Effects of attractiveness on face memory separated from distinctiveness: Evidence from event-related brain potentials.

Holger Wiese*, Carolin S. Altmann*, Stefan R. Schweinberger

DFG Research Unit Person Perception and Department of General Psychology and Cognitive Neuroscience, Friedrich Schiller University of Jena, Jena, Germany

Corresponding author:

Holger Wiese

DFG Research Unit Person Perception

Friedrich Schiller University of Jena

Am Steiger 3/1

07743 Jena

Germany

Phone: +49 (0)3641 945185

Fax: +49 (0)3641 945182

E-Mail: holger.wiese@uni-jena.de

* These authors contributed equally to this work

Abstract

The present study examined effects of attractiveness on behavioral and event-related potential (ERP) correlates of face memory. Extending previous reports, we controlled for potential moderating effects of distinctiveness, a variable known to affect memory. Attractive and unattractive faces were selected on the basis of a rating study, and were matched for distinctiveness. In a subsequent recognition memory experiment, we found more accurate memory for unattractive relative to attractive faces. Additionally, an attractiveness effect in the Early Posterior Negativity (EPN) during learning, with larger amplitudes for attractive than unattractive faces, correlated significantly with the magnitude of the memory advantage for unattractive faces at test. These findings establish a contribution of attractiveness to face memory over and above the well-known effect of distinctiveness. Additionally, as the EPN is typically enhanced for affective stimuli, our ERP results imply that the processing of emotionally relevant attractive faces during learning may hamper their encoding into memory.

Keywords: Event-related potentials, faces, attractiveness, distinctiveness, recognition

1. Introduction

Attractive people profit from multiple advantages in social interactions due to their appealing looks. For instance, attractive children achieve both better marks and more attention in class (Lerner & Lerner, 1977), and as adults, beautiful individuals are more successful in their professions and are helped more readily in dire situations (Benson, Karabenick, & Lerner, 1976; Harrell, 1978; Mims, Hartnett, & Nay, 1975). Whereas attractiveness is thus usually considered a highly desirable attribute, it is largely unclear whether attractive people are also particularly memorable.

A number of studies examined memory for attractive and unattractive faces, with rather discrepant results. Several studies reported more accurate memory for attractive relative to unattractive faces (Cross, Cross, & Daly, 1971; Marzi & Viggiano, 2010; Zhang et al., 2011), whereas others either found the opposite pattern (Light, Hollander, & Kayra-Stuart, 1981; Sarno & Alley, 1997), or no difference in memory (Brigham, 1990; Wickham & Morris, 2003). We considered that this inconsistency may be partly related to other facial characteristics which were not systematically controlled in previous research. A particularly important characteristic in this context is distinctiveness. Highly distinctive faces strongly deviate from an average or prototypical face, as they, for instance, contain unusually sized or shaped facial features (such as particularly small eyes), or unusual facial texture or colouration. By contrast, less distinctive or typical faces are perceptually closer to the prototype. Importantly, it is well known that distinctive faces are remembered particularly well (e.g., Valentine, 1991), such that more accurate memory for either attractive or unattractive faces in previous studies may have been influenced by differences in distinctiveness in the respective sets of faces.

Most theoretical accounts on facial attractiveness suggest a systematic relationship to distinctiveness. The direction of this relation, however, is a matter of scientific debate.

Initially, it had been suggested that attractive faces are 'average', and thus typical rather than distinctive. This suggestion is supported by results indicating that an average face, created by merging a number of individual faces into a single face morph, is typically rated as more attractive than the individual faces that constitute the morph (Langlois & Roggman, 1990). Averageness per se, however, cannot fully explain why certain faces are judged as more attractive than others. For instance, DeBruine, Jones, Unger, Little, and Feinberg (2007) demonstrated that a morph across highly attractive faces was rated as more attractive than a morph across randomly chosen faces. In addition, systematic deviations from the average towards increased sexual dimorphisms (such as pronounced cheek bones in male faces) are perceived as more attractive than average characteristics (Perrett et al., 1998). Recently, it has been reported that averageness is attractive in some dimensions (especially those related to shape information) but not in others (particularly those related to reflectance information; Said & Todorov, 2011). In sum, it seems justified to conclude that distinctiveness (or averageness) explains variance in attractiveness ratings, and thus may affect memory differences between attractive and unattractive faces. Critically, the main question for the present study was whether and how attractiveness modulates face memory, even when distinctiveness is held constant for attractive and unattractive faces.

Distinctiveness is traditionally measured with so-called Face-In-The-Crowd (FITC) ratings, in which participants indicate how likely they would spot a given face in a crowd of people (e.g., Valentine & Endo, 1992). This measure, however, may not be ideal in the present context, as attractiveness potentially biases such ratings, i.e., participants may have a tendency to indicate a high probability of detecting a face in a crowd because it is attractive, independent of whether the face is typical or distinct ('I would notice such a beautiful person'). Deviation measures have therefore been introduced as an alternative to assess distinctiveness (Wickham & Morris, 2003). Here, participants rate how strongly a face deviates from typical or average familiar faces. We considered that these two measures of distinctiveness might only partially relate to the same construct, and would not necessarily relate to attractiveness in the same manner.

Apart from distinctiveness, other factors may also influence memory for attractive versus unattractive faces. For instance, a recent socio-cognitive account suggests that participants' motivation to individuate faces affects memory (Hugenberg, Young, Bernstein, & Sacco, 2010). In support of this, participants have been reported to more accurately recognize faces randomly assigned to their own university, compared to faces assigned to a different university (Bernstein, Young, & Hugenberg, 2007), a finding which was thought to reflect the higher motivation to individualize social in- relative to out-group faces. Of relevance, it has been reported that attractive faces are more likely categorized as belonging to the viewer's social in- rather than out-group (Johnson, 1981), and that participants are more motivated to view attractive faces (Aharon et al., 2001). Accordingly, socio-cognitive accounts would predict more accurate memory for attractive relative to unattractive faces, an effect which should be more likely detected if other contributing factors such as distinctiveness are controlled for.

Importantly, behavioral measures of recognition memory only depict the outcome of a cascade of cognitive sub-processes. By contrast, the analysis of event-related potentials (ERP) allows investigating neural correlates of these processes as they unfold over time, and by inference to identify the underlying cognitive or affective mechanisms. The first component typically examined in face processing studies is the P1, a positive peak at occipital sites occurring approximately 100 ms post stimulus presentation. This component is sensitive to physical stimulus characteristics, such as luminance or contrast (Luck, 2005), and may thus reflect early stages of visual processing.

The following occipito-temporal N170 (Bentin, Allison, Puce, Perez, & McCarthy, 1996), a negative peak at approximately 170 ms, is typically larger for face stimuli relative to other object classes (see e.g., Eimer, 2011). It is commonly assumed to reflect structural face encoding (Eimer, 2000) or the detection of a face-like pattern in the visual field (Amihai, Deouell, & Bentin, 2011; Schweinberger & Burton, 2003). Previous reports of attractiveness effects on the N170 are inconsistent, with some studies reporting larger N170 to unattractive faces (experiment 2 in Halit, de Haan, & Johnson, 2000), others reporting larger amplitudes to attractive faces (Marzi & Viggiano, 2010), and still others reporting no difference (Roye, Höfel, & Jacobsen, 2008; Schacht, Werheid, & Sommer, 2008).

Subsequent to N170, a positive occipito-temporal peak is observed at approximately 220-250 ms. This P2 has been interpreted to reflect the processing of metric distances between facial features (e.g., Latinus & Taylor, 2006) or the perceived typicality of a face (e.g., Wiese, Kaufmann, & Schweinberger, in press), and is modulated by an observer's expertise with a specific facial category (Stahl, Wiese, & Schweinberger, 2008). Interestingly, a number of recent studies found smaller P2 components for naturally distinctive relative to more typical faces (Schulz, Kaufmann, Kurt, & Schweinberger, 2012), as well as for spatial caricatures relative to veridical faces (Kaufmann & Schweinberger, 2012; Schulz, Kaufmann, Walther, & Schweinberger, 2012). To the best of our knowledge, no previous study examined attractiveness effects on P2 using natural faces (though Halit et al., 2000, experiment 1, report a smaller P2 for unattractive faces with artificially increased distances between features).

The following negative wave, the N250, is known to be larger for learned relative to novel facial identities (Kaufmann, Schweinberger, & Burton, 2009; Tanaka, Curran, Porterfield, & Collins, 2006). Previous recognition memory studies observed stronger memory effects in the N250 time range for specific categories of faces, for instance for young relative to old faces in young participants (e.g., Wiese, Schweinberger, & Hansen, 2008). Moreover, distinctive faces have been reported to elicit larger N250 amplitudes than typical faces (Schulz, Kaufmann, Kurt, et al., 2012; Schulz, Kaufmann, Walther, et al., 2012). Importantly, previous studies also reported more negative amplitudes for attractive relative to unattractive faces in the so-called early posterior negativity (EPN; e.g., Werheid, Schacht, &

Sommer, 2007). EPN is typically interpreted as reflecting enhanced perceptual processing of affective stimuli, and has been found to be larger for emotional relative to neutral faces (Rellecke, Sommer, & Schacht, 2012; Schupp et al., 2004) and for affective relative to neutral pictures (Schupp et al., 2007). The N250 and EPN originate from different research traditions, and may therefore be assumed to reflect different processes. However, they substantially overlap with respect to timing and scalp topography, which may complicate an unequivocal interpretation of a given ERP effect as reflecting an N250 or EPN in this time range. For the present study, it was of particular interest whether or not any larger N250/EPN amplitudes for attractive faces in previous studies were related to enhanced distinctiveness.

Finally, a late posterior component (LPC) typically occurs at centro-parietal scalp sites and is maximal between 300 and 700 ms. The LPC has been observed to be larger for affective than neutral pictures (Schupp et al., 2007), for emotional than neutral facial expressions (Schacht et al., 2008; Schupp et al., 2004), and for distinctive than typical faces (Schulz, Kaufmann, Kurt, et al., 2012; Schulz, Kaufmann, Walther, et al., 2012). The LPC has been interpreted as reflecting an engagement towards motivationally significant stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000), and has also been shown to be larger for attractive relative to unattractive faces (Schacht et al., 2008; Werheid et al., 2007). Importantly, ERP effects of episodic memory occur in a similar time range. These so-called old/new effects reflect more positive amplitudes for correctly remembered learned (i.e., hits) relative to correctly rejected new items (i.e., correct rejections) and are commonly subdivided into an earlier frontal (300 – 500 ms) and a later more posterior effect (500 - 700 ms; see e.g., Rugg & Curran, 2007). While most researchers agree that the later old/new effect reflects recollection, i.e., the conscious retrieval of study phase detail, the exact processes reflected by the earlier effect are still debated (e.g., Curran, 2000; Paller, Voss, & Boehm, 2007). Of particular interest, Marzi and Viggiano (2010) found an early old/new effect for attractive but not for unattractive faces, which they interpreted as enhanced familiarity-based recognition, i.e., a stronger feeling of knowing for attractive faces.

In light of the literature discussed above, the aims of the present study were threefold: First, we aimed at determining effects of attractiveness on face memory while controlling for effects of distinctiveness. In doing so, we reasoned that the discrepancies regarding effects of attractiveness on face memory may well reflect differential confounds with distinctiveness that had been largely neglected in earlier research. Second, we aimed to test whether attractive relative to unattractive faces elicited larger amplitudes in the N250/EPN and LPC components when stimuli are matched for distinctiveness, as previous results could similarly have been confounded by this variable. Finally, the only previous study on ERP correlates of memory for attractive versus unattractive faces revealed an early old/new effect for attractive faces only. Again, we wanted to examine whether this effect was related to distinctiveness. To address these issues, we first conducted a rating experiment in which two measures of distinctiveness (deviation and FITC) and attractiveness were assessed in a large set of face stimuli. In a second step, we then tested ERP correlates of recognition memory for subsets of attractive and unattractive faces that were matched for distinctiveness.

2. Rating study

2.1. Methods

2.1.1. Participants

20 participants (18 – 35 years; *M* = 23.8 years ± 3.08 *SD*; 10 female) were recruited and gave written informed consent prior to testing. All participants reported normal or corrected to normal vision and were right-handed as assessed by the Edinburgh Handedness

Inventory (Oldfield, 1971). None of the participants reported neurological or psychiatric disorders. Participants received either course credit or monetary reimbursement after testing.

2.1.2. Stimuli

We collected 560 full-color facial photographs of young adults (50 % female faces) from various internet sources. Using Adobe Photoshop CS5™ all pictures were cropped to show only the face without clothing or hair, and placed before a standardized black background with a constant image size of 440 x 400 pixels, corresponding to a viewing angle of approximately 7.4° x 6.9° at a viewing distance of 90 cm. Luminance of each individual face (without background) was equated to match the overall mean luminance of all faces by employing gradation curve adjustments in Photoshop. All stimuli were presented on a 17' CRT computer monitor using *E*-Prime™.

2.1.3. Procedure and experimental design

Participants were seated in a dimly lit room with their head in a chin rest positioned approximately 90 cm away from a computer screen. In one block, participants were asked to rate the attractiveness of every face on a six-point scale (from 1 = very unattractive to 6 = very attractive). In one further block, a face-in-the-crowd (FITC) measure of distinctiveness for each of the faces was obtained following Valentine and Bruce (1986). Participants were instructed to rate distinctiveness on a scale between 1 (very lowly distinctive) and 6 (very distinctive) by asking themselves how easily they would spot the face in a group of people (e.g., a crowded platform). In a third block, a second measure of distinctiveness was assessed using an adapted version of the deviation ratings used by Wickham and Morris (2003). Participants were asked to rate typicality based on the extent to which the presented faces deviated from other faces that they know on a scale between 1 and 6 (1 = very typical to 6 = very atypical). To avoid any systematic effect of a previous task on the present block, task order was randomized across participants.

Each participant was presented with one of two subsets of 280 pictures (50% female, respectively). Images remained on the screen until a response was recorded, and participants were instructed to respond as spontaneously as possible.

2.2. Results

A common measure of inter-rater reliability indicated good agreement for attractiveness ratings (Cronbach's alpha = .86). In addition we calculated the permeation coefficient (see Bronstad & Russell, 2007), which reflects the proportion of shared variance (r^2) between an individual rater and the average ratings. The mean coefficient was 0.44 (± 0.11 *SD*), and substantially larger than the values reported in Bronstad & Russell (2007), again indicating good inter-rater agreement.

On average, faces were rated as being slightly less attractive than the mid-point of the scale (M = 3.08 ± 0.03 *SD*). Similarly, on average, face stimuli were rated as rather non-distinctive, both on the FITC (M = 3.09 ± 0.03 *SD*) and the deviation scale (M = 2.96 ± 0.03 *SD*)[1]. To analyze interrelations between these measures, Spearman's Rho (ρ) was calculated for each combination of these variables. Importantly, this procedure revealed a significant positive correlation between rated attractiveness and the FITC measure ($\rho[558] = .24$, $p < .001$), but a negative correlation between attractiveness and the deviation measure ($\rho[558] = -.35$, $p < .001$). Accordingly, more attractive faces were rated as more distinct as assessed by the FITC measure, but were rated as less distinct as assessed by the deviation measure. Finally, a significant positive correlation between the FITC and deviation measures was observed, ($\rho[558] = .46$, $p < .001$). Overall, this pattern of results suggests that a non-shared portion of variance between the FITC and deviation measures largely drives the reversed correlations with the attractiveness measure.

[1] To compare the difficulty of the FITC and deviation task, we analyzed response times, which were highly similar (FITC: M = 2007.84 ± 708.68 *SD*, deviation: M = 2016.61 ± 830.58 *SD*; $t[19]$=.097, p=0.923, Cohen's d = 0.01).

To further investigate the independent and combined influences of both distinctiveness measures on attractiveness ratings, stepwise multiple linear regression analyses were performed using deviation and FITC as regressors. Deviation alone significantly predicted perceived attractiveness explaining 12 % of its variance ($R^2 = .12$; $\beta = -.35$; $F[1, 558] = 76.24$; $p < 0.001$). In a second model, FITC alone yielded a significant relation, explaining 6.1 % of variance ($R^2 = .061$; $\beta = .25$; $F[1, 558] = 37.34$; $p < .001$). Taking both predictors into account in a combined model resulted in a significant increase in explained variance as compared to both single-regressor models ($R^2_{combined} = .37$; $F[1,557] = 164.1$; $\beta_{Deviation} = -.65$; $\beta_{FITC} = .58$; $p < .001$; $\Delta R^2_{Deviation} = .25$, $\Delta F_{Deviation}[1, 557] = 221.82$; $p < .001$; $\Delta R^2_{FITC} = .31$, $\Delta F_{FITC}[1,557] = 272.82$; $p < .001$).

3. Recognition Experiment

3.1. Methods

3.1.2. Participants

We recruited 20 participants (ten female, mean age = 24 years ± 2.4 *SD*, all right-handed according to the Edinburgh Handedness Inventory), who had not participated in the rating experiment. Data from five additional participants had to be excluded from analyses due to insufficient trial numbers for ERP averaging ($N < 15$) and/or chance performance in the memory task. All participants reported normal or corrected to normal vision, and none reported neurological or psychiatric disorders. All participants either received a monetary compensation of 5€/h or course credits, and gave written informed consent prior to testing.

3.1.2. Stimuli

Two hundred faces rated as either unattractive ($M = 2.17 \pm 0.32$ *SD*) or attractive ($M = 4.19 \pm 0.43$ *SD*) were chosen from the stimulus pool of Experiment 1 (50% female, respectively), with the mean of each category being approximately equidistant from the mean rated attractiveness in the whole set of Experiment 1. To minimize saccades during EEG-recording, image size was down-sampled to 275 x 250 px, corresponding to a viewing angle of approximately 4.6° x 4.4° at a viewing distance of 90 cm. Importantly, faces in both attractiveness groups were matched as closely as possible for deviation ($M_{attractive}$ = 3.11 ± 0.49 *SD*; $M_{unattractive}$ = 3.24 ± 0.56 *SD*). At the same time, FITC ratings for attractive faces were slightly higher relative to unattractive faces ($M_{attractive}$ = 3.48 ± 0.59 *SD*; $M_{unattractive}$ = 2.74 ± 0.67 *SD*). We decided to match the stimuli for perceived deviation rather than the FITC score, as this measure was presumably less biased (see introduction) and additionally explained more variance in the attractiveness ratings. Mann-Whitney-U tests were calculated to test for differences between stimulus ratings. The two face categories differed significantly with regard to attractiveness ($U = 10,000.00$; $z = 12.23$; $df = 198$; $p < .001$; $r = .86$), as expected, but not with respect to deviation ($U = 4,291.5$; $z = -1.73$; $df = 198$; $p = .083$; $r = -.12$). By contrast, the test of the FITC measure revealed higher scores for attractive relative to unattractive faces ($U = 8,206.50$; $z = 7.84$; $df = 198$; $p < .001$; $r = .55$).

3.1.3. Experimental Design and Procedure

Participants were seated in an electrically shielded and sound-attenuated cabin (400-A-CT-Special, Industrial Acoustics, Niederkrüchten, Germany), with their head in a chin rest approximately 90 cm away from a computer monitor. Each session began with a short practice block, which was excluded from data analysis. The main experiment consisted of 4 blocks, each divided into a study and a subsequent test phase. During each study phase 25 faces (50% attractive, 50% female across blocks) were presented in randomized order. Participants were instructed to categorize the faces according to gender via key presses and memorize them. Each study trial consisted of a fixation cross (500 ms), followed by a face stimulus (5 s) and a final blank screen (500 ms). Study and test phases were separated by fixed breaks of 30 s duration. In each of the subsequent test phases, those 25 faces shown in the immediately preceding study phase and additional 25 new faces were presented for 2000 ms in randomized order. Thus, across blocks, 50 old attractive, 50 old unattractive, 50 new attractive, and 50 new unattractive faces were presented during the test phases. Each test phase trial started with an initial fixation cross (500 ms) and ended with a blank screen (500 ms). Participants were instructed to indicate via key presses whether the faces had been presented in the preceding study phase ("old") or not ("new"). In case of an "old" response, an additional remember/know/guess decision was requested (see Gardiner & Richardson-Klavehn, 2000). Key allocation and assignment of stimuli to studied or non-studied conditions was counterbalanced across participants.

For the study phases, mean correct reaction times (RT) and accuracies served as dependent variables. Behavioral test phase data was analyzed according to signal detection theory (Green & Swets, 1966). Trials were sorted into hits (correctly identified studied faces), misses (studied faces wrongly classified as new), correct rejections (CR, new faces correctly identified as new), and false alarms (FA, new faces wrongly classified as studied), separately for attractive and unattractive faces. Measures of sensitivity (d') and response bias (C) were calculated. Statistical analyses were performed by means of paired samples t-tests and repeated-measures analyses of variance (ANOVAs), with degrees of freedom corrected via the Greenhouse-Geisser procedure where appropriate.

3.1.4. EEG recording and analyses

EEG was recorded from 32 active sintered Ag/Ag-Cl electrodes using a Biosemi Active II system (BioSemi, Amsterdam, Netherlands). Please note that BioSemi systems work with a "zero-Ref" set-up with ground and reference electrodes replaced by a so-called CMS/DRL circuit (cf. http://www.biosemi.com/faq/cms&drl.htm for further information). EEG was recorded continuously with a 512-Hz sample rate from DC to 155 Hz. Recording sites corresponded to an extended version of the 10-20-system (Fz, Cz, Pz, Iz, FP1, FP2, F3,

F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, F9, F10, FT9, FT10, TP9, TP10, P9, P10, PO9, PO10, I1 and I2).

Blinks were corrected using the algorithm implemented in BESA 5.1.8 (see Berg & Scherg, 1994). EEG was then segmented from −200 until 1000 ms relative to stimulus onset, with the first 200 ms serving as a baseline. Artifact rejection was carried out using an amplitude threshold of 100 µV and a gradient criterion of 50 µV. Only trials with correct responses in the study and test phase (hits, CR) were analyzed. The remaining trials were recalculated to average reference, averaged according to experimental condition and digitally low-pass filtered at 40 Hz (12 db/oct, zero phase shift). Three different waveforms (study phase, hits, CR) were calculated separately for attractive and unattractive faces. The minimum number of trials for an individual subject in any of these conditions was 15 (mean number of trials = 32.4).

Mean amplitude of the P1 (100 – 140 ms) was analyzed at O1/O2, while mean amplitudes of N170 (145 - 185 ms), P2 (220 - 270 ms), and N250/EPN (270 - 400 ms) were analyzed at electrode sites P9/P10. Two additional time windows (300 – 500 ms and 500 – 700 ms) were inspected at electrodes Fz, Cz, Pz, F3, F4, C3, C4, P3, P4, to capture the LPC and old/new effects at test (see e.g. Rugg & Curran, 2007).

3.2. Results

3.2.1. Behavioral Results

During learning, gender categorizations were slightly faster on average for attractive than unattractive faces ($t[19] = -2.13$; $p = .047$; $d = -0.15$; see Table 1). Attractive faces were also categorized more accurately than unattractive faces ($t[19] = 5.92$; $p < .001$; $d = 1.96$).

At test, a paired samples t-test on *d'* revealed less accurate memory for attractive as compared to unattractive faces ($t[19] = -3.5$; $p = .002$; $d = -0.70$)[2]. Moreover, the response

[2] Following a reviewer's suggestion, we additionally inspected effects of participant and stimulus sex on memory for attractive and unattractive faces in an exploratory analysis to test whether memory would be more

bias measure *C* was less conservative for attractive relative to unattractive faces ($t[19] = -7.7$; $p < .001$; $d = -1.00$).

An additional analysis on correct responses was conducted by calculating a repeated-measures ANOVA with the factors attractiveness (attractive, unattractive) and response type (correct rejections, hits). This analysis yielded a significant main effect of response type, with more correct rejections than hits ($F[1,19] = 6.44$; $p = 0.02$; $\eta p^2 = 0.25$), as well as a significant interaction ($F[1,19] = 24.73$; $p < 0.001$; $\eta p^2 = 0.57$). Pairwise comparisons revealed higher hit rates ($t[19] = -2.85$; $p = 0.01$; $d = 0.43$), but lower correct rejection rates for attractive relative to unattractive faces ($t[19] = 4.43$; $p < 0.001$; $d = -0.87$), again reflecting a less conservative criterion for attractive faces.

To analyze the 'Remember/Know' ratings, the mean percentage of remember, know, and guess responses for each face category relative to all possible hits per condition ($N = 50$) was calculated (see e.g. Gardiner, Java, & Richardson-Klavehn, 1996; see Table 1; Gardiner & Richardson-Klavehn, 2000). A repeated-measures ANOVA with attractiveness (attractive, unattractive) and response type (remember, know, guess) was calculated. This analysis revealed significant main effects of attractiveness ($F[1,19] = 8.33$; $p = .009$; $\eta_p^2 = 0.31$), indicating overall more judgments for attractive than unattractive faces (reflecting the higher hit rate for attractive faces). A further main effect of response type ($F[1.12,21.29] = 93.16$; $p < .001$; $\eta_p^2 = 0.83$) reflected substantially more remember relative to know responses, which in turn were more frequent than guess responses. More importantly, the response factor did not interact with attractiveness ($F[2,38] = 1.6$; $p = .215$; $\eta_p^2 = 0.08$), which is suggestive of similar contributions of recollection and familiarity to the recognition of attractive versus unattractive faces.

---

accurate for attractive opposite-sex faces. A corresponding mixed-model ANOVA revealed no significant interaction of stimulus sex x participant sex x attractiveness ($F < 1$). Numerically, attractive faces were remembered less accurately than unattractive faces in all combinations of participant and stimulus sex.

To test for a potential influence of distinctiveness as assessed by the FITC measure on memory, an additional item analysis was conducted. A univariate ANCOVA with item d' as cases, attractiveness as a two-level between-items factor, and FITC as a covariate yielded a significant effect of FITC ($F[1,197] = 17.69$; $p < .001$; $\eta_p^2 = 0.08$), with larger FITC scores relating to more accurate memory. Importantly, the main effect of attractiveness, with more accurate memory for unattractive relative to attractive faces, was still significant in this analysis ($F[1,197] = 21.87$; $p < .001$; $\eta_p^2 = 0.10$).

3.2.2. Event-related Potentials

For the learning phase, ERP analyses were conducted by calculating repeated-measures ANOVAs with the within-subject factors attractiveness (attractive, unattractive) and hemisphere (left, right). For the test phases, the additional factor response type (hits, CR) was included. In our report of ERP analyses below, we focus on effects of facial attractiveness, memory and interactions of these factors. Main effects and interactions with factors exclusively specifying electrode positions are omitted.

During learning, no significant main effects or interactions of interest were found in P1, N170 and P2 (all *F*s < 2.75, all *p*s > .114; see figure 1). Although P1 amplitude was slightly larger for unattractive faces at electrode O2 during learning (see figure 1), no significant interaction of hemisphere x attractiveness was observed ($F[1,19] = 1.59$; $p = .222$; $\eta_p^2 = 0.078$).

In the N250 time range, attractive faces elicited more negative amplitudes than unattractive faces ($M_{attr} = -2.33$ µV ± 0.46 *SD*; $M_{unattr} = -1.62$ µV ± 0.49 *SD*; $F[1,19] = 10.40$; $p = .004$; $\eta_p^2 = 0.35$). Critically, this difference in N250 during learning (mean amplitudes of unattractive – attractive faces, measured at P10) correlated significantly with the differences in d' at test (unattractive – attractive faces; $r[18] = .545$; $p = .013$). No significant analogous correlation was obtained with the difference in response criterion C at test ($r[18] = .316$; $p =$

.174). Moreover, to analyze the LPC, two repeated-measures ANOVAs with topographical factors laterality (left, midline, right) and site (frontal, central, parietal) were calculated for two time ranges (300-500 ms, 500-700 ms). In the 300-500 ms time window a main effect for attractiveness was found (M_{attr} = 2.72 µV ± 0.49 *SD*; M_{unattr} = 1.79 µV ± 0.46 *SD*; $F[1,19] = 13.11$; $p = .002$; $\eta_p^2 = 0.41$), reflecting larger amplitudes for attractive relative to unattractive faces (see figure 2). A corresponding main effect of attractiveness was also observed between 500-700 ms (M_{attr} = 4.38 µV ± 0.48 *SD*; M_{unattr} = 3.55 µV ± 0.43 *SD*; $F[1,19] = 7.14$; $p = .015$; $\eta_p^2 = 0.27$). LPC attractiveness effects measured at Cz did neither correlate significantly with attractiveness effects in d' nor C (all |*r*s| [18] < .224, all *p*s > .344).

At test, no significant effects of interest were observed in P1 and N170 (see figure 3). Of note, in the N170 time range a statistical trend for a main effect of attractiveness was found ($F[1,19] = 4.08$; $p = 0.058$; $\eta_p^2 = 0.18$), indicating marginally larger N170 amplitudes for attractive faces. In the subsequent P2 time range, a main effect of attractiveness was observed (M_{attr} = -1.97 µV ± 0.58 *SD*; M_{unattr} = -1.49 µV ± 0.50 *SD*; $F[1,19] = 7.50$; $p = 0.013$; $\eta_p^2 = 0.28$), with attractive faces eliciting smaller P2 amplitudes. Similarly, in the N250 time range, attractive faces elicited more negative amplitudes than unattractive faces (M_{attr} = -3.07 µV ± 0.54 *SD*; M_{unattr} = -2.21 µV ± 0.49 *SD*; $F[1,19] = 21.91$; $p < 0.001$; $\eta_p^2 = 0.54$). Additionally, an effect of response type (M_{hits} = -2.84 µV ± 0.55 *SD*; M_{CR} = -2.43 µV ± 0.48 *SD*; $F[1,19] = 5.31$; $p < 0.033$; $\eta_p^2 = 0.22$) reflected more negative N250 amplitudes for hits compared to CR. Neither the attractiveness effects in P2 nor in N250 at P10 correlated significantly with the attractiveness effects in d' or C (all |*r*s| [18] < .306, all *p*s > .190).

An ANOVA in the 300 – 500 ms time window at frontal, central, and parietal electrodes, with the factors laterality, site, response type, and attractiveness yielded a significant main effect of response type (M_{hits} = 2.15 µV ± 0.47 *SD*; M_{CR} = 1.74 µV ± 0.46 *SD; F*[1,19] = 7.28; $p = 0.014$; $\eta_p^2 = 0.28$; see figure 4), with more positive amplitudes for hits. This main effect was further qualified by an interaction of laterality x response type, suggesting larger old/new effects over midline electrodes (left: M_{hits} = 1.67 µV ± 0.46 *SD*; M_{CR} = 1.32 µV ± 0.47 *SD,* midline: M_{hits} = 2.38 µV ± 0.59 *SD*; M_{CR} = 1.76 µV ± 0.55 *SD,* right: M_{hits} = 2.4 µV ± 0.44 *SD*; M_{CR} = 2.14 µV ± 0.46 *SD*; $F[1,19] = 3.81$; $p = 0.031$; $\eta_p^2 = 0.17$).

An additional main effect of attractiveness (M_{attr} = 2.32 µV ± 0.49 *SD*; M_{unattr} = 1.58 µV ± 0.45 *SD*; $F[1,19] = 17.65$; $p < 0.001$; $\eta_p^2 = 0.48$) reflected more positive amplitudes for attractive faces, which, however, did not interact significantly with response type ($F < 1$). Interestingly, the attractiveness effect at Cz in this time range correlated significantly with the attractiveness effect in d' ($r[18] = .544$; $p = .013$), but not with the analogous effect in C ($r[18] = .051$; $p = .832$). In the 500 – 700 ms time range, a main effect of response type was found (M_{Hits} = 3.69 µV ± 0.45 *SD*; M_{CR} = 3.08 µV ± 0.46 *SD*; $F[1,19] = 5.32$; $p = 0.032$; $\eta_p^2 = 0.22$), which again did not interact with attractiveness ($F < 1$). Furthermore, a main effect of attractiveness was detected (M_{attr} = 3.73 µV ± 0.46 *SD*; M_{unattr} = 3.05 µV ± 0.42 *SD*; $F[1,19] = 13.91$; $p < 0.001$; $\eta_p^2 = 0.42$), reflecting larger amplitudes for attractive faces. The attractiveness effect at Cz between 500 and 700 ms did neither correlate with the attractiveness effect in d' ($r[18] = -.214$; $p = .365$) nor C ($r[18] = -.107$; $p = .655$).

4. Discussion

The present study examined effects of attractiveness on face memory. For that purpose we assessed two measures of distinctiveness (FITC and deviation) as well as attractiveness for a large set of faces in a rating study, and used a subset of these stimuli that were matched for deviation scores in a recognition paradigm. With respect to the first aim stated in the introduction, we observed an effect of attractiveness on face memory (as measured with d'), reflecting more accurate recognition of unattractive relative to attractive faces, over and above the well-known distinctiveness effect. Of note, at the same time attractive faces were more likely rated as studied by our participants, independent of whether this was actually the case or not, which was reflected by increased hit and reduced correct rejection rates, and consequently by a less conservative response bias. Pertaining to our second research question, the occipito-temporal N250/EPN was more negative and the LPC was more positive for attractive relative to unattractive faces. Attractiveness effects in these ERP components are therefore independent of deviation-based distinctiveness. Finally, ERP old/new effects were not modulated by attractiveness, and previous reports of early old/new effects for attractive but not unattractive faces may thus reflect a potential confound of uncontrolled distinctiveness. An important additional finding was that the attractiveness effect in N250/EPN during learning correlated significantly with the attractiveness effect in memory at test. We discuss these findings in more detail below.

In our rating study, the two measures of distinctiveness were positively related. However, under an assumption that both measures assess the same construct, this correlation was surprisingly small. More importantly, whereas FITC was positively correlated to attractiveness, the correlation between deviation and attractiveness was negative. This indicates that, at least to some extent, the two operationalizations of distinctiveness capture qualitatively different aspects of the construct. While the present data alone do not permit a detailed specification of these aspects, Vokey and Read (1992) suggested that typicality (or distinctiveness) can be subdivided into two components: context-free familiarity and memorability. Whereas familiarity relates to a feeling of knowing a face resulting from similarity with previously encountered faces, memorability is supposed to reflect a meta-memorial judgment how easy a face will be remembered. We speculate that deviation, as measured in the present study, is more closely related to familiarity, and that the FITC measure is stronger related to memorability. Notably, the shared variance between both measures cannot account for the reversed relationship of each variable with attractiveness. These results indicate that the relation between distinctiveness and attractiveness observed in a particular study critically depends on the exact measures used (see also Wickham & Morris, 2003).

We matched the subsets of stimuli for the main experiment on the basis of the deviation scores, since deviation is conceptually closely related to distinctiveness defined as the respective difference between an individual and a prototypical face (see e.g., Valentine, 1991). This difference also determines attractiveness according to averageness accounts (Langlois & Roggman, 1990). Furthermore, in the present context the FITC measure may be biased by meta-cognitions of the participants. More specifically, as suggested in the introduction, when asked how likely they would notice a given face in a crowd, participants may confuse their distinctiveness judgments with a tendency to favor attractive over unattractive faces ('I would notice such a beautiful face'). Of note, however, our finding of more accurate memory for unattractive faces was also observed in an item analysis, which additionally took variations in FITC into account. In that sense, the finding of superior memory for unattractive faces does not depend on the specific operationalization of distinctiveness.

Overall, our study is the first to establish a role of attractiveness on face memory irrespective of distinctiveness. Our findings contrast with the suggestion of enhanced memory for faces that elicit stronger affective processing (see e.g., Marzi & Viggiano, 2010), to the extent that this was presumably the case for attractive faces in the present study as well (see ERP findings below). Moreover, our finding is also at variance with predictions derived from socio-cognitive accounts of face memory (Hugenberg et al., 2010), which would suggest more accurate recognition of attractive faces resulting from a stronger motivation to view such stimuli (see e.g., Aharon et al., 2001).

Alternatively, more accurate memory for unattractive faces may be related to differences in our learning task. More specifically, participants were slightly faster on average to categorize the gender of attractive faces, which may be well due to differences in sexual dimorphism in those groups of faces (Perrett et al., 1998). One might assume that elongated processing of unattractive faces during categorization may have led to increased memory. We consider this explanation unlikely, because all face stimuli were presented for 5 s during learning, and a detailed encoding of all faces, independent of RT in the categorization task, was well possible after the gender decision was made. Comparably small differences in RT (approximately 50 ms) are thus unlikely to substantially affect memory encoding, particularly as participants were informed about the mnemonic nature of the experiment. In addition, if the attractiveness effect during learning were related to the later memory advantage for unattractive faces, one would assume that the two effects are interconnected. However, the difference in RTs was not significantly correlated with the memory advantage for unattractive faces ($r[18] = -.25$, $p = .29$).

Finally, while differences in sensitivity were the main focus of the present study, an interesting additional finding was that the response criterion was less conservative, or relatively more liberal, for attractive faces. In other words, attractive faces are more likely judged as previously seen, regardless of whether or not they were actually presented. This finding is reminiscent of similar results concerning the role of emotional expression and face memory, which are suggestive of a bias towards more liberal responses for faces with positive or happy expressions (Baudouin, Gilibert, Sansone, & Tiberghien, 2000; Lander & Metcalfe, 2007), or for emotional as compared to neutral faces (Johansson, Mecklinger, & Treese, 2004).

In the present study, no effects of attractiveness were observed in early ERP components, which is in line with previous findings of no differential amplitudes for attractive relative to unattractive faces in P1 (Roye et al., 2008; Schacht et al., 2008; Werheid et al.,

2007) and N170 (Roye et al., 2008; Schacht et al., 2008). Both components are influenced by the luminance of the stimuli (for a recent discussion see e.g., Rossion & Jacques, 2008), which was controlled in the present experiment but not in former studies that reported attractiveness effects in these components (Halit et al., 2000; Marzi & Viggiano, 2010). Here, the earliest ERP attractiveness effect was observed in the test phase P2, with more positive amplitudes for unattractive faces. P2 has been shown to be more positive for veridical relative to spatially caricatured (Schulz, Kaufmann, Walther, et al., 2012), as well as for typical relative to naturally distinct faces (Schulz, Kaufmann, Kurt, et al., 2012). As the stimuli in the present study were matched for distinctiveness, attractiveness appears to affect P2 amplitude in addition to the distinctiveness effect described in these previous studies. Of note, in our rating study we observed that more faces were rated as being unattractive than attractive, which may suggest that attractive faces tend to be less frequent. If so, a larger P2 may relate to more common (rather than prototypical) faces. It should be noted, however, that attractiveness effects in P2 were not significant during learning. Hence, it is also possible that the more pronounced negativity for attractive faces apparent in the subsequent N250 time range (see below), and thus the processes associated with this ERP effect, started earlier in the test relative to the learning phase (which may be related to task factors, such as more efficient processing of attractiveness at test when no prior categorization of the faces according to gender is necessary), thus influencing the P2 amplitude measurement during the 220 to 270 ms time segment (cf. Figures 1 and 3).

The earliest ERP attractiveness effect consistently observed in both learning and test phases occurred in the N250/EPN time range. Similar to previous studies (Marzi & Viggiano, 2010; Werheid et al., 2007), attractive faces elicited more negative amplitudes than unattractive faces. Importantly, the observed correlation of this ERP effect during learning with the magnitude of the memory advantage for unattractive faces at test suggests a functional link between the two measures. It is not clear whether this effect is best interpreted as reflecting an N250 or EPN modulation. On the one hand, an interpretation in terms of an N250 learning effect appears less plausible, as typically those faces remembered more accurately elicit a larger N250 (Schulz et al., 2012a, b). On the other hand, a more pronounced EPN is commonly interpreted to reflect stronger affective processing (Schupp et al., 2004). Accordingly, the present finding may suggest that those participants with stronger affective processing of attractive faces during learning were particularly poor at remembering them at test. This finding is reminiscent of similar ERP results on the own-race bias (i.e., the finding that own-race faces are more accurately remembered than other-race faces; see e.g., Meissner & Brigham, 2001). In a recent study from our group (Wiese et al., in press), which yielded the standard memory bias, we observed more negative N250/EPN amplitudes for other-race faces. One might suggest that such effects reflect the processing of characteristics that make faces emotionally salient (e.g., characteristics related to high attractiveness or ethnic out-group membership), which is not necessarily the same information that makes faces unique and therefore easy to recognize.

Although such disruptive effects of emotional content have not been described previously in the context of face memory, similar phenomena are known from other areas of research. For instance, in the emotional Stroop task, irrelevant emotional words interfere more strongly with color naming than neutral words (e.g. McKenna & Sharma, 1995). Moreover, participants are slower to respond in a shape discrimination task when emotional images are presented as distracters (Mitchell et al., 2008). Similarly, we propose that a more negative N250/EPN for specific face categories hampers rather than supports memory. More specifically, the affective processing of attractive faces during learning may have impeded a detailed perceptual analysis of facial identity[3], resulting in less efficient encoding into memory.

---

[3] Please note that the finding from the learning phase of faster gender classification for attractive faces is not necessarily in contradiction with this idea, since any cost to perceptual processing could be more than offset by the fact that attractive faces tend to be more sexually dimorphic than unattractive faces (Perrett et al., 1998).

At the same time, N250 amplitudes are typically larger for learned relative to novel faces (Kaufmann et al., 2009; Tanaka et al., 2006), an effect that was also detected in the present study. This learning effect, which may represent accessing a newly-established mental representation of a previously unfamiliar face, seems to add up with the above described face category effect both in the present study and in previous reports on the own-race bias (Wiese et al., in press). While the exact processes underlying category and learning effects in the N250/EPN time range are not entirely clear at present, it appears that they reflect different cognitive or affective mechanisms, with opposite effects on memory.

In the 300 to 700 ms time windows the LPC was larger for attractive relative to unattractive faces, replicating previous findings (Marzi & Viggiano, 2010; Werheid et al., 2007). Larger LPC amplitudes have also been observed for affective relative to neutral stimuli (Schacht et al., 2008; Schupp et al., 2004). In the present study the ERP effect in the earlier time range at test correlated significantly with the attractiveness effect in memory, suggesting that enhanced affective processing of attractive faces interferes with retrieval from face memory.

Finally, ERPs at test revealed significant old/new effects, both in the earlier (300 – 500 ms) and later (500 – 700 ms) time windows. These old/new effects were not significantly modulated by attractiveness, which suggests comparable contributions of familiarity and recollection to memory for attractive and unattractive faces (for an alternative interpretation of early old/new effects in terms of conceptual priming, see Paller, Voss, & Westerberg, 2009). Similarly, remember/know judgments also revealed no differential pattern for attractive versus unattractive faces. This ERP finding is at variance with a previous experiment that found an early old/new effect for attractive but not unattractive faces (Marzi & Viggiano, 2010), which was interpreted as reflecting enhanced familiarity for the former category. A critical difference of the present to this previous study lies in the fact that we matched attractive and unattractive faces for distinctiveness, and the absence of a differential old/new effect in the present study may be related to this matching. At the same time, larger early old/new effects in Marzi and Viggiano's study (2010) may have occurred due to differences in distinctiveness rather than attractiveness.

In conclusion, the present study suggests that attractiveness modulates face memory over and above the well-known effect of distinctiveness. Since our ERP results in the N250/EPN and LPC time windows indicate enhanced affective processing of attractive faces, our finding of less accurate memory for attractive faces is not in line with the general idea that any kind of affective processing is beneficial for face memory. Critically, the significant correlation between N250/EPN attractiveness effects during learning and the magnitude of the later memory bias suggests that pronounced affective processes, which accompany the perception of attractive faces, hamper the detailed encoding of facial identity and therefore reduce later recognition. Overall, the present findings reveal novel insights into the cognitive and neural mechanisms underlying attractiveness effects on face memory.

Acknowledgment

This study was supported by a grant of the Deutsche Forschungsgemeinschaft (DFG) to H.W. and S.R.S. (WI 3219/5-2). We are thankful for help during data acquisition by Kathrin Rauscher.

References

Aharon, I., Etcoff, N., Ariely, D., Chabris, C. F., O'Connor, E., & Breiter, H. C. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron, 32*(3), 537-551. doi: 10.1016/j.bbr.2011.03.031

Amihai, I., Deouell, L. Y., & Bentin, S. (2011). Neural adaptation is related to face repetition irrespective of identity: A reappraisal of the N170 effect. *Experimental Brain Research, 209*(2), 193-204. doi: 10.1007/s00221-011-2546-x

Baudouin, J. Y., Gilibert, D., Sansone, S., & Tiberghien, G. (2000). When the smile is a cue to familiarity. *Memory, 8*(5), 285-292. doi: 10.1080/09658210050117717

Benson, P. L., Karabenick, S. A., & Lerner, R. M. (1976). Pretty Pleases - Effects of Physical Attractiveness, Race, and Sex on Receiving Help. *Journal of Experimental Social Psychology, 12*(5), 409-415. doi: 10.1016/0022-1031(76)90073-1

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*(6), 551-565. doi: 10.1162/jocn.1996.8.6.551

Berg, P., & Scherg, M. (1994). A Multiple Source Approach to the Correction of Eye Artifacts. *Electroencephalography and Clinical Neurophysiology, 90*(3), 229-241. doi: 10.1016/0013-4694(94)90094-9

Bernstein, M. J., Young, S. G., & Hugenberg, K. (2007). The cross-category effect: Mere social categorization is sufficient to elicit an own-group bias in face recognition. *Psychological Science, 18*(8), 706-712. doi: 10.1111/j.1467-9280.2007.01964.x

Brigham, J. C. (1990). Target Person Distinctiveness and Attractiveness as Moderator Variables in the Confidence Accuracy Relationship in Eyewitness Identifications. *Basic and Applied Social Psychology, 11*(1), 101-115. doi: 10.1207/s15324834basp1101_7

Cross, J. F., Cross, J., & Daly, J. (1971). Sex, race, age, and beauty as factors in recognition of faces. *Perception & Psychophysics, Vol. 10(6)*(6), 393-396. doi: 10.3758/bf03210319

Curran, T. (2000). Brain potentials of recollection and familiarity. *Mem Cognit, 28*(6), 923-938. doi: 10.3758/Bf03209340

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biol Psychol, 52*(2), 95-111. doi: 10.1016/S0301-0511(99)00044-7

DeBruine, L. M., Jones, B. C., Unger, L., Little, A. C., & Feinberg, D. R. (2007). Dissociating averageness and attractiveness: attractive faces are not always average. *J Exp Psychol Hum Percept Perform, 33*(6), 1420-1430. doi: 10.1037/0096-1523.33.6.1420

Eimer, M. (2000). The face-specific N170 component reflects late stages in the structural encoding of faces. *Neuroreport, 11*(10), 2319-2324. doi: 10.1097/00001756-200007140-00050

Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. In A. R. Calder, G.; Johnsohn, M.; Haxby, J. (Ed.), *Oxford Handbook of Face Perception* (Vol. 1, pp. 329-344). Oxford: University Press.

Gardiner, J. M., Java, R. I., & Richardson-Klavehn, A. (1996). How level of processing really influences awareness in recognition memory. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale, 50*(1), 114-122. doi: 10.1037/1196-1961.50.1.114

Gardiner, J. M., & Richardson-Klavehn, A. (2000). Remembering and knowing. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford hand-book of memory* (pp. 229-244). New York: Oxford University Press.

Green, D. M., & Swets, J. A. (1966). *Signal Detection Theory and Psychophysics*. New York: Wiley.

Halit, H., de Haan, M., & Johnson, M. H. (2000). Modulation of event-related potentials by prototypical and atypical faces. *Neuroreport, 11*(9), 1871-1875. doi: 10.1097/00001756-200006260-00014

Harrell, W. A. (1978). Physical attractiveness, self-disclosure, and helping behavior. *The Journal of Social Psychology, 104*(1), 15-17. doi: 10.1080/00224545.1978.9924033

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The Categorization-Individuation Model: An Integrative Account of the Other-Race Recognition Deficit. *Psychological Review, 117*(4), 1168-1187. doi: 10.1037/A0020463

Johansson, M., Mecklinger, A., & Treese, A. C. (2004). Recognition memory for emotional and neutral faces: An event-related potential study. *Journal of Cognitive Neuroscience, 16*(10), 1840-1853. doi: 10.1162/0898929042947883

Johnson, R. W. (1981). Perceived Physical Attractiveness of Supporters of Canadas Political-Parties - Stereotype or in-Group Bias. *Canadian Journal of Behavioural Science-*

Revue Canadienne Des Sciences Du Comportement, 13(4), 320-325. doi: 10.1037/h0081203

Kaufmann, J. M., & Schweinberger, S. R. (2012). The faces you remember: Caricaturing shape facilitates brain processes reflecting the acquisition of new face representations. *Biol Psychol, 89*(1), 21-33. doi: 10.1016/j.biopsycho.2011.08.011

Kaufmann, J. M., Schweinberger, S. R., & Burton, A. M. (2009). N250 ERP Correlates of the Acquisition of Face Representations across Different Images. *Journal of Cognitive Neuroscience, 21*(4), 625-641. doi: 10.1162/jocn.2009.21080

Lander, K., & Metcalfe, S. (2007). The influence of positive and negative facial expressions on face familiarity. *Memory, 15*(1), 63-69. doi: 10.1080/09658210601108732

Langlois, J. H., & Roggman, L. A. (1990). Attractive Faces Are Only Average. *Psychological Science, 1*(2), 115-121. doi: 10.1111/j.1467-9280.1990.tb00079.x

Latinus, M., & Taylor, M. J. (2006). Face processing stages: Impact of difficulty and the separation of effects. *Brain Research, 1123*, 179-187. doi: 10.1016/j.brainres.2006.09.031

Lerner, R. M., & Lerner, J. V. (1977). Effects of age, sex, and physical attractiveness on child-peer relations, academic performance, and elementary school adjustment. *Developmental Psychology, 13*(6), 585-590. doi: 10.1037/0012-1649.13.6.585

Light, L. L., Hollander, S., & Kayra-Stuart, F. (1981). Why attractive people are harder to remember. *Personality and Social Psychology Bulletin, 7*(2), 269-276. doi: 10.1177/014616728172014

Luck, S. J. (2005). An introduction to the event-related potentials technique. Cambridge: Massachusetts Institute of Technology: MIT Press.

Marzi, T., & Viggiano, M. P. (2010). When memory meets beauty: Insights from event-related potentials. *Biol Psychol, 84*(2), 192-205. doi: 10.1016/j.biopsycho.2010.01.013

McKenna, F. P., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional Stroop task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(6), 1595-1607. doi: 10.1037/0278-7393.21.6.1595

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces - A meta-analytic review. *Psychology Public Policy and Law, 7*(1), 3-35. doi: 10.1037//1076-8971.7.1.3

Mims, P. R., Hartnett, J. J., & Nay, W. R. (1975). Interpersonal Attraction and Help Volunteering as a Function of Physical Attractiveness. *Journal of Psychology, 89*(1), 125-131. doi: 10.1080/00223980.1975.9923913

Mitchell, D. G. V., Luo, Q., Mondillo, K., Vythilingam, M., Finger, E. C., & Blair, R. J. R. (2008). The interference of operant task performance by emotional distracters: An antagonistic relationship between the amygdala and frontoparietal cortices. *Neuroimage, 40*(2), 859-868. doi: 10.1016/j.neuroimage.2007.08.002

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

Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. *Trends in Cognitive Sciences, 11*(6), 243-250. doi: 10.1016/j.tics.2007.04.002

Paller, K. A., Voss, J. L., & Westerberg, C. E. (2009). Investigating the Awareness of Remembering. *Perspectives on Psychological Science, 4*(2), 185-199.

Perrett, D. I., Lee, K. J., Penton-Voak, I., Rowland, D., Yoshikawa, S., Burt, D. M., . . . Akamatsu, S. (1998). Effects of sexual dimorphism on facial attractiveness. *Nature, 394*(6696), 884-887. doi: 10.1038/29772

Rellecke, J., Sommer, W., & Schacht, A. (2012). Does processing of emotional facial expressions depend on intention? Time-resolved evidence from event-related brain potentials. *Biol Psychol, 90*(1), 23-32. doi: 10.1016/j.biopsycho.2012.02.002

Rossion, B., & Jacques, C. (2008). Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170. *Neuroimage, 39*(4), 1959-1979. doi: 10.1016/j.neuroimage.2007.10.011

Roye, A., Höfel, L., & Jacobsen, T. (2008). Aesthetics of Faces Behavioral and Electrophysiological Indices of Evaluative and Descriptive Judgment Processes. *Journal of Psychophysiology, 22*(1), 41-57. doi: 10.1027/0269-8803.22.1.41

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11*(6), 251-257. doi: 10.1016/j.tics.2007.04.004

Said, C. P., & Todorov, A. (2011). A Statistical Model of Facial Attractiveness. *Psychological Science, 22*(9), 1183-1190. doi: 10.1177/0956797611419169

Sarno, J. A., & Alley, T. R. (1997). Attractiveness and the memorability of faces: Only a matter of distinctiveness? *The American Journal of Psychology, 110*(1), 81-92. doi: 10.2307/1423702

Schacht, A., Werheid, K., & Sommer, W. (2008). The appraisal of facial beauty is rapid but not mandatory. *Cognitive Affective & Behavioral Neuroscience, 8*(2), 132-142. doi: 10.3758/Cabn.8.2.132

Schulz, C., Kaufmann, J. M., Kurt, A., & Schweinberger, S. R. (2012). Faces forming traces: Neurophysiological correlates of learning naturally distinctive and caricatured faces. *Neuroimage, 63*(1), 491-500. doi: 10.1016/j.neuroimage.2012.06.080

Schulz, C., Kaufmann, J. M., Walther, L., & Schweinberger, S. R. (2012). Effects of anticaricaturing vs. caricaturing and their neural correlates elucidate a role of shape for face learning. *Neuropsychologia, 50*(10), 2426-2434. doi: 10.1016/j.neuropsychologia.2012.06.013

Schupp, H. T., Öhman, A., Junghöfer, M., Weike, A. I., Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: An ERP analysis. *Emotion, 4*(2), 189-200. doi: 10.1037/1528-3542.4.2.189

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *Journal of Neuroscience, 27*(5), 1082-1089. doi: 10.1523/Jneurosci.3223-06.2007

Schweinberger, S. R., & Burton, A. M. (2003). Covert recognition and the neural system for face processing. *Cortex, 39*(1), 9-30. doi: 10.1016/S0010-9452(08)70071-6

Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: an event-related potential study. *Neuroreport, 19*(5), 583-587. doi: 10.1097/WNR.0b013e3282f97b4d

Tanaka, J. W., Curran, T., Porterfield, A. L., & Collins, D. (2006). Activation of preexisting and acquired face representations: The N250 event-related potential as an index of face familiarity. *Journal of Cognitive Neuroscience, 18*(9), 1488-1497. doi: 10.1162/jocn.2006.18.9.1488

Valentine, T. (1991). A Unified Account of the Effects of Distinctiveness, Inversion, and Race in Face Recognition. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 43*(2), 161-204. doi: 10.1080/14640749108400966

Valentine, T., & Bruce, V. (1986). The Effects of Distinctiveness in Recognizing and Classifying Faces. *Perception, 15*(5), 525-535. doi: 10.1068/P150525

Valentine, T., & Endo, M. (1992). Towards an Exemplar Model of Face Processing - the Effects of Race and Distinctiveness. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 44*(4), 671-703. doi: 10.1080/14640749208401305

Vokey, J. R., & Read, J. D. (1992). Familiarity, memorability, and the effect of typicality on the recognition of faces. *Mem Cognit, 20*(3), 291-302.

Werheid, K., Schacht, A., & Sommer, W. (2007). Facial attractiveness modulates early and late event-related brain potentials. *Biol Psychol, 76*(1-2), 100-108. doi: 10.1016/j.biopsycho.2007.06.008

Wickham, L. H. V., & Morris, P. E. (2003). Attractiveness, distinctiveness, and recognition of faces: Attractive faces can be typical or distinctive but are not better recognized. *American Journal of Psychology, 116*(3), 455-468. doi: 10.2307/1423503

Wiese, H., Kaufmann, J. M., & Schweinberger, S. R. (in press). The Neural Signature of the Own-Race Bias: Evidence from Event-Related Potentials. *Cereb Cortex*. doi: 10.1093/cercor/bhs369

Wiese, H., Schweinberger, S. R., & Hansen, K. (2008). The age of the beholder: ERP evidence of an own-age bias in face memory. *Neuropsychologia, 46*(12), 2973-2985. doi: 10.1016/j.neuropsychologia.2008.06.007

Zhang, Y., Kong, F., Chen, H., Jackson, T., Han, L., Meng, J., . . . Najam ul Hasan, A. (2011). Identifying cognitive preferences for attractive female faces: an event-related potential experiment using a study-test paradigm. *J Neurosci Res, 89*(11), 1887-1893. doi: 10.1002/jnr.22724

Figure captions

Figure 1. Grand mean ERPs from the learning phases of the recognition memory experiment at occipital and occipito-temporal electrodes. Dashed lines indicate N170, P2, and N250 time ranges.

Figure 2. Grand mean ERPs from the learning phases of the recognition memory experiment at frontal, central and parietal electrodes. Dashed lines indicate early (300-500 ms) and late (500-700 ms) LPC time ranges.

Figure 3. Grand mean ERPs from the test phases of the recognition memory experiment at occipital and occipito-temporal electrodes. Dashed lines indicate N170, P2, and N250 time ranges. CR = Correct Rejections.

Figure 4. Grand mean ERPs from the test phases of the recognition memory experiment at frontal, central and parietal electrodes. Dashed lines indicate early (300-500 ms) and late (500-700 ms) old/new effect time ranges. CR = Correct Rejections.

Table 1

Table 1: Behavioral data from the main experiment

	Attractive Faces	**Unattractive Faces**
Study phases		
RT (ms)	1051.2 ± 355.5 *SD*	1103.5 ± 356.2 *SD*
ACC	.99 ± 0.02 *SD*	.94 ± 0.03 *SD*
Test phases		
p (hit)	.76 ± 0.12 *SD*	.71 ± 0.11 *SD*
p (correct rejections)	.78 ± 0.14 *SD*	.89 ± 0.11 *SD*
d'	1.65 ± 0.50 *SD*	2.09 ± 0.73 *SD*
C	.07 ± 0.41 *SD*	.46 ± 0.37 *SD*
'Remember/Know' rating		
p (remember)	.52 ± 0.16 *SD*	.49 ± 0.15 *SD*
p (know)	.19 ± 0.10 *SD*	.17 ± 0.08 *SD*
p (guess)	.02 ± 0.03 *SD*	.02 ± 0.05 *SD*

Figure 1

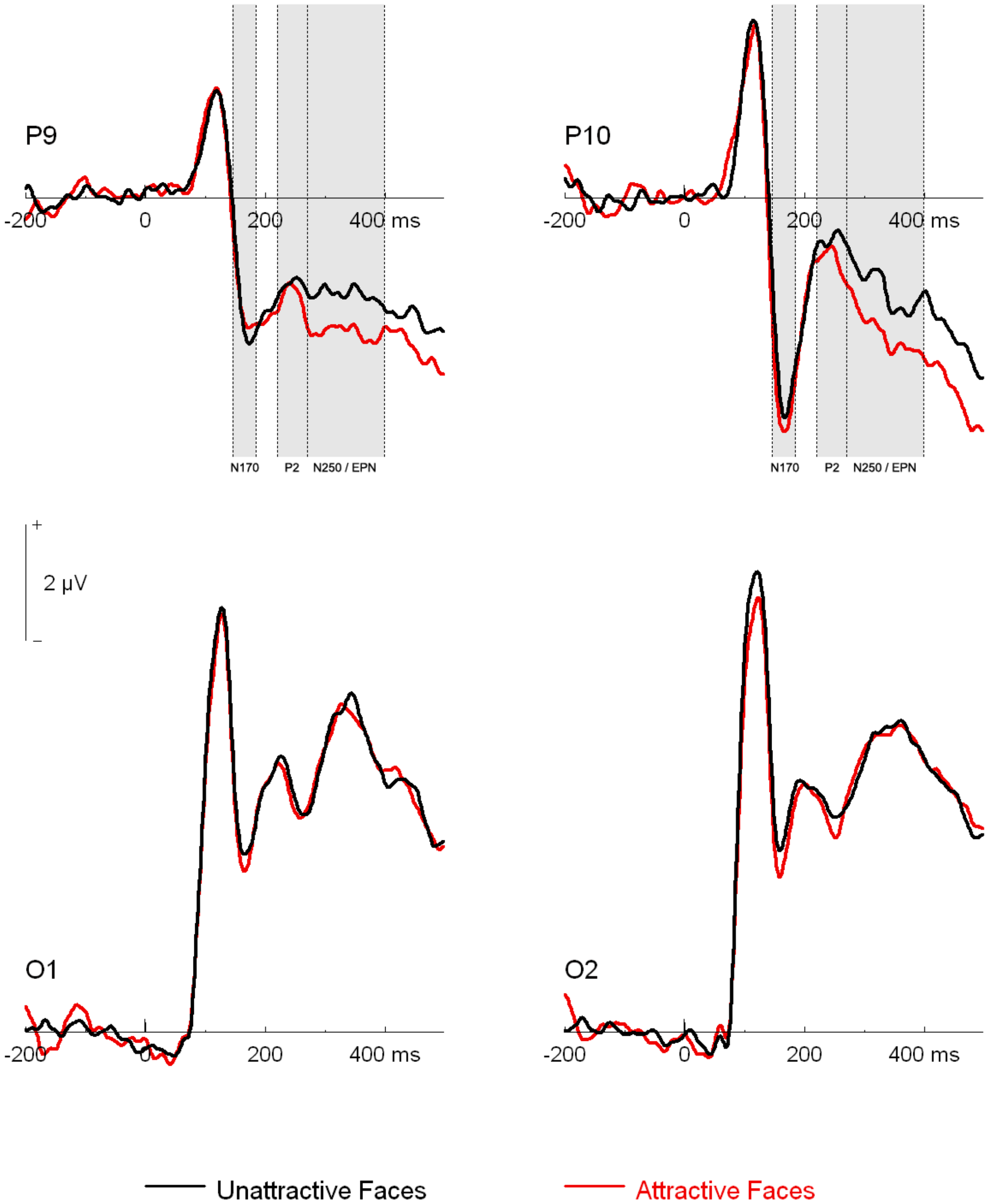

P9
-200
0
200
400 ms
N170
P2
N250 / EPN
P10
-200
0
200
400 ms
N170
P2
N250 / EPN
+
2 µV
–
O1
-200
0
200
400 ms
O2
-200
0
200
400 ms
Unattractive Faces
Attractive Faces

Figure 2

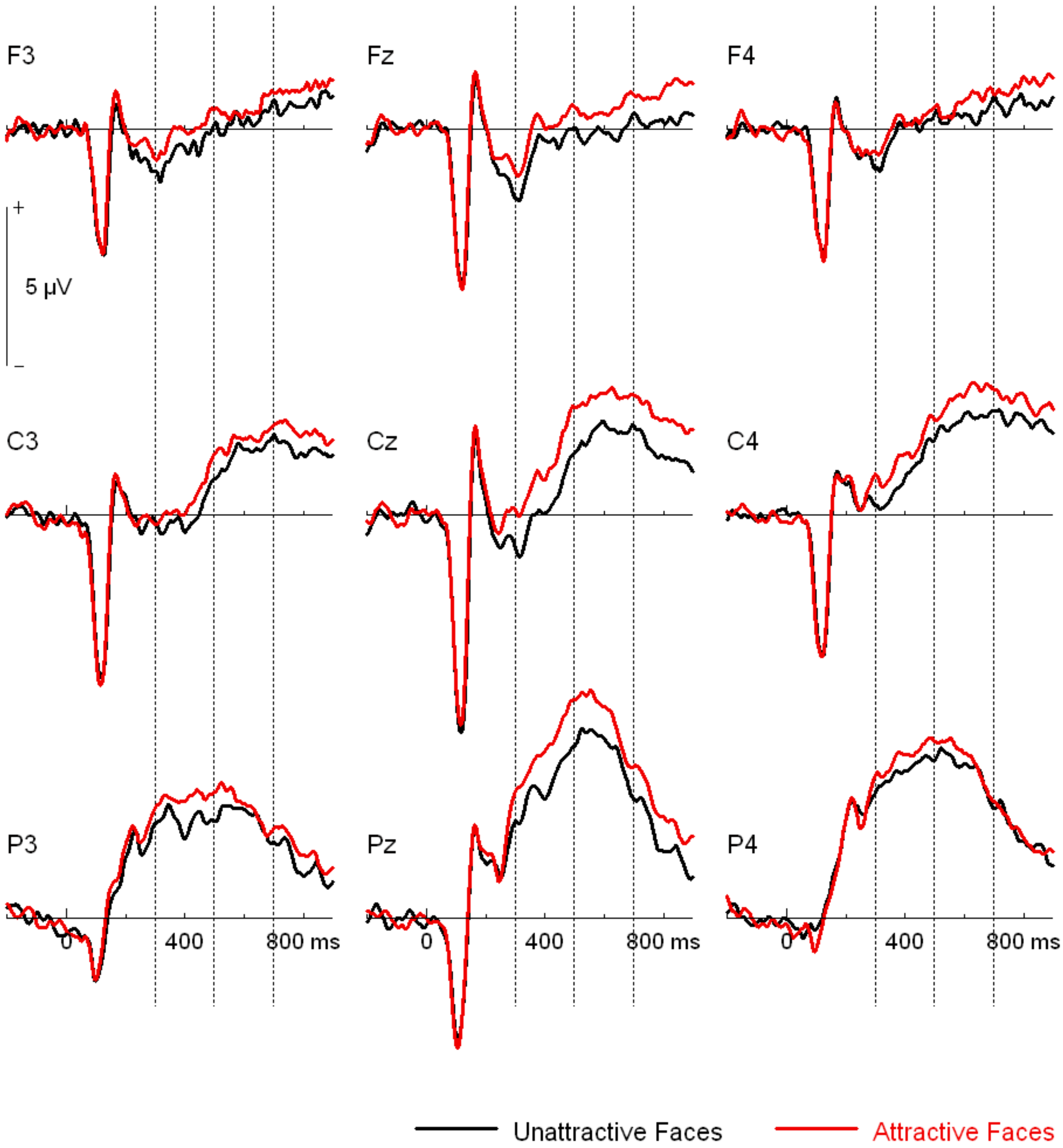

F3
Fz
F4
+
5 µV
–
C3
Cz
C4
P3
Pz
P4
0
400
800 ms
Unattractive Faces
Attractive Faces

Figure 3

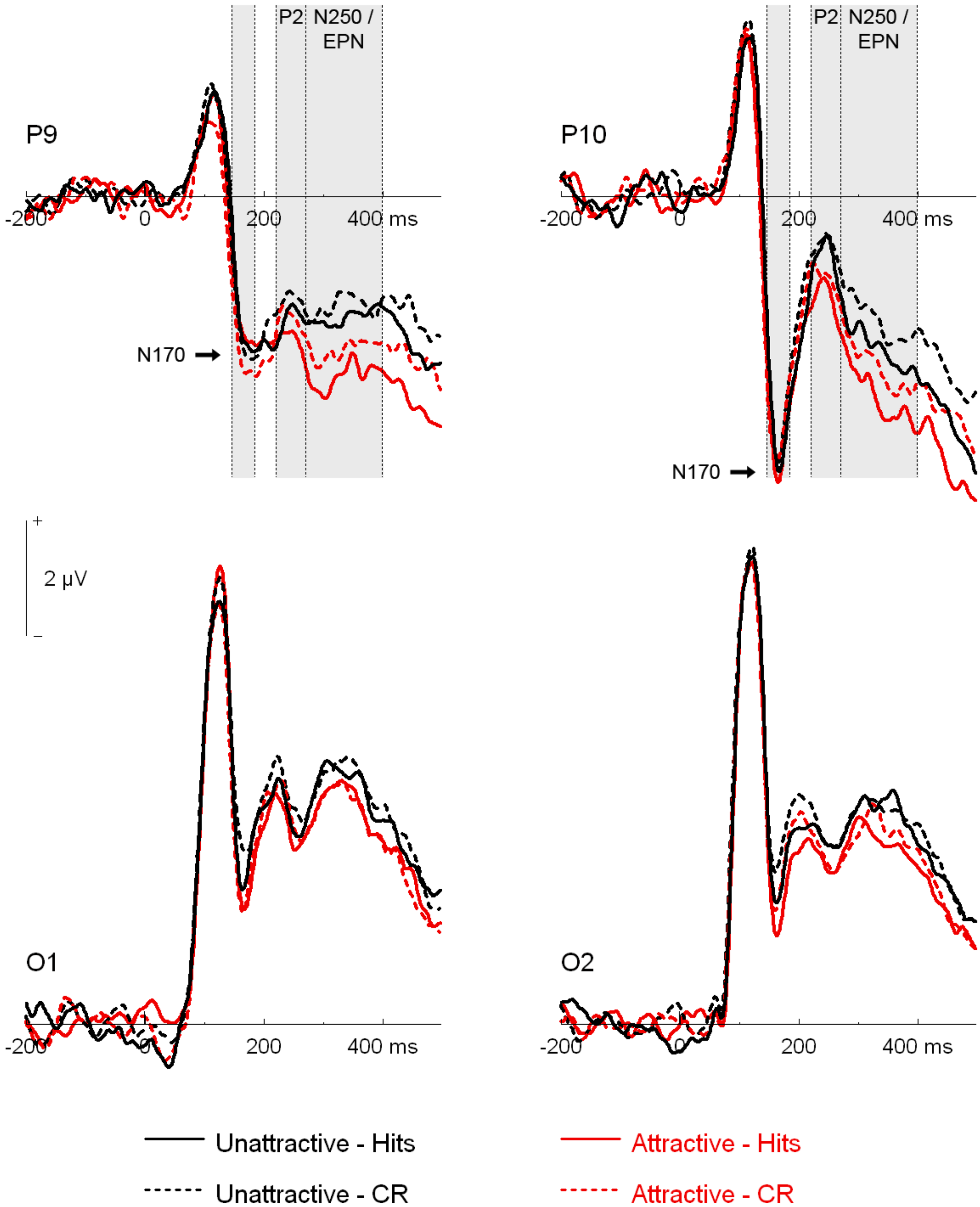
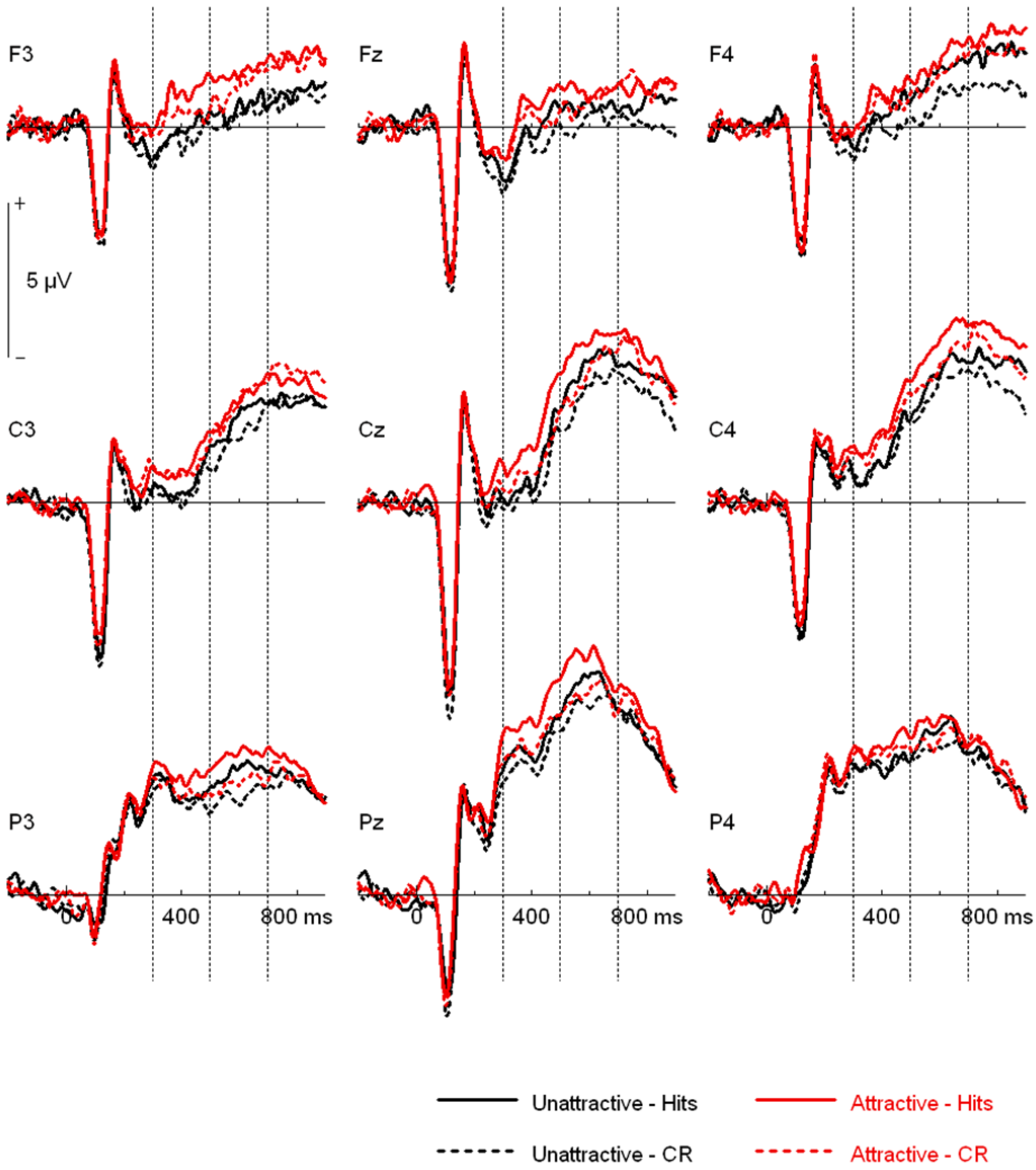

P2
N250 /
EPN
P9
-200
0
200
400 ms
N170
P2
N250 /
EPN
P10
-200
0
200
400 ms
N170
+
2 µV
–
O1
-200
0
200
400 ms
O2
-200
0
200
400 ms
Unattractive - Hits
Unattractive - CR
Attractive - Hits
Attractive - CR

Figure 4


F3
Fz
F4
+
5 µV
–
C3
Cz
C4
P3
Pz
P4
0
400
800 ms
Unattractive - Hits
Attractive - Hits
Unattractive - CR
Attractive - CR