Facial emotion processing in young people with subjective memory complaints: an ERP study

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Abstract

Subjective memory complaints (SMCs) are commonly related to aging, but they are also presented by young adults. Their neurophysiological mechanisms are not thoroughly understood, although some aspects related to affective state have been mentioned. Here, we investigated whether facial emotion processing is different in young people with (n = 41) and without SMCs (n = 39) who were exposed to positive, negative, and neutral faces, by recording the event-related potential (ERP) activity. From the ERP activity, the N170 (an index of face processing) and the LPP (an index of motivated attention) components were extracted. Regarding N170, results showed less amplitude for positive and neutral faces in the participants with SMCs than in those without SMCs. Moreover, women with SMCs displayed longer latencies for neutral faces than women without SMCs. No significant differences were found between the groups in the LPP component. Together, our findings suggest deficits in an early stage of facial emotion processing in young people with SMCs, and they emphasize the importance of further examining affective dimensions.

1. Introduction

Subjective memory complaints (SMCs) have been defined as a subjective awareness of memory loss in the absence of any organic or identifiable condition in neuropsychological examinations [1]. Although memory complaints are frequently reported by older people, the available evidence indicates that SMCs are also reported by young adults [2, 3]. As in older people, research in young people has shown that SMCs are not associated with objective memory performance [4, 5]. However, SMCs have been related to perceived stress [4, 6] and anxiety symptoms [7, 8, 9] in young samples, and depression in a mixed-age sample [10]. In this regard, it is important to investigate the mechanisms that may contribute to an increased perception of stress and even the development of stress-related disorders, such as anxiety and depression, in young adults with SMCs.

Within this context, a recent study in older people with SMCs reported deficits in facial emotion processing, especially for negative faces [11]. Taking into account that correct facial emotion processing is necessary for successful human interactions [12], its impairment could at least partly contribute to the development of stress-related disorders reported in people with SMCs [13, 14, 15]. Facial emotion processing is a complex process that involves many cerebral structures, including the occipitotemporal and orbitofrontal cortices and amygdala [16]. In addition, facial emotion processing is an important source of knowledge about the emotions of others and social information, for a review, see: [17]. The ability to recognize emotional facial expressions efficiently correlates with the problem-solving capacity, induces social interactions, and promotes adequate adaptation to a new environment [18, 19]. Moreover, there is available evidence supporting the idea that, in disorders related to cognitive impairment, rather than deteriorating general cognition, facial emotion processing influences social behavior [20, 21]. Along these lines, previous studies have shown a relationship between cognitive perceptual abnormality for facial emotion processing and anxiety [22, 14], long-term stress [23], and depression [15] in young people. Therefore, investigating deficits in facial emotion processing in young people with SMCs may provide
important knowledge that can help to understand the development of stress-related disorders and cognitive deficits in this population.

Facial emotion processing can be analyzed by event-related potentials (ERPs) [17], which are considered reliable biomarkers of cognitive operations [11] that allow the assessment of neural reactivity to affective events with a high temporal resolution [24]. Electrophysiological data reveal that ERPs are sensitive to the emotional content of facial expressions in early stages of emotional processing [17]. More specifically, the main components related to faces and facial emotion processing are the N170 [17] and the Late Positive Potential (LPP) [15]. The N170 component is an early negative component that is detected at 120–200 ms and peaks at approximately 170 ms post-stimulus, and it is only induced by face stimuli [25, 26]. Located primarily in the occipitotemporal brain region, the N170 usually shows a greater response over the right hemisphere than over the left hemisphere [27], and it can be modulated by emotion processing [28]. Moreover, Lazarou et al. [11], in their study on negative faces (anger and fear), demonstrated that older people with SMCs show larger N170 amplitude to negative faces than healthy controls. The LPP component is a slow positive potential that occurs at approximately 400–600 ms post stimulus onset, with a maximum peak at the midline central and parietal electrodes, and it shows higher amplitudes for emotional images than for neutral images [29, 30]. This component reflects brain electrical activity during both automatic and controlled attentional processing for emotional information, and it indicates more elaborate emotion-related processing, such as high-level recognition processing [31, 32]. To the best of our knowledge, no previous studies have investigated the LPP component on a facial emotion processing task in people with SMCs.

With all this in mind, the present study aimed to investigate whether facial emotion processing is different in young people with and without SMC who were exposed to positive, negative, and neutral faces. To do so, we employed the two main components of processing usually studied in this context, and we also included behavioral data (reaction time, RT, and accuracy). Given that higher amplitudes and shorter latencies are observed when attentional resources are abundant, and that processing in N170 and LPP is sensitive to attentional resources [33], we expected longer latencies and smaller amplitudes in both the N170 and LPP components in participants with SMCs, compared to those without SMCs. Finally, sex-related differences in facial emotion processing have been found, with faster recognition times, better accuracy, shorter latencies, and greater N170 and LPP amplitude in women than in men [34, 35, 36]. Therefore, we included both women and men, in order to study possible sex-related differences in young people with and without SMCs.

2. Material And Methods

2.1. Participants

Eighty healthy young students participated in the study (41 men, 39 women; mean age = 22.1 years) (Table 1). Participants were recruited at the University of Valencia campus (Spain). Undergraduates who
met the criteria were contacted by telephone and asked to attend a session that took place in the Laboratory of Social Cognitive Neuroscience.

The exclusion criteria were: history of alcohol or drug abuse; smoking more than 10 cigarettes a day; having had surgery under general anesthesia in the past year; presence of severe vision or hearing problems or an illness that involves an alteration of the nervous system; and a neurological or psychiatric disorder. In addition, participants were excluded if they took drugs that might affect cognitive or emotional function, psychotropic substances, beta-blockers, or benzodiazepines, or if they had experienced a stressful event in the past 6 months. All the participants were right-handed, as evaluated by the Edinburgh Handedness Inventory [37].

Participants were distributed into two groups: SMCs (N = 41; 20 men and 21 women) and no SMCs (noSMCs) (N = 39; 21 men and 18 women), according to the scores obtained on the Spanish adaptation [3] of the modified version of the Memory Failures of Everyday (MFE-30) questionnaire [38]. This questionnaire consists of 30 items about situations and activities of daily life, rated on a 5-point Likert scale ranging from 0 (never or almost never) to 4 (always or almost always). We employed these scores to distribute participants into two groups according to the scores obtained on this questionnaire. The participants who scored equal to or below 21 were included in the noSMC group, whereas the participants who scored above 21 were included in the SMC group (descriptive data for each condition and sex group are summarized in Table 1).

The study was carried out according to the Declaration of Helsinki, and the Ethics Committee of the University of Valencia approved the protocol. All the participants received verbal and written information about the study and signed an informed consent for publication of identifying information or images in an online open-access publication.

| Table 1 | Demographic data (mean and SD) for each group and sex. |
|---------|------------------------------------------------------|
|         | SMCs        | noSMCs       | Men            | Women         |
| Age (years) | 21.17 (3.27) | 23.22 (4.0)  | 22.87 (3.89)  | 21.46 (3.53)  |
| BMI (Kg/m2) | 21.93 (3.26) | 23.16 (3.89) | 23.10 (3.96)  | 21.96 (3.17)  |
| SES       | 5.7 (1.22)   | 6.0 (1.14)   | 6.0 (1.20)     | 5.71 (1.16)   |

BMI = Body Mass Index; SES = Socioeconomic Status; SMCs = Subjective Memory Complaints.

2.2. Procedure

Participants arrived at the laboratory, and the experimenter verified that they had followed the instructions given before the experiment: sleep as long as usual, refrain from heavy physical activity the day before the session, and not consume alcohol or any stimulants since the night before the session.
The experimental session took 2 h and was carried out in the morning (between 10 and 14:00 h) or in the afternoon (between 15:00 and 19:00 h). Half of the participants attended the morning shift and the other half the afternoon shift. There were no differences in the number of participants in each group in each shift ($\chi^2 = 2.8, p = 0.423$).

The session started with a habituation period to the laboratory lasting 15 min. Then, the participants were prepared for the EEG register (10 min) and performed two blocks of resting EEG collection (i.e. closed eyes and opened eyes) for three minutes each. Next, the face stimulus task was presented, which lasted 12 min. After the task, weight and height were measured, and then the participants had 40 min to answer the MFE-30 and a General Questionnaire where demographic data were collected. As part of a larger research project not related to the research question of the current study, the participants completed other cognitive tasks and questionnaires (data not included here).

2.3. Face Stimulus task

Images of human facial expressions with positive, negative, and neutral valences were used as stimuli. Each valence contained 68 images. All images were adapted from a standard set of pictures to generate emotional stimuli [39]. Images of men and women and the valences of the images were presented randomly to the participants and in equal proportion. All images were presented in grayscale on a black background and displayed in the center of a 24-inch size screen.

The stimuli were presented in the following sequence: (1) fixation mark (+) appeared for 1000 to 1300 ms; (2) presentation of the face for 200 ms; and (3) display of a blank screen for 800 ms (Fig. 1). The images were presented using the E-prime program (v2.0). Participants were instructed to press the 1 key if the facial expression was positive, 2 if it was negative, and 3 if it was neutral. The participants were seated 70 cm away from the screen in a dimly lit and sound attenuated room. The task started with practice trials containing 12 images. Each participant received feedback after each of these 12 trials, indicating whether he/she had done it correctly or incorrectly.

2.4. ERP recording and data analyses

The EEG was collected using an elastic cap from a 29 channel system, according to the international 10–20 system (Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, A1, T3, C3, Cz, T4, C4, A2, T5, P3, Pz, P4, T6, O1, OZ and O2), using a Brain Vision Amplifier System (Brains product, Germany). The electrode AFz was used as the system ground, and electrodes were referenced to Fcz. Both vertical and horizontal electro-oculograms were captured by additional electrodes (VEOG-, VEOG+, HEOG-, HEOG+) placed around the eyes. The electrode-to-skin impedances were lowered using electrolyte gel (SUPER-VISC High Viscosity Electrolyte-Gel, EasyCap, GmbH), and they were kept below 5 kΩ before starting the recording. The BrainVision Analyzer (BrainProducts, Germany) was used to analyze the EEG data. Data were re-referenced to a common average signal of 23 electrodes [40]. The EEG and EOG were amplified and then passed through (0.1 Hz – 30 Hz) band-pass filtering using an IIR filter (24 db/octave roll-off). One-second epochs were extracted in a range from − 200 to 800 ms. Epochs were then corrected to the mean voltage of the baseline − 200. Trials with EOG artifacts, including blinking, eye movement, and skin potentials, were
corrected offline with the algorithm from Gratton and Coles [41], and trials with wrong answers were removed from averaging. Based on the overall mean chart, the early ERP component (i.e. N170) generated by the stimuli showed clear peaks. A time window of 130–200 ms was used to measure the ERP peak and peak latency in data collected at electrode sites T6 (right temporal lobe) and T5 (left temporal lobe) for N170. The LPP component was calculated at the Pz electrode, with a mean value of the amplitude within a 400–700 ms time-window.

2.5. Statistical Analyses
For behavioral performance, RT and accuracy were analyzed using ANOVAs for repeated measures with Emotional Valence (positive, negative, and neutral) as a within-subject factor and Sex (men and women) and Group (SMCs and noSMCs) as between-subject factors.

To study the amplitudes and latencies of the N170 and LPP components, we carried out ANOVAs for repeated measures with Emotional Valence (positive, negative, neutral) as a within-subject factor and Sex and Group as between-subject factors. In the analyses with N170, Hemisphere (Right and Left) was also included as a within-subject factor. In cases of violation of sphericity, Greenhouse-Geisser correction was applied. The analyses were performed using Bonferroni correction for main effects and interactions.

The level of significance was taken as \( p = 0.05 \). There were no outliers (± 3SD) in this study. We used SPSS 24.0 to perform the statistical analysis.

3. Results

3.1. Behavioral performance
Table 2 shows RTs and accuracy. For RTs, a significant effect of Emotional Valence, \( F(1.963, 149.189) = 204.095, \ p = 0.001, \eta^2 = 0.729 \), was found. RTs were shorter for positive faces than for negative and neutral faces (both \( p < 0.001 \)), and shorter for negative faces than for neutral (\( p = 0.005 \)) faces. Neither the Sex (\( p = 0.627 \)) and Group (\( p = 0.349 \)) factors nor their interactions were significant (all \( p > 0.994 \)).

For accuracy, a significant effect of Emotional Valence, \( F(1.973, 149.964) = 51.899, \ p < 0.001, \eta^2 = 0.406 \), was found. Thus, accuracy was higher for positive faces than for negative and neutral faces (both \( p < 0.001 \)), and it was higher for neutral faces than for negative faces (\( p = 0.003 \)). Neither the main effects of Sex (\( p = 0.190 \)) and Group (\( p = 0.089 \)) nor the rest of the interactions reached statistical significance (\( ps > 0.542 \)).
Table 2
Means and standard deviations for the behavioral performance for each group and sex.

| Reaction time (ms) | SMCs       | noSMCs     | Men        | Women      |
|-------------------|------------|------------|------------|------------|
| Positive          | 684.794 (75.85) | 664.897 (86.89) | 669.679 (79.30) | 680.787 (84.43) |
| Negative          | 807.672 (85.21) | 789.868 (107.44) | 798.334 (88.0) | 799.685 (102.71) |
| Neutral           | 833.604 (99.35) | 813.818 (116.77) | 814.646 (107.28) | 833.748 (109.20) |

Response accuracy (%)

| Positive          | 94.6 (2.93) | 95.8 (2.05) | 94.9 (2.92) | 95.6 (2.12) |
| Negative          | 77.5 (11.57) | 79.7 (5.92) | 79.5 (6.43) | 77.6 (11.52) |
| Neutral           | 80.5 (14.08) | 87.8 (6.43) | 87.6 (5.74) | 80.3 (14.67) |

ms = milliseconds; SMCs = Subjective Memory Complaints

3.2. ERP data analysis

3.2.1. N170 component

For N170 latencies, the analyses revealed that the Emotional Valence, F (1.955, 136.858) = 1.553 p = 0.216, ηp² = 0.216, Hemisphere, F (1,70) = 0.615 p = 0.436, ηp² = 0.009, Sex, F (1, 70) = 0.353 p = 0.554, ηp² = 0.005, and Group, F (1, 70) = 1.338 p = 0.251, ηp² = 0.019, factors were not significant. The Emotional Valence x Group interaction, F (1.955, 136.858) = 3.256 p = 0.043, ηp² = 0.044, was statistically significant; however, post hoc comparisons did not show significant differences (all ps > 0.926) (Fig. 2.a). The Emotional Valence x Hemisphere x Group x Sex interaction was also significant, F (1.878, 131.4556) = 3.226 p = 0.046, ηp² = 0.044. Post hoc analyses revealed that women SMCs showed longer latencies in the right hemisphere for neutral faces than women noSMCs (p = 0.005). None of the other post hoc analyses revealed significant effects (all ps > 0.082). The other interactions were not significant (ps > 0.764)

For N170 amplitudes, the effect of Emotional Valence was significant, F (2, 140) = 21.274 p = 0.001, ηp² = 0.233, with the amplitudes being higher for positive faces than for negative (p = 0.049) and neutral (p = 0.001) faces, and higher for negative faces than for neutral (p = 0.001) faces. The Group factor was also significant, F (1, 70) = 4.563 p = 0.036, ηp² = 0.061, indicating that SMC participants showed less amplitude than noSMCs. In addition, a significant effect of the Emotional Valence x Group interaction, F (2, 140) = 5.331 p = 0.006, ηp² = 0.071, was found. Post hoc comparisons revealed that the SMC
participants showed a lower amplitude than noSMCs for positive \( (p = 0.007) \) and neutral \( (p = 0.050) \) faces, but not for negative faces \( (p = 0.148) \) (Fig. 2.a).

We also found a significant effect of the Hemisphere, \( F (1, 70) = 17.550 \ p < 0.001, \eta^2 = 0.200 \), and Sex, \( F (1, 70) = 4.200 \ p = 0.044, \eta^2 = 0.057 \), factors (Fig. 2.b). Thus, we observed higher amplitude in the right hemisphere than in the left hemisphere, and men showed less amplitude than women. Other interactions were not statistically significant \( (ps > 0.711) \).

3.2.2. LPP component
For LPP latencies, results showed a significant effect of Emotional Valence, \( F (2, 136) = 9.475 \ p < 0.001, \eta^2 = 0.122 \). LPP latency was shorter for positive faces compared to neutral \( (p = 0.001) \) faces, and for negative faces compared to neutral \( (p = 0.034) \) faces. Other effects or interactions were not significant \( (ps > 0.614) \).

For LPP amplitudes, the Emotional Valence was significant, \( F (1.912, 131.924) = 5.431 \ p = 0.006, \eta^2 = 0.073 \). \textit{Post hoc} comparison revealed that amplitudes were significantly higher for negative faces than for positive \( (p = 0.003) \) faces, but no other significant differences were found \( (all \ p > 0.232) \) (Fig. 2.c).

In addition, the Sex factor was significant, \( F (1, 69) = 5.261 \ p = 0.025, \eta^2 = 0.071 \), with men showing smaller LPP amplitudes than women. Other effects and interactions were not significant \( (ps > 0.827) \) (Fig. 2.d).

4. Discussion
The aim of the present study was to investigate whether facial emotion processing (i.e. positive, negative, and neutral faces) is different in young women and men with SMCs compared to other groups without SMCs. At the behavioral level, only positive valences showed clearly significant effects on both RT and accuracy, with no significant differences due to SMCs or sex. Regarding ERPs, we found that participants with SMCs showed lower amplitude than noSMC participants in the N170 component, specifically for positive and neutral faces. In addition, women SMCs showed longer latencies in N170 for neutral faces compared to women noSMCs. For the LPP component, no differences depending on SMCs were found for latency and amplitude. Notably, the participants showed higher amplitudes for negative faces. Finally, we observed that women showed higher amplitudes than men for both the N170 and LPP components, although no differences in latencies were found.

Regarding behavioral data, neither RT nor accuracy was significantly different between the SMCs and noSMCs groups, indicating similar performance for both groups. Regardless of groups and sex, participants showed less latency and more accuracy for positive expressions, and they were slower for neutral faces and less accurate for negative faces. This may be because negative faces are emotionally stronger and would enable interferences in identifying them. Complementary to this, Calvo and Beltran [42] demonstrated that positive expressions have a salient and unique facial feature, the smile, which
allows quick and accurate identification. By contrast, negative or neutral expressions contain more overlapping features, which would generate confusion, making the decision process slower [42].

The N170 component is considered an indicator of facial structure encoding [25], and the amplitude was smaller in SMCs compared to noSMCs, suggesting that early facial structure processing could be impaired in this population. Moreover, on closer examination, the N170 amplitude was lower for positive and neutral faces in SMCs than in noSMCs, whereas negative faces elicited similar amplitudes in both groups. To the best of our knowledge, no previous studies have investigated the N170 component with positive, negative, and neutral faces jointly in relation to SMCs. Only one study carried out in older people with a diagnosis of SMCs, Alzheimer disease, mild cognitive impairment, and healthy older participants focused on the N170 component for negative stimuli [11]. In contrast to our results, these authors found larger N170 amplitudes in response to faces showing fear in SMCs than in healthy participants, suggesting that processing for negative faces is deteriorated in participants with SMCs. However, there is enough evidence confirming that low amplitudes (in regions involved in face processing, particularly in frontal and temporal areas) would be related to a decline in emotion processing [43]. Along these lines, it is possible that the processing of positive and neutral faces is reduced in young people with SMCs, whereas normal processing of negative faces is consistent with the adaptive function perspective. From a biological point of view, negative face recognition is more relevant because these expressions are signs of potential harm [44].

The relationship between SMCs and facial emotion processing is complex and poorly understood. Some studies indicate that impaired emotional face processing affects quality of life and interactions in everyday social life [20, 18]. Consequently, impaired facial emotion processing can have a negative impact on social behavioral competence [12], and it could play an important role in the development of stress-related psychopathology in young people with SMCs.

In addition, we found that N170 elicited in the right hemisphere were higher than those elicited in the left hemisphere in both conditions. This result supports evidence showing that neurons in the superior temporal gyrus respond to the processing of facial expressions of emotion [25, see review: 45].

Regarding the LPP, we found no differences between the SMC and noSMC groups in latency or in amplitude. However, regardless of the group, participants presented shorter latencies for positive faces than for negative and neutral faces, whereas the amplitude was greater for negative faces than for positive and neutral faces. This result is consistent with our behavioral data showing slower and less accurate responses for negative faces. In agreement with this, prior research suggests that positive faces are more easily processed in this late stage [44]. In addition, more attentional resources and greater cortical activation are allocated for negative faces than for positive and neutral faces in this stage of processing [33]. This probably occurs because negative faces have greater biological relevance, and so the attention is directed toward these significant stimuli. Together, our results suggest that, in contrast to the results for early processing of facial emotions (N170), young people with SMCs would not present difficulties in the late processing of negative, positive, and neutral facial expressions.
Finally, we found that men showed smaller amplitudes for both the N170 and LPP components than women. This finding could suggest that, in general, women show a more sensitive attentional processing of emotional faces than men. In addition, this processing begins in the first stage and is maintained in the late evaluative process. This result is in line with studies that have shown that women are more responsive to face stimuli than men, which could suggest greater empathy or greater attention to facial features and more interest in social information [46].

Despite the relevance and novelty of our results, some limitations should be considered. First, further studies may benefit from investigating the effect of the arousal of emotional expressions when exploring the LPP component because valence mainly modulates the early stage of emotional processing, whereas arousal mainly modulates the late stage [for review see: 24]. Second, we used static and grayscale facial pictures as stimuli, and they subtract important lively information that people use to recognize facial expressions in natural contexts. In contrast, colors and three-dimensional stimuli provide a more real effect than our stimuli [47]. Despite these weaknesses, this study has main strengths, such as the thorough selection of the participants and the sample size.

In conclusion, our study is the first to show that young people with SMCs present difficulties in the early stage of emotion processing (as reflected in N170). Moreover, we did not observe differences in behavioral data or the LPP component between young people with and without SMC in facial emotion recognition. Our results provide important evidence that helps to understand some difficulties that characterize this population and could be the cause of greater vulnerability to developing subjective deficits and other stress-related disorders.

Declarations

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Competing Interests

The author(s) declare no competing interests.

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**Figures**
Figure 1

Timeline of events during the session. Note: ms = milliseconds. The images are an example of faces of each emotion extracted from the Karolinska Emotional Directed Faces database. Image id: AF01DIS,

Figure 2

Latencies and amplitudes of N170 and LPP induced by groups and sex. (a) Grand average N170 for positive (green), negative (red), and neutral (blue) faces recorded in the right and left hemisphere in young people with and without subjective memory complaints. (b). Grand average N170 for positive, negative, and neutral faces recorded in the right and left hemisphere in young women and men. (c). Grand average LPP for positive, negative, and neutral faces in young people with and without subjective memory complaints. (d). Grand average LPP for positive, negative, and neutral faces recorded in young women and men.