An ERP study. *Neuropsychologia, 98,* 4–12. https://doi.org/10.1016/j.neuropsychologia.2016.08.015

Cohen, J. (1988) *Statistical Power Analysis for the Behavioral Sciences, 2nd ed*. New York: Lawrence Erlbaum Associates.

Dancey C.P., & Reidy J. (2007). Statistics without Maths for Psychology. Essex: Pearson Education;.

Davey, C. G., Pujol, J., & Harrison, B. J. (2016). Mapping the self in the brain's default mode network. *NeuroImage, 132,* 390–397. https://doi.org/10.1016/j.neuroimage.2016.02.022

Durkee, P. K., Lukaszewski, A. W., & Buss, D. M. (2019). Pride and shame: Key components of a culturally universal status management system. *Evolution and Human Behavior, 40),* 470-478.

Fields, E. C., & Kuperberg, G. R. (2019). Having your cake and eating it too: Flexibility and power with mass univariate statistics for ERP data. *Psychophysiology, 57*(2), e13468. https://doi.org/10.1111/psyp.13468

Flinn, M. V., Geary, D. C., & Ward, C. V. (2005). Ecological dominance, social competition, and coalitionary arms races: Why humans evolved extraordinary intelligence. *Evolution and human behavior, 26*(1), 10–46. https://doi.org/10.1016/j.evolhumbehav.2004.08.005

Gilead, M., Katzir, M., Eyal, T., & Liberman, N. (2016). Neural correlates of processing "self-conscious" vs "basic" emotions. *Neuropsychologia*, *81*, 207–218. https://doi.org/10.1016/j.neuropsychologia.2015.12.009

Gilbert, P. (2000). The relationship of shame, social anxiety and depression: The role of the evaluation of social rank. *Clinical Psychology & Psychotherapy, 7*(3), 174–189. https://doi.org/10.1002/1099-0879(200007)7:3<174::AID-CPP236>3.0.CO;2-U

Groppe, D. M., Urbach, T. P., & Kutas, M. (2011a). Mass univariate analysis of event-related brain potentials/fields I: a critical tutorial review. *Psychophysiology, 48*(12), 1711-1725. https://doi.org/10.1111/j.1469-8986.2011.01273.x

Groppe, D. M., Urbach, T. P., & Kutas, M. (2011b). Mass univariate analysis of event-related brain potentials/fields II: Simulation studies. *Psychophysiology, 48*(12), 1726–1737. https://doi.org/10.1111/j.1469-8986.2011.01272.x

Haidt, J. (2003). The moral emotions. In: Davidson, R. J., Scherer, K. R., & Goldsmith, H. H., (Eds.), *Handbook of Affective Sciences* (pp. 852–870). Oxford University Press.

Hong, Y. J., Park, S., Kyeong, S., & Kim, J. J. (2019). Neural basis of professional pride in the reaction to uniform wear. *Frontiers in human neuroscience, 13*, 253. https://doi.org/10.3389/fnhum.2019.00253

Jiménez-Ortega, L., Ramos-Badaya, E., Hernández-Gutiérrez, D., Silvera, M., Espuny, J., Garcia, J. S., ... & Martín-Loeches, M. (2020). Effects of reader's facial expression on syntactic processing: A brain potential study. *Brain Research*, 146745.

Keuken, M. C., Hardie, A., Dorn, B. T., Dev, S., Paulus, M. P., Jonas, K. J., … & Pineda, J. A. (2011). The role of the left inferior frontal gyrus in social perception: an rTMS study. *Brain research, 1383*, 196–205. https://doi.org/10.1016/j.brainres.2011.01.073

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Frontiers in psychology, 4, 863. https://doi.org/10.3389/fpsyg.2013.00863

Leng, B., Wang, X., Cao, B., & Li, F. (2016). Frontal negativity: An electrophysiological index of interpersonal guilt. *Social neuroscience, 12*(6), 649–660. https://doi.org/10.1080/17470919.2016.1223749

Lewis, M. & Haviland-Jones, J. M. (2000). *Handbook of emotions* (2nd ed.). Guilford Press.

Lopes da Silva, F.; Niedermeyer, E. (2005). *Electroencephalography: Basic Principles, Clinical Applications, and Related Fields.* Lippincott Williams & Wilkins.

Lou, H. C., Luber, B., Crupain, M., Keenan, J. P., Nowak, M., Kjaer, T. W., Sackeim, H. A., & Lisanby, S. H. (2004). Parietal cortex and representation of the mental Self. *Proceedings of the National Academy of Sciences of the United States of America, 101*(17), 6827–32. https://doi.org/10.1073/pnas.0400049101

Luck, S. J. (2014). *An Introduction to the Event-Related Potential Technique.* MIT Press

Luck, S. J., & Hillyard, S.A. (1984) Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31*(3), 291–308. https://doi.org/10.1111/j.1469-8986.1994.tb02218.x

Makeig, S., Enghoff, S., Jung, T. P., & Sejnowski, T. J. (2000, June 19-22). *Moving-window ICA decomposition of EEG data reveals event-related changes in oscillatory brain activity* [Conference paper]. Second International Workshop on Independent Component Analysis and Signal Separation, Helsinki, Finland. https://sccn.ucsd.edu/~scott/pdf/ICA00a.pdf

Menesini, E., & Camodeca, M. (2008). Shame and guilt as behaviour regulators: Relationships with bullying, victimization and prosocial behaviour. *British journal of developmental psychology, 26*(2), 183–196. https://psycnet.apa.org/doi/10.1348/026151007X205281

Michl, P., Meindl, T., Meister, F., Born, C., Engel, R. R., Reiser, M., & Hennig-Fast, K. (2014). Neurobiological underpinnings of shame and guilt: a pilot fMRI study. *Social cognitive and affective neuroscience, 9*(2), 150–157. https://doi.org/10.1093/scan/nss114

Mochizuki, A. A., Sudo, M.M., Kirino, E, & Itoh, K. (2014). Brain activation associated with motor imagery of coordination exercises and social abilities. *European journal of sport science, 14*(7), 671–677. https://doi.org/10.1080/17461391.2014.893019

Moll, J., Zahn, R., de Oliveira-Souza, R., Krueger, F., & Grafman, J. (2005). The neural basis of human moral cognition. *Nature reviews neuroscience, 6*(10), 799-809.

Northoff, G., Heinzel, A., De Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—a meta-analysis of imaging studies on the self. *NeuroImage, 31*(1), 440–457. https://doi.org/10.1016/j.neuroimage.2005.12.002

Oldfield, R.C. (1971). The assessment and analysis of handiness: the Edinburgh inventory. *Neuropsychologia, 9*(1) 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Pascual-Marqui R. D., Esslen M., Kochi K., & Lehmann D. (2002). Functional imaging with low resolution brain electromagnetic tomography (LORETA): a review. *Methods and findings in experimental and clinical pharmacology,* 24 Suppl C, 91–95.

Qin, P., & Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *NeuroImage, 57*(3), pp. 1221–1233. https://doi.org/10.1016/j.neuroimage.2011.05.028

Robertson, T. E., Sznycer, D., Delton, A. W., Tooby, J., & Cosmides, L. (2018). The true trigger of shame: Social devaluation is sufficient, wrongdoing is unnecessary. *Evolution and human behavior*, *39*(5), 566–573. https://doi.org/10.1016/j.evolhumbehav.2018.05.010

Roth, L., Kaffenberger, T., Herwig, U., & Brühl, A.B. (2014). Brain activation associated with pride and shame. *Neuropsychobiology, 69*(2), 95–106. https://doi.org/10.1159/000358090

Sánchez-García, J., Espuny, J., Hernández-Gutiérrez, D., Casado, P., Muñoz, F., Jiménez-Ortega, L., ... & Martín-Loeches, M. (2019). Neurofunctional characterization of early prefrontal processes contributing to interpersonal guilt. *Cognitive, affective, & behavioral neuroscience*, *19*(5), 1192–1202. https://doi.org/10.3758/s13415-019-00748-6

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of mind: a meta-analysis of functional brain imaging studies. *Neuroscience and biobehavioral reviews, 42*, 9–34. https://doi.org/10.1016/j.neubiorev.2014.01.009

Simon-Thomas, E. R., Godzik, J., Castle, E., Antonenko, O., Ponz, A., Kogan, A., & Keltner, D. J. (2012). An fMRI study of caring vs self-focus during induced compassion and pride. *Social cognitive and affective neuroscience*, 7(6), 635–648. https://doi.org/10.1093/scan/nsr045

Sznycer, D., Al-Shawaf, L., Bereby-Meyer, Y., Curry, O. S., De Smet, D., Ermer, E., ... & McClung, J. (2017a). Cross-cultural regularities in the cognitive architecture of pride. *Proceedings of the National Academy of Sciences, 114*, 1874-1879.

Sznycer, D., Cosmides, L., & Tooby, J. (2017b). Adaptationism carves emotions at their functional joints. *Psychological Inquiry, 28*, 56-62.

Sznycer, D., Xygalatas, D., Agey, E., Alami, S., An, X. F., Ananyeva, K. I., ... & Fukushima, S. (2018a). Cross-cultural invariances in the architecture of shame. *Proceedings of the National Academy of Sciences, 115*, 9702-9707.

Sznycer, D., Xygalatas, D., Alami, S., An, X. F., Ananyeva, K. I., Fukushima, S., ... & Onyishi, I. E. (2018b). Invariances in the architecture of pride across small-scale societies. *Proceedings of the National Academy of Sciences, 115*, 8322-8327.

Takahashi, H., Matsuura, M., Koeda, M., Yahata, N., Suhara, T., Kato, M., & Okubo, Y. (2008). Brain activations during judgments of positive self-conscious emotion and positive basic emotion: pride and joy. *Cerebral cortex, 18*(4), 898–903. https://doi.org/10.1093/cercor/bhm120

Tangney, J.P., & Dearing, R.L. (2003). *Shame and Guilt*. Guilford Press.

Tangney, J. P., Wagner, P. E., Fletcher, C., & Gramzow, R. (1992). Shamed into anger? The relation of shame and guilt to anger and self-reported aggression. *Journal of personality and social psychology, 62*(4), 669–675. https://doi.org/10.1037//0022-3514.62.4.669

Tangney, J. P., Miller, R., Flicker, L., & Barlow, D. H. (1996). Are shame, guilt, and embarrassment distinct emotions?. *Journal of personality and social psychology, 70*(6), 1256–1269. https://doi.org/10.1037//0022-3514.70.6.1256

Tangney, J. P., Stuewig, J., & Mashek, D. J. (2007). Moral emotions and moral behavior. *Annual review of psychology, 58*, 345–372. https://doi.org/10.1146/annurev.psych.56.091103.070145

Tracy, J.L., & Randles, D. (2011). Four models of basic emotions: a review of Ekman and Cordaro, Izard, Levenson,and Panksepp and Watt. *Emotion review, 3*(4), 397–405. https://doi.org/10.1177/1754073911410747

Tracy, J. L., & Robins, R. W. (2007). The psychological structure of pride: a tale of two facets. *Journal of personality and social psychology, 92*(3), 506-525 https://doi.org/10.1037/0022-3514.92.3.506

Whittle, S., Liu, K., Bastin, C., Harrison, B. J., & Davey, C. G. (2016). Neurodevelopmental correlates of proneness to guilt and shame in adolescence and early adulthood. *Developmental cognitive neuroscience*, *19*, 51-57.

Zahn, R., Moll, J., Paiva, M., Garrido, G., Krueger, F., Huey, E. D., & Grafman, J. (2009). The neural basis of human social values: evidence from functional MRI. *Cerebral cortex,* 19(2), 276–283. https://doi.org/10.1093/cercor/bhn080

Zahn, R., Garrido, G., Moll, J., & Grafman, J. (2014). Individual differences in posterior cortical volume correlate with proneness to pride and gratitude. *Social cognitive and affective neuroscience, 9*(11), 1676–1683. https://doi.org/10.1093/scan/nst158

Zhu, R., Wu, H., Xu, Z., Tang, H., Shen, X., Mai, X., & Liu, C. (2017). Early distinction between shame and guilt processing in an interpersonal context. *Social neuroscience*, *14*(1), 1–14. https://doi.org/10.1080/17470919.2017.1391119

Zhu, R., Feng, C., Zhang, S., Mai, X., & Liu, C. (2019). Differentiating guilt and shame in an interpersonal context with univariate activation and multivariate pattern analyses. *NeuroImage*, *186*, 476–486. https://doi.org/10.1016/j.neuroimage.2018.11.012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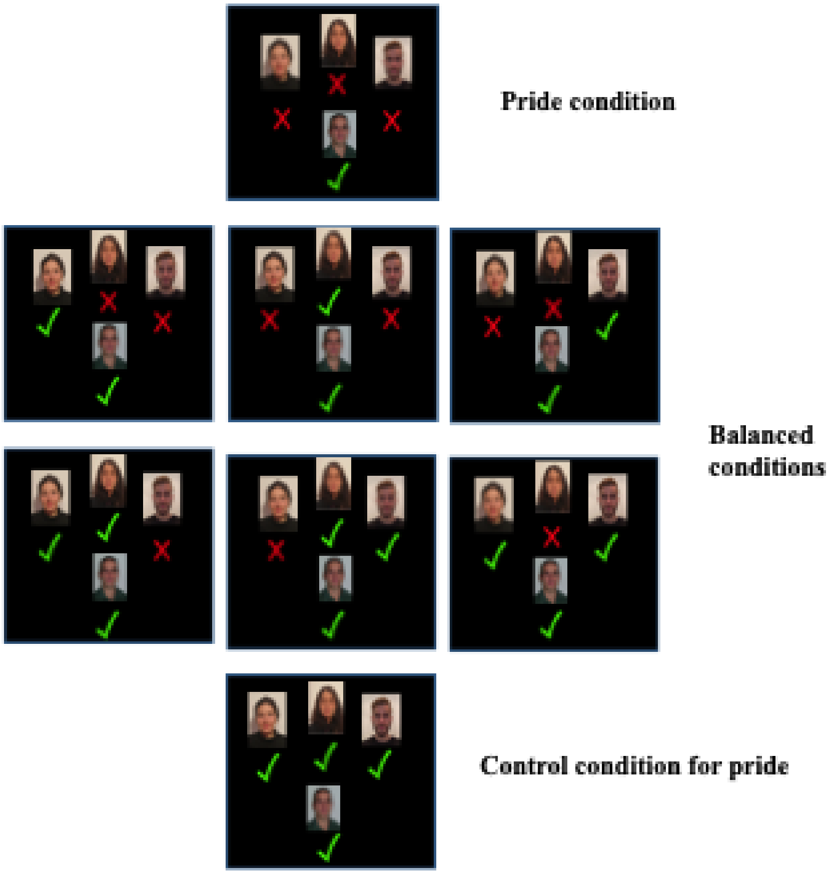
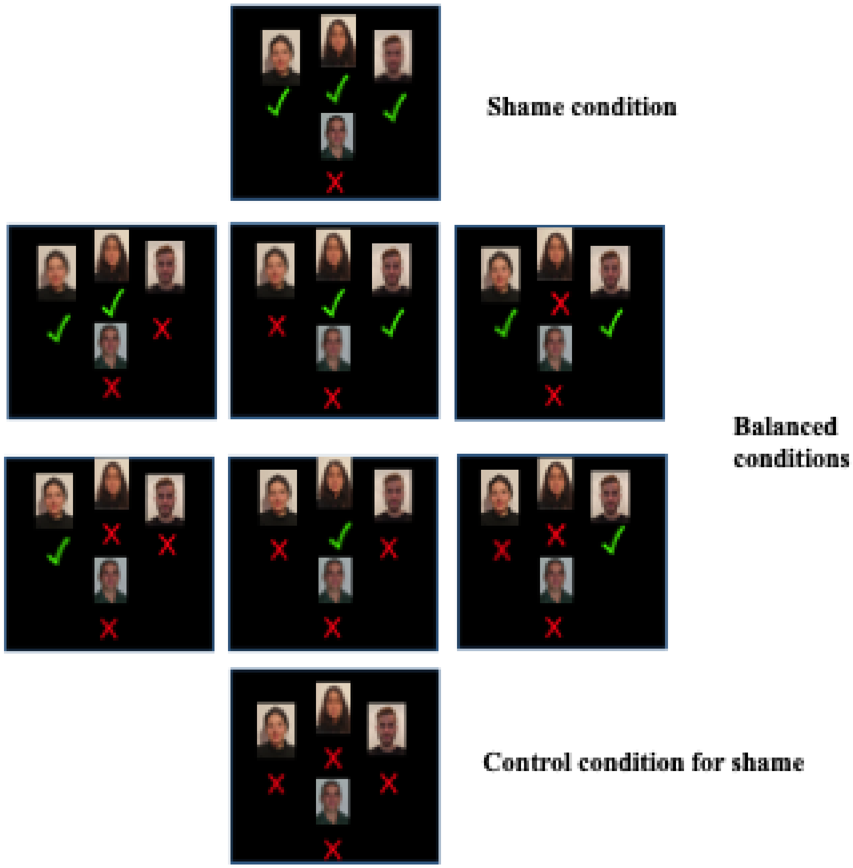

Pride condition
Balanced conditions
Control condition for pride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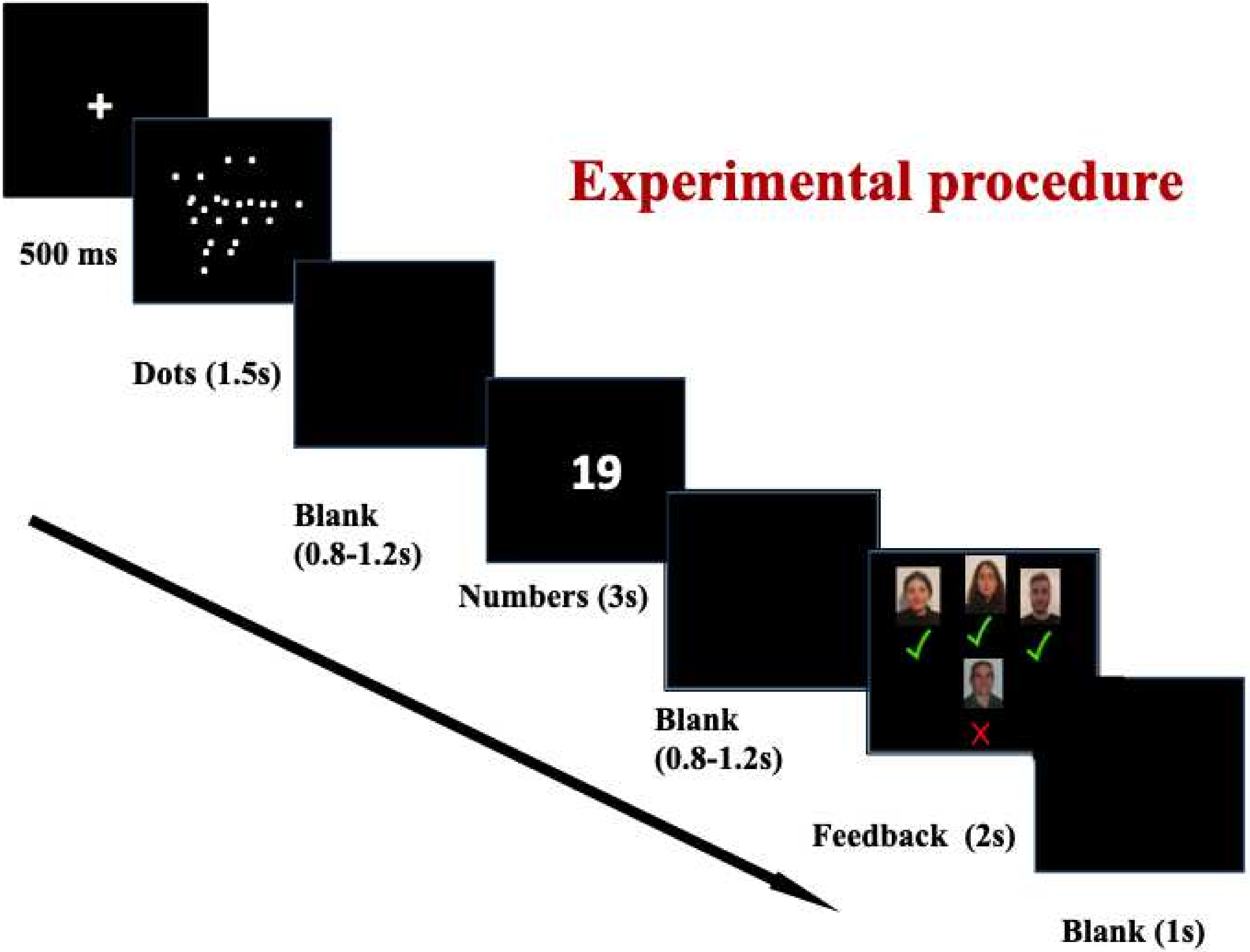
Balanced conditions
Control condition for shame


Experimental procedure
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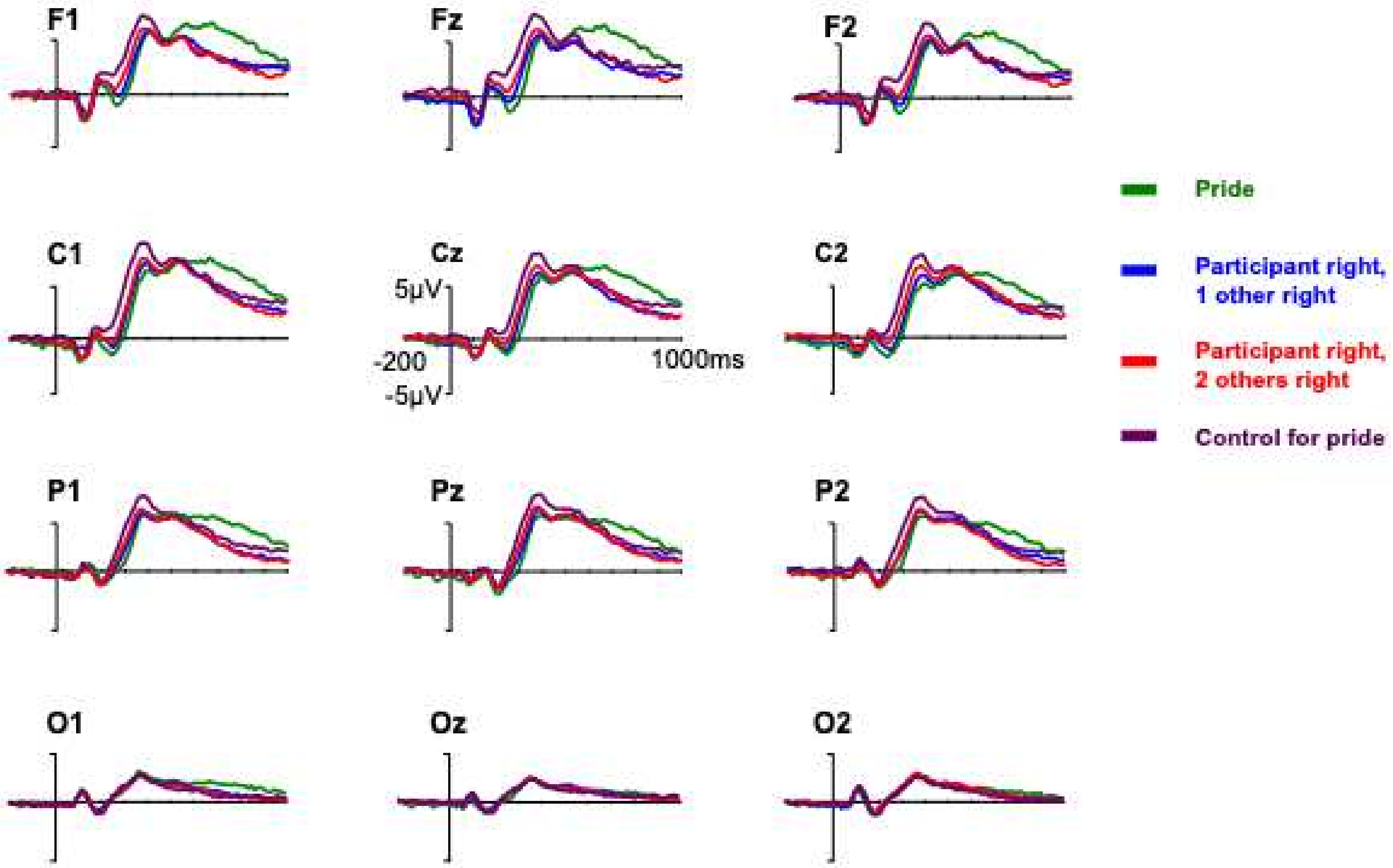
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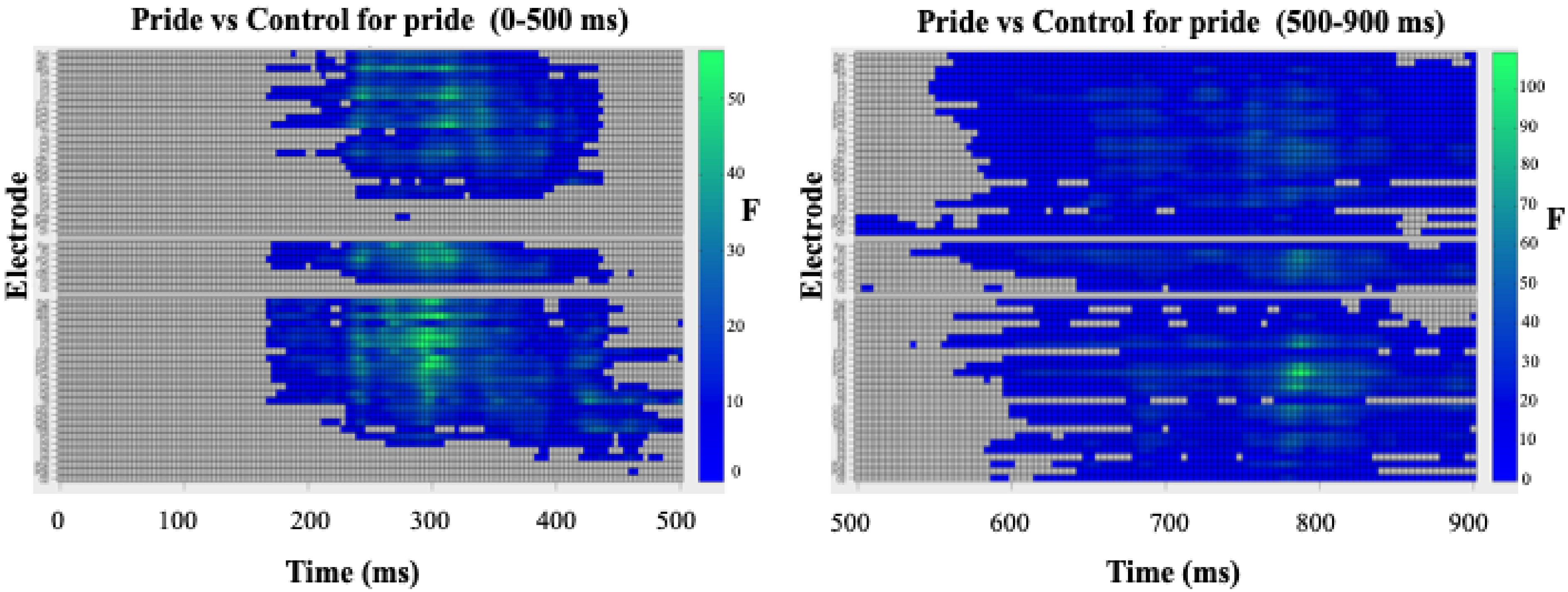
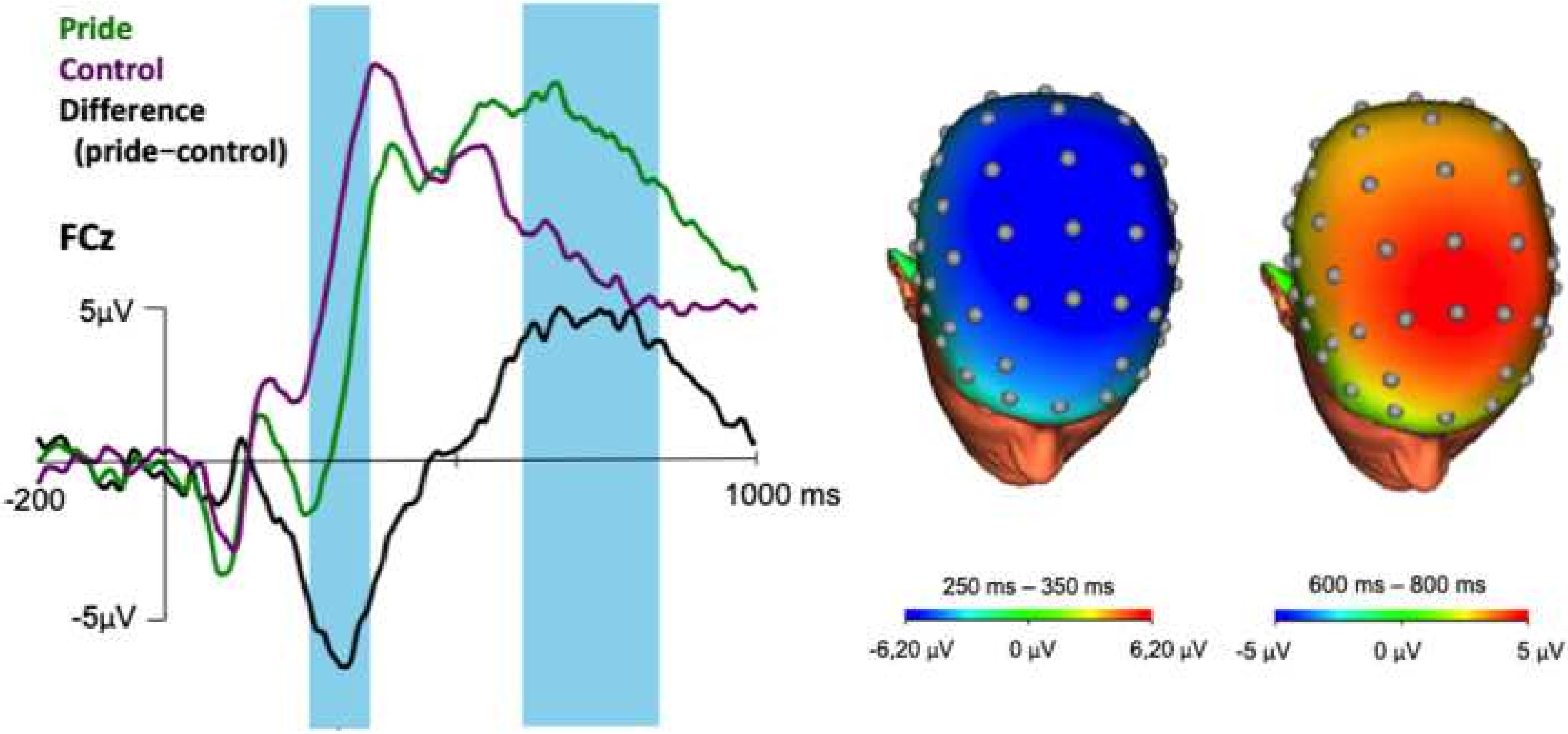
Participant right,
2 others right
Control for pride



Pride vs Control for pride (0-500 ms)

Pride vs Control for pride (500-900 ms)


Pride
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(pride–control)
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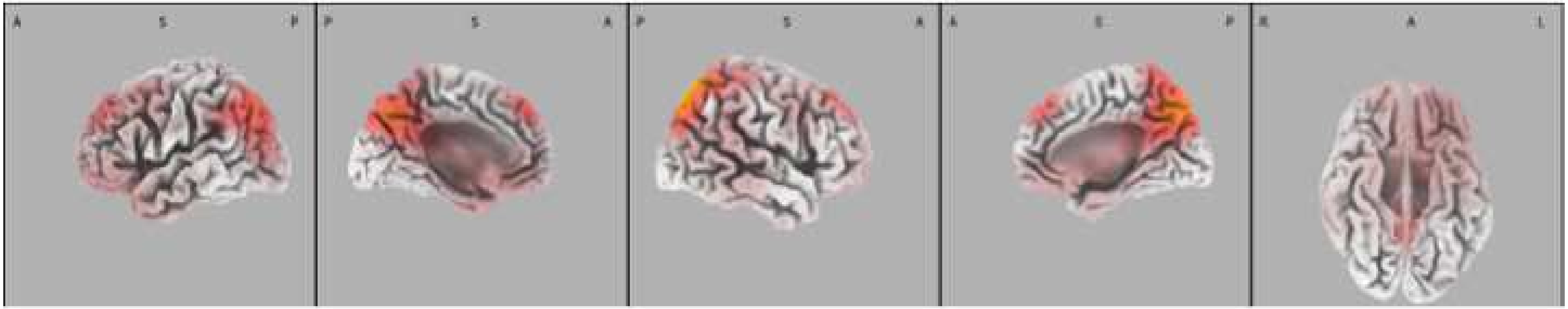
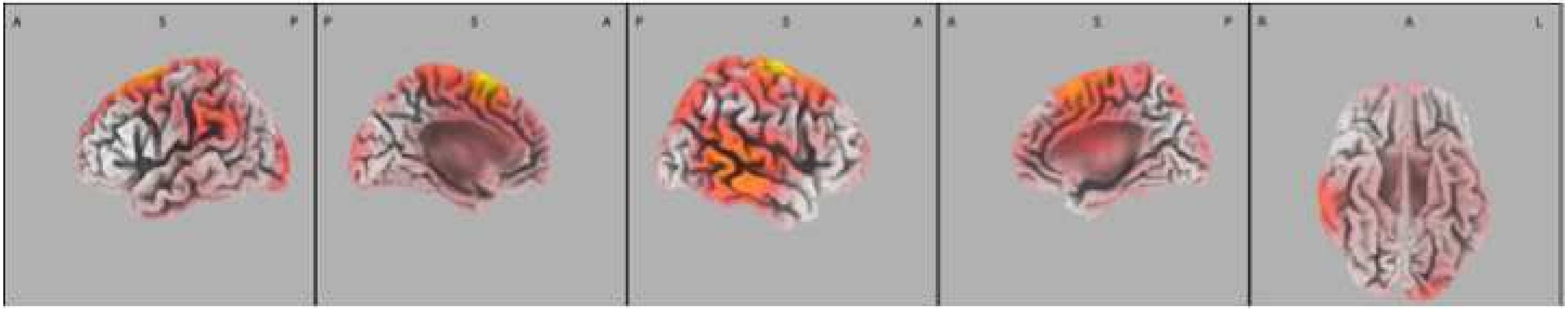
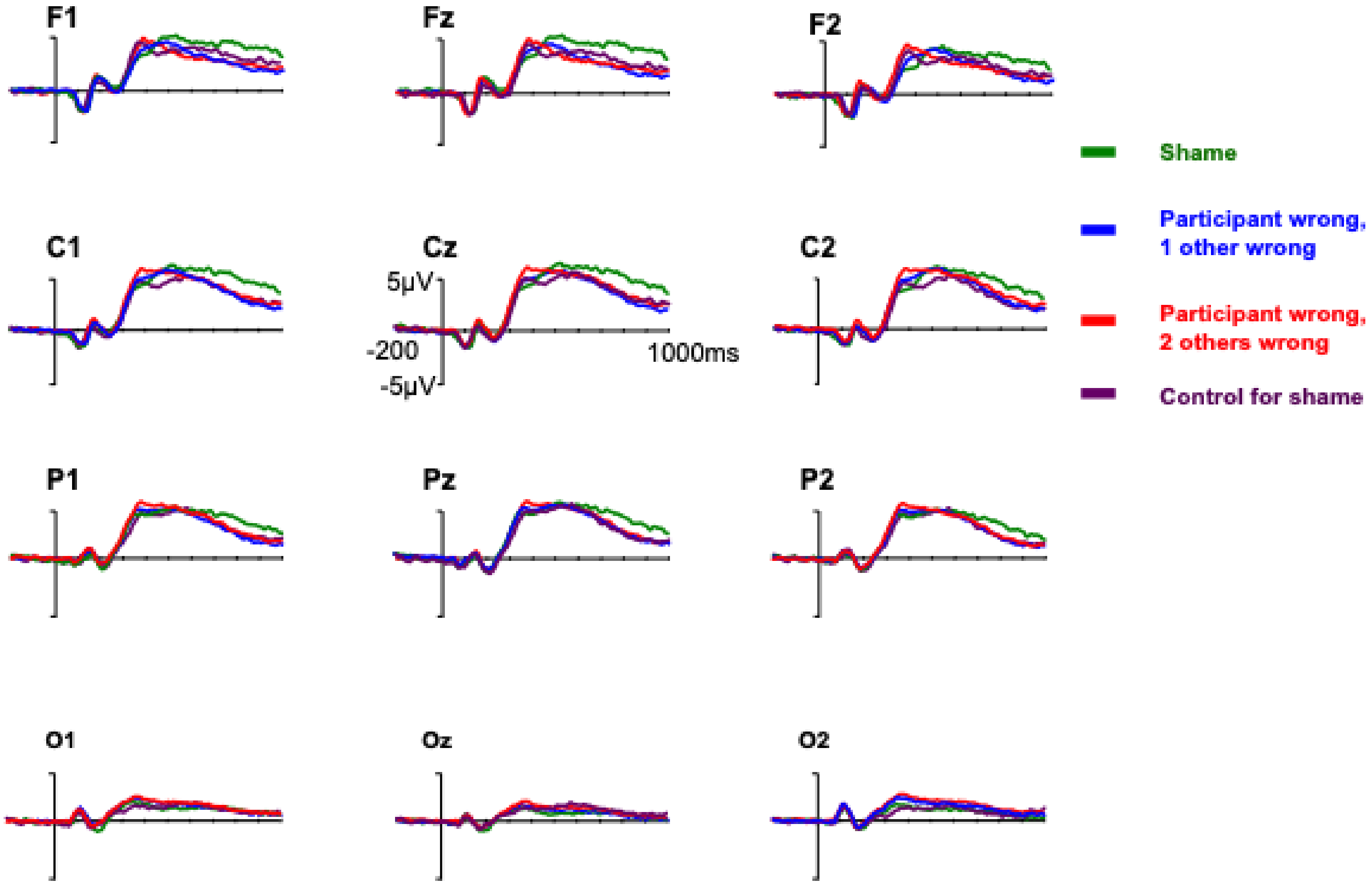
6,20 μV
600 ms – 800 ms
-5 μV
0 μV
5 μV

Pride: Early component



Pride: Late component

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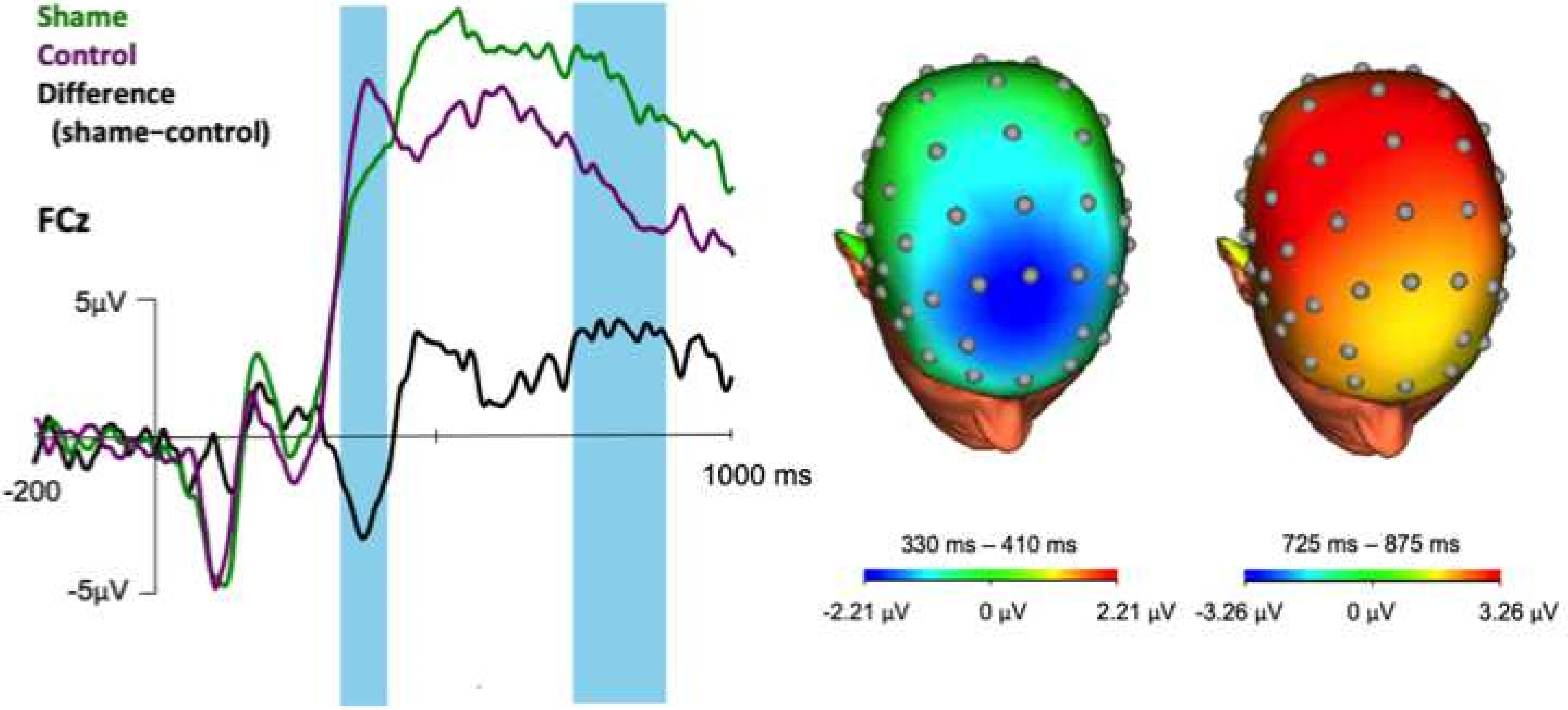
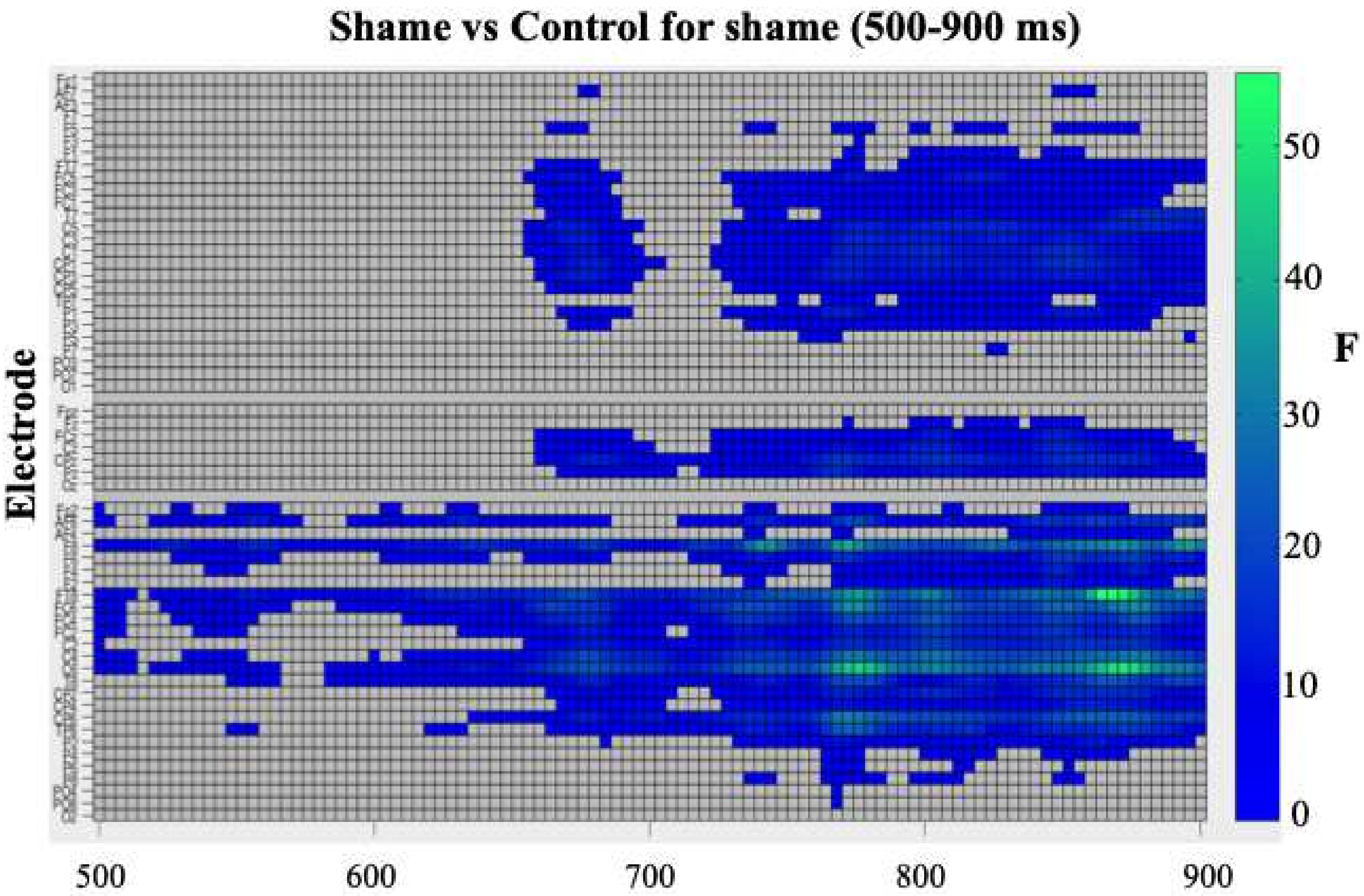
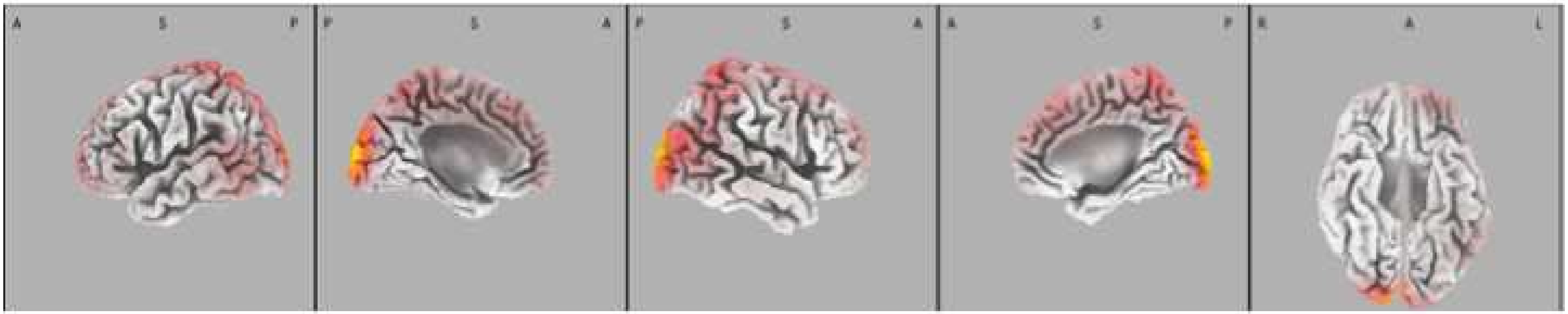
5μV
-200
1000ms
-5μV
P1
Pz
P2
O1
Oz
O2
Shame
Participant wrong, 1 other wrong
Participant wrong, 2 others wrong
Control for shame


Shame
Control
Difference
(shame−control)
FCz
5µV
-5µV
-200
1000 ms
330 ms – 410 ms
-2.21 µV
0 µV
2.21 µV
725 ms – 875 ms
-3.26 µV
0 µV
3.26 µV


Shame vs Control for shame (500-900 ms)
Electrode
F
0
10
20
30
40
50
500
600
700
800
900

Shame: Early component



Shame: Late component