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The age of the beholder: ERP evidence of an own-age bias in face memory

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ABSTRACT

Unfamiliar faces from the viewer's own ethnic group are more accurately recognized than other-race faces. The present study examined whether similar effects occur for own-age versus other-age faces, analyzing both behavioural and event-related potential (ERP) measures. Young and elderly participants were to recognize previously studied young and old faces. Whereas young participants demonstrated enhanced recognition memory for own-age faces, no corresponding effect was observed in elderly participants. During recognition tests, enhanced N170 and decreased P2 amplitudes were observed for old faces. Of particular importance, increased N250 amplitudes at right occipito-temporal electrodes as well as enhanced centro-parietal old/new recognition memory effects (more positive ERPs to hits than correct rejections) were observed to own-age compared to other-age faces in the young but not in the elderly participants' ERPs. In young participants, the right occipito-temporal N250 suggests easier access to temporary structural representations for young as compared to old faces, whereas the centro-parietal old/new recognition effect (400–600 ms) suggests an advantage in retrieving episodic information for young faces. The early (<300 ms) neuro-cognitive correlates of the own-age bias in young participants were similar to those of an own-race bias studied previously, suggesting that similar mechanisms underlie these face memory biases. The results are discussed with respect to a perceptual learning account, in which asymmetrical perceptual experience of young and elderly people with faces from different age groups may underlie the differential pattern of own-age effects.

1. Introduction

As people grow older, a number of changes occur with respect to cognitive abilities. Thus, a considerable amount of research on the link between cognitive and cerebral aging has been undertaken, and has revealed age-related changes in perceptual, attentional and working memory processes (see Cabeza, Nyberg, & Park, 2005). Perhaps most prominent, however, the efficiency of long-term memory declines with increasing age (e.g. Light, 1991), a phenomenon which has been examined with various experimental paradigms and neuroimaging methods (see, e.g. Cabeza, 2002). At the same time, age not only affects cognitive abilities, but also alters physical body and facial appearance. Age-related facial changes concern the quantity and colour of the hair, skin elasticity and texture, distribution of adipose tissue, length of the nose and ears, thickness and texture of the eyebrows, apparent eye size and lip shape (Burt & Perrett, 1995). The present research examined the interaction between age-dependent differences in the participants' recognition memory for faces and the age of those faces. More specifically, we investigated recognition memory for old and young faces in elderly and young participants, analyzing behavioural measures as well as event-related brain potentials (ERP).

1.1. Face processing and categorization

The human face not only carries information about a person's identity, but also reveals information about age, gender, ethnic group, and emotional state. Whereas the first kind of information is per definition only available for known people (so-called identity-specific semantic codes), the latter information can be derived from any face, be it familiar or unfamiliar to the observer (visually derived semantic codes, see Bruce & Young, 1986). However, whereas a large body of research exists on familiar face identification, relatively little is known about the processing of unfamiliar faces.

As described above, unfamiliar faces can be categorized on various visually available dimensions. Facial age, though not invariant over time, changes slowly compared to other facial information such as expression (Bruyer, Mejias, & Doublet, 2007; Haxby, Hoffman, & Gobbini, 2000). Processing of age in facial stimuli interferes with various operations during face perception such as the processing of ethnicity (Dehon & Bredart, 2001) and identity

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(Bruyer et al., 2007). However, the age of unfamiliar faces can be determined on the basis of the two-dimensional configuration of the face plus information about surface texture only (George & Hole, 2000). Moreover, in a recent experiment using facial age and gender categorization tasks, it has been demonstrated that facial age is processed implicitly even when irrelevant for the task at hand, while gender information is not (Wiese, Schweinberger, & Neumann, in press).

Relatively little is known about the influence of facial age on recognition memory (see below). However, studies examining the so-called own race bias (or other-race effect) usually observe enhanced recognition memory performance for faces of the observer's own ethnic group in comparison to 'out-group' stimuli (Meissner, Brigham, & Butz, 2005; Sporer, 2001). This effect has been explained by the multi-dimensional face space model (Valentine, 1991). According to Valentine (1991), each individual face is coded in a face space on multiple dimensions which evolve due to the individuals' life-time experience with faces. Since other-race faces are less frequently encountered, the dimensions of the individual face space are less appropriate for faces from another ethnic group (Valentine & Endo, 1992), which in turn is thought to lead to decreased recognition memory performance. Accordingly, this interpretation represents a perceptual learning account to the differential processing of 'in-group' vs. 'out-group' faces.

In contrast, the race feature theory (Levin, 1996, 2000) assumes that the difference between own- and other-race faces is coded as a feature-present/feature-absent relationship. Findings from visual search tasks suggested that people tend to code race-specifying featural information in other-race faces (e.g. skin tone in Black faces or eye shape in Asian faces for Caucasian participants), but code own-race faces as having no such feature. Accordingly, a Caucasian participant might classify the face of an Asian or Black person as being the member of an "out-group" by detecting such a race-specifying feature. Cognitions about out-group members are assumed to emphasize category-level information. As a result, other-race faces are suggested to be processed at a categorical level to a larger extent whereas own-race faces are more likely processed as individuals, which in turn results in more accurate recognition memory for own- compared to other-race faces.

Finally, recent studies proposed that own-race faces are processed more holistically than other-race faces (Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004), which means that other-race faces are processed as a whole or gestalt to a lesser extent, and therefore spatial relations between features in other-race faces are encoded less efficiently. Recent results suggested that holistic processing is a necessary prerequisite for accurate other-race face recognition, but that it is not sufficient to overcome the other-race effect (Michel, Caldara, & Rossion, 2006).

Both the multi-dimensional face space (Valentine & Endo, 1992) and the holistic processing account (Michel, Caldara, et al., 2006; Tanaka et al., 2004) assume differential experience with own-and other-race faces as the basis for the other-race effect. Given that people have more contact and current experience with faces from their own-age group, a similar own-age memory bias could reasonably be expected. Moreover, from the perspective of feature processing theory (Levin, 2000), it could be hypothesized that age is similarly coded in a feature-present/feature-absent manner (with, e.g. skin texture or the presence/absence of wrinkles in a face as the relevant features). Consequently, other-age faces would be more likely processed on a categorical level whereas own-age faces were individualized to a larger extent, again leading to the prediction of an own-age bias in face memory.

1.2. An own-age memory bias?

Studies on eyewitness identification found that the processing of face age is not independent of the viewer's age. Wright and Stroud (2002) demonstrated that older participants were better at identifying older culprits than younger culprits whereas young adult participants showed the opposite pattern. Perfect and Harris (2003) demonstrated an 'own-age bias' for young participants on the false identification of 'innocent bystanders'.

Asymmetrical effects of stimulus and participants' age have also been reported in recognition memory studies. In two early studies, an own-age bias for young participants but not for older participants was observed (Bartlett & Leslie, 1986; Fulton & Bartlett, 1991). Similarly, Bäckman (1991) demonstrated that young participants were better at recognizing young in comparison to older unfamiliar faces, whereas participants aged between 63 and 70 years showed the opposite pattern. Two additional groups of elderly participants aged 76 and 85 years, respectively, did not show any effect of stimulus age on the recognition of unfamiliar faces. In contrast, more recent studies observed an own-age bias for children and older participants while young adults did not show consistent effects of stimulus age (Anastasi & Rhodes, 2005, 2006; Lamont, Stewart-Williams, & Podd, 2005).

In summary, behavioural studies that examined the interaction of the participants' and stimulus age in face recognition memory yielded mixed results, with evidence for all possible combinations of own-age biases in elderly and young adults. Variables that might contribute to these discrepancies involve the quality and quantity of the stimuli, the strictness of experimental control, as well as age and performance variability of the elderly participants. In the present study, we sought additional evidence for or against an own-age bias in face memory. Moreover, we reasoned that a putative own-age bias might be caused by comparable mechanisms as the own-race bias. Whereas several previous studies examined the neural basis of the own-race bias, neural processes underlying an own-age bias have not been investigated until now.

1.3. ERP studies on face processing

Event-related potentials (ERPs) consist of transient voltage changes in the electroencephalogram (EEG) time-locked to a certain event, e.g. the presentation of a specific stimulus type. Accordingly, ERPs provide fine-grained chronometric measures of the neural operations following stimulus presentation. ERPs to faces, as to visual stimuli in general, consist of an early positive deflection over occipital areas (P1) peaking approximately 100 ms after stimulus onset. P1 is assumed to reflect early visual processing and is sensitive to basic stimulus attributes such as contrast, brightness or spatial frequency (see, e.g. Schendan, Ganis, & Kutas, 1998). P1 has also been shown to be sensitive to the direction of spatial attention (see, e.g. Hillyard, Vogel, & Luck, 1998) and to the participants' state of arousal (Vogel & Luck, 2000).

Perhaps the most intensively investigated ERP component associated with the processing of faces is the N170, a negative peak appearing approximately 170 ms after stimulus onset with a maximum at right posterior temporal electrodes (Bentin, Allison, Puce, Perez, & McCarthy, 1996). The N170 reflects processes prior to the identification of individual faces (Bentin & Deouell, 2000; Eimer, 2000a), it is modulated by expertise (Scott, Tanaka, Sheinberg, & Curran, 2006; Tanaka & Curran, 2001), and may be engaged in both the structural analysis of face components and their configuration (Eimer, 2000b; Sagiv & Bentin, 2001). This in turn might correspond to the structural encoding level in cognitive models of face processing (Bruce & Young, 1986; Burton, Bruce, & Johnston, 1990; Schweinberger & Burton, 2003). N170 has been shown to be delayed and increased for inverted in comparison to upright faces (Eimer, 2000b; Itier & Taylor, 2002; Rossion et al., 1999, 2000), which has been interpreted to represent disrupted processing of configural information. In a recent study, Itier, Alain, Sedore, and McIntosh (2007) observed this amplitude increase for inverted faces to mainly reflect the processing of the eye region.

With regard to N170 elicited by own-race versus other-race faces, varying results have been reported. Whereas earlier studies did not detect N170 differences (Caldara, Rossion, Bovet, & Hauert, 2004; Caldara et al., 2003; James, Johnstone, & Hayward, 2001), one study reported more negative N170 amplitudes for own- compared to other-race faces (Ito & Urland, 2005). In contrast to these findings, two recent studies reported the N170 to be increased for other-race faces (Herrmann et al., 2007; Stahl, Wiese, & Schweinberger, 2008).

Following N170, a positive deflection is commonly observed over occipital and occipito-temporal regions (posterior P2). This posterior P2 has been shown to be larger for typical compared to atypical faces (Halit, de Haan, & Johnson, 2000), for normal compared to thatcherized faces (Milivojevic, Clapp, Johnson, & Corballis, 2003), and for photographic compared to Mooney faces (Latinus & Taylor, 2006). Latinus and Taylor (2006) ascribed the posterior P2 to so-called second-order configural processing necessary for face identification. Most interestingly for the present purpose, the above cited study of Stahl et al. (2008) observed more positive P2 components for own- in comparison to other-race faces. This effect was modulated by expertise, as a Caucasian group of experts for Asian faces yielded no comparable effect over the right hemisphere.

Whereas the N170 may reflect processes of structural face encoding, the N250r appears sensitive to the activation of a specific structural face representation (Schweinberger & Burton, 2003). In repetition priming experiments, more negative amplitudes for immediately repeated compared to non-repeated faces were observed over right occipito-temporal regions between approximately 200 and 350 ms (Begleiter, Porjesz, & Wang, 1995; Schweinberger, Pfütze, & Sommer, 1995). This N250r effect has been demonstrated to be stronger for familiar compared to unfamiliar faces (Herzmann, Schweinberger, Sommer, & Jentzsch, 2004; Pfütze, Sommer, & Schweinberger, 2002). Itier and Taylor (2004) observed delayed N250r repetition effects for inverted and contrast-reversed faces, which was interpreted as representing more difficult access to the representation of faces whose configuration has been altered. With respect to the own-race bias, a recent study reported no difference of N250r for repetitions of same versus other-race faces (Herrmann et al., 2007). Note that the N250r has been observed as a correlate of short-term face repetitions, and that this component reflects the ERP difference between repeated and new faces, with relatively more negative ERPs at occipitotemporal electrodes for repeated faces (Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002). Of particular importance for the present study, there is more recent evidence that the right occipito-temporal N250 ERP response is also sensitive to longer term acquisition of face representations. Specifically, both Tanaka, Curran, Porterfield, and Collins (2006) and Kaufmann, Schweinberger, and Burton (in press) reported the N250 to increase in the course of learning initially unfamiliar faces.

Finally, in recognition memory experiments using words as stimuli, correctly remembered studied items elicit more positive going ERPs than correctly rejected new items, an effect starting at approximately 400 ms and maximal at left parietal electrodes (see, e.g. Rugg, 1995). This phenomenon is known as the parietal old/new effect and has been ascribed to the conscious recollection from episodic memory (for a recent review, see Rugg & Curran, 2007). Similar effects have been observed when participants remember pre-experimentally unfamiliar faces (Curran & Hancock, 2007; Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000). Moreover, recent research suggests that the parietal old/new effect is sensitive to the amount of information recollected from episodic memory (Vilberg, Moosavi, & Rugg, 2006). Accordingly, when more information about 'own-group' (own-race, own-age etc.) compared to other-group faces is available, e.g. as the result of more fine-grained configural processing, the old/new effect might be expected to be enhanced for these 'in-group' faces. Interestingly, although many studies on the own-race bias come from the domain of memory research, to our knowledge no ERP study on differential old/new effects for own-race versus other-race faces exists. James et al. (2001) included studied and non-studied own- and other-race faces in their experiment, but did not analyze race-specific effects on memory-related components.

1.4. The present study

On the basis of the literature described in the previous paragraphs, the present study examined the following predictions. Given that face memory biases depend on differential experience with own-group versus other-group faces, we hypothesized that young participants (with greater perceptual experience for young faces) should demonstrate enhanced recognition memory for young in comparison to old faces. However, because elderly participants had been young in the course of their life-time before, and therefore had increased experience with the other-age young faces, one might expect the own-age bias to be either reduced or absent in elderly participants.

With regard to ERPs the following hypotheses were tested. (1) Since enhanced and delayed N170 components were observed for other-race faces in a recent study on the own-race bias (Stahl et al., 2008), we expected similar effects in the present study, namely increased and delayed N170 peaks for old compared to young faces in both groups of participants. (2) Recently, the posterior P2 has been shown to be increased for own in comparison to other-race faces, but only in a group of non-experts for other-race faces who demonstrated a large memory bias. Accordingly, in those conditions that would exhibit a strong own-age bias in performance, we expected a similar P2 increase for own in comparison to other-age faces. Such a finding would add considerable weight to the idea that the own-race and own-age biases share a common basis. (3) Third, based on evidence that the right occipito-temporal N250 is larger for more familiar faces, we reasoned that if structural representations for learned faces from one's own-age group (compared to other-age learned faces) are easier to activate in memory, then a larger N250 for own-age faces would be predicted. (4) Finally, the old/new effect has been described to be related to the amount of information retrieved from episodic memory (Vilberg et al., 2006). Accordingly, in those conditions exhibiting an own-age bias, we also expected increased old/new effects for own-age faces.

2. Methods

2.1. Participants

The studied population consisted of 18 young (three males, 19–28 years, mean age = 22.3) and 18 elderly (two males, 61–76 years, mean age = 66.4) participants. Young participants were undergraduate students from the University of Jena, elderly participants were recruited from a local centre for retired people. The elderly group was paid €5 per hour; young participants chose between the monetary reward or course credits. All participants were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) and reported normal or corrected to normal vision. None of the participants reported neurological or psychiatric disorders or received central-acting medication. All elderly participants resided in independent living conditions.

2.2. Stimuli

Stimuli consisted of 240 pictures showing 120 old (mean age 69 years ± 7.2 S.D.) and 120 young faces (mean age 22 years ± 3.0 S.D.), respectively. Half of the old and half of the young faces were female. Pictures were taken from the CAL/PAL face database (Minear & Park, 2004). They were edited using Adobe Photoshop, converted to grey-scale with black background so that all information apart from the face (clothing, etc.) was deleted. All stimuli were framed within an area of 170 × 216 pixels (6.0 cm × 7.6 cm), corresponding to a visual angle of approximately 3.8° × 4.8° at a viewing distance of 90 cm. All stimuli were presented on a computer monitor using E-Prime™. Responses were recorded using the E-Prime response box attached to the computer.

2.3. Experimental design and procedure

Participants were seated in an electrically shielded, sound-attenuated and dimly lit cabin (IAC™) with their heads in a chin rest and an approximate distance of 90 cm between the eyes and the computer screen. Each trial consisted of the presentation of a face stimulus for various durations depending on experimental condition (see below). Each face was preceded by a fixation cross presented for 500 ms. The trial ended with a blank screen for 500 ms. Participants had to respond via button presses within 2000 ms after stimulus onset.

The experiment consisted of six blocks, each divided into a study and a test phase. During the study phase 10 young and 10 elderly faces, half of each female, were presented to the participants for 5 s. The task was to decide as fast and accurately as possible whether the current face was old or young. Participants were additionally instructed to memorize the faces for a later memory test. Study and test phases were separated by breaks of 30 s duration. During each test phase the 20 studied faces from the directly preceding study phase as well as 20 new faces (again half old, half young, 50% female in each face age group) were presented for 2000 ms each. Participants were asked to decide as fast and accurately as possible whether these faces had been presented in the directly preceding study phase. Stimuli during study and test phases were presented in pseudo-randomized order, assuring that at least five interleaving faces were shown between any presentations of identical faces in the study and test phase. Between each block, subjects were allowed a self-timed period of rest.

Table 1
Behavioural data

	Young participants		Elderly participants	
	Old faces	Young faces	Old faces	Young faces
Study phases				
RT (ms)	760	804	993	1115
S.D.	162	212	160	212
ACC	.98	.97	.92	.91
S.D.	.03	.04	.14	.13
Test phases				
RT hits (ms)	859	839	1010	1089
S.D.	86	102	130	142
RT false alarms (ms)	1013	1063	1083	1175
S.D.	122	185	150	129
Hits	.77	.87	.73	.68
S.D.	.13	.07	.16	.20
False alarms	.18	.13	.46	.35
S.D.	.11	.08	.14	.10
d'	1.65	2.26	.71	.86
C	.07	.00	−.25	−.04

RT, Reaction times (for correct responses only); ACC, accuracy.

During study phases reaction time (RT) and accuracy data were analyzed for old and young faces and each group of participants. RT data were calculated from correct classifications only. Data from the test phase were sorted into four conditions for both old and young faces: hits (correctly identified studied faces), misses (studied faces wrongly classified as new), correct rejections (CorrRej, new faces correctly identified as new), and false alarms (FA, new faces wrongly classified as studied). Measures of sensitivity (d') and response bias (C) were calculated for the two classes of faces in each subject group (cf. Green & Swets, 1966). Sensitivity relates to the probability of detecting target stimuli (i.e. studied faces) from background events (i.e. new faces). d' was calculated by subtract-

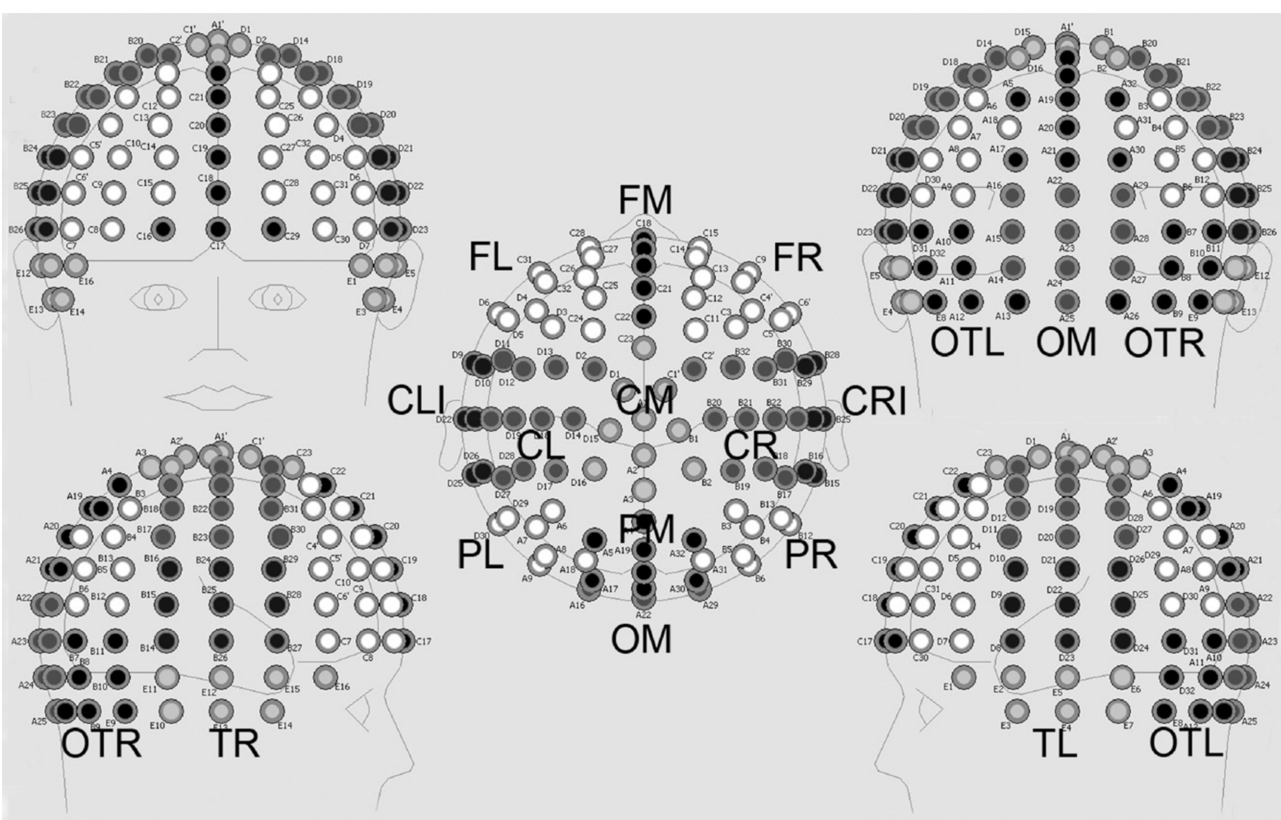

Fig. 1. Positions of the 144 electrodes. Grey tones indicate regions of interest. FL, Frontal left; FM, frontal medial; FR, frontal right; CLI, central left inferior; CL, central left; CM, central medial; CR, central right; CRI, central right inferior; PL, parietal left; PM, parietal medial; PR, parietal right; TL, temporal left; OTL, occipito-temporal left; OM, occipital medial; OTR, occipito-temporal right; TR, temporal right.

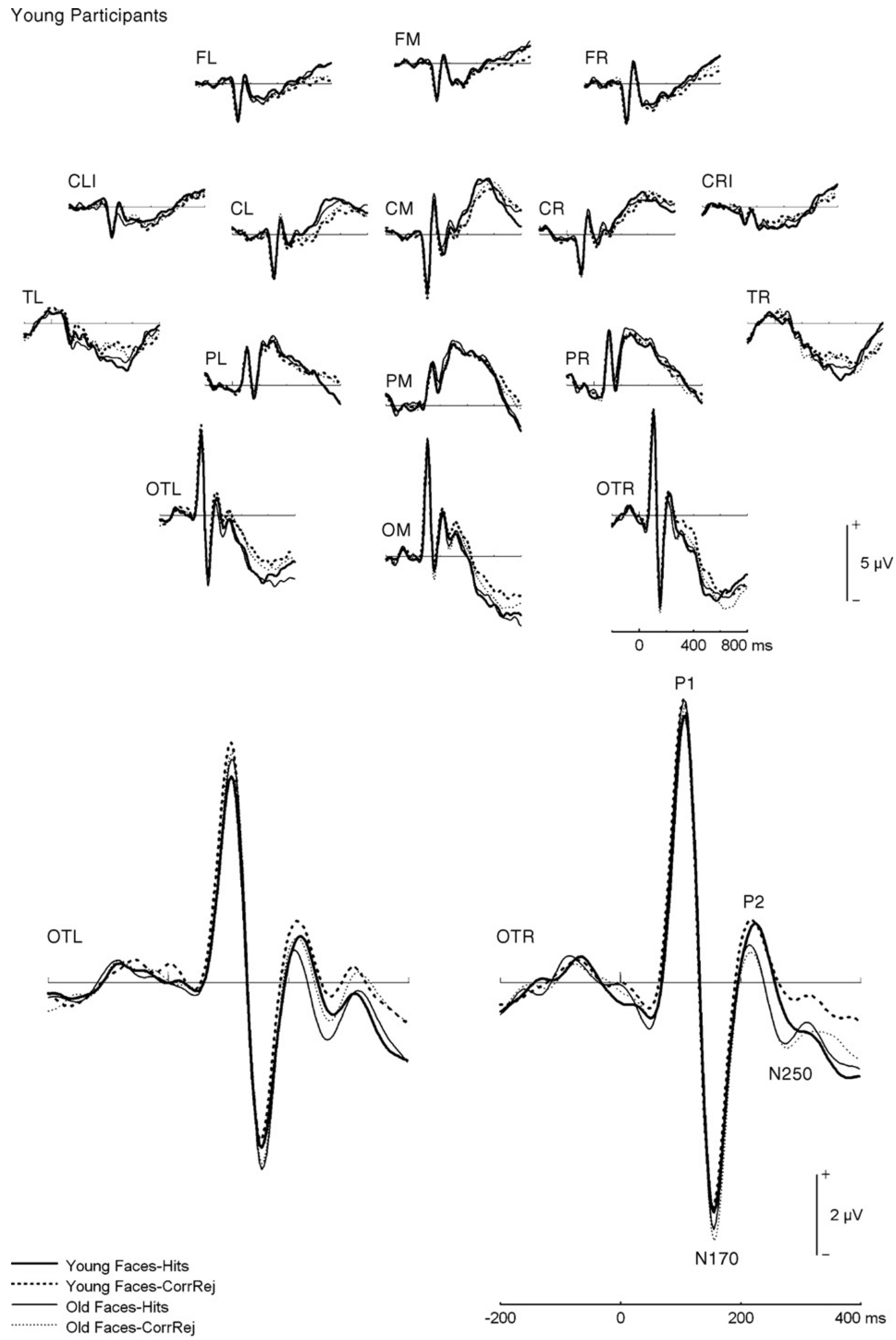

Fig. 2. Test phase grand mean ERPs for young participants. Note the differential processing of old and young faces at the N170, P2, and N250 components (lower part).

ing the *z*-transformed false alarm rate from the *z*-transformed hit rate. Larger d' values correspond to a higher sensitivity. The response bias reflects the tendency of participants to prefer one of the two response alternatives ('studied' or 'new'), independent of whether the item is learned or new. Response bias (C) was calculated as follows: $C = -(z[\text{hits}] + z[\text{false alarms}])/2$. Negative C values correspond to a liberal response bias, with 'studied' responses being more likely compared to 'new' responses, while positive C values correspond to a conservative response bias, with 'studied' responses being less likely compared to 'new' responses.

2.4. EEG recording and analysis

During test phases, 144-channel EEG was recorded using a BioSemi Active II system (BioSemi, Amsterdam, Netherlands). Active sintered Ag/Ag–Cl electrodes were placed according to the standard BioSemi 128-channel layout, with 16 additional electrodes placed below these positions at inferior occipito-temporal and temporal sites. EEG was recorded from DC to 75 Hz with a 256 Hz sample rate. Contributions of blink artefacts were corrected using the algorithm implemented in BESA 5.1 (Berg & Scherg, 1994). Continuous EEG data was segmented from −200 to 1200 ms relative to stimulus onset, with the first 200 ms as baseline. Trials contaminated by non-ocular artefacts and saccades were rejected from further analysis. Artefact rejection was carried out using the BESA 5.1 tool, which sets an individual criterion of maximum amplitude difference within the chosen time segments for each participant. When appropriate, a more conservative criterion was chosen manually, resulting in an average amplitude threshold of 100 µV. Furthermore, a gradient criterion, rejecting all trials with more than 75 µV difference between two consecutive data points was chosen. Remaining trials were recalculated to average reference, digitally low-pass filtered at 20 Hz (12 db/oct, zero phase shift), and averaged according to the experimental conditions. Since sufficient numbers of trials from misses and false

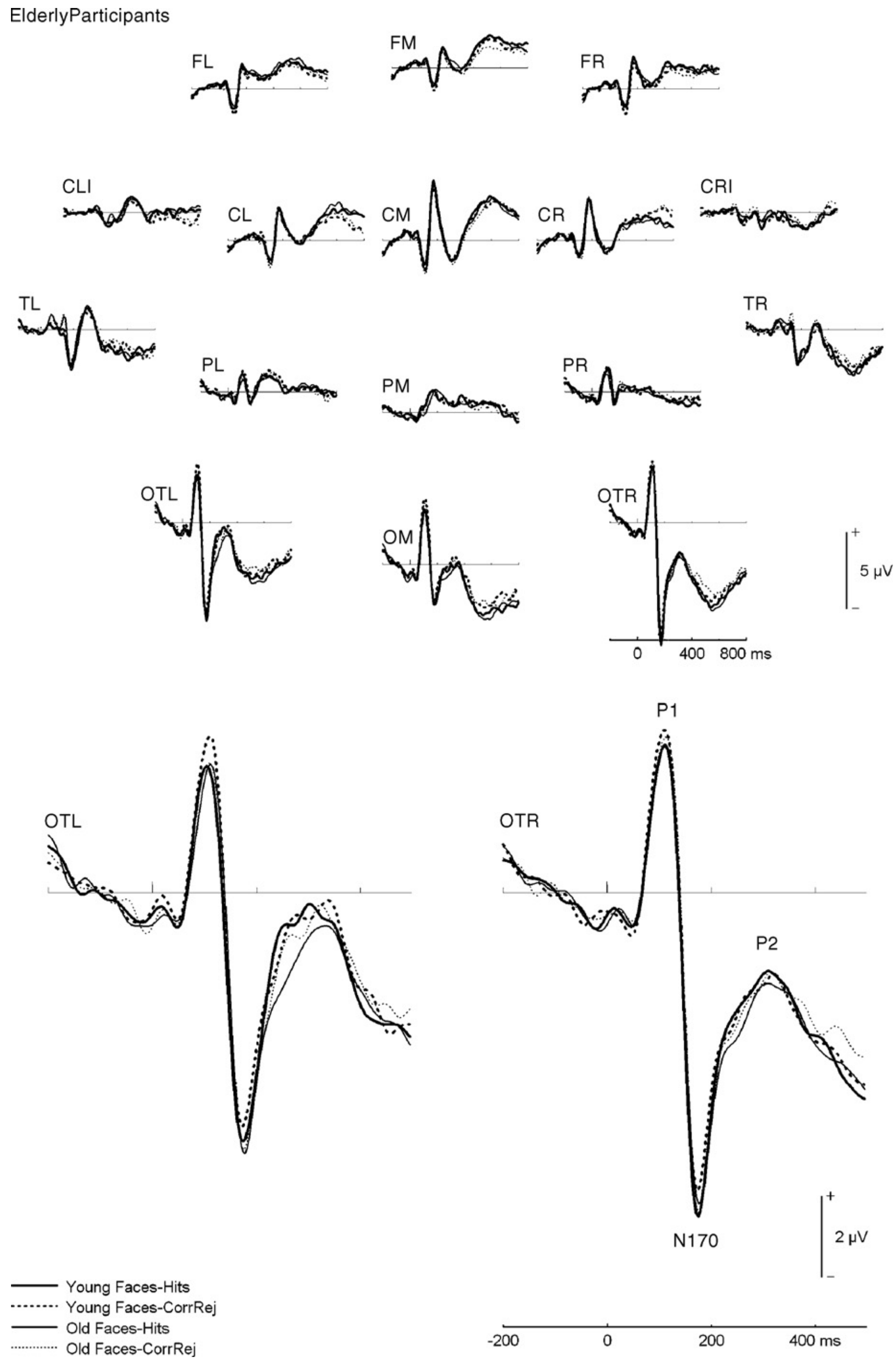

Fig. 3. Test phase grand mean ERPs for elderly participants.

alarms were not available for most of the participants, four different average waveforms were calculated for the test phases of each group, namely hits to old faces (with a mean of 46 and 41 trials for young and elderly participants, respectively), CorrRej to old faces (46/28 trials), hits to young faces (44/37 trials), and CorrRej to young faces (45/33 trials). Minimum trial number per condition was 16. For statistical analysis, channels were pooled to 16 regions of interest (left frontal [FL], right frontal [FR], medial frontal [FM], left central [CL], right central [CR], medial central [CM], left parietal [PL], right parietal [PR], medial parietal [PM], left inferior central [CLI], right inferior central [CRI], medial occipital [OM], left occipito-temporal [OTL], right occipito-temporal [OTR], left temporal [TL], right temporal [TR] regions; cf. Fig. 1). These ROIs were chosen on the basis of previous experience with experiments on face recognition memory (Stahl et al., 2008).

In the resulting waveforms, peak latencies for two early components (P1, N170) were determined. P1 latency was analyzed at OM between 80 and 130 ms, N170 latency was analyzed at OTL and OTR between 130 and 200 ms. Individual peak amplitudes were determined at OTL, OM, and OTR for the P1, as well as at OTL and OTR for N170. Moreover, mean amplitudes relative to a 200 ms baseline were calculated for three additional time segments. These components were the P2 (measured at OTL/OTR) and N250 (OTL/OTR), with mean amplitudes derived from time windows ranging 40 ms around the grand mean peaks for the respective components in each group of participants. Specifically, P2 peaks occurred at ~220 ms for young and at ~310 ms for elderly participants, and N250 peaks were observed at ~285 ms for young and at ~410 ms for elderly participants. In case of no clear local negative peaks of N250, the time window was centered at a flattened part of the negative slope in the N250 time range. Finally, the old/new effect was measured (mean amplitudes from 400 to 600 ms for young and 500–700 ms for elderly participants; measured at FL/FM/FR/CL/CM/CR/PL/PM/PR). Statistical analysis was performed by calculating mixed-model and repeated-measures ANOVAs. When appropriate, degrees of freedom for the repeated-measures factors were corrected according to Greenhouse–Geisser.

Table 2
Latency and amplitude measures of the examined ERP components

	Peak latencies			Amplitude measures								
	P1 (OM) (ms) ± S.D.	N170 (OTL) (ms) ± S.D.	N170 (OTR) (ms) ± S.D.	P1 (OTL) (μV) ± S.D.	P1 (OM) (μV) ± S.D.	P1 (OTR) (μV) ± S.D.	N170 (OTL) (μV) ± S.D.	N170 (OTR) (μV) ± S.D.	P2 (OTL) (μV) ± S.D.	P2 (OTR) (μV) ± S.D.	N250 (OTL) (μV) ± S.D.	N250 (OTR) (μV) ± S.D.
Young participants												
Young faces—hits	108.7 ± 6.5	155.1 ± 12.4	157.6 ± 9.5	5.2 ± 3.4	7.7 ± 3.7	6.8 ± 4.0	−4.7 ± 2.9	−6.4 ± 7.0	.9 ± 2.3	1.3 ± 3.8	−.6 ± 2.6	−1.0 ± 4.0
Young faces—CR	107.8 ± 7.1	154.7 ± 12.6	156.4 ± 6.7	5.9 ± 3.2	7.8 ± 3.4	7.0 ± 4.1	−4.6 ± 2.7	−6.2 ± 6.3	1.3 ± 2.1	1.5 ± 3.3	−.0 ± 2.4	−.3 ± 3.4
Old faces—hits	109.1 ± 5.2	156.3 ± 9.9	155.9 ± 5.6	5.8 ± 3.4	8.1 ± 3.3	7.1 ± 4.3	−5.2 ± 2.6	−6.8 ± 6.5	.5 ± 2.5	.9 ± 4.3	−1.0 ± 3.1	−1.3 ± 4.7
Old faces—CR	108.6 ± 6.5	155.8 ± 10.1	156.6 ± 6.6	5.9 ± 3.2	7.9 ± 3.8	7.0 ± 3.8	−5.3 ± 2.4	−7.2 ± 6.0	.9 ± 2.1	.7 ± 3.8	−.5 ± 2.9	−1.5 ± 4.2
Elderly participants												
Young faces—hits	107.7 ± 21.4	175.1 ± 18.4	173.7 ± 12.1	3.6 ± 2.2	5.0 ± 3.5	4.0 ± 2.1	−7.5 ± 4.4	−9.2 ± 5.5	−.5 ± 2.7	−2.1 ± 2.7	−3.1 ± 2.4	−3.8 ± 2.6
Young faces—CR	109.8 ± 19.2	177.2 ± 18.0	173.4 ± 11.6	4.3 ± 2.2	5.5 ± 3.6	4.4 ± 2.1	−6.9 ± 4.1	−8.4 ± 4.6	−.4 ± 2.2	−2.1 ± 2.5	−2.6 ± 2.0	−3.8 ± 1.9
Old faces—hits	111.4 ± 20.8	177.6 ± 15.7	176.3 ± 13.3	3.6 ± 2.3	4.6 ± 3.6	3.8 ± 2.2	−7.6 ± 4.3	−9.1 ± 5.6	−.9 ± 2.0	−2.3 ± 2.7	−2.8 ± 2.0	−4.0 ± 2.2
Old faces—CR	109.6 ± 19.2	177.6 ± 14.5	176.1 ± 11.6	3.5 ± 2.8	5.1 ± 3.9	4.2 ± 2.4	−7.3 ± 4.3	−9.0 ± 5.6	−.5 ± 2.1	−2.1 ± 2.5	−2.6 ± 2.1	−3.4 ± 1.9

3. Results

3.1. Behavioural data

Behavioural data from the study and test phases are given in Table 1.

In the study phases, a mixed-model ANOVA for RT with the between-subject factor 'group' (young vs. elderly participants) and the within-subject factor 'face age' (old vs. young faces) resulted in significant main effects for both 'face age' (F[1,34] = 18.5, p < .001) and 'group' (F[1,34] = 20.7, p < .001), indicating faster RTs for young participants and old faces. The corresponding ANOVA for accuracies yielded no significant effects, but a trend for the between-subjects factor (F[1,34] = 3.9, p = .058).

Since the z transformation used to calculate d' and C is non-linear, non-parametric tests were used to statistically compare these measures. Mann–Whitney tests yielded significantly higher d' scores for young in comparison to elderly participants, for both young (U = 9.0; p < .001) and old face stimuli (U = 28.0; p < .001). Wilcoxon tests on d' revealed that young participants were significantly more accurate in recognizing young compared to old faces (z = −3.2; p < .01), whereas no significant difference between the recognition of young and old faces was observed in elderly participants (z = −1.4; p > .05). A comparison of C between groups revealed no significant difference between young and elderly participants for young faces (U = 140.0; p > .05). However, compared to young participants the elderly group responded significantly more liberal to old faces (U = 73.0; p < .01). Whereas in young participants no significant difference between C for old and young faces was observed (z = −.5; p > .05), elderly participants demonstrated significantly more liberal response biases for old in comparison to young faces (z = −2.3; p < .05).

3.2. Event-related potentials

Figs. 2 and 3 illustrate the grand mean ERPs for elderly and young participants during the test phases. Latency and amplitude measures derived for the examined components are given in Table 2. Analyses of variance were calculated with the within-subjects factors 'face age' (young vs. old faces), 'response' (hits vs. CorrRej), and ROI (see below), as well as the between subjects factor 'group' (young vs. elderly participants).

3.2.1. P1

Analysis of P1 latency at OM did not yield any significant effects. ANOVA for P1 peak amplitude (at OTL/OM/OTR) resulted in significant main effects for 'group' (F[1,34] = 6.4, p < .05), reflecting smaller amplitudes for elderly participants, and 'ROI' (F[1.9,66] = 12.6, p < .001), with larger amplitudes at the central in comparison to the more lateral ROIs.

3.2.2. N170

ANOVA for N170 peak latency (at OTL/OTR) yielded a significant main effect of the 'group' factor (F[1,34] = 30.5, p < .001), reflecting later N170 peaks for elderly participants. Analysis of N170 peak amplitude (at OTL/OTR) resulted in a significant main effect for 'ROI' (F[1,34] = 4.3, p < .05), reflecting larger N170 amplitudes over the right hemisphere, as well as a significant main effect 'face age' (F[1,34] = 18.1, p < .001), with larger amplitudes for old in comparison to young face stimuli. This effect appeared to be more pronounced for young compared to elderly participants by visual inspection, which was reflected in a trend for a significant interaction of 'face age × group' (F[1,34] = 2.9, p = .09). Although generally larger N170 amplitudes were observed in the elderly participant group, the 'group' factor did not reach significance ($F[1,34] = 2.8$, $p = .10$).

3.2.3. P2

Analysis of the P2 time window was carried out at OTL and OTR. The corresponding ANOVA resulted in a significant main effect for 'group' ($F[1,34] = 8.3$, $p < .01$), reflecting more positive going ERPs in the young participants, a significant main effect for 'face age' ($F[1,34] = 5.2$, $p < .05$), with larger amplitudes for young in comparison to old faces, a significant interaction of 'ROI × group' ($F[1,34] = 5.2$, $p < .05$), reflecting smaller P2 amplitudes at OTR in the elderly participants only, as well as a significant interaction of 'ROI × response' ($F[1,34] = 6.0$, $p < .05$). A subsequent ANOVA calculated at OTL revealed a significant effect of 'response' ($F[1,34] = 5.2$, $p < .05$), reflecting more positive amplitudes for correct rejections compared to hits. The corresponding ANOVA at OTR did not reveal a significant effect of 'response' ($F < 1$).

3.2.4. N250

Repeated-measures ANOVA for the N250 time window calculated at OTR and OTL revealed significant main effects of 'ROI' ($F[1,34] = 4.9$, $p < .05$), reflecting more negative amplitudes at OTR, 'response' ($F[1,34] = 6.1$, $p < .05$), with more negative amplitudes for hits compared to correct rejections, and 'group' ($F[1,34] = 8.5$, $p < .01$), with more negative amplitudes for elderly participants. Moreover, a significant interactions of 'face age × group' ($F[1,34] = 4.7$, $p < .05$), as well as a significant four-way interaction of 'ROI × face age × response × group' ($F[1,34] = 6.8$, $p < .05$) was detected. Subsequent ANOVAs calculated for young participants at OTL revealed a significant main effect of 'response' ($F[1,17] = 7.0$, $p < .05$), reflecting more negative amplitudes for hits compared to correct rejections. At OTR, a significant main effect of 'face age' ($F[1,17] = 7.9$, $p < .05$), as well as a significant interaction of 'face age × response' ($F[1,17] = 5.2$, $p < .05$) was observed, reflecting more negative amplitudes for hits compared to correct rejections for young faces only. Corresponding ANOVAs for elderly participants yielded no significant effects (all $F < 1$, except for the main effects of 'response' both at OTL, $F[1,17] = 2.1$, $p > .05$, and OTR $F[1,17] = 1.7$, $p > .05$, as well as the interaction of 'face age × response' at OTR, $F[1,17] = 2.2$, $p > .05$).

3.2.5. Old/new effect

For young participants, an old/new effect (more positive ERPs for hits than correct rejections) was observed from 400 to 600 ms after stimulus onset. For elderly participants, the corresponding old/new effect started at ~500 ms. Accordingly, in order to quantify the old/new effect, mean amplitudes were calculated from 400 to 600 ms in the young and from 500 to 700 ms in the elderly group. Fig. 4 illustrates the amplitudes and topographies of the old/new effects for the two groups.

Statistical analysis was carried out using ERP data from nine ROIs, namely FL, FM, FR, CL, CM, CR, PL, PM, PR (cf. Table 3 for mean amplitude measures). An ANOVA with the within-subjects factors 'anterior/posterior ROI' (frontal, central, or parietal ROIs), 'left/middle/right ROI', 'face age' (young versus old face), and 'response' (hits, correct rejections), and the between-subjects factor 'group' (young versus elderly participants) was calculated. A significant interaction of 'left/middle/right ROI × response' ($F[1.7,56.8] = 5.0$; $p < .05$) was further qualified by a significant three-way interaction of 'anterior/posterior ROI × left/middle/right ROI × response' ($F[3.2,108.2] = 7.8$; $p < .001$), suggesting a maximum old/new effect at CL. Furthermore, a significant interaction of 'response × group' ($F[1,34] = 4.7$; $p < .05$) was observed, indicating smaller old/new effects in the elderly. Most importantly for the present purpose, a significant interaction of

Table 3
Mean amplitude measures in μV ± S.D. in the old/new effect time window for each of the nine ROIs separately and averaged over these nine regions

	FL (μV) ± S.D.	FM (μV) ± S.D.	FR (μV) ± S.D.	CL (μV) ± S.D.	CM (μV) ± S.D.	CR (μV) ± S.D.	PL (μV) ± S.D.	PM (μV) ± S.D.	PR (μV) ± S.D.	Average (μV) ± S.D.
Young participants										
Young faces–hits	0 ± 1.5	0 ± 1.7	−.1 ± 1.6	2.0 ± 1.6	3.2 ± 1.7	2.3 ± 1.1	1.4 ± 1.0	3.0 ± 2.2	1.7 ± 1.9	1.5 ± .6
Young faces–CR	−.4 ± 1.3	−.3 ± 1.4	−.6 ± 1.3	.8 ± 1.4	2.4 ± 1.5	1.8 ± .9	1.1 ± 1.2	3.0 ± 2.3	1.7 ± 1.8	1.1 ± .5
Old faces–hits	−.1 ± 1.5	.1 ± 1.3	−.2 ± 1.4	1.6 ± 1.4	3.1 ± 1.5	2.0 ± .9	1.3 ± 1.1	3.2 ± 2.0	2.0 ± 1.7	1.4 ± .5
Old faces–CR	−.3 ± 1.5	0 ± 1.3	−.4 ± 1.0	1.0 ± 1.4	2.7 ± 1.4	2.0 ± 1.1	1.1 ± 1.1	3.0 ± 1.6	1.6 ± 1.5	1.2 ± .6
Elderly participants										
Young faces–hits	1.5 ± 1.2	1.9 ± 1.4	1.4 ± 1.3	1.8 ± 1.0	2.6 ± 1.6	1.4 ± 1.2	.2 ± 1.7	.5 ± 1.7	−.6 ± 1.3	1.2 ± .7
Young faces–CR	1.3 ± 1.3	1.6 ± 1.4	1.1 ± 1.6	1.4 ± 1.0	2.4 ± 1.5	1.7 ± 1.4	.2 ± 1.8	.5 ± 1.5	−.4 ± 1.1	1.1 ± .6
Old faces–hits	1.7 ± 1.4	1.8 ± 1.3	1.3 ± 1.3	2.2 ± 1.2	2.5 ± 1.8	1.2 ± 1.2	.4 ± 1.7	.5 ± 1.8	−.5 ± 1.4	1.2 ± .7
Old faces–CR	1.4 ± 1.5	1.3 ± 1.6	.9 ± 1.4	1.6 ± 1.0	2.3 ± 1.6	1.5 ± 1.5	.2 ± 1.7	.3 ± 1.5	−.4 ± 1.4	1.0 ± .7

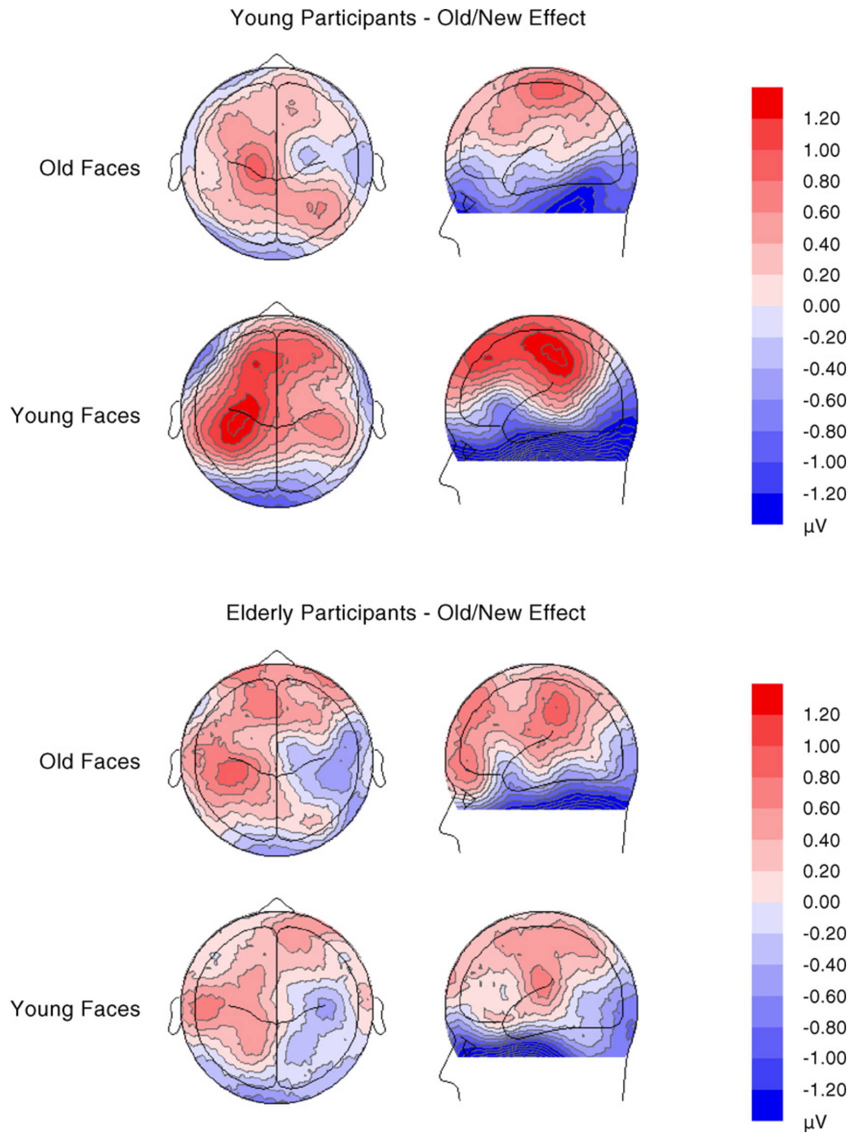

Fig. 4. Scalp topographical voltage maps (spherical spline interpolation, 90° equidistant projection) from 400 to 600 ms for young and from 500 to 700 ms for elderly participants of the difference curves from hits and correct rejections to old and young faces. Note the increased effect for own-age faces in the young participant group.

'face age × response × group' was observed ($F[1,34] = 4.7$; $p < .05$), reflecting enhanced old/new effects for young faces in young participants (cf. Fig. 4).[1]

4. Discussion

The present study examined elderly and young adult participants' recognition memory for pre-experimentally unfamiliar old and young faces. While young participants were significantly more accurate at recognizing faces from their own-age group, no corresponding own-age bias was observed in elderly participants. The behavioural findings were accompanied by ERP effects that revealed an analogous interaction between face stimulus age and the observer's age at various levels of neural processing. These results are discussed in detail in the following paragraphs.

4.1. Behavioural results

The current study demonstrated an own-age memory bias for young but not for elderly participants. The multi-dimensional face space framework (Valentine, 1991; Valentine & Endo, 1992) explains the own-race bias, which might be seen as potentially related to the present own-age bias, on the basis of perceptual learning. According to this model, each face is encoded as a location in a multi-dimensional space. The dimensions are unspecified, but are assumed to optimally discriminate between the faces. Furthermore, the dimensions within the space emerge from an individual's life-time experience with faces, and usually the majority of the faces encountered belong to the viewer's ethnic group. Accordingly, the dimensions of the space will be the best possible ones for discriminating between own-race faces, but not necessarily for faces of other ethnic groups.

[1] In addition, Spearman rank correlations between the old/new effect and d' were calculated. This analysis resulted in a significant positive correlation of d' and the old/new effect averaged over frontal, central, and parietal ROIs for young faces in the elderly participants ($r = .77$, $p < .001$). Correlations between d' and old/new measures for old faces in elderly participants, as well as the corresponding analyses for young participants yielded no significant results. Please note, that these analyses are limited by relatively small sample sizes and the large interindividual variance in the size of ERP effects due to individual anatomical prerequisites.

As Valentine and Endo (1992) explicitly pointed out, face space dimensions which are best suited to represent young faces might not be optimal for representing older faces. Accordingly, young participants, who presumably encountered a majority of young faces during their life-time and optimized their face representation system accordingly, should be more accurate at recognizing young compared to old faces. By contrast, elderly participants had been young in the past, and thus experience with both young (predominantly from the more distant past) and older faces (from the more recent past) may have made considerable contributions to their face space. While the relative contributions from those experiences remains unclear, the fact that elderly participants showed similar levels of recognition performance and memory-related ERP effects might point to contributions both from more remote and more recent experiences. Accordingly, the present findings are in line with a perceptual learning-based explanation to an asymmetrical own-age bias, which acts in addition to a more general decrease in memory capabilities with age. However, on the basis of the present data alone, alternative explanations cannot be ruled out. One possibility is that enhanced holistic processing of own-age faces might explain the effect observed in young participants, similar to the holistic processing account to the own-race bias (Michel, Rossion, et al., 2006; Tanaka et al., 2004).

A second alternative explanation for the results of the present study can be deduced from the feature-selection hypothesis (Levin, 1996, 2000). According to this account, the own-age effect in young participants could occur because young people code old-age-specifying features (such as wrinkles or changes in skin colour/texture) at the expense of individuating information. This is analogous to the suggestion that selecting race-specifying features in other-race faces reduces the processing of individuating information, which in turn reduces recognition memory (Levin, 2000). Future studies will aim at discriminating between these different theoretical accounts to the own-age bias.

In line with the present study, Bartlett and Leslie (1986) reported an own-age bias for young but not for elderly participants. Similar to the perceptual learning account, these authors argued that whereas younger adults have more knowledge of younger than of older faces, older adults, who have themselves been young, are equally knowledgeable of, and equally good at remembering, younger and older faces. By contrast, other studies observed an own-age bias for children and elderly participants (Anastasi & Rhodes, 2005), but not consistently so for young adults (Anastasi & Rhodes, 2006; Lamont et al., 2005). Anastasi and Rhodes (2006) proposed that the more consistent own-age bias for older participants in comparison to former studies might be explained by the fact that their participants lived in retirement communities. By contrast, the elderly participants in the present study all resided in independent living conditions, such that their contact to people of various age groups might be less restricted.

In summary, the own-age bias for young participants described in the present study is in line with the seminal studies on the phenomenon (Bartlett & Leslie, 1986; Fulton & Bartlett, 1991) and with a perceptual learning-based explanation (Valentine & Endo, 1992). As detailed below, the analysis of ERPs considerably enhances our understanding of the neuro-cognitive mechanisms mediating the present own-age bias.

4.2. N170

Two results were obtained from the N170 component. First, N170 was delayed for the elderly participants, whereas the latency of the P1 component did not differ between groups. Second, in both groups larger N170 peak amplitudes were observed for old in comparison to young faces.

The delay of the N170 in elderly participants might reflect a degree of age-related slowing, which starts to affect processing after those basic visual analyses reflected in the P1 have been completed, possibly at a stage of structural encoding of faces. However, the delayed N170 in the present study is in remarkable contrast to a study by Pfütze et al. (2002) who used a slightly different face recognition task, and who found age-related delays in ERP components to be specific for later ERP components, but to be absent for the N170. Similarly, Chaby and coworkers (Chaby, George, Renault, & Fiori, 2003; Chaby, Jemel, George, Renault, & Fiori, 2001) did not report age-related differences in N170 latency. The experimental task or the age of the population of young and elderly participants in our study would be plausible sources for this discrepancy. In particular, the studies by Chaby and coworkers compared groups with mean ages of approximately 25 and 50 years, respectively, whereas age-related latency delays might be observed at older ages only. At the same time, our young group was at best marginally younger, and our old group marginally older, than the respective samples tested by Pfütze et al. (2002). Overall, a difference between participant samples in those studies seems unlikely to fully explain the observed differences. At present, the reasons for these discrepancies must remain somewhat unclear, and the issue of age-related delays at various stages of face processing clearly deserves further investigation.[2]

With respect to enhanced N170 peak amplitudes for old faces, we note that similar results were observed recently for other-race faces (Herrmann et al., 2007; Stahl et al., 2008). Stahl et al. (2008) observed this N170 effect to occur independently from expertise with other-race faces, which again is in line with the current finding of enhanced N170 amplitudes for old faces independent of group. Rossion et al. (1999) suggested that the increased N170 amplitude for inverted faces reflects the greater difficulty of structurally encoding these stimuli. In a similar vein, structural encoding of old compared to young faces might be more difficult. In contrast, Sagiv and Bentin (2001) interpreted enhanced N170 amplitudes for inverted faces as reflecting enhanced analysis of their facial components relative to their gestalt, which might also hold true for old in comparison to young faces.

Alternatively, the N170 amplitude modulation could reflect a focus on details such as wrinkles in old faces. Given that the perception of such facial detail would seem to require the processing of high spatial frequencies, this interpretation is supported by a recent study that investigated the relationship between spatial frequencies and N170 in face processing. Halit, de Haan, Schyns, and Johnson (2006) found N170 amplitudes for high- plus low-spatial frequency faces, in which the middle frequencies were filtered, to be enhanced compared to low-spatial frequency faces, in which middle and high frequencies were filtered (but see also Holmes, Winston, & Eimer, 2005, who reported no influence of spatial frequency on N170 amplitude). Importantly, differences in N170 amplitude related to spatial frequency information in faces have been demonstrated to depend upon the task at hand (Goffaux, Jemel, Jacques, Rossion, & Schyns, 2003). Assuming that (1) young and old faces are similar with respect to low spatial frequencies, (2) old faces exhibit enhanced high spatial frequencies, and (3) that age of the stimuli is obviously a salient dimension throughout the experiment (although not directly task-relevant during test phases), these findings are well in line with an increased N170 for old in comparison to young faces. However, since a relatively larger

[2] Please note that although small N170 latency differences (in the range of 2–3 ms) have been detected in a recent study from our group (Wiese et al., in press) with a 256 Hz sampling rate and a very similar analysis strategy, a higher sampling interval would have been preferable for detecting very small latency differences.

negativity for old faces was not restricted to N170, but was similarly observed in the subsequent P2 time window, an alternative interpretation is described below.

4.3. P2 and N250

In the present study, more positive P2 amplitudes were observed in the young compared to the elderly participant group. Moreover, young and elderly participants demonstrated more positive P2 components for young in comparison to old faces. Intriguingly, similar results have been found in a recent study from our group on the other-race effect (Stahl et al., 2008). In a group of 'non-expert' Caucasian participants, increased P2 amplitudes were observed for Caucasian compared to Asian faces at occipito-temporal ROIs bilaterally, which may be seen in line with several studies that observed larger P2 amplitudes for more 'typical' face stimuli (Halit et al., 2000; Latinus & Taylor, 2006; Milivojevic et al., 2003). Also in general accordance with our findings, Latinus and Taylor (2005) suggested that P2 amplitude differences reflect deeper or more extensive processing as a function of stimulus ambiguity.

Taken together with the amplitude results from the N170 in both studies, these findings suggest an enhanced processing negativity (see, e.g. Czigler & Csibra, 1990) starting at approximately 150 ms. A similar phenomenon has been described by George, Evans, Fiori, Davidoff, and Renault (1996) in a study on normal versus moderately scrambled faces and has been associated with the difficulty of stimulus processing. For the present results, this interpretation would suggest that per default old faces are more difficult to encode at an individual level than young faces.

Furthermore, in the present study P2 was modulated by the 'response' factor (i.e. by hits versus correct rejections) at OTL, but not at OTR. This is in general accordance with Halit et al. (2000) who suggested that P2 could index early recognition processes. Also in line with the present study, Boehm, Klostermann, and Paller (2006) reported a more positive going waveform for repeated faces at left occipito-temporal sites, which started in a similar time range. Our findings thus indicate that in the present study several processes co-occur in the P2 time range, probably related to more in-depth perceptual analysis related to the probably more ambiguous old faces, as well as early memory-related processes (seen in the left hemisphere only).

Importantly, in the young participants group only, more negative N250 components for hits compared to correct rejections to young faces were observed, while no corresponding effect for old faces was evident. In addition, no corresponding effects were detected in elderly participants. Accordingly, at this processing stage, probably reflecting access to temporary structural representations of the studied faces (cf. Schweinberger & Burton, 2003), an initial ERP correlate of the own-age bias in young participants was observed. Such structural representations might have been more difficult to access for old faces which may not be optimally represented in the young participants' face space. Please note that a similar N250 effect for own-race faces is evident in the data of Stahl et al. (2008), although it is not described in the paper.

4.4. Old/new effects

Finally, the present ERP old/new effects indicate a clear interaction of stimulus age with the participants' age. Whereas young participants demonstrated more pronounced ERP old/new effects for own-age faces, no such bias was observed for elderly participants.

Li, Morcom, and Rugg (2004) observed smaller left parietal old/new effects for items more difficult to recognize (presented once during study) in comparison to easy to recognize items (presented twice) in young participants. More recently, Vilberg et al. (2006) demonstrated the old/new effect to be related to the amount of retrieved information. Following the face space model of Valentine and Endo (1992), one could assume that the dimensions of the young participants' face space are not optimal for representing old faces. Accordingly, representations of old faces are less distinctive and therefore contain less information relevant for recognition. Thus, compared to young faces, recognition of individual old faces during test may be based on a smaller amount of distinctive information, which might result in a smaller old/new effect. A comparable effect was not observed in the elderly participants. Thus, the ERP old/new results parallel our behavioural findings (d') in demonstrating an own-age bias for young but not elderly participants.

Itier and Taylor (2002) reported the parietal old/new effect to be absent for inverted faces compared to upright faces, probably reflecting less accurate recognition processes for these stimuli, which are more difficult to process. In a more recent study, the authors reported larger old/new effects in a second compared to a first repetition for upright faces only, paralleled by an improvement of behavioural accuracy, which was interpreted as reflecting a better stabilization of facial representations when in upright position (Itier & Taylor, 2004). Whereas the parietal old/new effect is assumed to reflect recollection (Curran, 2000; Curran & Hancock, 2007; Paller et al., 2000; Rugg & Curran, 2007), the studies by Itier and Taylor also demonstrated frontal repetition effects, which were interpreted to reflect processes of familiarity (Itier & Taylor, 2004, but see Paller, Voss, and Boehm (2007), for an alternative interpretation of frontal old/new effects). Visual inspection of the old/new effects' topographical distribution in the present study also suggests a frontal memory effect, especially in elderly participants. Further studies that directly address this issue (e.g. in remember/know paradigms) are needed to elucidate the role of familiarity and recollection in own- and other age face recognition memory.

In addition to stimulus-age-related effects, differences in the later components of young and elderly participants were observed, especially with regard to a delayed old/new effect in the elderly. It has been suggested that the posterior old/new effect is largely preserved in older adults (Friedman, 2000). In accordance to this finding, Mark and Rugg (1998) found that neither the left parietal old/new effect's magnitude nor its scalp distribution differed between young and elderly participants. However, the authors found the old/new effect to be delayed for about 100 ms for older in comparison to young participants, which was similarly observed in several other studies (Li et al., 2004; Wegesin, Friedman, Varughese, & Stern, 2002). Finally, recent studies described the old/new effects of elderly participants to be reduced over the parietal scalp (Swick, Senkfor, & Van Petten, 2006) and more pronounced at anterior electrode sites (Walhovd et al., 2006). In line with the earlier studies cited above, no statistically significant difference in the scalp distribution of the old/new effect for young and elderly participants was detected in the present study.

4.5. Conclusions

In line with early studies on the role of the participants' age in face memory, the present study found an own-age bias in face recognition memory for young, but not for elderly participants. While the N170 was generally enhanced and the P2 decreased for old in comparison to young faces, two later ERP components paralleled the interaction found in the behavioural results. Both the right occipito-temporal N250, possibly associated with accessing temporary structural representations of the learned faces, and a centro-parietal old/new recognition effect, which has been demonstrated to be sensitive to the amount of retrieved information, were enhanced during the recognition of young compared to old faces in the young participants only. While further research is needed to differentiate in more detail between competing explanations, the present results provide important novel information about the neuro-cognitive mechanisms of the own-age bias in face recognition memory.

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References

Anastasi, J. S., & Rhodes, M. G. (2005). An own-age bias in face recognition for children and older adults. *Psychonomic Bulletin & Review*, *12*, 1043–1047.
Anastasi, J. S., & Rhodes, M. G. (2006). Evidence for an own-age bias in face recognition. *North American Journal of Psychology*, *8*, 237–252.
Bäckman, L. (1991). Recognition memory across the adult life-span—The role of prior knowledge. *Memory & Cognition*, *19*, 63–71.
Bartlett, J. C., & Leslie, J. E. (1986). Aging and memory for faces versus single views of faces. *Memory & Cognition*, *14*, 371–381.
Begleiter, H., Porjesz, B., & Wang, W. Y. (1995). Event-related brain potentials differentiate priming and recognition to familiar and unfamiliar faces. *Electroencephalography and Clinical Neurophysiology*, *94*, 41–49.
Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience*, *8*, 551–565.
Bentin, S., & Deouell, L. Y. (2000). Structural encoding and identification in face processing: ERP evidence for separate mechanisms. *Cognitive Neuropsychology*, *17*, 35–54.
Berg, P., & Scherg, M. (1994). A multiple source approach to the correction of eye artifacts. *Electroencephalography and Clinical Neurophysiology*, *90*, 229–241.
Boehm, S. G., Klostermann, E. C., & Paller, K. A. (2006). Neural correlates of perceptual contributions to nondeclarative memory for faces. *Neuroimage*, *30*, 1021–1029.
Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*, 305–327.
Bruyer, R., Mejias, S., & Doublet, S. (2007). Effect of face familiarity on age decision. *Acta Psychologica*, *124*, 159–176.
Burt, D. M., & Perrett, D. I. (1995). Perception of age in adult Caucasian male faces—Computer graphic manipulation of shape and color information. *Proceedings of the Royal Society of London Series B-Biological Sciences*, *259*, 137–143.
Burton, A. M., Bruce, V., & Johnston, R. A. (1990). Understanding face recognition with an interactive activation model. *British Journal of Psychology*, *81*, 361–380.
Cabeza, R. (2002). Hemispheric asymmetry reduction in older adults: The HAROLD model. *Psychology and Aging*, *17*, 85–100.
Cabeza, R., Nyberg, L., & Park, D. C. (2005). *Cognitive neuroscience of aging*. Oxford: Oxford University Press.
Caldara, R., Rossion, B., Bovet, P., & Hauert, C. A. (2004). Event-related potentials and time course of the 'other-race' face classification advantage. *Neuroreport*, *15*, 905–910.
Caldara, R., Thut, G., Servoir, P., Michel, C. M., Bovet, P., & Renault, B. (2003). Face versus non-face object perception and the 'other-race' effect: A spatio-temporal event-related potential study. *Clinical Neurophysiology*, *114*, 515–528.
Chaby, L., George, N., Renault, B., & Fiori, N. (2003). Age-related changes in brain responses to personally known faces: An event-related potential (ERP) study in humans. *Neuroscience Letters*, *349*, 125–129.
Chaby, L., Jemel, B., George, N., Renault, B., & Fiori, N. (2001). An ERP study of famous face incongruity detection in middle age. *Brain and Cognition*, *45*, 357–377.
Curran, T. (2000). Brain potentials of recollection and familiarity. *Memory & Cognition*, *28*, 923–938.
Curran, T., & Hancock, J. (2007). The FN400 indexes familiarity-based recognition of faces. *Neuroimage*, *36*, 464–471.
Czigler, I., & Csibra, G. (1990). Event-related potentials in a visual-discrimination task—Negative waves related to detection and attention. *Psychophysiology*, *27*, 669–676.
Dehon, H., & Bredart, S. (2001). An 'other-race' effect in age estimation from faces. *Perception*, *30*, 1107–1113.
Eimer, M. (2000a). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology*, *111*, 694–705.
Eimer, M. (2000b). Effects of face inversion on the structural encoding and recognition of faces—Evidence from event-related brain potentials. *Cognitive Brain Research*, *10*, 145–158.
Friedman, D. (2000). Event-related brain potential investigations of memory and aging. *Biological Psychology*, *54*, 175–206.
Fulton, A., & Bartlett, J. C. (1991). Young and old faces in young and old heads—The factor of age in face recognition. *Psychology and Aging*, *6*, 623–630.
George, N., Evans, J., Fiori, N., Davidoff, J., & Renault, B. (1996). Brain events related to normal and moderately scrambled faces. *Cognitive Brain Research*, *4*, 65–76.
George, P. A., & Hole, G. J. (2000). The role of spatial and surface cues in the age-processing of unfamiliar faces. *Visual Cognition*, *7*, 485–509.
Goffaux, V., Jemel, B., Jacques, C., Rossion, B., & Schyns, P. G. (2003). ERP evidence for task modulations on face perceptual processing at different spatial scales. *Cognitive Science*, *27*, 313–325.
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*, 1871–1875.
Halit, H., de Haan, M., Schyns, P. G., & Johnson, M. H. (2006). Is high-spatial frequency information used in the early stages of face detection? *Brain Research*, *1117*, 154–161.
Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*, 223–233.
Herrmann, M. J., Schreppel, T., Jager, D., Koehler, S., Ehlis, A. C., & Fallgatter, A. J. (2007). The other-race effect for face perception: An event-related potential study. *Journal of Neural Transmission*, *114*, 951–957.
Herzmann, G., Schweinberger, S. R., Sommer, W., & Jentzsch, I. (2004). What's special about personally familiar faces? A multimodal approach. *Psychophysiology*, *41*, 688–701.
Hillyard, S. A., Vogel, E. K., & Luck, S. J. (1998). Sensory gain control (amplification) as a mechanism of selective attention: Electrophysiological and neuroimaging evidence. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, *353*, 1257–1270.
Holmes, A., Winston, J. S., & Eimer, M. (2005). The role of spatial frequency information for ERP components sensitive to faces and emotional facial expression. *Cognitive Brain Research*, *25*, 508–520.
Itier, R. J., Alain, C., Sedore, K., & McIntosh, A. R. (2007). Early face processing specificity: It's in the eyes!. *Journal of Cognitive Neuroscience*, *19*, 1815–1826.
Itier, R. J., & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: A repetition study using ERPs. *Neuroimage*, *15*, 353–372.
Itier, R. J., & Taylor, M. J. (2004). Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. *Neuroimage*, *21*, 1518–1532.
Ito, T. A., & Urland, G. R. (2005). The influence of processing objectives on the perception of faces: An ERP study of race and gender perception. *Cognitive Affective & Behavioral Neuroscience*, *5*, 21–36.
James, M. S., Johnstone, S. J., & Hayward, W. G. (2001). Event-related potentials, configural encoding, and feature-based encoding in face recognition. *Journal of Psychophysiology*, *15*, 275–285.
Kaufmann, J. M., Schweinberger, S. R., & Burton, A. M. (in press). N250 ERP correlates of the acquisition of face representations across different images. *Journal of Cognitive Neuroscience*.
Lamont, A. C., Stewart-Williams, S., & Podd, J. (2005). Face recognition and aging: Effects of target age and memory load. *Memory & Cognition*, *33*, 1017–1024.
Latinus, M., & Taylor, M. J. (2005). Holistic processing of faces: Learning effects with Mooney faces. *Journal of Cognitive Neuroscience*, *17*, 1316–1327.
Latinus, M., & Taylor, M. J. (2006). Face processing stages: Impact of difficulty and the separation of effects. *Brain Research*, *1123*, 179–187.
Levin, D. T. (1996). Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology-Learning Memory and Cognition*, *22*, 1364–1382.
Levin, D. T. (2000). Race as a visual feature: Using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition. *Journal of Experimental Psychology-General*, *129*, 559–574.
Li, J., Morcom, A., & Rugg, M. D. (2004). The effects of age on the neural correlates of successful episodic retrieval: An ERP study. *Cognitive, Affective, & Behavioral Neuroscience*, *4*, 279–293.
Light, L. L. (1991). Memory and aging—4 hypotheses in search of data. *Annual Review of Psychology*, *42*, 333–376.
Mark, R. E., & Rugg, M. D. (1998). Age effects on brain activity associated with episodic memory retrieval—An electrophysiological study. *Brain*, *121*, 861–873.
Meissner, C. A., Brigham, J. C., & Butz, D. A. (2005). Memory for own- and other-race faces: A dual-process approach. *Applied Cognitive Psychology*, *19*, 545–567.
Michel, C., Caldara, R., & Rossion, B. (2006). Same-race faces are perceived more holistically than other-race faces. *Visual Cognition*, *14*, 55–73.
Michel, C., Rossion, B., Han, J., Chung, C. S., & Caldara, R. (2006). Holistic processing is finely tuned for faces of one's own race. *Psychological Science*, *17*, 608–615.
Milivojevic, B., Clapp, W. C., Johnson, B. W., & Corballis, M. C. (2003). Turn that frown upside down: ERP effects of thatcherization of misorientated faces. *Psychophysiology*, *40*, 967–978.
Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods Instruments & Computers*, *36*, 630–633.
Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*, 97–113.
Paller, K. A., Gonsalves, B., Grabowecky, M., Bozic, V. S., & Yamada, S. (2000). Electrophysiological correlates of recollecting faces of known and unknown individuals. *Neuroimage*, *11*, 98–110.
Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. *Trends in Cognitive Sciences*, *111*, 243–250.
Perfect, T. J., & Harris, L. J. (2003). Adult age differences in unconscious transference: Source confusion or identity blending? *Memory & Cognition*, *31*, 570–580.

Pfütze, E. M., Sommer, W., & Schweinberger, S. R. (2002). Age-related slowing in face and name recognition: Evidence from event-related brain potentials. *Psychology and Aging*, *17*, 140–160.

Rossion, B., Delvenne, J. F., Debatisse, D., Goffaux, V., Bruyer, R., Crommelinck, M., et al. (1999). Spatio-temporal localization of the face inversion effect: An event-related potentials study. *Biological Psychology*, *50*, 173–189.

Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., et al. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: An electrophysiological account of face-specific processes in the human brain. *Neuroreport*, *11*, 69–74.

Rugg, M. D. (1995). ERP studies of memory. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind. Event-related potentials and cognition* (pp. 132–170). Oxford: Oxford University Press.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences*, *11*, 251–257.

Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: Holistic and part-based processes. *Journal of Cognitive Neuroscience*, *13*, 937–951.

Schendan, H. E., Ganis, G., & Kutas, M. (1998). Neurophysiological evidence for visual perceptual categorization of words and faces within 150 ms. *Psychophysiology*, *35*, 240–251.

Schweinberger, S. R., & Burton, A. M. (2003). Covert recognition and the neural system for face processing. *Cortex*, *39*, 9–30.

Schweinberger, S. R., Pfütze, E. M., & Sommer, W. (1995). Repetition priming and associative priming of face recognition—Evidence from event-related potentials. *Journal of Experimental Psychology-Learning Memory and Cognition*, *21*, 722–736.

Schweinberger, S. R., Pickering, E. C., Jentzsch, I., Burton, A. M., & Kaufmann, J. M. (2002). Event-related brain potential evidence for a response of inferior temporal cortex to familiar face repetitions. *Cognitive Brain Research*, *14*, 398–409.

Scott, L. S., Tanaka, J. W., Sheinberg, D. L., & Curran, T. (2006). A reevaluation of the electrophysiological correlates of expert object processing. *Journal of Cognitive Neuroscience*, *18*, 1453–1465.

Sporer, S. L. (2001). Recognizing faces of other ethnic groups—An integration of theories. *Psychology Public Policy and Law*, *7*, 36–97.

Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: An event-related potential study. *Neuroreport*, *19*, 583–587.

Swick, D., Senkfor, A. J., & Van Petten, C. (2006). Source memory retrieval is affected by aging and prefrontal lesions: Behavioral and ERP evidence. *Brain Research*, *1107*, 161–176.

Tanaka, J. W., & Curran, T. (2001). A neural basis for expert object recognition. *Psychological Science*, *12*, 43–47.

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*, 1488–1497.

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: Evidence from a cross-cultural study. *Cognition*, *93*, B1–B9.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology*, *43A*, 161–204.

Valentine, T., & Endo, M. (1992). Towards an exemplar model of face processing: The effects of race and distinctiveness. *The Quarterly Journal of Experimental Psychology*, *44A*, 671–703.

Vilberg, K. L., Moosavi, R. F., & Rugg, M. D. (2006). The relationship between electrophysiological correlates of recollection and amount of information retrieved. *Brain Research*, *1122*, 161–170.

Vogel, E. K., & Luck, S. J. (2000). The visual N1 component as an index of a discrimination process. *Psychophysiology*, *37*, 190–203.

Walhovd, K. B., Fjell, A. M., Reinvang, I., Lundervold, A., Fischl, B., Quinn, B. T., et al. (2006). The functional and structural significance of the frontal shift in the old/new ERP effect. *Brain Research*, *1081*, 156–170.

Wegesin, D. J., Friedman, D., Varughese, N., & Stern, Y. (2002). Age-related changes in source memory retrieval: An ERP replication and extension. *Cognitive Brain Research*, *13*, 323–338.

Wiese, H., Schweinberger, S. R., & Neumann, M. F. (in press). Perceiving age and gender in unfamiliar faces: Brain potential evidence for implicit and explicit person categorization. *Psychophysiology*.

Wright, D. B., & Stroud, J. N. (2002). Age differences in lineup identification accuracy: People are better with their own age. *Law and Human Behavior*, *26*, 641–654.