

# Electrophysiological correlates of processing faces of younger and older individuals

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**The 'own-age bias' in face processing suggests that the age of a face constitutes one important factor that influences attention to and memory for faces. The present experiment investigated electrophysiological correlates of processing faces of younger and older individuals. Younger participants were presented with pictures of unfamiliar younger and older faces in the context of a gender categorization task. A comparison of event-related potentials showed that early components are sensitive to faces of different ages: (i) larger positive potential peaking at 160 ms (P200) for older than younger faces at fronto-central electrodes; (ii) larger negative potential peaking at 252 ms (N200) for younger than older faces at fronto-central electrodes; (iii) larger negative-going deflection peaking at 320 ms (N250) for younger than older faces at occipito-temporal electrodes; and (iv) larger late positive potential peaking at 420 ms (LPP 420) for older than younger faces at parietal and other electrodes. We discuss similarities between the present study and a previously published study of faces of different races as suggesting involvement of comparable electrophysiological responses when differentiating between stimulus categories.**

**Keywords:** event-related potentials; face processing; own-age effect; own-race effect; in-group/out-group

## INTRODUCTION

Human faces are biologically and socially important stimuli (Bruce and Young, 1998). Even brief exposure to faces results in heightened activation of neural structures involved in emotion and attention (Cunningham *et al.*, 2004; Pourtois *et al.*, 2004) and are sufficient to extract person-related information such as identity, trustworthiness, ethnic origin, gender or age (Engell *et al.*, 2007; Palermo and Rhodes, 2007).

### Age of face effects

The present study focuses on the 'age of a face'. Facial appearance changes with age (Berry and McArthur, 1986; Burt and Perrett, 1995). For example, there are changes in shape, which mainly occur through growth or weight gain or loss, and changes in the surface texture and coloration of skin and hair. Human vision appears sensitive to these sometimes subtle differences when determining the age of a face (Bruce and Young, 1998).

Though the literature is somewhat mixed, there is behavioral evidence suggesting that the age of a face affects how a face is attended and encoded in memory ('own-age bias';

Baekman, 1991; Bartlett and Fulton, 1991). For example, younger and older participants are more distracted by own-age than other-age faces during a face-unrelated task (Ebner and Johnson, in press). There also is some (mixed) evidence for better old/new recognition memory for own-age than other-age individuals in children (Anastasi and Rhodes, 2005), younger and middle-aged adults (Wright and Stroud, 2002), and/or older adults (Lamont *et al.*, 2005).

The advantaged processing of own-age faces may reflect greater familiarity with (expertise), and interest in (motivational salience), own-age than other-age faces (Anastasi and Rhodes, 2005; Ebner and Johnson, 2009; Harrison and Hole, 2009). Due to daily routines and environments, people's social networks are often largely populated by own-age individuals, who may consequently be evaluated more positively (Wright *et al.*, 2008; but Ebner, 2008) and whose attitudes and behaviors may have more impact than those of other-age individuals (see Harrison and Hole, 2009, for further discussion of the possibility that perceptual expertise and/or motivational salience underlie own-age vs other-age effects).

Little is known about the neural time course of the own-age bias, and particularly, differences in initial processing of unfamiliar faces of different ages. A recent study asked younger and older adults to memorize faces of younger and older individuals while making age judgments and recorded event-related potentials (ERPs) during later old/new face recognition (Wiese *et al.*, 2008). Younger participants were better at remembering younger than older faces, with no own-age advantage for older participants. The earliest ERP difference at recognition was in the N170 (a face-selective

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ERP component; Bentin *et al.*, 1996), with increased negative amplitude over occipito-temporal scalp for older than younger faces in both age groups (but especially pronounced in younger participants). A second positive deflection over occipito-temporal scalp peaking at 220 ms (referred to as P2 in Wiese *et al.*, 2008) for younger, and at 310 ms for older, participants was larger for younger than older faces in both age groups. In addition, a larger negative component (N250; peaking at 285 ms) at right occipito-temporal electrodes was elicited by younger than older faces in younger but not older participants.

### Race of face effects

The race of a face also constitutes a salient feature with important social implications (Blair *et al.*, 2004). There are apparent similarities between the early electrophysiological correlates of the age of face effect (Wiese *et al.*, 2008) and those of the race of face (He *et al.*, 2009; Kubota and Ito, 2007). In the context of a gender categorization task, He *et al.* (2009) observed a larger positive deflection peaking at 116 ms (P100) for Black than White faces in White participants at occipital sites. In line with other studies, there was no N170 difference between Black and White faces (Caldara *et al.*, 2004; Ito *et al.*, 2004; but Herrmann *et al.*, 2007; Stahl *et al.*, 2008; Walker *et al.*, 2008). Furthermore, He *et al.* (2009) found a larger positive deflection peaking at 168 ms (P200) for Black than White faces and a larger negative deflection peaking at 244 ms (N200) for White than Black faces both at fronto-central sites (Kubota and Ito, 2007). A late positive potential peaking at 592 ms was observed at T6, with larger amplitude for White than Black faces (but see Ito *et al.*, 2004, for a larger late positive potential peaking at 520 ms over parietal scalp evoked by Black other-race than White own-race faces). Response times and accuracy for gender categorization did not differ for Black and White faces in He *et al.*

### Aim of the present study

The aim of the present study was: (i) to identify the electrophysiological correlates of initial processing of faces of unfamiliar younger and older individuals, and (ii) to directly compare the electrophysiological responses when processing own-age *vs* other-age faces with own-race *vs* other-race faces, as two representatives of social in-group *vs* out-group faces, under the same task context.

We recorded younger adults' ERPs to unfamiliar faces of younger and older individuals in the context of a gender categorization task taken from He *et al.* (2009). This task involved processing the faces, but had minimal task demands, and did not direct attention toward age information or face identity. Wiese *et al.* (2008) used an age identification task at encoding but they only reported ERPs to younger and older faces during a later old/new face recognition task.

Based on the ERP components observed in age and/or race in-group/out-group studies (He *et al.*, 2009; Ito *et al.*,

2004; Wiese *et al.*, 2008), we had the following predictions about our younger participants<sup>1</sup>: (i) in accordance with findings of a greater P100 for Black than White faces (He *et al.*, 2009), we expected a larger positive amplitude for older than younger faces at around 100 ms at occipital sites. (ii) We did not have specific expectations regarding N170 differences at occipito-temporal sites, as the N170 may reflect early structural encoding that is sensitive to features indicating 'facedness' but may not represent complex differentiation processes among different types of faces (Ito *et al.*, 2004) and may be insensitive to familiarity effects (Bentin and Deouell, 2000). (iii) In line with race of face effects over the temporal range of P200-N200 (Kubota and Ito, 2007; He *et al.*, 2009), we predicted a larger positive deflection for older than younger faces and a larger negative amplitude for younger than older faces at around 200 ms at fronto-central electrodes. (iv) In line with a larger P200 for younger than older faces in younger adults (Wiese *et al.*, 2008), we expected a larger positive potential for younger than older faces at occipito-temporal scalp. (v) Consistent with Wiese *et al.* (2008), we expected a larger N250 at occipito-temporal scalp for younger than older faces. (vi) In accordance with race of face effects at later time points at temporal (He *et al.*, 2009, White > Black) or parietal sites (Ito *et al.*, 2004; Black > White), we hypothesized differences between younger and older faces after 400 ms but did not have a specific hypothesis about the direction of this effect. (vii) Finally, in a direct comparison of the present study with the findings of He *et al.* (2009) we expected similar electrophysiological responses when processing age-based (younger and older) and race-based (White and Black, as the most studied race-based faces) in-group *vs* out-group faces.

## METHODS

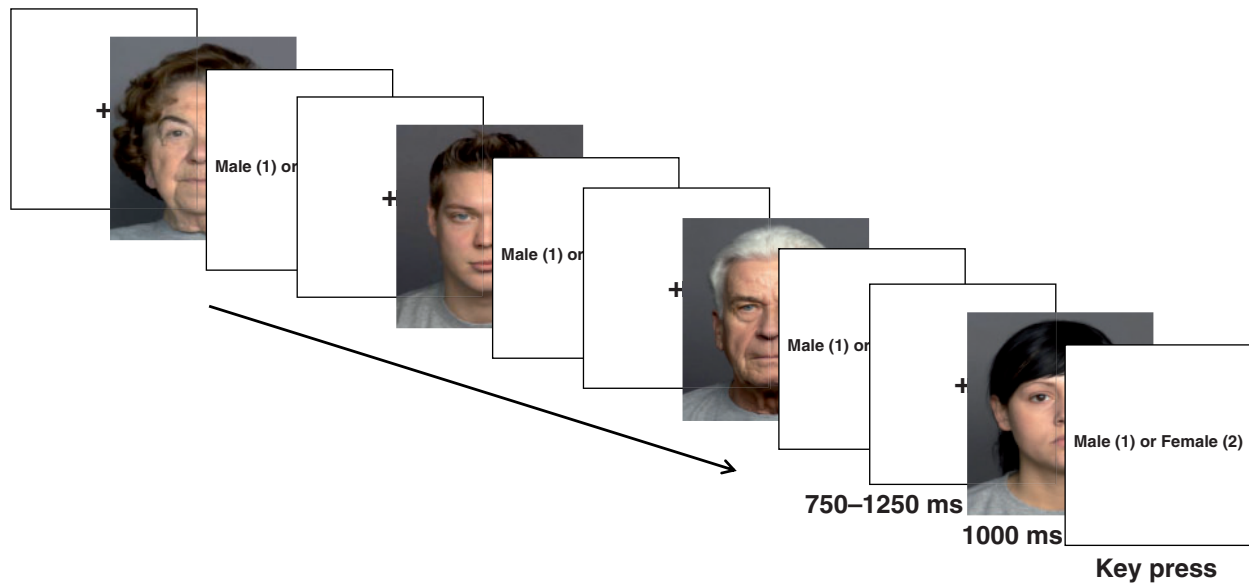
### Participants

Twenty-two younger adults ( $M=20.7$  years,  $s.d.=3.1$ , 14 males) provided written consent to volunteer in this experiment. Participants were either Yale University students or recruited from the community and received course credit or financial reimbursement for participation. Participants were screened for neurological and psychiatric disorders, substance abuse and current use of psychotropic medications. Data from two additional participants were excluded due to excessive artifacts in the EEG signal (i.e. >33% of trials of any of the gender by age condition were rejected due to eye movement or other artifacts).

### Task parameters

Participants saw faces of unfamiliar younger and older individuals on a computer screen and were asked to indicate the gender of the individual. As shown in Figure 1, each trial started with the presentation of a crosshair for 750–1250 ms,

<sup>1</sup>The nomenclature used for components reported in this article is based on polarity and latency information.



**Fig. 1** Experimental task: event timing and sample faces.

followed by the presentation of a single face for 1000 ms. Participants were told to withhold their responses until 'Male (1) or Female (2)' appeared on the screen and then to press a key corresponding to their choice, which advanced the next slide. There were 112 trials (28 trials per gender by age category). The presentation order was pseudo-randomized with the constraints that in every four stimuli each of the category types were represented and that not more than three faces of the same category repeated sequentially.

After the ERP recording session, participants completed the Older–Younger Implicit Association Task (Age IAT; Hummert *et al.*, 2002). In different blocks, participants pressed one key for younger faces and positive (or negative) words and another key for older faces and negative (or positive) words. A higher positive IAT score reflects more positive associations to younger than older faces.

### Stimuli

Faces were taken from the FACES database, a validated set of color photographs of Caucasian faces (front view), standardized in terms of production procedure, visible clothes, and color (Ebner *et al.*, 2010). We selected 112 faces with neutral expressions, half younger (18–31 years) and half older (69–80 years), with half of each age group male and female (Figure 1 presents sample faces).<sup>2</sup> The CIGAL presentation software (Voyvodic, 1999) displayed the faces (height: 26 cm, width: 21 cm) on a 17-in LCD positioned 60 cm away from the participant (vertical visual angle: 25°).

<sup>2</sup>Mean luminance was higher for older than younger faces [ $F(1,110) = 4.66, P < 0.05, \eta_p^2 = 0.04$ ]. Mean spatial frequency was higher for older than younger faces [ $F(1,110) = 100.66, P < 0.001, \eta_p^2 = 0.48$ ].

### EEG recordings

The EEG was recorded simultaneously from 32 electrodes in a custom cap (Electro-Cap International, Inc., Eaton, OH, USA). The nose was used as reference. Horizontal eye movements were monitored by two electrodes at the outer canthi of the eyes, and vertical eye movements and eye blinks were detected by an electrode placed below the orbital ridge of the right eye. Electrode impedances were maintained below 10 k $\Omega$  for the facial electrodes, and below 5 k $\Omega$  for all remaining electrodes. The EEG was recorded with a bandpass of 0.1–100 Hz and a gain of 20 000. The raw signal was continuously digitized at a sampling rate of 250 Hz. Recordings took place in an electrically shielded, sound-attenuated chamber. Electrodes are identified to the nearest 10–20 position.

### EEG data reduction

Artifact rejection was performed off-line by discarding epochs of the EEG that revealed eye movements, eye blinks, excessive muscle-related potentials or drifts. For the 22 participants included in the analysis, 17% of trials were excluded due to artifacts. Averages were calculated across younger and older faces separately. The averages were calculated for an epoch extending from 100 ms before to 600 ms after stimulus onset. All averages were digitally notch filtered at 60 Hz (to filter out electrical noise generated by the 60 Hz refresh rate of the monitor). ERP averages for individual participants were then combined into group averages across all participants, separately for younger and older faces.

### ERP data analysis

Age of face effects were calculated by computing the differences between younger and older faces. Planned *t*-tests were

used to compare average peak amplitudes from younger vs older faces for particular ERP components. As outlined in the 'Introduction' section, based on previous findings (Ito *et al.*, 2004; Wiese *et al.*, 2008; He *et al.*, 2009), comparisons were made over the following time ranges at respective electrodes: 100–116 ms for P100 at occipital scalp, 160–172 ms for N170, 200–216 ms for P200 and 320–360 ms for N250 at occipito-temporal scalp, 160–176 ms for P200 and 224–264 ms for N200 at fronto-central scalp, and after 400 ms for LPP at multiple electrode sites.

We then examined correlations between the chronological age of the faces and the amplitude strength at each of the components examined in the present study that showed significant differences between younger and older faces (P200 and N200 at Fz, N250 at T6 and LPP 420 at CPz). For this purpose, we extracted the time wave for each face and averaged the time waves across participants.

For direct comparison of age-based and race-based in-group vs out-group effects across the present study and the study by He *et al.* (2009;  $N = 21$  younger White participants;  $M = 20.0$  years,  $s.d. = 1.5$ , 7 males; 50 White and 50 Black faces),<sup>3</sup> we conducted a 2 'Study' (present study, He *et al.*) X 2 'Type of Face' (younger/White in-group, older/Black out-group) X 8 'ERP Component' [P100 at Oz, N170 at T6, P200 at Fz, N200 at Fz, P200 at Oz, N250 at T6, LPP at CPz (400–440 ms) and LPP at T6 (572–612 ms)] repeated-measures analysis of variance (ANOVA) on ERP amplitudes.<sup>4</sup> The present study had a different composition of male and female participants than did the He *et al.* (2009) study [ $\chi^2_{(1, N=43)} = 3.95$ ,  $P < 0.05$ ], but the participants in the two studies did not differ in age, race, or education.

## RESULTS

### Behavioral data

Behavioral data from the gender categorization task from one participant were lost due to computer error. Any trials with incorrect answers or trials where response times were shorter than 100 ms were excluded from the analysis. There was no difference in accuracy of gender categorization between younger (97.4%) and older faces [97.9%;  $t(20) = 0.90$ ,  $P = 0.38$ ]. Participants responded faster to younger ( $M = 354$  ms,  $s.d. = 190$ ) than older faces ( $M = 388$  ms,  $s.d. = 211$ ;  $t(20) = 2.59$ ,  $P < 0.02$ ). The mean Older–Younger IAT score was 0.48 ( $s.d. = 0.54$ ), which was larger than zero [ $t(21) = 4.10$ ,  $P < 0.001$ ], reflecting more positive associations to younger than older faces. He *et al.*

<sup>3</sup>Mean luminance was higher for White than Black faces [ $F(1,98) = 34.05$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.26$ ]. Mean spatial frequency was higher for Black than White faces [ $F(1,98) = 80.40$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.45$ ]. Luminance did not differ between younger/White and older/Black faces ( $P = 0.79$ ), but spatial frequency was higher for older/Black faces than younger/White ( $P < 0.001$ ).

<sup>4</sup>A full-factorial design for comparing age of face and race of face effects and their interaction would have required four groups of stimuli (younger White, younger Black, older White, older Black). The present study, however, aimed at comparing social in-group vs out-group faces, either based on the age or the race of the faces, across the two studies. Thus, faces from both studies were classified as either in-group (i.e. younger/White) or out-group (i.e. older/Black) faces.

(2009) had found Black–White differences to be correlated with implicit racial associations. However, in the present study there were no correlations between Older–Younger ERP differences and Older–Younger IAT scores at the investigated ERP components (all  $r$ 's  $< \pm 0.39$ , all  $P$ 's  $> 0.05$ ).

### ERPs

An overall 2 'Age of Face' (younger, older) X 7 'ERP Component' (P100 at Oz, N170 at T6, P200 at Fz, N200 at Fz, P200 at Oz, N250 at T6, LPP at CPz) repeated-measures ANOVA on ERP amplitudes showed main effects for 'Age of Face' (Wilks'  $\lambda = 0.75$ ,  $F(1,21) = 6.88$ ,  $P < 0.05$ ,  $\eta_p^2 = 0.25$ ) and 'ERP Component' (Wilks'  $\lambda = 0.09$ ,  $F(6,16) = 26.76$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.91$ ) and, importantly, an interaction (Wilks'  $\lambda = 0.30$ ,  $F(6,16) = 6.18$ ,  $P < 0.01$ ,  $\eta_p^2 = 0.70$ ). Presentation and discussion of the results will focus on peak differences at representative electrodes. Table 1 presents a summary of all time points and electrode sites with differences between younger and older faces.

#### Occipital P100

We observed a positive potential at Oz (peak latency: 108 ms), with no difference between younger (7.32  $\mu\text{V}$ ) and older faces [7.70  $\mu\text{V}$ ;  $t(21) = 0.92$ ,  $P = 0.37$ ].

#### Occipito-temporal N170

There were negative potentials at T5 and T6 (peak latencies: 168 ms), which both did not differ between younger (T5: 1.04  $\mu\text{V}$ ; T6: 0.16  $\mu\text{V}$ ) and older faces [T5: 0.74  $\mu\text{V}$ ,  $t(21) = 0.51$ ,  $P = 0.62$ ; T6:  $-0.77$   $\mu\text{V}$ ,  $t(21) = 1.54$ ,  $P = 0.14$ ; Figure 2A and B].

#### Fronto-central P200

A positive potential was observed at fronto-central electrodes (Fz, peak latency: 160 ms). Figure 3A shows the grand average ERPs elicited by younger and older faces at Fz, which showed the largest difference (see also Figure 3B). The amplitude was larger for older (4.47  $\mu\text{V}$ ) than younger faces [2.18  $\mu\text{V}$ ;  $t(21) = 4.13$ ,  $P < 0.001$ ].

#### Fronto-central N200

A negative potential was observed at several fronto-central electrodes (peak latency: 244–256 ms). Figure 3A shows the grand average ERPs elicited by younger and older faces at Fz (see also Figure 3C). The amplitude was larger for younger ( $-1.08$   $\mu\text{V}$ ) than older faces [0.43  $\mu\text{V}$ ;  $t(21) = 2.92$ ,  $P < 0.01$ ].

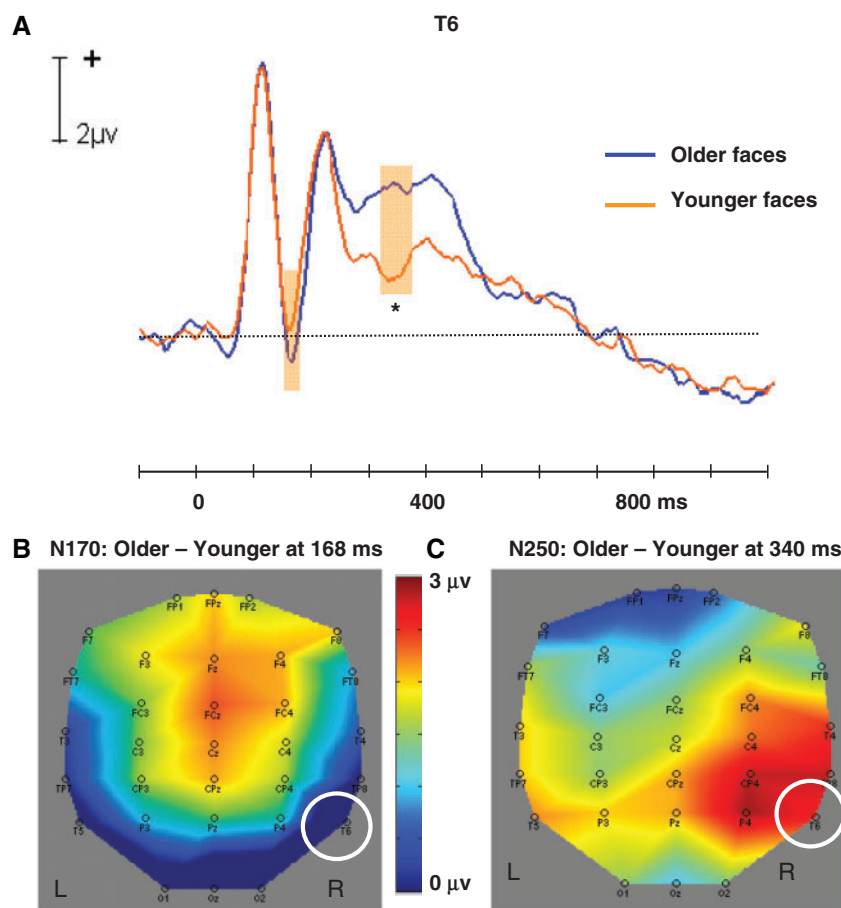
#### Occipital P200

A positive potential was observed at Oz (peak latency: 212 ms). Figure 4A shows the grand average ERPs elicited by younger and older faces at Oz (see also Figure 4B). There was a trend for a larger amplitude evoked by younger (8.61  $\mu\text{V}$ ) than older faces [7.49  $\mu\text{V}$ ;  $t(21) = 1.90$ ,  $P = 0.07$ ].

**Table 1** Summary of ERP amplitude differences between younger and older faces at representative and additional electrodes

	P200	N200	N250	LPP 420
Peaking time	160 ms	244–256 ms	300 ms	420 ms
Representative electrode	Fz	Fz	T6	CPz
Amplitude difference at representative electrode	O > Y ( $P < 0.001$ )	Y > O ( $P < 0.01$ )	Y > O ( $P < 0.01$ )	O > Y ( $P < 0.001$ )
Amplitude differences at additional electrodes (all following same pattern as at representative electrode)	FPz, FCz, FP1, F3 ( $P < 0.001$ ) Cz, CPz, FP2, F4, F7, F8, FC3, FC4, FT7, C4 ( $P < 0.01$ ) Pz, FT8, C3, CP3, CP4 ( $P < 0.05$ )	FPz, FCz, FP1, FP2, F3, F4, F8, FC4, FT8, C4, CP4 ( $P < 0.01$ ) Cz, CPz, FC3, FT7, C3, CP3, TP8, P4 ( $P < 0.05$ )	TP8 ( $P < 0.001$ ) FCz, Cz, CPz, Pz, F8, FC4, FT8, C4, T4, CP4, P4 ( $P < 0.01$ ) Fz, F4, C3, T3, TP7, P3, T5 ( $P < 0.05$ )	FCz, Cz, Pz, FC4, C3, C4, CP4, TP8, P3, P4 ( $P < 0.01$ ) Fz, F3, F4, F8, FC3, FT8, T3, T4, CP3, T5, T6 ( $P < 0.05$ )

Y, Younger faces; O, Older faces.



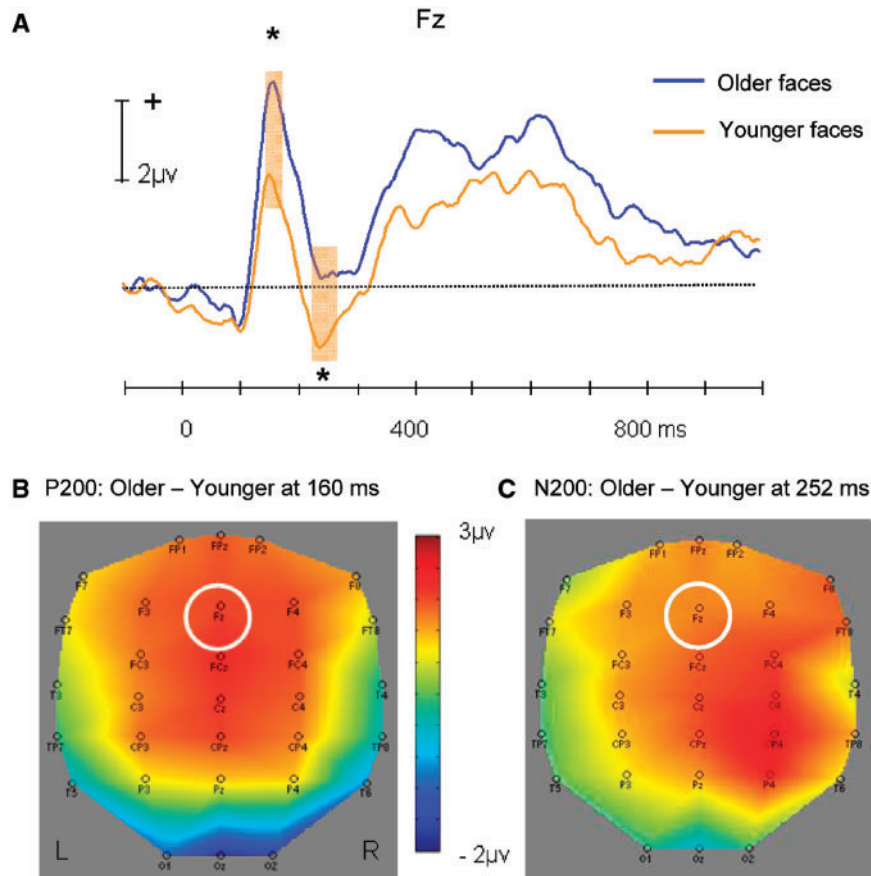
**Fig. 2** (A) Average ERP time waves for younger and older faces at the T6 electrode, illustrating the difference in N170 (not significant) and N250 amplitudes. (B) Topographic map illustrating the scalp distribution of the (non-significant) ERP amplitude difference between older and younger faces at 168 ms (T6 highlighted). (C) Topographic map illustrating the scalp distribution of the ERP amplitude difference between older and younger faces at the peaking time of N250 (T6 highlighted). Shaded areas indicate time range for comparisons: 160–172 ms (N170); 320–360 ms (N250). Significance tests were performed within the time windows around the peak amplitudes.  $*P < 0.05$

**Occipito-temporal N250**

We observed a negative-going deflection at T6 (peak latency: 300 ms). Figure 2A shows the grand average ERPs elicited by younger and older faces at T6, which was more negative-going for younger (1.61 µV) than older faces [4.12 µV,  $t(21) = 3.48, P < 0.01$ ; see also Figure 2C].

**Late positive potential**

A prominent late positive potential (LPP 420) was observed at parietal sites (peak latency: 420 ms). Figure 5A shows the grand average ERPs elicited by younger and older faces at CPz, which showed the largest difference (see also Figure 5B). LPP amplitude was larger for older



**Fig. 3** (A) Average ERP time waves for younger and older faces at the Fz electrode, illustrating the difference in P200 and N200 amplitudes. (B) Topographic map illustrating the scalp distribution of the ERP amplitude difference between older and younger faces at the peaking time of P200 (Fz highlighted). (C) Topographic map illustrating the scalp distribution of the ERP amplitude difference between older and younger faces at the peaking time of N200 (Fz highlighted). Shaded areas indicate time range for comparisons: 160–176 ms (P200); 224–264 ms (N200). Significance tests were performed within the time windows around the peak amplitudes. \* $P < 0.05$

(9.19  $\mu\text{V}$ ) than younger faces [6.17  $\mu\text{V}$ ;  $t(21) = 3.87$ ,  $P < 0.001$ ].<sup>5</sup>

### Correlations between age of face and amplitude strength

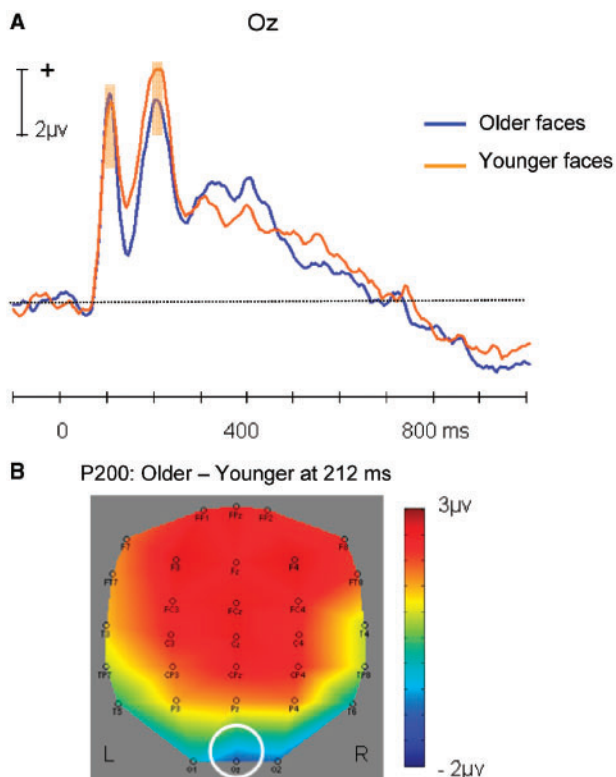
Younger faces ranged from 19 to 31 years ( $M = 24.0$  years,  $s.d. = 3.4$ ), older faces from 69 to 80 years ( $M = 73.2$  years,  $s.d. = 2.9$ ). When collapsing across younger and older faces, age of face was significantly correlated with amplitude strength for P200 at Fz ( $r = 0.27$ ,  $P < 0.01$ ), N250 at T6 ( $r = 0.21$ ,  $P < 0.05$ ), LPP 420 at CPz ( $r = 0.20$ ,  $P < 0.05$ ) and, marginally, for N200 at Fz ( $r = 0.14$ ,  $P = 0.15$ ), reflecting the group effects already noted. When examining younger and older faces separately, there was no evidence of a correlation with age in any component for younger faces ( $r$ 's  $< \pm 0.09$ ,  $P$ 's  $> 0.48$ ). Although not significant, for older faces, there was somewhat more evidence for correlations with age, especially in the N250 at T6 (P200 at Fz:  $r = 0.18$ ,  $P = 0.19$ ; N200 at Fz:  $r = 0.19$ ,  $P = 0.16$ ; N250 at

T6:  $r = 0.24$ ,  $P = 0.08$ ). These preliminary findings suggest that in future work it would be worth exploring the hypothesis that, at least with respect to older faces, younger participants may make finer age discriminations than simply categorical 'older face' responses at relatively early stages of processing.

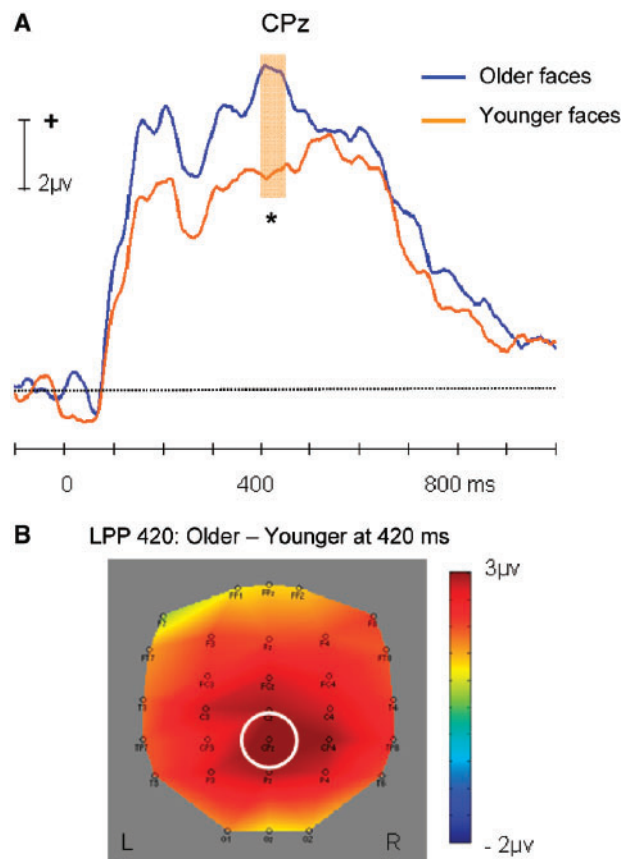
### Comparison of age-based and race-based in-group vs out-group effects

The interaction 'Study X Type of Face X ERP Component' was significant (Wilks'  $\lambda = 0.45$ ,  $F(7,35) = 6.18$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.55$ ). As shown in Figure 6, follow-up repeated-measures ANOVAs separately for each ERP component showed a 'Type of Face' main effect for P100, P200 at Fz, N200, P200 at Oz and LPP 420. The main effect for 'Study' was significant for N200, with greater negative deflection in He *et al.* (2009;  $M = -2.52$ ,  $s.d. = 2.41$ ) than in the present study ( $M = -0.32$ ,  $s.d. = 2.73$ ), and for LPP 420, with greater positive deflection in the present study ( $M = 7.68$ ,  $s.d. = 5.93$ ) than in He *et al.* ( $M = 2.57$ ,  $s.d. = 5.43$ ). The only significant 'Study X Type of Face' interaction emerged for N250, with a more negative-going deflection for younger

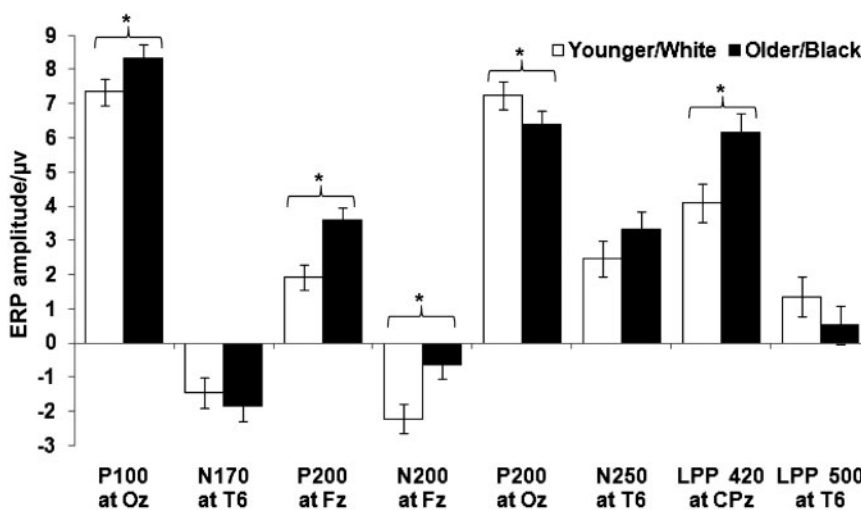
<sup>5</sup>There was no difference between younger (10.01  $\mu\text{V}$ ) and older faces [10.38  $\mu\text{V}$ ;  $t(21) = 0.04$ ,  $P = 0.97$ ] at T6 over the temporal range of 572–612 ms as taken from He *et al.* (2009).



**Fig. 4** (A) Average ERP time waves for younger and older faces at the Oz electrode, illustrating the trend difference in occipital P200 amplitude. (B) Topographic map illustrating the scalp distribution of the ERP amplitude difference between older and younger faces at 212 ms (Oz highlighted). Shaded areas indicate time range for comparisons: 100–116 ms (P100); 200–216 ms (P200). Significance tests were performed within the time windows around the peak amplitudes.



**Fig. 5** (A) Average ERP time waves for younger and older faces at the CPz electrode, illustrating the difference in LPP amplitude peaking at 420 ms. (B) Topographic map illustrating the scalp distribution of the ERP amplitude difference between older and younger faces at the peaking time of LPP (CPz highlighted). Shaded area indicates time range for comparison: 400–440 ms (LPP 420). Significance tests were performed within the time windows around the peak amplitudes. \* $P < 0.05$



**Fig. 6** Summary of the direct comparison between ERPs in-/out-group effects in present study and He *et al.* (2009). Error bars represent standard errors of the condition mean differences. ‘Type of Face’: P100 at Oz: Wilks’  $\lambda = 0.86$ ,  $F(1,41) = 6.70$ ,  $P < 0.05$ ,  $\eta_p^2 = 0.14$ ; P200 at Fz: Wilks’  $\lambda = 0.67$ ,  $F(1,41) = 20.38$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.33$ ; N200 at Fz: Wilks’  $\lambda = 0.75$ ,  $F(1,41) = 13.68$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.25$ ; P200 at Oz: Wilks’  $\lambda = 0.91$ ,  $F(1,41) = 4.12$ ,  $P < 0.05$ ,  $\eta_p^2 = 0.09$ ; LPP between 400–440 ms at CPz: Wilks’  $\lambda = 0.74$ ,  $F(1,41) = 14.63$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.26$ . ‘Study’: N200 at Fz:  $F(1,41) = 7.80$ ,  $P < 0.01$ ,  $\eta_p^2 = 0.16$ ; LPP 420 at CPz:  $F(1,41) = 8.64$ ,  $P < 0.01$ ,  $\eta_p^2 = 0.17$ . ‘Study X Type of Face’: N250 at T6: Wilks’  $\lambda = 0.76$ ,  $F(1,41) = 12.93$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.24$ . No other effect was significant. Younger/White, in-group faces (collapsed across younger faces and White faces); Older/Black, out-group faces (collapsed across older faces and Black faces). \* $P < 0.05$ .

than older faces in the present study and no difference between White and Black faces in He *et al.*<sup>6</sup> No other effect was significant.

## DISCUSSION

We observed early electrophysiological components sensitive to differences in initial processing of unfamiliar younger and older faces in younger adults. In addition, we found striking similarities between the electrophysiological responses when processing age- and race-based in-group *vs* out-group faces across two studies.

### Electrophysiological components of initial processing of unfamiliar younger and older faces in younger adults

We observed a larger fronto-central P200 for older than younger faces and a larger fronto-central N200 for younger than older faces. P200 at fronto-central sites has been associated with automatic vigilance and sensitivity to unfamiliar stimuli such as angry *vs* happy faces or out-group *vs* in-group faces (Eimer *et al.*, 2003; Kubota and Ito, 2007). In the present study, older faces, as the faces younger adults have less experience with (Ebner and Johnson, 2009; He *et al.*, in press), may have received more immediate attention than the more familiar younger faces.

The N200 at fronto-central sites has been broadly associated with selective attention to, and deeper processing of, faces participants have practice individuating, such as race-based in-group *vs* out-group faces (Ito *et al.*, 2004; Kubota and Ito, 2007). Thus, the larger N200 for younger than older faces may reflect greater attention to, and more differentiated processing of, younger faces, as the faces younger adults are more motivated to individuate. Additionally, in the context of race, the differences in this component have been discussed as reflecting implicit preference for in-group over out-group faces, or as a controlled process to regulate bias against members of the out-group (He *et al.*, 2009).

There was a trend for larger occipital P200 for younger than older faces. This finding is consistent with Wiese *et al.* (2008) and for 'typical' *vs* 'atypical' faces such as normal as compared to inverted and/or distorted faces (Milivojevic *et al.*, 2003). In line with evidence that younger participants report more frequent contact with younger than older persons (Ebner and Johnson, 2009; He *et al.*, in press), and rate younger faces as more familiar than older faces (Bartlett and Fulton, 1991), this P200 difference may reflect younger adults' greater familiarity and experience with younger faces. In addition, it may also reflect processing of compositional (e.g. nose–mouth distance) or low-level perceptual

(e.g. spatial frequency) differences due to age-related changes, as discussed below.

In accord with Wiese *et al.* (2008), we observed a more negative-going occipito-temporal N250 for younger than older faces. This component may reflect easier access to temporary structural representations of younger than older faces (Wiese *et al.*, 2008), possibly due to more optimal representation of younger faces in younger adults' face space (see Valentine, 1991, for 'Face Space Theory'). It may also reflect younger participants' greater familiarity with younger than older faces (Schweinberger *et al.*, 2002; Tanaka *et al.*, 2006).

There also was a late-response ERP difference between younger and older faces: larger LPP (peaking at 420 ms) was elicited by older than younger faces at parietal and multiple other electrodes. Ito *et al.* (2004) found that greater LPP difference over parietal scalp evoked by other-race than own-race faces was related to more biased self-reported attitudes against other-race faces. Thus, it is possible that the present LPP difference reflects intentional or spontaneously activated evaluations, representing differences in the valence of younger adults' affective reactions or more controlled processing of older than younger faces with the attempt to suppress bias against the age-based out-group. However, in the present study, we did not find any significant correlations between Older–Younger IAT scores and Older–Younger ERP differences, neither over the time range of P200–N200 nor for LPP 420.<sup>7</sup>

Contrary to expectations, we did not observe differences between younger and older faces at P100. Also, there were no age of face differences in the N170.<sup>8</sup> This is consistent with prior studies reporting no N170 differences between race-based in- and out-group faces (Caldara *et al.*, 2004; Ito *et al.*, 2004) and the suggestion that the N170 reflects an early encoding stage that is sensitive to features indicating 'faceness' but not to more complex processes that allow for differentiation among different types of faces or different levels of familiarity (Ito *et al.*, 2004). Also, it appears that studies of the own-race bias that did find N170 differences required the processing of facial identity (Herrmann *et al.*, 2007; Walker *et al.*, 2008; Wiese *et al.*, 2009).

However, Wiese *et al.* (2008) found greater N170 for older than younger faces (with this effect more pronounced for younger than older participants; and with no reported difference between target and distracter faces). The present study may be in line with this finding if a component often shown concomitant to the N170, the vertex positive potential (VPP; Jeffreys, 1989; Bentin *et al.*, 1996), is taken into account. The VPP may be represented in the present study's greater fronto-central P200 for older than younger

<sup>6</sup>This interaction may have occurred as the daily social interaction context at a university may have brought with it that the younger participants in the present study have relatively less frequent contact, and thus be relatively less familiar, with older than younger faces. The younger participants in the He *et al.* (2009) study, in contrast, may have experienced less of a relative difference between their contact, and familiarity, with Black as opposed to White faces.

<sup>7</sup>Alternatively, the observed differences in LPP may reflect greater difficulty (longer response times) in gender categorization of older than younger faces. However, as we used a delayed response paradigm, latencies need to be interpreted with caution.

<sup>8</sup>The negative-going deflections for N170 at T5 and T6 were relatively small. These may have been related to the present comparison of faces of different types but not faces with non-face stimuli; they could also have been driven by the large P100 preceding the N170.



faces. There are suggestions that the N170 and the VPP co-vary in functional and temporal properties across recording parameters, representing two aspects of the same underlying brain process (Joyce and Rossion, 2005).

### Shared neural mechanisms for differentiating between stimulus categories?

To our knowledge, the present study is the first to directly compare time courses of processing age- and race-based in-group vs out-group faces. The similarity in the context of the gender categorization task between the ERP components that differentiate between younger and older faces and those that differentiated between Black and White faces (He *et al.*, 2009) is striking.

For various reasons, this consistency across studies is not likely explained by assuming that the cognitive system exclusively classifies between types of faces based on lower and/or higher level perceptual differences (e.g. wrinkles–no wrinkles, dark–light) that are unspecific to social group membership. For example, younger/White in-group and Older/Black out-group faces did not differ in overall luminance. Note, however, that in- and out-group faces differed in overall spatial frequency (measured as the magnitude of 2D discrete Fourier transforms of the grey-scaled pictures, averaged within each face type). This may have contributed to some of the early ERP differences at occipital sites (that were, however, only marginally significant or significant when collapsing across studies). These perceptual differences may in fact serve as important cues for (perhaps non-social as well as social) stimulus categorization. However, in addition to differences at occipital sites, we observed various differences between in- and out-group faces at later time points at fronto-central and parietal electrode sites (over the time range of P200–N200), suggesting additional processing differences after early perceptual processing.

The present study represents a first step toward a better description and understanding of processing of, and differentiation between, younger and older faces. We acknowledge, however, that the extent to which the present findings represent neural correlates that are sensitive to categorizations in terms of ‘social group belongingness’ will have to be determined in future research that systematically targets and disentangles various factors. At this point, we can only speculate about potential underlying lower level perceptual mechanisms (e.g. compositional detail) and/or higher level cognitive mechanisms (e.g. differential representations based on prototypicality, familiarity or expertise, and/or differences related to attention, arousal or social motivation) involved (Bartlett and Fulton, 1991; Ebner and Johnson, 2009, in press; Harrison and Hole, 2009; He *et al.*, in press). In addition, the present study only included younger but not older participants and only examined differences between younger and older faces but not faces from other age groups (e.g. children, middle-aged adults), which limits the generalizability of the observed effects. Nevertheless, the

clear differences in amplitude strength between younger and older faces for different components indicates that sufficient information is available to younger adults for relatively rapid differentiation of at least a categorical nature between younger adult/older adult face stimuli. Replicating these findings and detecting conditions under which more fine-grained distinction mechanisms come into play as well as determining whether the effects hold across other age groups of perceivers and faces and hold both for ‘naturally occurring’ and ‘experimentally assigned’ social groups represent important directions for future research.

In conclusion, we provide novel information about the neurocognitive mechanisms involved in processing of faces of unfamiliar younger and older individuals. As early as ~160 ms, electrophysiological components are sensitive to differences between younger and older faces. ERP differences occurred at times and electrode sites where in-/out-group differences have been seen in studies on the effects of age and race in face processing. The striking similarity between our study and He *et al.*'s (2009) study on faces of different races that used the same task but another out-group category invites the speculation, for future research to test, that there are mechanisms generally deployed for differentiating between salient stimulus categories (e.g. in- and out-group) rather than merely age- or race-specific processes.

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