Remembering faces: The effects of emotional valence and temporal recency

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ABSTRACT

It is known that the longer an information has been memorized, the stronger is its memory trace, and that emotionally-valenced information is more solid than neutral one. We investigated whether the emotional content of recent information might enhance its memory, making it as familiar as information known for a long time. We compared ERPs alternately recorded in response to old and solid information from long term memory (i.e., faces of popular movie stars), to recently acquired emotional information (faces of fictional characters), and to completely new information (faces of previously unknown people). Initially participants familiarized with the fictional police dossiers of 10 victims of dramatic deaths (recent faces), twice a day for seven days before EEG recordings. Recent faces were compared with faces of movie stars and unknown faces in an old/new recognition task. N200 and FN400 responses were affected by face familiarity (with no difference between old and recent faces), while parietal late positivity (LP) was sensitive to temporal recency, being it greater to old than recent faces. Interestingly, LP amplitude was similar for old and recent own-sex faces (victims) that were therefore equally memorable. It is shown that emotional memory can overcome temporal recency thus improving memory recall.

## 1. Introduction

The goal of present study was to investigate whether the emotional content of an information might act as a memory enhancer, able to strengthen and consolidate recent, therefore weaker, traces in virtue of their emotional valence.

At this aim we designed an old/new memory paradigm in which faces of popular movie stars known for at least 5–8 consecutive years (therefor “old” faces), were contrasted with recently learned faces of fictional characters studied during the week preceding the EEG re-cording (“recent” faces) as opposed to previously unknown faces (“new” faces). The time course and functional properties of ERP re-sponses elicited during face recognition were compared. In this way the effect of temporal recency on face remembering was investigated, by considering the gradient: old, recent, and new. Previous literature (e.g., Moreton & Ward, 2010) investigated the extent to which retrieval from long-term memory differs as a function of the retention time. In Moreton and Ward (2010), for example, participants were given 4 min to recall autobiographical events from the last 5 weeks, the last 5 months, or the last 5 years, and the results showed similar retrieval rates. This results has been interpreted in the light of the so-called SIMPLE model (Brown, Neath, & Chater, 2007), according to which correct memory recognitions would be a function of the relative temporal distinctiveness of the items to be remembered, not just of their recency. However, the neuroscientific literature provides evidence of a different neural representation of short vs. long term memories. For example, it has long been known that in case of damage to hippocampal or medial temporal regions, the retrograde amnesia deficit involves only the recent past (for example memories relative to the last few years preceding the cerebral insult) and not the remote past of the patient, thus indicating a greater strength of older memory traces ("Con-solidation theory" by Manns, Hopkins, & Squire, 2003, see also Markowitsch & Staniloiu, 2013; Kopelman & Bright, 2012). In addition, according to the "Episodic-to-semantic shift" theory, also called "semanticisation", episodic memories would acquire a more 'semantic' form as they get older, thereby protecting them against the effects of brain damage (Cermak, 1984) or oblivion. Furthermore neurophysiological data have provided multiple evidences that brain encoding of very recent memories would have a bioelectrical nature (e.g. Zamora, Corina, & Ojemann, 2016), while the deep encoding in LTM would be based on plastic structural changes and dendritic formations, also called long-term potentiation (LTP). Interestingly, evidences have been pro-vided that

Notwithstanding that, not many studies in humans have directly compared the neural markers of remembering information of different temporal recency, especially with the ERP technique, which is actually very sensitive to both recollection and familiarity processes. Stimuli recognized as known (as opposed to unknown) typically modulate the amplitude of two ERP components: a mid-frontal negativity FN400 sensitive to stimulus familiarity (Curran, 1999, 2000) and parietal old/ new late positivity, indexing stimulus conscious recollection (Evans & Wilding, 2012; Hoppstädter, Baeuchl, Diener, Flor, & Meyer, 2015; Rugg, Schloerscheidt, Doyle, Cox, & Patching, 1996; Wilding & Rugg, 1996; Wilding & Sharpe, 2003). According to the dual-process model of recognition memory, judgments produced on the basis of familiarity are quick, automatic, and reflect a general feeling of knowing that a stimulus was previously presented. On the other hand, recollection re-quires actively reporting details about studied items and results in slow, more effortful judgments (Aggleton & Brown, 1999; Atkinson & Juola, 1974; Yonelinas, Kroll, Dobbins, & Soltani, 1999, 2002).

The present research applied the ERP technique to investigate whether emotional valence might affect recollection of recent memories with respect to old memories. We sought to comprehend if the possible memory enhancement involved face familiarity (N2 and FN400) and/or recognition (LP) and source memory (indexed by frontal responses, such as *Late anterior negativity*, LAN). In fact, a frontally distributed N400 (FN400), has been directly related to the concept of familiarity. For example, Curran (Curran, 1999, 2000) found an enhanced negative response between 300 and 500 ms post-stimulus at scalp anterior regions, which was larger to new than old items. Additionally, we expected a modulation of an earlier familiarity-related response (frontal N2) recently found to precede F/N400 effects, and being also larger to unknown than familiar items (Lawson et al., 2012). On the other hand, as previously mentioned, the parietal old/new LP has been associated to stimulus conscious recollection (Wilding & Rugg, 1996; Wilding & Sharpe, 2003).

At this aim the temporal course of brain bioelectrical activity was measured during recognition of faces of different emotional valence, sex, learning context and temporal recency. The study involved the presentation of 300 faces: some belonged to famous people (movie and TV stars), others were learned during a study phase starting one week before the experiment (very recent material), and the remaining were new faces (no familiarity). Faces to be studied (previously unknown) were presented as victims of murders or accidents with a description provided in the form of a police dossiers featuring a short text accompanied by several pictures of the victims. This experimental manipulation was included to explore the effect of emotional memory in the episodic encoding of faces. Indeed, convergent evidence suggests that emotional events attain a privileged status in memory (LaBar & Cabeza, 2006) and that memory tends to be better for emotionally arousing information than for neutral information (Buchanan & Lovallo, 2001). The reason for this potentiation has been explained by neuroscientific studies providing evidence of a more intense brain activity during coding of emotional information. For example, Mueller and Pizzagalli (2016) have provided direct electrophysiological evidence (via intracranial recordings) that faces that had been fear-conditioned (to become threatening stimuli) evoke increased activity in or in proximity of the left fusiform gyrus as early as 80 ms post-stimulus after presentation. The effect was visible starting from the same day of conditioning and, remarkably, it was still very strong one year after the fear-conditioning. In another experiment Proverbio, LaMastra, and Zani (2016) investigated the effect of social prejudice on memory for faces, by presenting hundreds of faces of male and female individuals in as-sociation with a derogatory or an appreciative description, and found that faces associated with a negative (vs. positive) prejudice elicited larger anterior negativities during encoding, smaller FN400s and larger LPs during recollection. The larger potentials for negatively-valenced faces were associated to increased activations of the limbic and para-hippocampal areas.

Based on previous ERP literature, we predicted a significant modulation of FN400 and LP components as a function of stimulus familiarity (known vs. unknown). Both processes are thought to be related to two spatiotemporally different ERP effects (FN400 and LP), namely the early mid-frontal negativity (familiarity) and the late parietal old/new effect (recollection) (Evans & Wilding, 2012; Hoppstädter et al., 2015; Rugg et al., 1996; Wilding & Rugg, 1996; Wilding & Sharpe, 2003).

We sought also to investigate the impact of emotional valence on the remembering of recent faces, in the hypothesis that the threatening learning context of recently faces might made them equally memorable than robustly coded information (i.e., popular faces). Had this been the case we would have expected to find equally large FN400 responses to recent and old faces. Furthermore, we also expected a modulation of an earlier familiarity-related response (anterior N200) recently found to precede FN400 effects, and to be larger to unknown than familiar items (Lawson et al., 2012).

Additionally we also wished to investigate whether face sex significantly affected memory recollection. Indeed previous research on emotions and empathic resonance mechanisms showed that some specific factors can facilitate emotional mirroring, like perceived similarity (e.g., sex of viewer); it would influence empathic responding through the tendency to identify more closely with others who appear as being more similar in features such as personality (Gruen & Mendelsohn, 1986) or appearance (Bufalari, Porciello, Sperduti, & Minio-Paluello, 2015). On the basis of this literature (Proverbio, Riva, Martin, & Zani, 2010) we predicted a better recall of own-sex faces, sharing sexual gender with the viewer.

## 2. Materials and methods

### *2.1. Participants*

Twenty-two university students (11 males and 11 females) volunteered for this experiment. Females ranged in age from 20 to 26 years (mean age = 22.91 years, SD = 1.76) and had a high level of education (15.73 years in school, SD = 1.01). Males ranged in age from 20 to 27 years (mean age = 24.18 years, SD = 2.05) with the same level of education as females (15.82 years in school, SD = 1.66). All participants had heterosexual preferences as ascertained by a written questionnaire, had normal or corrected-to-normal vision with right eye dominance, and were right-handed as assessed by the Edinburgh Inventory with no left-handed relatives. Experiments were conducted with the understanding and written consent of each participant ac-cording to the Declaration of Helsinki (BMJ 1991; 302: 1194) with approval from the Ethical Committee of University of Milano-Bicocca and in compliance with APA ethical standards for the treatment of human volunteers (1992, American Psychological Association). All participants received academic credits for their participation. Data from 3 male subjects were subsequently discarded because of excessive eye movements and electroencephalogram (EEG) artifacts (more than 20% of trials rejected). The final sample included nineteen university students (8 males and 11 females). Males ranged in age from 20 to 27 years (mean age = 24 years, SD = 2.27) with a mean of 15.9 years in school (SD = 1.96).

*2.2. Stimuli*

Stimulus set included three different face categories: famous (old), recently studied and new faces. Famous faces belonged to actors or TV anchors who have been extremely popular for at least 5 years (namely within the 2005–2010 period) but still very popular for people of about 23 years of age (in 2013). For example, when considering actors, it was verified the date of hit movies or TV shows that put them in the spot-light, (for example the famous TV series “Doctor House” played by Hugh Laurie (broadcasted from 2005 to 2012 in Italy), or the movie “Speed” (2006) played by Sandra Bullock, or the movie “The Devil wears Prada” (2006) played by Meryl Streep. New faces, instead, were completely unknown to the participants and were downloaded from free online databases. Recently studied faces (previously unknown) were memorized by participants during a study phase lasting one week and preceding the experimental session, in which they were depicted as victims of a homicide or accidental death, as reported in a short pamphlet (a sort of dossier on the victims) to be studied twice a day for 7 days (see Fig. 1 for an example).

*2.3. Stimuli validation*

All characters were rated for familiarity and attractiveness in a validation phase. Validation aimed at proofing that famous faces were easily recognizable and that new and recent faces were absolutely un-known to a sample of control subjects representative of an Italian population of University students. Similarly, it was ascertained that male and female identities did not differ in terms of familiarity and attractiveness. The whole set consisted of pictures relative to 30 different individuals (30 Caucasian attractive people, of about 45 years old: 10 Old, 10 New and 10 to be studied). The sex was matched across categories (half male, half female, each). Pictures were rated for familiarity and attractiveness by a group of 10 judges, 5 men and 5 women, which were blind to the study's aim.

26 years (mean age = 24.4 years, SD = 1.81), had the same level of education as the females (16.6 years in school, SD = 2.19). Judges were asked to rate each face for its familiarity on a 3-point scale (0 = not familiar, 1 = somewhat familiar, 2 = extremely familiar) and for its perceived attractiveness on a 3-point scale (0 = not attractive, 1 = somewhat attractive, 2 = extremely attractive). The pictures were presented for 2 s to judges in a randomized order by means of a PowerPoint presentation.

Familiarity and attractiveness ratings were subjected to two separate multifactorial ANOVAs whose factors of variability were 2 within-subject factors: Familiarity, or Attractiveness (Not at all, Somewhat, Extremely) and Sex of faces (Same, Opposite). Sex variable was coded considering subject's gender with respect to picture's gender, which could thus be "Same" or "Opposite" sex.

The ANOVA carried out on familiarity scores revealed a significant effect of Familiarity ($F_{2,18}$ = 1694, $p < 0.00001$). Post-hoc comparisons indicated how old faces were rated extremely familiar (1.96; SE = 0.02) as compared to recent faces (unknown prior to the study) (0.12, SE = 0.04; $p < 0.0001$) or new faces (0.05, SE = 0.02;

$p < 0.0001$) who were rated as absolutely unknown. No effect of face sex was found.

For what concerns perceived attractiveness, no significant difference was found across classes, or as a function of face sex. The mean attractive value of faces was 0.90 (SE = 0.08) indicating how, overall,

faces were considered fairly attractive (overlearned = 0.88, re-cent = 0.88, new = 0.91).

For each of the 30 characters 10 different pictures (i.e., head shots in slightly different orientations and hairstyles) were used, for a total of 300 pictures to be shown during the recognition phase (100 new, 100 recent, 100 old). The reason for having 300 different pictures (and not repeating the same 30 pictures) was to avoid short term memory effects such as repetition suppression, habituation, stimulus recognition, etc… (Hermann, Grotheer, Kovács, & Vidnyánszky, 2017) within the re-cording session. The 300 final pictures were evaluated for two other possible confounding variables: brightness and facial expression. For what concerns brightness, stimuli's luminance was measured by means of a Minolta luminance meter, and luminance values were compared across categories by a two-way ANOVA that proved equiluminance between face categories ($F_{2,294} = 0.43$; $p = 0.65$). Photographs had same size (8 cm × 9 cm) and were presented at a visual angle of 4° 1′ 26″ in length and 4° 31′ 2″ in height.

For what concerns facial expression, faces were coded by two judges as "neutral" or "smiling". Then, for each character, the number of photographs including neutral or smiling expressions was assessed: evaluations were then entered into a repeated-measures ANOVA which revealed that the number of neutral and smiling faces were comparable across categories ($F_{2,24} = 0.12$; $p = 0.89$) and face sex ($F_{1,24} = 3.2$; $p = 0.09$).

*2.4. Task and procedure*

The task included two different phases: a study phase and a re-cognition phase.

Study phase. During the week preceding the EEG recording participants were required to familiarize with the 10 “victim” characters, twice a day, 5 min per session: once in the morning after waking up, and once in the evening before going to bed. They were required to carefully read all the ten dossiers and to try to figure out the person’s characteristics and personality (when alive) and to imagine their death circumstances. The folder contained a description of each fictions character as a written file, one for each person, in form of a police dossier. Each sheet contained on the front a mug shot and a brief description of the person, including personal details like height, age, civil status, family composition, as well as the circumstances and causes of death. On the back, instead, a collection of five further photos, different from those used for the successive recognition phase, was attached to furnish supplementary cues about the person’s appearance and personality (see Fig. 1). Six different pictures of the same characters were used in line with the available knowledge that providing multiple photographs of an unfamiliar face improves identity verification accuracy (Menon, White, & Kemp, 2015).

Instructions stated: “*Dear participant, thank you very much for your precious contribution to the study. You are asked to carefully read these instructions for the task you are required to perform. In this folder you’ll find the identikits of 10 victims who have died in dramatic and sometimes horrible circumstances. Try to memorize the faces of these characters by studying each dossier, focusing on the photographs. You’ll have to browse the documents twice a day, in the morning and in the evening, for a total of 10 min a day. For a good outcome of the experiment a constant and repeated study throughout the entire week is fundamental. We recommend your utmost seriousness in following these instructions. Thanks again for your co-operation”.*

Recognition phase. After the study phase, participants were called to perform a face recognition task associated to EEG/ERPs recording. Participants were comfortably seated in a dark and acoustically/elec-trically shielded test area in front of a PC computer screen located 114 cm from their eyes. They were instructed to gaze at the center of the screen where a small red circle served as fixation point, and to avoid any eye or body movements during the recording session. The task consisted in an old/new recognition task. Participants were instructed to decide whether they knew the persons whose faces were presented (whether because they were famous stars or because had studied their police dossier) by pressing a response key, as quickly and accurately as possible, with the index finger for answering yes, and with the middle finger for answering no. The two hands were alternated during the recording session and the hand order was counterbalanced across participants. At the beginning of each session, they were told which hand should have been used to respond. The experimental session was pre-ceded by a training session in which faces from the three categories, different from those used for the experimental session, were provided to make sure that the task was correctly understood. The training session also included answering with both hands, in alternated order. Each face was displayed for 1000 ms in central visual field, with an inter-stimulus interval (ISI) that ranged from 900 to 1100 ms. The EEG was synchronized to the onset of the stimulus.

Overall the experimental session included 5 experimental runs of 48 pictures each (8 pictures for each category: old male, old female, recent victim, recent female, new male, new female) and the last one by 60 pictures, in a randomized order (see Fig. 2). Behavioural data were recorded by means of EEVoke system (*ANT Software*, Enschede, The Netherlands)

*2.5. EEG recording and analysis*

EEG was recorded continuously using the EEprobe application algorithm (*ANT Software*, Enschede, The Netherlands*)* from 128 scalp sites and at the sampling rate of 512 Hz. Horizontal and vertical eye movements were also recorded using the linked mastoids as the reference lead. The EEG and electro-oculogram (EOG) were amplified with a half-amplitude band pass of 0.016–100 Hz. Electrode impedance was maintained below 5 kΩ. EEG epochs were synchronized with the onset of the face presentation. Computerized artifact rejection was performed by means of *EEprobe-ANT* algorithm (Enschede, Netherlands) to discard epochs in which eye movements, blinks, excessive muscle potentials or amplifier blocking occurred. The channels considered for automatic artifact rejection procedure were HEOG, VEOG and FZ. The artifact rejection criterion was a peak-to-peak amplitude that exceeded 50 μV, which resulted in a rejection rate of ∼5% (SE = 0.65). ERPs were averaged from 100 ms before (−100 ms) to 1000 ms after stimulus onset. They were digitally filtered off-line with low-pass filter of 30 Hz. ERP components were identified and measured with respect to the average baseline voltage over the interval from −100 to 0 ms. Time windows and electrode sites were selected on the basis of where on the scalp and when in time the deflections reached their maximum with respect to the average baseline voltage (following the guidelines for psychophysiological recordings described in Zani and Proverbio (2003) and Picton et al. (2000). The mean area amplitude of the N200, which reached its maximum amplitude between 200 and 250 ms, and of FN400 component, which reached its maximum amplitude between 350 and 450 ms, were measured at anterior frontal and frontocentral sites (AFF1, AFF2, FC3, FC4). The mean area amplitude of the LP, which reached its maximum amplitude between 500 and 600 ms, was measured at centroparietal and parietal sites (CP1, CP2, P3, P4). The amplitude of the LAN was quantified between 650 and 850 ms at AF3, AF4, AFp3h, AFp4h electrode sites.

Multifactorial repeated-measures analyses of variance (ANOVA) were applied to ERP amplitude values. Factors were: face familiarity (Old, Recent, New), sex of the face with respect to the viewers (Same, Opposite), electrode (2 levels: AFF1,2 and FC3,4 for N200 and FN400 responses, and CP1,2 and P3,4 for LP component) and hemisphere (Left, Right) as within factor. Post-hoc comparisons were performed by using the Tukey test. Reaction times (RTs) that exceeded the mean value ± 2 standard deviations were discarded, which resulted in a rejection rate of about 5%. Data normality was assessed through Shapiro-Wilk test ($p < 0.15$).

Accuracy percentages were converted to arcsine values in order to undergo an analysis of variance. As well known (e.g., Snedecor & Cochran, 1989) percentage values do not respect homoscedasticity necessary for ANOVA data distribution and for this reason they need to be transformed in arcsine values. In fact the distribution of percentages is binomial while arcsine transformation of data makes the distribution normal.

The percentage of correct recognitions (hits) for old and recent faces, and of correct rejections for the new faces, were computed. Both RTs and accuracy percentages were subjected to separate multifactorial repeated-measures ANOVAs with 2 within-subject factors: Familiarity (with three levels: Old, Recent, New) and face sex (with two levels: Same, Opposite). The percentage of omissions was negligible (0.87%).

## 3. Results

### *3.1. Behavioral results*

*Hits (familiarity factor)*: The analysis of correct responses (recognition of known faces and rejection of unknown faces) revealed a main effect of Familiarity ($F_{2,42} = 6.06$, $p < 0.005$); post-hoc comparisons showed that participants were less accurate in the recognition of new faces (71.17%, SE = 2.01) compared to old ones ($p < 0.005$; 78.73%, SE = 1.38), while no difference was found in the percentage of correct recognition of old vs. recent faces, new vs. recent faces, same vs. opposite face sex or other interactive effects (see Fig. 3).

*RTs (familiarity factor):* The ANOVA performed on RTs revealed a significant effect of Familiarity ($F_{2,42} = 125.53$, $p < 0.00001$). Post-hoc comparisons showed that responses were significantly faster ($p < 0.0001$) to old (626.22 ms, SE = 10.98) than recent faces (668.31 ms, SE = 9.79). Furthermore both of them were faster ($p < 0.0001$) than responses to new faces (757.02 ms, SE = 14.9).

*RTs (Sex and familiarity × Sex interaction):* Moreover, the analysis revealed a significant main effect of Sex ($F_{1,21} = 5.94$, $p < 0.05$) with faster responses for Same-sex (675.54 ms, SE = 10.63) compared to Opposite-sex (692.16 ms, SE = 12.45) faces. Also, an almost significant interaction effect emerged between Familiarity and Sex ($F_{2,42} = 3.06$, $p = 0.057$); post-hoc comparisons showed that, when compared to Opposite-sex faces, Same-sex faces elicited faster RTs, but only for known faces, no matter whether recent ($p < 0.005$, Same: 655.25 ms, SE = 9.44; Opposite: M = 681.37, SE = 11.33) or old ($p < 0.05$; Same: 616.28 ms, SE = 11.36; Opposite: 636.16 ms, SE = 13.18).

Same-sex faces elicited faster RTs if compared to Opposite-sex ones, but only for known faces, whether recent faces ($p < 0.005$, Same: 655.25 ms, SE = 9.44; Opposite: M = 681.37, SE = 11.33) or old faces ($p < 0.05$; Same: 616.28 ms, SE = 11.36; Opposite: 636.16 ms, SE = 13.18). Conversely, face sex had no effect for new faces ($p = 0.99$; Same: 755.08 ms, SE = 14.08; Opposite: 758.95 ms, SE = 16.44). Overall, these effect are clearly visible in Fig. 4.

### *3.2. Electrophysiological results*

The grand-average ERPs recorded in response to old, recent and new faces are shown in Fig. 5. Responses related to the three kinds of stimuli differed in the amplitude of N200, FN400, LP and LAN responses, especially over prefrontal sites.

*3.3. Anterior N200 response*

*(Familiarity factor)*: The ANOVA performed on N200 area amplitudes (measured at anterior frontal and frontocentral sites between 200 and 250 ms) revealed a significant effect of Familiarity ($F_{2,36} = 8.27$, $p < 0.005$) for which processing of new faces was associated with a larger N200 (−4.41 μV, SE = 0.93) as compared to both old ($p < 0.001$; −3.29 μV, SE = 0.87) and recent faces ($p < 0.001$; −3.77 μV, SE = 0.87), with no significant difference between the latter. Moreover, the ANOVA revealed a significant effect of electrode ($F_{1,18} = 8.73$, $p < 0.01$) with larger N200 potentials at anterior frontal (−4.15 μV, SE = 0.9) than frontocentral (−3.5 μV, SE = 0.87) sites.

*3.4. FN400 response*

*(Familiarity factor)*: The ANOVA performed on the FN400 amplitudes (measured at anterior frontal and frontocentral sites between 350 and 450 ms) revealed a significant effect of Familiarity ($F_{2,36} = 32.66$, $p < 0.00001$). Post-hoc analysis showed that the new faces elicited larger FN400 responses (−3.7 μV, SE = 0.81) than old ($p < 0.0005$; −1.5 μV, SE = 0.78) and recent faces ($p < 0.0005$; −2.13 μV, SE = 0.77), while no significant difference was found between the latter. The FN400 modulation can be appreciated in Fig. 5. (*Electrode × Hemisphere interaction*): Moreover, a significant interaction effect was found for Electrode × Hemisphere factors ($F_{1,18} = 6{,}23$, $p < 0.05$): post-hoc comparisons revealed that the largest FN400 response was observed over the left frontocentral sites (all $p < 0.05$; FC3: −2.77 μV, SE = 0.77 ; FC4: −2.1 μV, SE = 0.76 ; AFF1: −2.42 μV, SE = 0.82 ; AFF2: −2.48 μV, SE = 0.81), as clearly visible from topographical maps of Fig. 6. *(Familiarity × Sex × Electrode × Hemisphere interaction):* Finally, post-hoc comparisons of the significant four-way interaction of Familiarity × Sex × Electrode × Hemisphere ($F_{2,36} = 3.13$, $p = 0.05$) showed that Opposite-sex faces elicited larger negativities than Same-sex ones, but only when the faces were familiar. This was true especially for recent faces (Old ($p < 0.05$): Same: −1.3 μV, SE = 0.79; Opposite: −1.7 μV, SE = 0.84; Recent ($p < 0.0005$): Same: −1.88 μV, SE = 0.81; Opposite: −2.39 μV, SE = 0.78), while no sex difference was observed for New faces.

*3.5. LP response*

*(Familiarity factor)*: The ANOVA performed on the LP amplitude (measured at centroparietal and parietal sites between 500 and 600 ms) revealed a significant effect of Familiarity ($F_{2,36} = 7.43$; $p < 0.00001$). In fact old faces (6.56 μV, SE = 0.66) elicited larger LP responses compared to recent faces ($p < 0.005$; 5.39 μV, SE = 0.54) which, in turn, elicited larger LP potentials than new faces ($p < 0.0005$; 3.15 μV, SE = 0.6). LP modulation can be appreciated in Fig. 5.

*(Electrode, and Hemisphere factors):* Also, the ANOVA revealed a significant main effect of electrode ($F1,18 = 9.32$, $p < 0.01$) with larger potentials at parietal (P3/P4: 5.51 µV, SE = 0.56) than centroparietal (CP1/CP2: 4.55 µV, SE = 0.62) sites. The Hemisphere main factor also proved to be significant ($F1,18 = 5.18$, $p < 0.5$), with larger LP responses over the right (5.23 µV, SE = 0.58) than the left hemisphere (4.83 µV, SE = 0.57).

*(Familiarity × Electrode, and Familiarity × Electrode × Hemisphere interactions):* Significant two way and three way interactions between Familiarity and Electrode ($F2,36 = 4.29$, $p < 0.05$) and Familiarity × electrode × Hemisphere ($F2,36 = 4.07$, $p < 0.05$), respectively, were also found. Post-hoc comparisons for these interactions showed that, overall, LP to old faces was larger over the right than left parietal area (Old: Overlearned: P4: 7.27 µV, SE = 0.68; P3: 6.53 µV, SE = 0.63. Recent: P4: 6.18 µV, SE = 0.57; P3: 5.59 µV, SE = 0.52.
New: P4: 3.99 µV, SE = 0.58; P3: 3.5 µV, SE = 0.59), and that the lateralization effect was smaller for the other face types and electrodes considered.

*(Sex factor and interactions):* The Sex main factor was also significant ($F1,18 = 8.53$, $p < 0.05$), with larger LP in response to same (5.38 µV; SE = 0.62) than opposite-sex faces (4.68 µV; SE = 0.55). However, the significant four-way interaction of Familiarity × Sex × Electrode × Hemisphere ($F2,36 = 3.34$, $p < 0.05$), and relative post-hoc comparisons, revealed that, although, as a whole, same-sex faces elicited larger LP than opposite-sex faces, the effect was particularly evident for recent faces. The effect emerged at parietal sites where no significant difference in LP amplitude was observed in response to old vs. recent faces whenever the faces belonged to the same-sex of viewer (P3: $p = 0.81$. Recent-same: 6.15 µV, SE = 0.57; old-opposite: 6.31 µV, SE = 0.64. P4: $p = 0.95$. Recent-same: 6.72 µV, SE = 0.63; old-opposite: 6.86 µV, SE = 0.7). The effect of face sex on LP modulation can be appreciated in Fig. 7 and in bargraph of Fig. 8.

### *3.6. Late anterior negativity (650–850 ms)*

*(Familiarity factor)*: The ANOVA performed on the LAN amplitudes measured at anterior frontal and prefrontal sites (AF3, AF4, AFp3h, AFp4h) revealed a significant effect of Familiarity ($F\ 2,36 = 9.2$,
$p < 0.00006$). In fact old faces (2.77 µV, SE = 0.62) elicited a smaller negativity as compared to recent faces ($p < 0.02$; 1.299 µV, SE = 0.58) and new faces ($p < 0.0005$; 0.58 µV, SE = 0.67), while the difference between the latter did not reach significance. No further effect of electrode, sex or hemisphere was found (see Fig. 9).

## 4. Discussion

The present paper was aimed at investigating whether the emotional content of recent information might overcome their weakness acting as a memory enhancer, able to strengthen and consolidate their memory in virtue of their emotional valence. With this aim, we com-pared the time course, amplitude and topography of ERPs elicited during recalling of old and solid information from long term memory (such as the faces of popular movie stars), with that of recently acquired emotional information (faces of fictional characters) as compared to new information (faces of previously unknown people).

*4.1. N200 and FN400: How emotional valence increases familiarity*

Our data showed that N200 anterior response was modulated by stimulus familiarity, similarly to FN400 response. This piece of data lends robust support to previous studies appeared in the recent literature (Lawson et al., 2012). In our study, recent and old faces elicited an equally smaller N2 response than new faces, with no effect of time recency. This finding suggests that the emotional valence strengthened the memory trace of recent faces, notwithstanding their recency. It can be assumed that both recently encountered (one week "old") and old faces required less prefrontal processing negativity than new faces at N200 level, because of their similar degree of visual familiarity (not-withstanding their profound difference in temporal recency). This interpretation agrees with neuroimaging literature on prefrontal encoding of unfamiliar information (e.g., Lee, Lee, Kim, & Jung, 2014; Tulving, Markowitsch, Craik, Habib, & Houle, 1996), as well as with electrophysiological literature predicting a smaller anterior negativity to more familiar than new items (e.g., Yonelinas, Aly, Wang, & Koen, 2010, Proverbio & Orlandi, 2016). At a more advanced processing stage FN400 response was also strongly modulated by face familiarity, being larger for new faces than known faces, and again equally large to old and recent faces. These results are consistent with available literature on face recognition (Curran & Hancock, 2007; Touryan, Gibson, Horne,

&Weber, 2011) suggesting that FN400 would reflect stimulus familiarity while later LP (in our study in the 500–600 ms latency range) would be associated with recollection. The functional distinction of the two components is also supported by their separate topographies over the scalp (Curran, 2000). In fact, in our case, the FN400 reached its maximum amplitude over the frontocentral sites, while the LP was more evident over parietal sites. In our study, accuracy data paralleled FN400 behavior, being sensitive to stimulus familiarity (regardless of learning recency). Hits percentage to old and recent faces (correct re-cognitions) were equally greater to those to new faces (correct rejections).

*4.2. LP: The effect of recency and face-sex on recollection*

On the other hand, response speed data (reflecting the efficiency/certainty of decisional processes), along with LP (parietal late positivity) data, were heavily sensitive to face temporal recency. Indeed, LP amplitude was larger to faces belonging to famous people (old), rather than fictional characters (recent). LP to known faces was much larger than to never encountered faces, indicating a lack of stimulus re-collection for the latter category. In the same vein, RTs were faster to old than recent faces, while new faces were processed with a considerable delay. Both RTs and LP measures possibly reflected the memory temporal recency, very likely related to engram robustness. Indeed it is possible to assume that face known for many years had a stronger and more redundant neural representation, due to the many recollections in different contexts, reactivations and re-coding across time (Kuhl, Bainbridge, & Chun, 2012) than faces learned only 7 days before (recent ones). Clinical literature (e.g., Müller, Mychajliw, Reichert, Melcher, & Leyhe, 2016) shows that in elderly and Alzheimer patients memory loss is reduced for remote compared to more recent life events, and that this also depends on the number of trace re-activations (retrieval frequency of autobiographical memories). This is of particular interest in the light of the ERP literature indicating the generators of LP as lying in the hippocampal formation. For example, Hoppstädter et al. (2015) recorded simultaneous EEG-fMRI signals study during an old/new memory task for words and found that the early frontal effect (350–550 ms) was based on a the dorsolateral pre-frontal cortex activation while the late parietal old new effect (580–750 ms) was based on the activation of the right posterior hippocampus, parahippocampal cortex and retrosplenial cortex.

As for the other variables of interest, face sex significantly affected memory recollection of recent information ("victims"). Effects were found both at behavioral and electrophysiological level. In fact, RTs showed a significant effect of Familiarity × Sex, with faster responses for own- than opposite-sex faces. Previous research on emotions and empathic resonance or mimicry (i.e., an intersubjective induction process by which the observation of an emotion elicits the activation of an analogous representation in the observers (Decety & Meyer, 2008) showed that some specific factors can facilitate emotional mirroring, like perceived similarity; it can influence empathic responding through the tendency to identify more closely with others who appear as being more similar in appearance (Bufalari et al., 2015). This effect was also found, for example, for ingroup versus outgroup identification bias (Tajfel and Turner, 1986) and could have emerged in the case of own-sex faces in the present study. Quite interestingly LP response was larger to familiar faces of viewer's own sex (either male or female). What is more interesting, nonetheless, is that the effect was particularly evident for recent faces (i.e. victims). Indeed there was no difference in the LP recorded in response to old vs recent own-sex faces. This suggests that the emotional content enhanced recollection of faces of own sex, possibly indicating that the threatening circumstances of victims' death had a stronger emotional impact when the character shared the sex with the participant. As already discussed in the Introduction, memory recognition of a face can be influenced by the specific context at en-coding time (Megreya & Burton, 2008), the type of the facial expressions (D'Argembeau & Van der Linden, 2011) or the level of the ob-server empathy (Bate, Parris, Haslam, & Kay, 2010). In our case the context provided during encoding was strongly emotional. Observation of victims face (in 6 different shots) was associated with details relative to their murder, rape or dramatic death. In all cases, persons were depicted as very nice and affectionate persons in life, with honorable and estimable professions, leaving small children (e.g. twin baby girls) or inconsolable spouses. Since victim faces were recent, and probably less familiar than movie stars, as known for a shorter time (a week vs. more than 5 years), as also revealed by slower response times and smaller LP amplitudes, the lack of FN400 difference for old vs. recent (victim) faces might be interpreted as an effect of additional emotional information regarding these characters that might (supposedly) re-inforced memory encoding.

More generally, the influence of emotions on memory has been demonstrated by using various types of materials, including complex real-life events (D'Argembeau, Comblain, & Van der Linden, 2005; Talarico, LaBar, & Rubin, 2004), film clips or slide shows

(Burke, Heuer, & Reisberg, 1992; Christianson, Loftus, Hoffman, & Loftus, 1991), and lists of words or pictures (Holland & Kensinger, 2013; Kensinger, 2004; LaBar & Cabeza, 2006; Phelps, 2004). It seems that emotionally significant stimuli are processed more efficiently than neutral stimuli. According to some authors (Richardson, Strange, & Dolan, 2004) the reason for the enhanced memory of emotional stimuli would depend on an amygdala-based hippocampal modulation. Indeed, while the hippocampus is a critical site for processes related to neuronal encoding, reciprocal modulatory influences between the left amygdala and hippocampus have been demonstrated for effective encoding of emotional material. And indeed, amygdala nuclei (in interaction with the hippocampus) would play a crucial role in memory for stimuli that possess affective or motivational significance (Anderson & Phelps, 2001; Bengner & Malina, 2007; Phelps, 2004).

### *4.3. LAN: The effect of temporal recency*

In a later range of processing (between 650 and 850 ms) LAN differed in amplitude to old than recent faces, thus showing a dissociation with earlier N200 and FN400 components and LP behavior. While the former were sensitive to face familiarity and did not discriminate be-tween old and recent faces, LP showed an effect of temporal recency but in interaction of face sex, possibly indexing a more conscious re-collection of faces, as discussed earlier. LAN only reflected temporal recency.

The scalp distributions of LAN suggest a possible reflection of epi-sodic retrieval, and especially source memory (Herron & Wilding, 2006; Ranganath & Paller, 1999; Wilding & Rugg, 1996). Source memory has been specifically studied for example byWilding and Rugg (1996) in an ERP study in which they compared memory recall of visually presented words in an old/new recognition paradigm. For words recognized as familiar, participants had to determine if they had been spoken by a male or female speaker (i.e. the circumstances of learning, or source memory).

They found that words correctly recognized as old elicited an enhanced parietal positivity (old/new parietal effect) starting at about 400 ms, while words correctly associated with the learning circum-stances (source memory) elicited a right frontal Late Positivity. In our study it might be hypothesized that the much larger positivity (in LAN range) to old than recent faces might relate to their degree of source memory content (since movie stars have been "encountered" repeatedly and in different time periods and circumstances, as opposed to the rather focussed and concentrated one week study of recent faces. It should be however mentioned that no overt recall of source memory in-formation was specifically required to perform the present task.

## 5. Conclusions

Overall, the present findings showed that the emotional content of recently learnt faces might enhance their memory traces regardless of their recency, making them as familiar as faces known for a long time. Accuracy and early negative potentials (N200 and FN400) indexing familiarity (Curran, 1999, 2000) were greater to old and recent (than new faces) with no distinctions between the two categories, thus suggesting a strong effect of the emotional manipulation of recent information. On the other hand LP indexing conscious recollection (Evans &Wilding, 2012; Hoppstädter et al., 2015) was larger to less recent than old information, thus showing that vivid recollection is affected by temporal recency. However, recent own-sex faces were better re-collected than other-sex faces (Yaoi, Osaka, & Osaka, 2015), by showing again the effect of stimulus emotional valence on memory. Interest-ingly, reaction times paralleled LP behavior, being faster to less recent than newer information and to own- than other-sex faces.

LAN potential, reflecting source memory (e.g., Ranganath & Paller, 1999; Ranganath & Jenkins, 2010) was only sensitive to temporal recency.

One limit of the present study is that the experimental design con-founds emotional valence and recency; victims faces were both higher in valence and more recently studied. Presently, the study design cannot distinguish the two factors. However, this specific manipulation has been intentionally designed to investigate whether the emotional valence of a weak recent memory trace might increase its strength in a way similar to what time does to old solid traces. In addition, we wished to find out which were the specific ERP markers reflecting stimulus temporal recency on one hand, and familiarity on the other hand, and which of the two was affected by emotional valence. So, the apparent overlapping was disentangled by the dissociation of ERP effects. Anyhow further investigations adopting a different experimental design might possibly solve in the future some of the unresolved issues.

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