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Event-related potential correlates of implicit processing of own- and other-race faces in children

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ABSTRACT

Human adults typically experience difficulties in recognizing and discriminating individual faces belonging to racial groups other than their own. The origin of this "other-race" effect is set in infancy, but the understanding of its developmental course is fragmented. We aimed to access the mechanisms of the other-race effect in childhood by unraveling the neural time course of own- and other-race face processing during a masked priming paradigm. White 6- and 7-year-old children (N = 19) categorized fully visible Asian (other-race) or White (own-race) target faces according to gender. Target faces were preceded by masked same-identity or different-identity prime faces, matching the target for race and gender. We showed an early priming effect on the N100 component, with larger amplitude to different-face pairs than to same-face pairs, and a later race effect on the N200 component, with larger amplitude to own-race face pairs than to other-race face pairs. Critically, race did not interact with priming at any processing stage (P100, N100, P200, N200, or P300). Our results suggest that race could have a temporally limited impact on face processing and that the implicit and unconscious identity processing of own- and other-race faces could be similar in 6- and 7-year-olds, depicting an immature other-race effect during childhood.

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Introduction

Human faces are arguably the most pervasive and significant stimuli in our visual environment since birth. Humans expertly extract much information from human faces, including idiosyncratic features to allow individuation. However, individuation is reduced for racial outgroup faces—a phenomenon known as the "other-race" effect (ORE) (Malpass & Kravitz, 1969; see Meissner & Brigham, 2001, and Serafini & Pesciarelli, 2023, for reviews). Recognizing a person or discriminating between people belonging to another racial group is typically challenging, with implications for the well-being of society (Birhane, 2022; McKone et al., 2023; Wilson et al., 2013). In the adult population the ORE is a robust effect found across racial groups, tasks (e.g., recognition, perceptual matching), and techniques [e.g., functional magnetic resonance imaging (fMRI), electroencephalography (EEG)] (see Meissner & Brigham, 2001, Natu & O'Toole, 2013, and Serafini & Pesciarelli, 2023, for reviews). In infants, a corresponding ORE has been reliably reported from 6 to 9 months of age (e.g., Kelly et al., 2007, 2009), and its neural substrate has been inspected using multiple techniques [e.g., functional near-infrared spectroscopy (fNIRS), EEG] (Balas et al., 2011; Roth & Reynolds, 2022; Timeo, Brigadoi, et al., 2019; Ujiie et al., 2020; Vogel et al., 2012).

However, in children the ORE proved to be more elusive, and its neural substrate received only partial investigation. Behavioral studies showed recognition deficits for other-race faces at 3 years of age (Macchi Cassia et al., 2014; Sangrigoli & de Schonen, 2004; Suhrke et al., 2014; but see Zhou et al., 2016) but yielded mixed findings at 4 to 7 years of age. Within this age range, some studies reported an ORE (Anzures et al., 2014, 2022; Chien et al., 2014; Corenblum & Meissner, 2006; de Heering et al., 2010; Feinman & Entwisle, 1976; Golarai et al., 2021; Hanley et al., 2020; Kehn et al., 2014; Macchi Cassia et al., 2014; Pezdek et al., 2003; Sangrigoli & de Schonen, 2004; Suhrke et al., 2015; Tham et al., 2017) and others failed (Chance et al., 1982; Chien et al., 2018; Ding et al., 2014; Goodman et al., 2007; Hu et al., 2014; Yi et al., 2016; Zhou et al., 2016). The ORE was then more reliably found from 11 years of age (but see Ding et al., 2014, and Zhou et al., 2016). In addition, the trajectory of the ORE throughout childhood appeared to be stable in some studies (Anzures et al., 2014, 2022; de Heering et al., 2010; Goodman et al., 2007; Pezdek et al., 2003; Tham et al., 2017) and increasing in others (Chance et al., 1982; Chien et al., 2018; Golarai et al., 2021; Sangrigoli & de Schonen, 2004). Discrepancies leave some critical questions open: whether the ORE is present or unreliable in childhood and, if present, whether it is adult-like or developing. Few recent fNIRS studies (Ding et al., 2014; Zhou et al., 2016) and fMRI studies (Golarai et al., 2021) revealed a *neural* ORE in children, which consistently increased from 7 to 13, 3 to 13, and 7 to 16 years of age, respectively. This neural ORE manifested as a differential activity or differential causal connections within and between frontal and occipital brain regions for racial ingroup and outgroup faces.

Crucially, despite the recent spatial investigations, only one study examined the time course of the neural ORE in children using the event-related potential (ERP) technique. The ERP technique (Luck, 2005) allows for a high-temporal-resolution investigation of the brain dynamics in response to own- and other-race faces. In adults, own- and other-race face perception has been associated with various ERP components (see Serafini & Pesciarelli, 2023, for a review). The P100, an early positive-going deflection maximal over occipital scalp locations, typically showed a differential but inconsistent response to own- and other-race faces. This component has been associated with low-level stimulus processing (Regan, 1989) and spatial attention (Van Voorhis & Hillyard, 1977). The frontocentral N100, a negative-going ERP component reflecting early attention (Hillyard & Münte, 1984; Luck & Hillyard, 1994; Ritter et al., 1983; Wijers et al., 1989) and vigilance processes (Carretié et al., 2001; Näätänen, 1992), typically showed larger amplitudes to other-race faces (but see, e.g., Pesciarelli et al., 2021). At frontocentral sites, the following P200 and N200, associated with early attention processes (Hillyard & Münte, 1984; Luck & Hillyard, 1994; Ritter et al., 1983; Wijers et al., 1989), consistently showed larger amplitudes to other- and own-race faces, respectively. Last, a late positive component over centroparietal and centrofrontal scalp locations, the P300, associated with arousal and attention to motivationally significant events (Nieuwenhuis et al., 2005; Polich & Kok, 1995) or context updates (Donchin, 1981), typically showed larger amplitudes to other-race faces. These effects

were found also when race was implicitly processed (e.g., Dickter & Bartholow, 2007; Fishman et al., 2012; He et al., 2009; Ito & Urland, 2003; Leo & Pesciarelli, 2018; Lipp et al., 2011; Pesciarelli et al., 2021).

These ERP components were also identified in children (e.g., Thai et al., 2016), but they typically showed longer latencies and different amplitudes as compared with the corresponding components in adults (see Brooker et al., 2020, Hervé et al., 2022, and Riggins & Scott, 2020, for reviews). In the only ERP study in children, Anzures et al. (2022) examined early (P100 and N170) ERP effects and found larger P100 amplitudes to other-race faces than to own-race faces, with no difference among 5- to 7-year-olds, 8- to 10-year-olds, and adults. However, the race effect on the P100 latency varied with age, depending on children's implicit racial bias. These findings suggest that in children race can have an early impact, which can vary to some extent across age, but whether race also affects later processing stages is unknown.

Here we aimed at filling this knowledge gap by investigating the neural time course of the ORE in children. To get insights into its implicit and unconscious (i.e., nonstrategic) functioning, we adopted a novel approach consisting of presenting own- and other-race faces within a masked priming paradigm. This paradigm allows overcoming issues linked to task difficulty in children (Anzures et al., 2014) and shedding light on the mechanisms of own- and other-race face processing. To our knowledge, this is the first attempt to investigate the ERP correlates of the ORE in children beyond early processing stages and to investigate the ORE at an unconscious level in children. Here, White 6- and 7-year-old children were presented with fully visible Asian (other-race) and White (own-race) face stimuli, the "target" that they categorized by gender. Some behavioral and ERP evidence exists in favor of differential processing of face gender as a function of face race (e.g., Bayet et al., 2015; Bulut & Erdeniz, 2020; Damon et al., 2023; Dickter & Bartholow, 2007; Goff et al., 2008; O'Toole et al., 1996). These studies typically reported faster or better gender classification in own-race faces than in other-race faces or a modulation of the gender effect on the ERP components (i.e., N200 and P300) as a function of race. However, evidence for this effect is still limited and inconsistent (see Fishman et al., 2012, He et al., 2009, Ito & Urland, 2003, and Volpert-Esmond & Bartholow, 2019, for null findings).

Previously, the gender categorization task has been successfully used to examine the ERP correlates of implicit race processing in adults (e.g., He et al., 2009; Ito & Urland, 2003). Here, we used it to prevent participants from explicitly processing race information and to examine the extent to which both race and identity information in own- and other-race faces are implicitly encoded.

Each target always followed the presentation of another face stimulus, the "prime," which was the same-identity face or a different-identity face, always belonging to the same gender and race as the target. The prime was presented very briefly (33 ms) and interposed between two masking stimuli (scrambled faces). With this procedure, children were left unaware of the presence of the prime. Nonetheless, if identity could be processed from the prime face in the absence of intention and awareness, the prime was expected to facilitate the computation of the target when it was identical versus nonidentical to it (Henson et al., 2008; Kouider et al., 2009). If the implicit and unconscious activation of identity from own- and other-race faces *differed,* then the priming effect was expected to occur *differently* for own- and other-race faces. We recently used the same paradigm, including both masked and unmasked conditions, with adult participants (Pesciarelli et al., 2021). In adults, race affected all examined ERP stages (P100, N100, N200, and P300). When the prime was unmasked (visible), priming effects emerged at the N100, N200, and P300 ERP stages as a function of race. When the prime was masked (not visible), a priming effect emerged exclusively on the P300 as a function of race. These results suggest that race could affect identity processing automatically and unconsciously in adults.

Here, we expected similar but reduced race and priming-by-race effects as compared with adults (Pesciarelli et al., 2021) owing to the prevalent evidence for an increasing ORE from childhood to adulthood. Specifically, we expected race and priming effects to emerge within the ERP range in which these effects were found in Pesciarelli et al. (2021), that is, race effects on the P100, N100, N200, and P300 and priming effects on the N100, N200, and P300. If the implicit processing of race is reduced in children as compared with adults, we expected race to affect fewer and possibly earlier components (see Anzures et al., 2022) as compared with adults. Furthermore, if children process own- and other-race faces' identity differently at an implicit and unconscious level, we expected the priming effect to differ according to face race. This interaction could possibly emerge on the P300 component, as

observed in Pesciarelli et al. (2021), or at different ERP stages as compared with adults, considering the mixed literature on the ORE in children, no prior similar investigation in children, and the unprecedented approach.

Method

Participants

A total of 19 6- and 7-year-old children of White racial background (8 girls; M_{age} = 6.31 years, SD = 0.48; twins = 2 pairs) participated in the study. An additional 2 participants were excluded from all analyses for the low quality of the EEG signal (i.e., <25 artifact-free trials per condition) or for the refusal to take part in the study. One participant did not perform the last block of the experiment but produced enough artifact-free trials (i.e., >26 per condition) to be included in the analyses. All participants were first- or second-graders in primary schools in Modena, Italy. They were recruited through the collaboration of local schools and advertisements at the University of Modena and Reggio Emilia. Of the 19 children, 15 were right-handed and 4 were ambidextrous, as assessed with an Italian version of the Edinburgh Handedness Inventory (Oldfield, 1971). All children had normal or corrected-to-normal visual acuity. All children reported no history of neurological or psychiatric disorders but one child who reported pharmacologically treated epilepsy.

Most of the children reported no close friends or relatives belonging to the Asian population (representing the other race in this study) (n = 13); a minority reported contact with a single Asian classmate [for about 2 months (n = 4) or 2 years (n = 2)]; among these, 1 participant also reported lifelong contact with an Asian nursemaid. The experiment was approved by the local ethical committee of the host institution of the second author (School of Psychology of the University of Padua), and it was run in accordance with the Italian Association of Psychology ethical guidelines and the Declaration of Helsinki. Both parents or caregivers provided informed consent for the participation of their child/children and received no monetary compensation.

Sample size was based on resource constraints, deriving from the difficulty of recruiting the specified population. Thus, we performed an a posteriori sensitivity power analysis using G*Power 3.1 (Faul et al., 2007) to establish the smallest effect sizes we were able to detect (as suggested by Lakens, 2022). With a sample size of 19 participants and an alpha level set to .05, our analyses yielded 80% power to detect effects as small as η_p^2 =.33 and 50% power to detect effects as small as η_p^2 =.19. We consider that effects bigger than η_p^2 =.33 could be plausible for the behavioral and ERP main effects of race and identity [in adults using the same stimuli and paradigm, we observed an η_p^2 range of .25–.59 for behavioral or ERP main effects (Pesciarelli et al., 2021), but in children using similar stimuli and a different design, Anzures et al. (2022) observed an η_p^2 of .07 for the ERP main effect of race]. However, they seem less plausible for an interaction effect of Race × Identity [for which the η_p^2 range was equal to .10–.26 in adults (Pesciarelli et al., 2021)]. Thus, we deem that our study could be informative for main effects but could be underpowered for interaction effects. To help discern absence of evidence from evidence of absence for statistically nonsignificant findings, we accompanied traditional frequentist analyses with Bayesian analyses, which can provide the evidence for the effect or for the absence of an effect irrespective of the sample size (e.g., Keysers et al., 2020; see "Statistical analyses" section below). Critically, no study so far has investigated the neural time course of own- and other-race face processing in children beyond early processing stages; thus, our study provides the first evidence in this respect. Effect sizes and confidence intervals can be useful to conduct future meta-analyses.

Stimuli

A total of 88 pictures of adult faces, 44 White and 44 Asian and 50% of each female, were used in the experiment. All face stimuli were previously used in Pesciarelli et al. (2021). Face pictures were selected from the Face Recognition Technology (FERET) database (FERET Facial Image Database Release 2; Phillips et al., 1998). All pictures represented faces with neutral and frontal poses. Face stimuli were converted to grayscale, and the background and external details of the face were hidden

using an oval Passepartout template. Faces appeared on a black background. The luminance of face stimuli did not differ between racial categories (see details in Pesciarelli et al., 2021). All face stimuli were previously selected to be prototypical of both race and gender, as rated by adult samples (see details in Pesciarelli et al., 2021), but were further rated for race and gender reliability by two samples of age-matched White children [for the race survey: n = 48 (23 girls; M_{age} = 6.40 years, SD = 0.54, range = 5–7); for the gender survey: n = 36 (18 girls; M_{age} = 6.42 years, SD = 0.55, range = 5–7)]. In the race survey, participants rated how much each face was associated with a White or Asian face; in the gender survey, they rated how much each face was associated with a female or male face. Both surveys used a 7-point Likert scale ranging from 1 (White/female) to 7 (Asian/male). Scales were counterbalanced across participants. The overall average for Asian faces was 6.31 (SD = 0.49, range = 3–7), for White faces was 1.40 (SD = 0.46, range = 1–7), for female faces was 1.84 (SD = 1.22, range = 1–7), and for male faces was 6.81 (SD = 0.42, range = 2–7). Critically, Asian and White faces did not differ for gender reliability (the task-relevant dimension) (female faces: M_{Asian} = 2.12, SD = 1.16; M_{White} = 1.56, SD = 1.24; male faces: M_{Asian} = 6.67, SD = 0.57; M_{White} = 6.95, SD = 0.05; ps >.10).

As in Pesciarelli et al. (2021), face stimuli appeared as prime and target stimuli in the priming paradigm. Prime–target pairs were either same-face pairs (prime and target were identical faces) or different-face pairs (prime and target were different faces), with half of each White (own-race) and half Asian (other-race). Prime and target faces on each pair always belonged to the same race and gender. This resulted in four experimental conditions of 88 trials each: (a) Own-Race Same, (b) Own-Race Different, (c) Other-Race Same, and (d) Other-Race Different. In the current experiment, differently from Pesciarelli et al. (2021), only a masked priming condition (and not an additional unmasked one) was used. Thus, a masking stimulus preceded and followed the prime face in each trial. The masking stimulus consisted of a scrambled picture of a face with the same luminance and contrast as the prime and target but with the same dimensions and visual angle as the prime.

Across the whole experiment, each face was repeated four times as the target (twice preceded by an identical prime and twice preceded by a different prime) and repeated four times as the prime (twice followed by an identical target and twice followed by a different target) for a total of 352 target stimuli and 352 prime stimuli. Prime–target pairs were the same across participants, but they were randomized within each of the four blocks. Within each block, conditions were intermixed and appeared with the same probability. An additional 8 faces, 4 Asian and 4 White and 50% female for each category, were used in a practice block preceding the experiment. These faces were not used in the main experiment.

Design and procedure

Children were accompanied to the laboratory by at least one parent or caregiver. While performing the experiment, they were comfortably seated in an electrically shielded sound-attenuated and darkened room. One experimenter stood beside children for the entire duration of the experiment and provided occasional support. An example of the stimulus presentation procedure is illustrated in Fig. 1.

As in Pesciarelli et al. (2021), stimuli were presented in the center of a 17-inch CRT monitor synchronous with the screen refresh [Philips 107B; refresh rate = 60 Hz (16.67 ms)]. At the viewing distance of 70 cm, target stimuli subtended 11.3° of visual angle. Prime and mask stimuli were 25% smaller (visual angle = 8.5°) to avoid perceptual overlapping. E-Prime software (Version 2; Psychology Software Tools, Pittsburgh, PA, USA) was used for stimulus presentation and behavioral response collection (see "Method" section of Pesciarelli et al., 2021, for further details on the setup). Each trial started with a fixation cross (+) presented in the middle of the screen for 800 ms. Participants were instructed to keep their eyes on the fixation cross for the duration of the experiment. After the fixation cross, a black screen appeared for 500 ms, followed by a 500-ms forward mask (a scrambled face) at the center of the screen. The forward mask was replaced by the prime face, which appeared very briefly (33 ms). The prime face was in turn replaced by a 50-ms backward mask (a scrambled face). Then, the target face appeared at the center of the screen and remained visible until response. After the response, a blank screen was displayed for 1000 ms. The use of a very brief prime duration and a prolonged mask duration was expected to make masking effective and to prevent participants from consciously perceiving the primes.
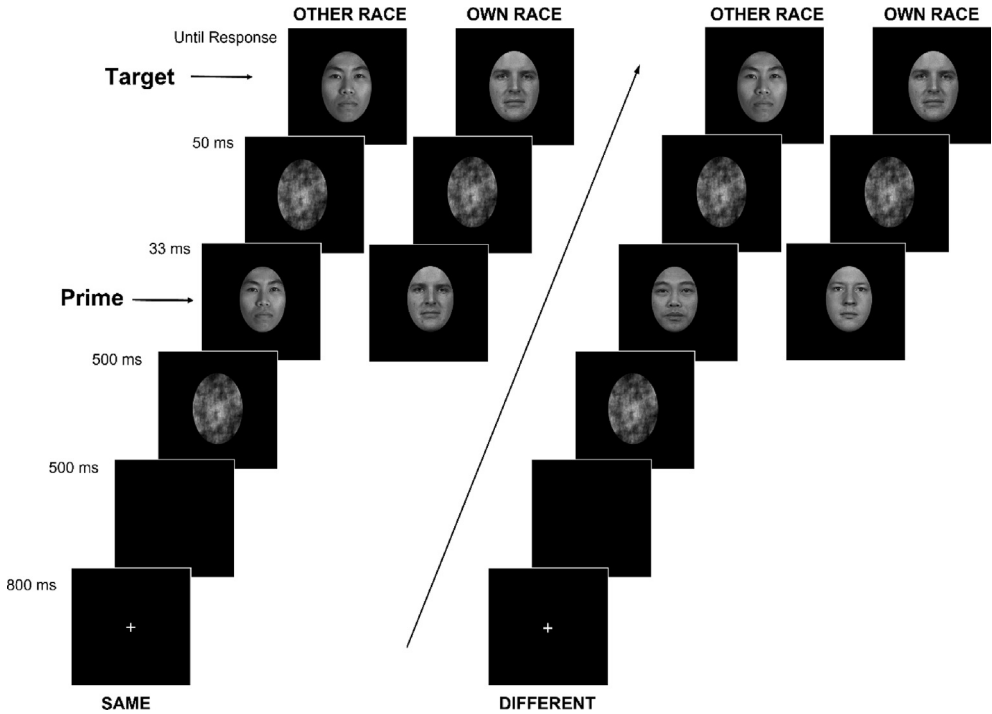
Fig. 1. Schematic depiction of the masked priming procedure used in the current experiment.

Participants were asked to indicate, as quickly and accurately as possible, whether each target face was a female or male face. They responded by pressing one of two keyboard keys, "c" or "m", with their left or right index finger, respectively. Response keys were counterbalanced across participants. The use of a gender-focused task (where face race was task irrelevant) allowed us to investigate race effects due to the implicit processing of race.

After the experiment, a self-report measure of prime visibility was collected. Participants were asked whether they saw "something between the fixation cross and the face." No participants' data needed to be excluded due to subjectively reporting seeing the prime face. No objective measure of prime visibility was collected due to time constraints and low compliance. However, an objective measure of prime visibility was collected for the same stimuli and same procedure from 35 adult participants (see Pesciarelli et al., 2021). Adults performed a gender categorization task on the *prime* faces and their performance was close to chance level, as expected by mere guessing. Thus, here we assume that the child participants did not consciously perceive the prime faces.

EEG recording and analyses

As in Pesciarelli et al. (2021), EEG was amplified and recorded with a BioSemi Active Two system using 30 active electrodes placed on the scalp according to the international 10–10 system. An additional 4 electrodes were used; of these, 2 were placed over the left and right mastoids and 2 were placed around the left eye for eye movement monitoring (one at the external ocular canthus and one below the eye). The EEG signal was recorded reference free using 2 additional electrodes placed close to Cz: the CMS (common mode sense) and DRL (driven right leg) electrodes. EEG and EOG (electro-oculography) signals were recorded with a sampling rate of 512 Hz. EEG signal was analyzed offline using BrainVision Analyzer (Version 2.2.0; Brain Products, Gilching, Germany). EEG signal was bandpass filtered between 0.1 and 30 Hz (instead of between 0.01 and 80 Hz as in Pesciarelli et al.,

2021) using a zero-phase IIR Butterworth bandpass frequency filter (12 dB/oct roll-off, 3 dB cutoff frequencies, two-pass). A notch filter at 50 Hz was applied only to participants who showed power line noise. EEG signal was referenced offline to the average activity of the two mastoids. Compromised channels were attributed the mean signal from the original channel (when not extremely noisy) and up to four non-noisy nearby channels. A maximum of two channels was interpolated per participant (representing 6.67% of the channels). EEG signal was corrected for eye movements using a restricted InfoMax ICA (independent component analysis) (Bell & Sejnowski, 1997) and a meaned slope detection algorithm (Gratton et al., 1983). Epochs (1000 ms) time-locked to the target face were extracted and baseline corrected using a 200-ms prestimulus baseline. Epochs were rejected if they contained portions of the signal with voltage steps > 75 μV, absolute voltage difference in 200 ms > 200 μV, activity in 50 ms < 0.5 μV, and voltage > ±120 μV (see Solomon et al., 2012) (note that more stringent criteria were used in Pesciarelli et al., 2021). The lost data due to artifacts were equal to 23.34% (SD = 10.21%). Epochs associated with correct responses were averaged across the four conditions (mean number of epochs for Own-Race Same = 51.32, SD = 11.23, range = 29–65; for Own-Race Different = 52.37, SD = 11.01, range = 33–73; for Other-Race Same = 47.68, SD = 14.66, range = 25–74; and for Other-Race Different = 47.95, SD = 12.10, range = 27–68). ERP components were identified for target onset at frontal (F3, Fz, and F4), central (C3, Cz, and C4), and parietal (P3, Pz, and P4) scalp sites, as in Pesciarelli et al. (2021). Based on visual inspection of the grand average ERP waveform and in line with previous literature (Bayet et al., 2021; Kujawa et al., 2015; MacNamara et al., 2016), the following time windows were selected from target onset: P100 from 80 to 180 ms, N100 from 180 to 300 ms, P200 from 300 to 360 ms, N200 from 360 to 450 ms, and P300 from 450 to 800 ms. For each ERP component, amplitude was measured as mean activity within the respective time window.

Statistical analyses

Statistical analyses were performed in JASP (2022). Behavioral analyses were carried out on individual trials with response times (RTs) > 200 ms and < 3500 ms (as in Roch et al., 2020), representing 96.54% of trials, to avoid anticipatory and late responses. Analyses of RTs and ERP analyses were carried out only on trials with correct responses. We found no significant correlation between mean correct RTs and the proportion of correct responses in any of the conditions (Own-Race Same, Own-Race Different, Other-Race Same, or Other-Race Different) (all ps >.10), suggesting the absence of a speed–accuracy trade-off (i.e., lower accuracy at faster RTs and higher accuracy at slower RTs). Thus, we analyzed speed and accuracy separately. Response accuracy was assessed as the percentage of correct responses and as the perceptual sensitivity (i.e., the sensitivity to discriminate the gender of the face) indexed by the signal detection theory d prime (d') (Macmillan & Creelman, 2005). Response bias, participants' tendency to respond "male" or "female" overall, was indexed by the signal detection theory's response criterion (c) (Macmillan & Creelman, 2005). Here, positive values indicate a bias to categorize faces as female, and negative values indicate a bias to categorize faces as male. RTs were calculated as the mean of the individual reaction times in milliseconds. Correct percentage, d', criterion c, and mean RTs were submitted to repeated-measures analyses of variance (ANOVAs) with two within-participant factors: race (other-race or own-race) and identity (same or different). ERP effects time-locked to the onset of the target face were evaluated at anterior (F3, Fz, and F4), central (C3, Cz, and C4), posterior (P3, Pz, and P4), left (F3, C3, and P3), midline (Fz, Cz, and Pz), and right (F4, C4, and P4) locations. Mean ERP amplitudes were submitted to repeated-measures ANOVAs with four within-participant factors: race (other-race or own-race), identity (same or different), latitude (left, midline, or right), and longitude (anterior, central, or posterior). Greenhouse–Geisser correction for degrees of freedom was applied for sphericity violation. Post hoc repeated-measures t tests were performed for single-level comparisons with Holm–Bonferroni-corrected p values. Only corrected p values are reported. The level of significance testing was p =.05. The 90% confidence intervals (CIs) for the effect sizes are reported (Steiger, 2004). Main effects of longitude and latitude are not central to the experimental question; thus, significant ERP effects of longitude and latitude are reported in the online supplementary material. To complement the ANOVA results, we conducted Bayesian repeated-measures ANOVAs. We kept default priors for ANOVA design (Cauchy distribution with a scale parameter of r =.50 for fixed effects and 1 for random effects). We interpreted BF$_{incl}$ between 1 and .33 as absence of evidence for either

the null or alternative model and interpreted BF_{incl} below .33 as evidence for the absence of an effect (see, e.g., Keysers et al., 2020).

Results

Behavioral results

Fig. 2 shows the percentage correct responses, the d', the mean RTs, and the criterion c to target faces preceded by same and different prime faces. See Table 1 for mean and SD values per condition.

The omnibus ANOVA performed on percentage of correct responses only revealed a significant main effect of race, $F(1, 18) = 20.38$, $p < .001$, $\eta_p^2 = .53$, 90% CI = [.23,.68], indicating that children performed better at categorizing White (own-race) target faces as compared with Asian (other-race) target faces for the gender dimension, and a tendency for a Race × Identity interaction that did not reach the significance level, $F(1, 18) = 3.27$, $p = .09$, $\eta_p^2 = .15$, 90% CI = [0,.38]. Despite the tendency, post hoc paired-samples t tests revealed better performance at categorizing White target faces as compared with Asian target faces irrespective of the prime. The main effect of identity was nonsignificant, $F(1, 18) = 0.02$, $p = .89$, $\eta_p^2 = .001$, 90% CI = [0,.07]. A complementary Bayesian ANOVA comparing the models with the identity or Identity × Race effects with the next simpler models without these effects showed evidence for the absence of an identity effect ($BF_{incl} = 0.24$) but showed inconclusive evidence for the presence or absence of an interaction effect ($BF_{incl} = 0.53$). Consistently, the omnibus ANOVA performed on the d' only revealed a significant main effect of race, $F(1, 18) = 34.68$, $p < .001$, $\eta_p^2 = .66$,
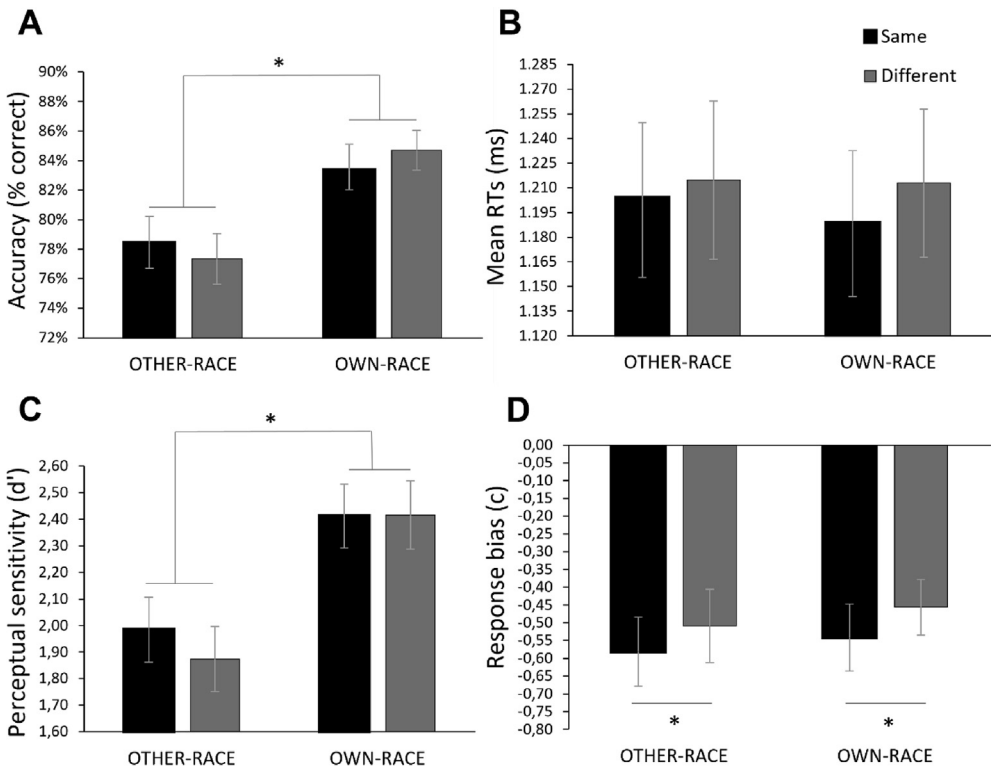
Fig. 2. Percentage (%) correct responses (A), mean response times (RTs) (B), perceptual sensitivity (d') (C), and response bias (c) (D) to target faces as a function of race (own-race or other-race) and identity (same or different). Error bars represent standard errors of the means. Statistically significant differences are marked by an asterisk (*).

Table 1

Means and Standard Deviations of Percentages of Correct Responses, Perceptual Sensitivity, Response Bias and Response Times to Target Faces as a Function of Race and Identity.

Conditions	Accuracy (% Correct)		Perceptual Sensitivity (*d'*)		Response Bias (*c*)		Response Times (ms)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Own-race Same	83.36	7.58	2.41	0.52	−0.54	0.41	1188.94	189.81
Own-race Different	84.71	5.83	2.42	0.56	−0.46	0.34	1212.90	196.47
Other-race Same	78.43	7.80	1.98	0.53	−0.58	0.42	1203.81	199.88
Other-race Different	77.34	7.50	1.87	0.54	−0.51	0.45	1214.80	210.02

90% CI = [.38,.77], suggesting that children were more perceptually sensitive to gender differences in own-race faces than in other-race faces. The main effect of identity or the Identity × Race interaction was statistically nonsignificant, $F(1, 18) = 0.39$, $p = .54$, $\eta_p^2 = .02$, 90% CI = [0,.20] and $F(1, 18) = 0.80$, $p = .38$, $\eta_p^2 = .04$, 90% CI = [0, 0.24], respectively, with a complementary Bayesian ANOVA showing evidence for the absence of the identity effect ($BF_{incl} = 0.28$) but showing inconclusive evidence for the presence/absence of the interaction effect ($BF_{incl} = 0.41$).

Children tended to categorize faces as belonging to the male gender (negative mean *c* values). The omnibus ANOVA performed on the response criterion *c* only revealed a significant main effect of identity, $F(1, 18) = 6.82$, $p = .02$, $\eta_p^2 = .27$, 90% CI = [.03,.49], indicating a greater bias toward categorizing target faces as male when preceded by the same prime faces as compared with different prime faces. We found no statistically significant main effect of race, $F(1, 18) = 0.29$, $p = .59$, $\eta_p^2 = .02$, 90% CI = [0,.19], or Identity × Race interaction, $F(1, 18) = 0.03$, $p = .87$, $\eta_p^2 = .002$, 90% CI = [0,.14], on the criterion, with a complementary Bayesian ANOVA showing evidence for the absence of these effects ($BF_{incl} = 0.31$ for both). This suggests that race had no influence on the response bias.

The omnibus ANOVA performed on mean RTs showed no significant main effect of race, $F(1, 18) = 0.20$, $p = .66$, $\eta_p^2 = .01$, 90% CI = [0,.17], identity, $F(1, 18) = 2.00$, $p = .17$, $\eta_p^2 = .10$, 90% CI = [0,.32], or Race × Identity interaction, $F(1, 18) = 0.20$, $p = .66$, $\eta_p^2 = .01$, 90% CI = [0,.17], with a complementary Bayesian ANOVA showing evidence for the absence of a race effect ($BF_{incl} = 0.26$) but showing inconclusive evidence for the presence/absence of the identity or interaction effect ($BF_{incl} = 0.41$ or 0.34, respectively).

Hence, children performed better at gender categorizing White own-race faces as compared with Asian other-race faces (i.e., an ORE for gender categorization) but took the same time to generate their response. In addition, children tended to categorize faces as belonging to the male gender category, and this bias was stronger when prime and target faces shared the same identity. Because response bias was not different for the two races, it is not discussed further. The masked priming procedure elicited no clear behavioral effects in terms of RT. In addition, behavioral data offered no clear support for the presence or absence of a modulation of the priming by race or vice versa.

ERP results

Grand-averaged ERP waveforms elicited by the target faces in the different experimental conditions are represented in Figs. 3 and 4.

P100

The omnibus ANOVA performed on the P100 amplitude showed a trend for a main effect of identity that did not reach the significance level, $F(1, 18) = 3.10$, $p = .09$, $\eta_p^2 = .15$, 90% CI = [0,.37], indicating more positive amplitudes to target faces preceded by same prime faces (μV = 6.52, $SE = 1.02$, 95% CI = [4.40, 8.65]) as compared with different prime faces (μV = 5.70, $SE = 1.02$, 95% CI = [3.58, 7.83]). A complementary Bayesian ANOVA comparing the model with the main effect of identity with the next simpler model without the effect consistently showed inconclusive evidence for the presence of an identity effect ($BF_{incl} = 2.46$). No other effects of interest to the study reached significance [race: $F(1, 18) = 0.12$, $\eta_p^2 = .007$, 90% CI = [0,.15]; Race × Identity: $F(1, 18) = 0.006$, $\eta_p^2 = .0003$, 90% CI = [0,.02];
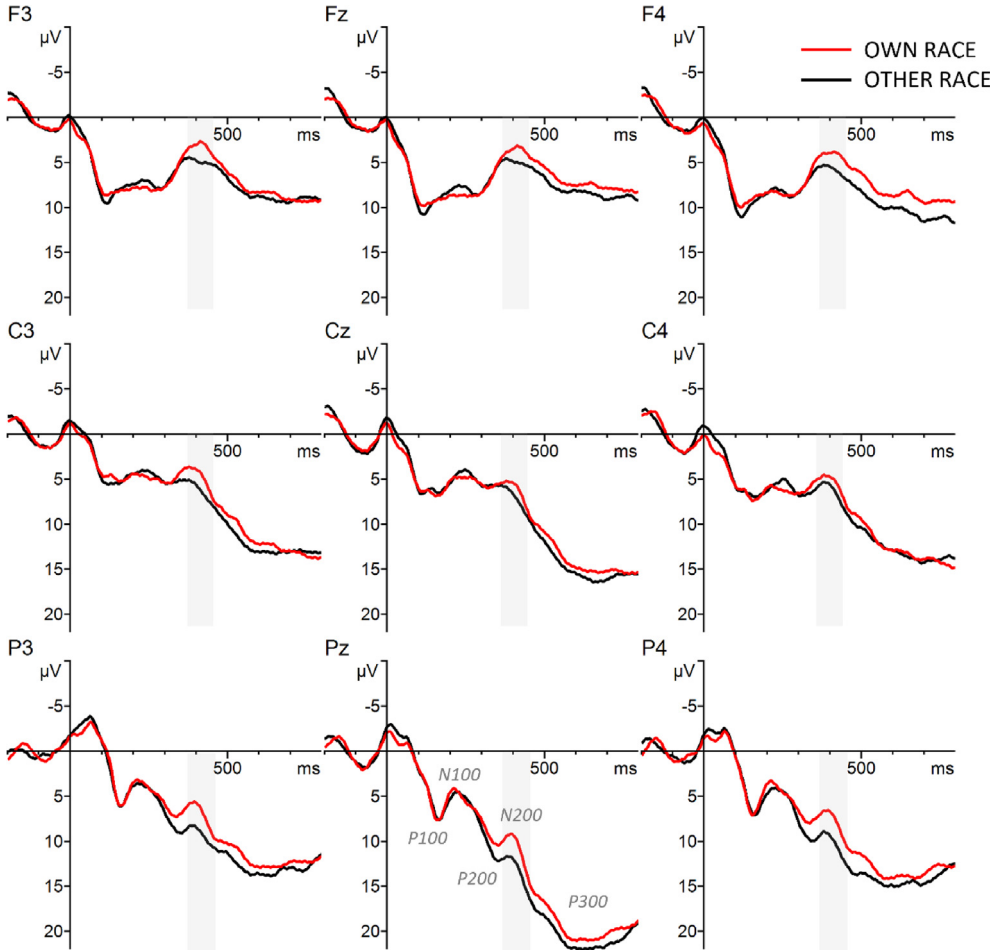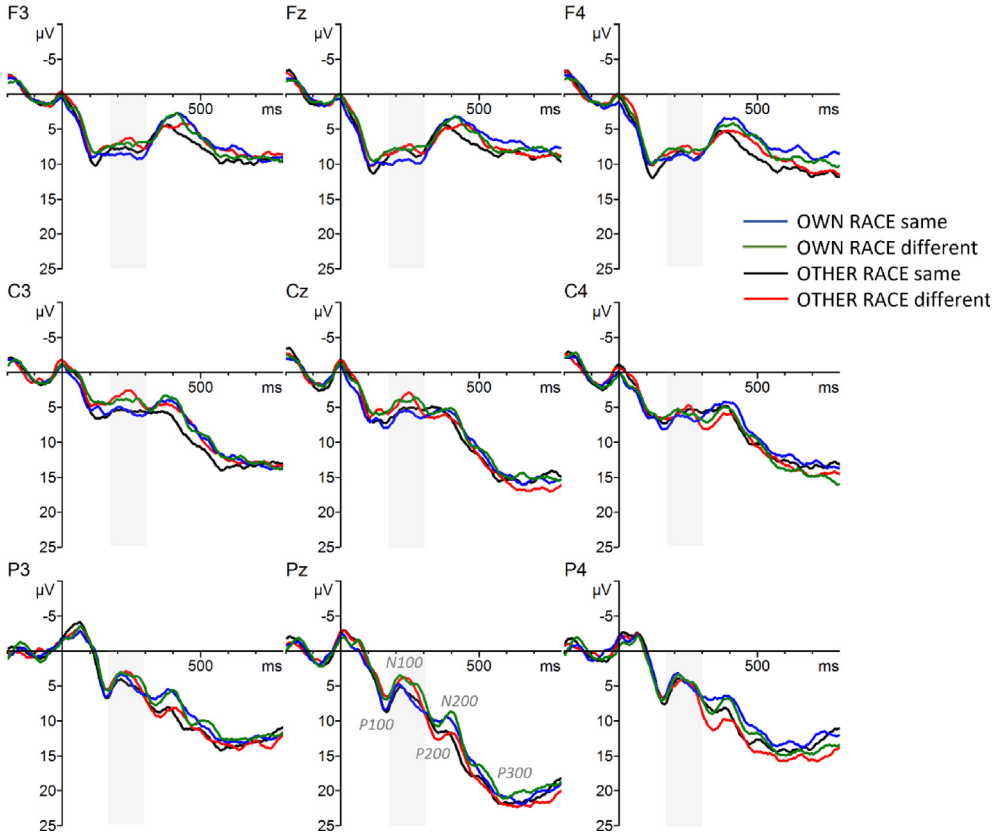
Fig. 3. Grand-averaged event-related potential (ERP) waveforms elicited by own-race target faces (in red or light gray) and other-race target faces (in black or dark gray) in 6- and 7-year-olds (*N* = 19) in the context of a masked priming paradigm. Shaded in gray is the time window of the N200 ERP component (360–450 ms), which revealed a significant effect of race. Target onset coincides with the intersection between the *y* axis and the *x* axis. Displayed waveforms are low-pass filtered to 20 Hz for display purposes. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

all *ps* >.10]. A complementary Bayesian ANOVA showed evidence for the absence of the main effect of race or Race × Identity interaction (BF$_{incl}$ = 0.10 or 0.12, respectively). Hence, face race did not affect the P100 amplitude, nor did it influence the priming effect on this component. The repetition of the same face seemed to relatively increase the P100 amplitude; however, the effect was supported by inconclusive evidence.

N100

The omnibus ANOVA on the successive N100 amplitude showed a significant main effect of identity, *F*(1, 18) = 4.90, *p* =.04, η_p^2 =.21, 90% CI = [.006,.44], indicating more negative amplitudes to target faces preceded by different prime faces (μV = 5.53, *SE* = 1.11, 95% CI = [3.20, 7.85]) as compared with same prime faces (μV = 6.61, *SD* = 1.11, 95% CI = [4.28, 8.93]) (Fig. 5). The effect was characterized by a trend for the identity and latitude interaction that did not reach the statistical significance level, *F*
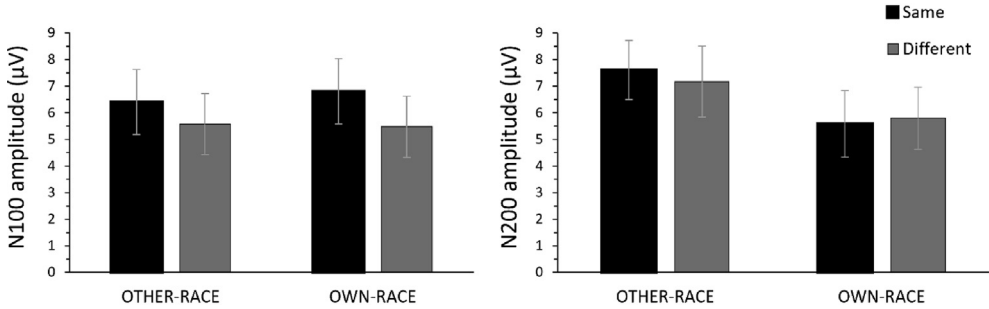
Fig. 4. Grand-averaged event-related potential (ERP) waveforms elicited by own- and other-race target faces preceded by same and different prime faces (identity condition) in 6- and 7-year-olds (*N* = 19) in the context of a masked priming paradigm. Target onset coincides with the intersection between the *y* axis and the *x* axis. Shaded in gray is the time window corresponding to the N100 ERP component (180–300 ms), for which a significant effect of identity (i.e., priming) was found. Displayed waveforms are low-pass filtered to 20 Hz for display purposes. (For interpretation of the references to color in the key at the top right of the figure, the reader is referred to the Web version of this article.)

(1.27, 22.79) = 2.82, *p* =.099, η_p^2 =.13, 90% CI = [0,.33], indicating more negative amplitudes to target faces preceded by different prime faces in the left region (μV = 4.81, *SE* = 1.15, 95% CI = [2.42, 7.20]) as compared with the middle region (μV = 7.03, *SE* = 1.15, 95% CI = 4.64, 9.42) (*p* =.03). No other effect of interest to the study reached significance [race: *F*(1, 18) = 0.05, η_p^2 =.003, 90% CI = [0,.11]; Race × Identity: *F*(1, 18) = 0.28, η_p^2 =.02, 90% CI = [0,.19]; all *p*s >.10]. A complementary Bayesian ANOVA showed evidence for the absence of a main effect of race or Race × Identity interaction (BF$_{incl}$ = 0.10 or 0.15, respectively). Thus, target faces elicited greater N100 amplitudes when primed by a different-identity face compared the same-identity face irrespective of the racial belonging. This neural priming effect confirmed that the masked priming procedure was effective.

P200

The omnibus ANOVA on the P200 amplitude showed no statistically significant effect of interest to the study [race: *F*(1, 18) = 0.54, η_p^2 =.03, 90% CI = [0, 0.22]; identity: *F*(1, 18) = 1.65, η_p^2 =.08, 90% CI = [0,.30]; Identity × Race: *F*(1, 18) = 0.19, η_p^2 =.01, 90% CI = [0,.17]; all *p*s >.10]. A complementary Bayesian ANOVA showed inconsistent evidence for the absence of the race and identity effects (BF$_{incl}$ = 0.38 and 0.37, respectively) but showed evidence for the absence of an Identity × Race inter-

Fig. 5. Mean amplitude of the N100 (left panel) and N200 (right panel) event-related potential components as a function of face race (own-race or other-race) and identity (same or different) averaged over the nine electrodes. Because these components were recorded in the positive field, less positive values indicate greater negativity. Error bars represent standard errors of the means.

action (BF_{incl} = 0.17). Hence, no priming or race effects were evident on the P200 component, with inconclusive evidence in favor of either, and face race had no impact on priming effects.

N200

The omnibus ANOVA on the N200 amplitude revealed a significant main effect of race, $F(1, 18)$ = 4.88, p =.04, η_p^2 =.21, 90% CI = [.005,.44], indicating more negative amplitudes for White (own-race) target faces (μV = 5.69, SE = 1.11, 95% CI = [3.39, 7.99]) than for Asian (other-race) target faces (μV = 7.39, SE = 1.11, 95% CI = [5.09, 9.69]) (Fig. 5). No other effect of interest to the study reached the significance level [identity: $F(1, 18)$ = 0.03, η_p^2 =.002, 90% CI = [0, 0.09]; Identity × Race: $F(1, 18)$ = 0.18, η_p^2 =.01, 90% CI = [0,.17]; all ps >.10]. A complementary Bayesian ANOVA showed evidence for the absence of the main effect of identity or Identity × Race interaction (BF_{incl} = 0.08 or 0.17, respectively). Hence, White own-race faces elicited larger N200 amplitudes than Asian other-race faces irrespective of the priming.

P300

The omnibus ANOVA on the P300 amplitude revealed no significant effect of interest to the study [race: $F(1, 18)$ = 0.98, η_p^2 =.05, 90% CI = [0, 0.26]; identity: $F(1, 18)$ = 0.10, η_p^2 =.006, 90% CI = [0,.14]; Race × Identity: $F(1, 18)$ = 0.09, η_p^2 =.005, 90% CI = [0,.14]; all ps >.10]. A complementary Bayesian ANOVA showed evidence for the absence of an identity or Identity × Race interaction effect (BF_{incl} = 0.09 or 0.12, respectively) but showed inconclusive evidence for a race effect (BF_{incl} = 0.49). Hence, unconsciously priming the target faces with the same or different faces did not affect the P300 amplitude, nor was any effect of priming different according to the face race. Evidence was inconclusive for the presence/absence of a race effect on the P300 amplitude.

Discussion

This study is the first after Anzures et al. (2022) to investigate the time course of the neural other-race effect in children. Unlike Anzures et al., our investigation extended beyond early ERP stages. We focused on the implicit and unconscious functioning of the ORE in White 6- and 7-year-olds using a masked priming paradigm. Here, face race was implicitly processed (gender-focused task) and face identity was implicitly and *unconsciously* activated (target faces preceded by identical/nonidentical subliminal prime faces). Our data show that face race influenced face processing at an early stage (i.e., N200). Even earlier, identity changes between the target face and a preceding subliminal prime face affected the N100 irrespective of face race. No modulation of the priming effect by face race was found across the time course of target face processing. Altogether, our results suggest that face

race had a temporally limited impact on face processing and that the unconscious access to face identity could occur similarly for own- and other-race faces.

Previous research on the ORE in children has been inconsistent. At the behavioral level, investigations provided contrasting evidence for an ORE, with the largest incongruency for the age range at 5 to 7 years of age (e.g., Anzures et al., 2014; Chance et al., 1982; Goodman et al., 2007). At the neural level, a few investigations reported a neural ORE. In an fNIRS study, Asian 7- to 13-year-olds showed greater neural activity in frontal brain areas (right medial frontal gyrus/inferior frontal gyrus) and occipital brain areas (left cuneus) when recognizing other-race faces (White) as opposed to own-race faces (Ding et al., 2014). In a different fNIRS study, Asian 3- to 13-year-olds showed stronger causal connections within the frontal area when recognizing other-race (White) faces as compared with own-race faces but showed stronger causal connections between occipital and frontal areas and within the occipital area when recognizing own-race faces as compared with other-race faces (Zhou et al., 2016). In an fMRI study, White 12- to 16-year-olds and adults, but not 7- to 11-year-olds, showed greater activation in the fusiform face area to own-races than to other-race (African American) faces while performing a one-back task (Golarai et al., 2021). In the only ERP study, White 5- to 10-year-olds showed larger P100 amplitudes to other-race (Asian) faces than to own-race faces when faces were implicitly processed (task focused on background color) (Anzures et al., 2022). These results suggest that neural measures could be more sensitive than behavioral measures to detect processing differences between own- and other-race faces in children.

Our results are the first to show the ERP correlates of the ORE in children beyond early processing stages (Anzures et al., 2022). They corroborate and expand previous knowledge by showing a neural ORE in 6- and 7-year-olds. This effect manifested as an increased amplitude of the N200 component for own-race faces as compared with other-race faces. Despite its novelty in children, the effect has been reliably observed in adults (e.g., Dickter & Bartholow, 2007; Willadsen-Jensen & Ito, 2006, 2008; Zhou et al., 2020; see Serafini & Pesciarelli, 2023, for a review), and it replicates the effect we found in adults using the same paradigm and stimuli (Pesciarelli et al., 2021). The N200 race effect has been generally interpreted as reflecting greater attention allocation to own-race faces than to other-race faces favoring in-depth processing. Thus, our results could indicate a different emphasis put on own- and other-race face processing, which possibly led to deeper processing of own-race faces. Of note, this occurred even though race was task irrelevant, as shown also in adults (e.g., Willadsen-Jensen & Ito, 2006, 2008).

Greater attention to own-race faces at this processing stage could have caused children to be more accurate at classifying own-race target faces than other-race target faces by gender, as we observed in this study. This interpretation is consistent with some evidence for a correlation between the N200 race effect and the response times to gender categorize own- and other-race faces in adults (Dickter & Bartholow, 2007; He et al., 2009). This ORE for the gender categorization finds antecedents in adults (e.g., Bulut & Erdeniz, 2020; O'Toole et al., 1996; Zhao & Bentin, 2008), children (Bayet et al., 2015), and infants (Damon et al., 2023). Differential perceptual experience with own- and other-race faces and the overlap of phenotypic (or stereotypic) cues between race and gender categories (e.g., female faces sharing more phenotypic cues with White faces) were suggested as possible causes of this effect (Carpinella et al., 2015; Johnson et al., 2012). However, the effect here was not predicted; thus, it needs further replication and investigation.

The finding of an ORE for gender categorization, besides its interest, together with previous evidence for a differential processing of gender in own- and other-race faces at the ERP level (e.g., N200) (Dickter & Bartholow, 2007), raises the possibility that our N200 result is due to other factors associated with the explicit gender task rather than race alone. For instance, the N200 result could be explained by task difficulty. Although this is possible given that the N200 has also been associated with task difficulty (Senkowski & Herrmann, 2002) and conflict monitoring (e.g., Dickter & Bartholow, 2010), we deem that it is unlikely because our effect (larger amplitude in the easier condition, i.e., own-race) is opposite in direction as compared with typically reported effects. On the other hand, our study failed to replicate the P100 race effect found by Anzures et al. (2022). Considering the P100 sensitivity to low-level stimulus features (Heinze et al., 1990; Johannes et al., 1995) and more consistent evidence for a P100 race effect in adults for color pictures than for grayscale pictures (Cunningham et al., 2012; Hahn et al., 2012; He et al., 2009; Herzmann et al., 2011), the inconsistency

could possibly owe to stimulus differences. Methodological differences, such as the different scalp locations at which the effect was examined (i.e., frontal, central, and parietal as compared with occipital) and the different offline reference (i.e., average mastoid as compared with overall average), could also have contributed to the inconsistency. Overall, the N200 race effect confirms that face race is implicitly encoded by children's brain, consistent with recent evidence of neural implicit race perception in children (Timeo, Mento, et al., 2019). It further suggests that race could affect face processing by facilitating a deeper processing of own-race faces, which is broadly in line with evidence for a behavioral and neural ORE in children.

Critically, whereas race had an early impact on face processing, it seemed not to affect face individuation specifically, at least when the processing of identity and race was implicit. Indeed, our findings show no modulation of the priming effect by face racial belonging in 6- and 7-year-old children. A priming effect, a differential responding to the same target when preceded by identical subliminal primes as compared with nonidentical subliminal primes, could only be ascribed to identity being processed from the prime faces in the absence of intention and awareness. We found a neural priming effect in children, confirming the effectiveness of the procedure, but this effect occurred irrespective of face race. The effect emerged on the N100 component, about 180 to 300 ms from target onset, with larger amplitude to target faces preceded by different subliminal prime faces than by same subliminal prime faces. The N100 has been generally associated with early attention capture or vigilance (Carretié et al., 2001; Näätänen, 1992). Hence, the effect could reflect an early attention capture by task-irrelevant and nonconsciously perceived identity changes. This N100 priming effect is in line with early priming effects in adults (Henson et al., 2008), and it is consistent with the effect we found in adults using the same paradigm and stimuli (Pesciarelli et al., 2021). However, in Pesciarelli et al. (2021) this effect reached statistical significance only when prime faces were unmasked, and it was limited to own-race faces. The lack of an impact of face race on the priming effect suggests that the implicit and unconscious individuation of own- and other-race faces in 6- and 7-year-olds could be similar rather supporting behavioral evidence showing no ORE at this age range.

Another important aspect that remains unclear from literature is how the ORE evolves across childhood into adulthood. Behavioral investigations provided contrasting evidence, either showing an increase in the magnitude of the ORE either across childhood (Sangrigoli & de Schonen, 2004) or from childhood to adulthood (Chance et al., 1982; Chien et al., 2018) or showing a stable ORE across childhood (Anzures et al., 2014; de Heering et al., 2010) or from childhood to adulthood (Goodman et al., 2007; Pezdek et al., 2003). However, the few neural studies consistently showed a modification of the ORE with age. fNIRS studies showed an age-related change in size and direction of the neural ORE and its related functional (Ding et al., 2014) or causal (Zhou et al., 2016) connectivity. In an fMRI study, Golarai et al. (2021) reported an increase in size and spatial extent of the race effects in the fusiform face area through childhood into adulthood. In the only ERP study, Anzures et al. (2022) reported age-related changes in the P100 latency and in the P100 to N170 peak-to-peak amplitude to own-race faces depending on the implicit racial bias and on the own-race face recognition proficiency, respectively. These results suggest that neural measures could also be more sensitive than behavioral measures to detect age-related changes in the race effect.

Our results corroborate and extend previous knowledge by showing changes in the neural time course of the ORE from childhood (the current study) to adulthood (our previous study: Pesciarelli et al., 2021). First, in adults using the same stimuli and paradigm, face race affected the entire neural time course of target face processing (i.e., P100, N100, N200, and P300), whereas in children the effect was limited to the N200 time window. This result, together with the results from Anzures et al. (2022), suggests that in children race might exert a limited early (attentional and perceptual) impact, whereas in adults it might exert a broader impact, possibly spanning more cognitive processes. Second, in adults (Pesciarelli et al., 2021) an interaction emerged between priming and race under the same conditions. This interaction was found at the P300 stage; the P300 showed a larger priming effect for other-race faces than for own-race faces. This seemingly counterintuitive finding was interpreted as a greater impact of identity repetition on other-race target processing due to greater processing difficulties of other-race faces. Altogether, the qualitative comparison of results from children and adults provides preliminary evidence that unconscious access to face identity of own- and other-race faces could be different in adults but similar in children.

The current findings have potential implications for the theories of the ORE. First, they could suggest that the representation of own- and other-race faces is substantially similar in 6- and 7-year-old children. An influential model of the ORE, the face-space model (Valentine, 1991; Valentine et al., 2016), attributes the ORE to a differential representation of own- and other-race faces within a memory "face space." Individual own-race faces would occupy distinct locations in this space, whereas individual other-race faces would be more densely clustered in this space. Given that masked priming has been attributed to, among other mechanisms, the preactivation of the target representation by the prime (for the prime's dimensions that can be activated unconsciously) (e.g., Marcel, 1983; Schnyer et al., 2002), a modulation by race could indicate that the activation of the identity representation differed. Our findings could suggest that in 6- and 7-year-old children face space is still malleable and identities are distinguishable even for other-race faces, in line with evidence of a still immature face space (Short et al., 2011, 2014) or with a refinement of an adult-like face space (Jeffery et al., 2010; 2013) in childhood. However, these findings could also fit alternative accounts of the ORE. Referring to sociocognitive models, they could indicate that ingroup and outgroup faces are automatically and unconsciously processed at a comparable depth in 6- and 7-year-olds (Rodin, 1987) or that attention is automatically directed to the identity of own- and other-race faces alike in 6- and 7-year-olds (Levin, 1996, 2000) given that attention was shown to affect masked priming effects (Naccache et al., 2002). However, these hypotheses would need more direct testing.

This investigation presents some limitations. Limitations pertaining to the sample are the limited size and the inclusion of a single racial group (White). Both limitations are due to the difficulty of recruiting children for EEG experiments. The use of a small sample size could affect the interpretation of the null findings; the lack of ERP race effects outside of the N200s or of interactions between race and priming at both behavioral and ERP levels could owe to low power rather than the absence of the effects. This is especially true for effects smaller than $\eta_p^2 = .33$, as calculated with a posteriori sensitivity analyses. Complementary Bayesian analyses provide additional information that supports the absence of the interaction effect but does not directly address this limitation. Similarly, the use of a single racial sample could undermine the generalizability of the effect across racial groups. Results may be specific to White perceivers or be driven by differences between Asian and White face stimuli besides their racial belonging. However, our review of the ERP correlates of the ORE (Serafini & Pesciarelli, 2023) showed typically converging evidence from cross-racial and non-cross-racial studies, also for the N200 race effect, suggesting that it is unlikely to be the case. Given these limitations, future studies would need to replicate our findings using larger sample sizes and cross-racial contrasts. A methodological limitation is the lack of an objective prime visibility test in children. This suggests caution when interpreting the priming effect observed on the N100 despite an objective test being obtained from adults using the same stimuli and procedure (Pesciarelli et al., 2021).

Conclusions

We investigated the other-race effect in 6- and 7-year-old children using a masked priming paradigm and the ERP technique. Our investigation resulted in a priming effect occurring fast, at about 180 to 300 ms (N100 component) following target face onset, for both own- and other-race and a race effect occurring later, at about 360 to 450 ms (N200 component) following target face onset irrespective of the identical or nonidentical prime face. Priming did not interact with race. Our results provide preliminary insight into the time course of the neural ORE in children. We interpret these results to suggest that there could be no difference in the unconscious implicit individuation of own- and other-race faces in 6- and 7-year-olds. Altogether, our findings seem to suggest that the ORE in 6- and 7-year-olds could still be immature as compared with the ORE in adults. However, due to the limitations of our study, further investigation is needed to replicate and extend our findings.

Author contributions

Luana Serafini: formal analysis, investigation, data curation, visualization, and writing–original draft; Irene Leo: conceptualization, methodology, and writing–review & editing; Francesca Pesciarelli:

conceptualization, methodology, investigation, supervision, project administration, funding acquisition, and writing–review & editing.

Data availability

Data will be made available on request.

Acknowledgments

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2023.105773.

References

Anzures, G., Kelly, D. J., Pascalis, O., Quinn, P. C., Slater, A. M., de Viviés, X., & Lee, K. (2014). Own- and other-race face identity recognition in children: The effects of pose and feature composition. *Developmental Psychology, 50*(2), 469–481. https://doi.org/10.1037/a0033166.

Anzures, G., Mildort, M., Fennell, E., Bell, C., & Soethe, E. (2022). Race and early face-sensitive event-related potentials in children and adults. *Journal of Experimental Child Psychology, 214*. https://doi.org/10.1016/j.jecp.2021.105287 105287.

Balas, B., Westerlund, A., Hung, K., & Nelson, C. A. I. (2011). Shape, color and the other-race effect in the infant brain. *Developmental Science, 14*(4), 892–900. https://doi.org/10.1111/j.1467-7687.2011.01039.x.

Bayet, L., Pascalis, O., Quinn, P. C., Lee, K., Gentaz, É., & Tanaka, J. W. (2015). Angry facial expressions bias gender categorization in children and adults: Behavioral and computational evidence. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.00346 346.

Bayet, L., Saville, A., & Balas, B. (2021). Sensitivity to face animacy and inversion in childhood: Evidence from EEG data. *Neuropsychologia, 156*. https://doi.org/10.1016/j.neuropsychologia.2021.107838 107838.

Bell, A. J., & Sejnowski, T. J. (1997). The "independent components" of natural scenes are edge filters. *Vision Research, 37*(23), 3327–3338. https://doi.org/10.1016/s0042-6989(97)00121-1.

Birhane, A. (2022). The unseen Black faces of AI algorithms. *Nature, 610*(7932), 451–452. https://doi.org/10.1038/d41586-022-03050-7.

Brooker, R. J., Bates, J. E., Buss, K. A., Canen, M. J., Dennis-Tiwary, T. A., Gatzke-Kopp, L. M., Hoyniak, C., Klein, D. N., Kujawa, A., Lahat, A., Lamm, C., Moser, J. S., Petersen, I. T., Tang, A., Woltering, S., & Schmidt, L. A. (2020). Conducting event-related potential (ERP) research with young children: A review of components, special considerations and recommendations for research on cognition and emotion. *Journal of Psychophysiology, 34*(3), 137–158. https://doi.org/10.1027/0269-8803/a000243.

Bulut, M., & Erdeniz, B. (2020). The other-race and other-species effect during a sex categorization task: An eye tracker study. *Behavioral Sciences, 10*(1). https://doi.org/10.3390/bs10010024 24.

Carpinella, C. M., Chen, J. M., Hamilton, D. L., & Johnson, K. L. (2015). Gendered facial cues influence race categorizations. *Personality and Social Psychology Bulletin, 41*(3), 405–419. https://doi.org/10.1177/0146167214567153.

Carretié, L., Mercado, F., Tapia, M., & Hinojosa, J. A. (2001). Emotion, attention, and the "negativity bias", studied through event-related potentials. *International Journal of Psychophysiology, 41*(1), 75–85. https://doi.org/10.1016/S0167-8760(00)00195-1.

Chance, J. E., Turner, A. L., & Goldstein, A. G. (1982). Development of differential recognition for own- and other-race faces. *Journal of Psychology, 112*(1), 29–37. https://doi.org/10.1080/00223980.1982.9923531.

Chien, S.-H.-L., Tai, C.-L., & Yang, S.-F. (2018). The development of the own-race advantage in school-age children: A morphing face paradigm. *PLoS One1, 13*(4). https://doi.org/10.1371/journal.pone.0195020 e195020.

Chien, S.-H.-L., Wang, L.-H., Chen, C.-C., Chen, T.-Y., & Chen, H.-S. (2014). Autistic children do not exhibit an own-race advantage as compared to typically developing children. *Research in Autism Spectrum Disorders, 8*(11), 1544–1551. https://doi.org/10.1016/j.rasd.2014.08.005.

Corenblum, B., & Meissner, C. A. (2006). Recognition of faces of ingroup and outgroup children and adults. *Journal of Experimental Child Psychology, 93*(3), 187–206. https://doi.org/10.1016/j.jecp.2005.09.001.

Cunningham, W. A., Van Bavel, J. J., Arbuckle, N. L., Packer, D. J., & Waggoner, A. S. (2012). Rapid social perception is flexible: Approach and avoidance motivational states shape P100 responses to other-race faces. *Frontiers in Human Neuroscience, 6*. https://doi.org/10.3389/fnhum.2012.00140 140.

Damon, F., Quinn, P. C., Méary, D., & Pascalis, O. (2023). Asymmetrical responding to male versus female other-race categories in 9- to 12-month-old infants. *British Journal of Psychology, 114*(Suppl. 1), 71–93. https://doi.org/10.1111/bjop.12582.

de Heering, A., de Liedekerke, C., Deboni, M., & Rossion, B. (2010). The role of experience during childhood in shaping the other-race effect. *Developmental Science, 13*(1), 181–187. https://doi.org/10.1111/j.1467-7687.2009.00876.x.

Dickter, C. L., & Bartholow, B. D. (2007). Racial ingroup and outgroup attention biases revealed by event-related brain potentials. *Social Cognitive and Affective Neuroscience, 2*(3), 189–198. https://doi.org/10.1093/scan/nsm012.

Dickter, C. L., & Bartholow, B. D. (2010). Ingroup categorization and response conflict: Interactive effects of target race, flanker compatibility, and infrequency on N2 amplitude. *Psychophysiology, 47*(3), 596–601. https://doi.org/10.1111/j.1469-8986.2010.00963.x.

Ding, X. P., Fu, G., & Lee, K. (2014). Neural correlates of own- and other-race face recognition in children: A functional near-infrared spectroscopy study. *NeuroImage, 85*, 335–344. https://doi.org/10.1016/j.neuroimage.2013.07.051.

Donchin, E. (1981). Surprise! Surprise? *Psychophysiology, 18*(5), 493–513. https://doi.org/10.1111/j.1469-8986.1981.tb01815.x.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/bf03193146.

Feinman, S., & Entwisle, D. R. (1976). Children's ability to recognize other children's faces. *Child Development, 47*(2), 506–510. https://doi.org/10.2307/1128809.

Fishman, I., Ng, R., & Bellugi, U. (2012). Neural processing of race by individuals with Williams syndrome: Do they show the other-race effect? (And why it matters). *Social Neuroscience, 7*(4), 373–384. https://doi.org/10.1080/17470919.2011.628759.

Goff, P. A., Thomas, M. A., & Jackson, M. C. (2008). "Ain't I a woman?": Towards an intersectional approach to person perception and group-based harms. *Sex Roles, 59*(5–6), 392–403. https://doi.org/10.1007/s11199-008-9505-4.

Golarai, G., Ghahremani, D. G., Greenwood, A. C., Gabrieli, J. D. E., & Eberhardt, J. L. (2021). The development of race effects in face processing from childhood through adulthood: Neural and behavioral evidence. *Developmental Science, 24*(3). https://doi.org/10.1111/desc.13058 e13058.

Goodman, G. S., Sayfan, L., Lee, J. S., Sandhei, M., Walle-Olsen, A., Magnussen, S., Pezdek, K., & Arredondo, P. (2007). The development of memory for own- and other-race faces. *Journal of Experimental Child Psychology, 98*(4), 233–242. https://doi.org/10.1016/j.jecp.2007.08.004.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55*(4), 468–484. https://doi.org/10.1016/0013-4694(83)90135-9.

Hahn, A. C., Jantzen, K. J., & Symons, L. A. (2012). Thatcherization impacts the processing of own-race faces more so than other-race faces: An ERP study. *Social Neuroscience, 7*(2), 113–125. https://doi.org/10.1080/17470919.2011.583080.

Hanley, M., Riby, D. M., Derges, M. J., Douligeri, A., Philyaw, Z., Ikeda, T., Monden, Y., Shimoizumi, H., Yamagata, T., & Hirai, M. (2020). Does culture shape face perception in autism? Cross-cultural evidence of the own-race advantage from the UK and Japan. *Developmental Science, 23*(5). https://doi.org/10.1111/desc.12942 e12942.

He, Y., Johnson, M. K., Dovidio, J. F., & McCarthy, G. (2009). The relation between race-related implicit associations and scalp-recorded neural activity evoked by faces from different races. *Social Neuroscience, 4*(5), 426–442. https://doi.org/10.1080/17470910902949184.

Heinze, H. J., Luck, S. J., Mangun, G. R., & Hillyard, S. A. (1990). Visual event-related potentials index focused attention within bilateral stimulus arrays: I. Evidence for early selection. *Electroencephalography and Clinical Neurophysiology, 75*(6), 511–527. https://doi.org/10.1016/0013-4694(90)90138-a.

Henson, R., Mouchlianitis, E., Matthews, W., & Kouider, S. (2008). Electro-physiological correlates of masked face priming. *NeuroImage, 40*, 884–895. https://doi.org/10.1016/j.neuroimage.2007.12.003.

Hervé, E., Mento, G., Desnous, B., & François, C. (2022). Challenges and new perspectives of developmental cognitive EEG studies. *NeuroImage, 260*. https://doi.org/10.1016/j.neuroimage.2022.119508 119508.

Herzmann, G., Willenbockel, V., Tanaka, J. W., & Curran, T. (2011). The neural correlates of memory encoding and recognition for own-race and other-race faces. *Neuropsychologia, 49*(11), 3103–3115. https://doi.org/10.1016/j.neuropsychologia.2011.07.019.

Hillyard, S. A., & Münte, T. F. (1984). Selective attention to color and location: An analysis with event-related brain potentials. *Perception & Psychophysics, 36*(2), 185–198. https://doi.org/10.3758/BF03202679.

Hu, C., Wang, Q., Fu, G., Quinn, P. C., & Lee, K. (2014). Both children and adults scan faces of own and other races differently. *Vision Research, 102*, 1–10. https://doi.org/10.1016/j.visres.2014.05.010.

Ito, T. A., & Urland, G. R. (2003). Race and gender on the brain: Electrocortical measures of attention to the race and gender of multiply categorizable individuals. *Journal of Personality and Social Psychology, 85*(4), 616–626. https://doi.org/10.1037/0022-3514.85.4.616.

JASP Team. (2022). *JASP* (Version 0.17.2) [computer software].

Jeffery, L., McKone, E., Haynes, R., Firth, E., Pellicano, E., & Rhodes, G. (2010). Four-to-six-year-old children use norm-based coding in face-space. *Journal of Vision, 10*(5). https://doi.org/10.1167/10.5.18 18.

Jeffery, L., Read, A., & Rhodes, G. (2013). Four year-olds use norm-based coding for face identity. *Cognition, 127*(2), 258–263. https://doi.org/10.1016/j.cognition.2013.01.008.

Johannes, S., Münte, T. F., Heinze, H. J., & Mangun, G. R. (1995). Luminance and spatial attention effects on early visual processing. *Cognitive Brain Research, 2*(3), 189–205. https://doi.org/10.1016/0926-6410(95)90015-X.

Johnson, K. L., Freeman, J. B., & Pauker, K. (2012). Race is gendered: How covarying phenotypes and stereotypes bias sex categorization. *Journal of Personality and Social Psychology, 102*(1), 116–131. https://doi.org/10.1037/a0025335.

Kehn, A., Renken, M. D., Gray, J. M., & Nunez, N. L. (2014). Developmental trends in the process of constructing own- and other-race facial composites. *Journal of Psychology, 148*(3), 287–304. https://doi.org/10.1080/00223980.2013.794122.

Kelly, D. J., Liu, S., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., & Ge, L. (2009). Development of the other-race effect during infancy: Evidence toward universality? *Journal of Experimental Child Psychology, 104*(1), 105–114. https://doi.org/10.1016/j.jecp.2009.01.006.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy: Evidence of perceptual narrowing. *Psychological Science, 18*(12), 1084–1089. https://doi.org/10.1111/j.1467-9280.2007.02029.x.

Keysers, C., Gazzola, V., & Wagenmakers, E. J. (2020). Using Bayes factor hypothesis testing in neuroscience to establish evidence of absence. *Nature Neuroscience, 23*(7), 788–799. https://doi.org/10.1038/s41593-020-0660-4.

Kouider, S., Eger, E., Dolan, R., & Henson, R. N. (2009). Activity in face-responsive brain regions is modulated by invisible, attended faces: Evidence from masked priming. *Cerebral Cortex, 19*(1), 13–23. https://doi.org/10.1093/cercor/bhn048.

Kujawa, A., MacNamara, A., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2015). Enhanced neural reactivity to threatening faces in anxious youth: Evidence from event-related potentials. *Journal of Abnormal Child Psychology, 43*(8), 1493–1501. https://doi.org/10.1007/s10802-015-0029-4.

Lakens, D. (2022). Sample size justification. *Collabra. Psychology, 8*(1). https://doi.org/10.1525/collabra.33267 33267.

Leo, I., & Pesciarelli, F. (2018). L'elaborazione implicita del volto e dell'effetto razza studiati attraverso i Potenziali Evento Relati. *Giornale italiano di psicologia, 45*(1), 245–255 https://www.rivistaweb.it/10.1421/90327.

Levin, D. T. (1996). Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(6), 1364–1382. https://doi.org/10.1037/0278-7393.22.6.1364.

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 deficit. *Journal of Experimental Psychology: General, 129*(4), 559–574. https://doi.org/10.1037/0096-3445.129.4.559.

Lipp, O. V., Mallan, K. M., Martin, F. H., Terry, D. J., & Smith, J. R. (2011). Electro-cortical implicit race bias does not vary with participants' race or sex. *Social Cognitive and Affective Neuroscience, 6*(5), 591–601. https://doi.org/10.1093/scan/nsq089.

Luck, S. J. (2005). *An introduction to the event-related potential technique.* MIT Press.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31*(3), 291–308. https://doi.org/10.1111/j.14698986.1994.tb02218.x.

Macchi Cassia, V., Luo, L., Pisacane, A., Li, H., & Lee, K. (2014). How race and age experiences shape young children's face processing abilities. *Journal of Experimental Child Psychology, 120*, 87–101. https://doi.org/10.1016/j.jecp.2013.11.016.

Macmillan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide* (2nd ed.). Lawrence Erlbaum.

MacNamara, A., Vergés, A., Kujawa, A., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. (2016). Age-related changes in emotional face processing across childhood and into young adulthood: Evidence from event-related potentials. *Developmental Psychobiology, 58*(1), 27–38. https://doi.org/10.1002/dev.21341.

Malpass, R. S., & Kravitz, J. (1969). Recognition for faces of own and other race. *Journal of Personality and Social Psychology, 13*(4), 330–334. https://doi.org/10.1037/h0028434.

Marcel, A. (1983). Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual processes. *Cognitive Psychology, 15*, 238–300. https://doi.org/10.1016/0010-0285(83)90010-5.

McKone, E., Dawel, A., Robbins, R. A., Shou, Y., Chen, N., & Crookes, K. (2023). Why the other-race effect matters: Poor recognition of other-race faces impacts everyday social interactions. *British Journal of Psychology, 114*(Suppl. 1), 230–252. https://doi.org/10.1111/bjop.12508.

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

Näätänen, R. (1992). *Attention and brain function.* Lawrence Erlbaum.

Naccache, L., Blandin, E., & Dehaene, S. (2002). Unconscious masked priming depends on temporal attention. *Psychological Science, 13*(5), 416–424. https://doi.org/10.1111/1467-9280.00474.

Natu, V., & O'Toole, A. J. (2013). Neural perspectives on the other-race effect. *Visual Cognition, 21*(9–10), 1081–1095. https://doi.org/10.1080/13506285.2013.811455.

Nieuwenhuis, S., Aston-Jones, G., & Cohen, J. D. (2005). Decision making, the P3, and the locus coeruleus–norepinephrine system. *Psychological Bulletin, 131*(4), 510–532. https://doi.org/10.1037/0033-2909.131.4.510.

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

O'Toole, A. J., Peterson, J., & Deffenbacher, K. A. (1996). An "other-race effect" for categorizing faces by sex. *Perception, 25*(6), 669–676. https://doi.org/10.1068/p250669.

Pesciarelli, F., Leo, I., & Serafini, L. (2021). Electrophysiological correlates of unconscious processes of race. *Scientific Reports, 11*(1), 11646. https://doi.org/10.1038/s41598-021-91133-2.

Pezdek, K., Blandon-Gitlin, I., & Moore, C. (2003). Children's face recognition memory: More evidence for the cross-race effect. *Journal of Applied Psychology, 88*(4), 760–763. https://doi.org/10.1037/0021-9010.88.4.760.

Phillips, P., Wechsler, H., Huang, J., & Rauss, P. (1998). The Feret database and evaluation procedure for face-recognition algorithms. *Image and Vision Computing, 16*, 295–306. https://doi.org/10.1016/S0262-8856(97)00070-x.

Polich, J., & Kok, A. (1995). Cognitive and biological determinants of P300: An integrative review. *Biological Psychology, 41*(2), 103–146. https://doi.org/10.1016/0301-0511(95)05130-9.

Regan, D. (1989). *Human brain electrophysiology: Evoked potentials and evoked magnetic fields in science and medicine.* Elsevier.

Riggins, T., & Scott, L. S. (2020). P300 development from infancy to adolescence. *Psychophysiology, 57*(7). https://doi.org/10.1111/psyp.13346 e13346.

Ritter, W., Simson, R., & Vaughan, H. G. (1983). Event-related potential correlates of two stages of information processing in physical and semantic discrimination tasks. *Psychophysiology, 20*(2), 168–179. https://doi.org/10.1111/j.1469-8986.1983.tb03283.x.

Roch, M., Pesciarelli, F., & Leo, I. (2020). How individuals with Down syndrome process faces and words conveying emotions? Evidence from a priming paradigm. *Frontiers in Psychology, 11.* https://doi.org/10.3389/fpsyg.2020.00692 692.

Rodin, M. J. (1987). Who is memorable to whom: A study of cognitive disregard. *Social Cognition, 5*(2), 144–165. https://doi.org/10.1521/soco.1987.5.2.144.

Roth, K. C., & Reynolds, G. D. (2022). Neural correlates of subordinate-level categorization of own- and other-race faces in infancy. *Acta Psychologica, 230.* https://doi.org/10.1016/j.actpsy.2022.103733 103733.

Sangrigoli, S., & de Schonen, S. (2004). Effect of visual experience on face processing: A developmental study of inversion and non-native effects. *Developmental Science, 7*(1), 74–87. https://doi.org/10.1111/j.1467-7687.2004.00324.x.

Schnyer, D. M., Ryan, L., Trouard, T., & Forster, K. (2002). Masked word repetition results in increased fMRI signal: A framework for understanding signal changes in priming. *Neuroreport, 13*(3), 281–284. https://doi.org/10.1097/00001756-200203040-00007.

Senkowski, D., & Herrmann, C. S. (2002). Effects of task difficulty on evoked gamma activity and ERPs in a visual discrimination task. *Clinical Neurophysiology, 113*(11), 1742–1753. https://doi.org/10.1016/s1388-2457(02)00266-3.

Serafini, L., & Pesciarelli, F. (2023). Neural timing of the other-race effect across the lifespan: A review. *Psychophysiology, 60*(4). https://doi.org/10.1111/psyp.14203 e14203.

Short, L. A., Hatry, A. J., & Mondloch, C. J. (2011). The development of norm-based coding and race-specific face prototypes: An examination of 5- and 8-year-olds' face space. *Journal of Experimental Child Psychology, 108*(2), 338–357. https://doi.org/10.1016/j.jecp.2010.07.007.

Short, L. A., Lee, K., Fu, G., & Mondloch, C. J. (2014). Category-specific face prototypes are emerging, but not yet mature, in 5-year-old children. *Journal of Experimental Child Psychology, 126*, 161–177. https://doi.org/10.1016/j.jecp.2014.04.004.

Solomon, B., DeCicco, J. M., & Dennis, T. A. (2012). Emotional picture processing in children: An ERP study. *Developmental Cognitive Neuroscience, 2*(1), 110–119. https://doi.org/10.1016/j.dcn.2011.04.002.

Steiger, J. H. (2004). Beyond the F test: Effect size confidence intervals and tests of close fit in the analysis of variance and contrast analysis. *Psychological Methods, 9*(2), 164–182. https://doi.org/10.1037/1082-989X.9.2.164.

Suhrke, J., Freitag, C., Lamm, B., Teiser, J., Fassbender, I., Poloczek, S., Teubert, M., Vöhringer, I. A., Keller, H., Knopf, M., Lohaus, A., & Schwarzer, G. (2014). The other-race effect in 3-year-old German and Cameroonian children. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00198 198.

Suhrke, J., Freitag, C., Lamm, B., Teiser, J., Poloczek, S., Fassbender, I., Teubert, M., Voehringer, I., Keller, H., Knopf, M., Lohaus, A., & Schwarzer, G. (2015). Experience with headwear influences the other-race effect in 4-year-old children. *Journal of Experimental Child Psychology, 137*, 156–163. https://doi.org/10.1016/j.jecp.2015.03.011.

Thai, N., Taber-Thomas, B. C., & Pérez-Edgar, K. E. (2016). Neural correlates of attention biases, behavioral inhibition, and social anxiety in children: An ERP study. *Developmental Cognitive Neuroscience, 19*, 200–210. https://doi.org/10.1016/j.dcn.2016.03.008.

Tham, D. S. Y., Bremner, J. G., & Hay, D. (2017). The other-race effect in children from a multiracial population: A cross-cultural comparison. *Journal of Experimental Child Psychology, 155*, 128–137. https://doi.org/10.1016/j.jecp.2016.11.006.

Timeo, S., Brigadoi, S., & Farroni, T. (2019). Perception of Caucasian and African faces in 5- to 9-month-old Caucasian infants: A functional near-infrared spectroscopy study. *Neuropsychologia, 126*, 3–9. https://doi.org/10.1016/j.neuropsychologia.2017.09.011.

Timeo, S., Mento, G., Fronza, E., & Farroni, T. (2019). Exposure to linguistic labels during childhood modulates the neural architecture of race categorical perception. *Scientific Reports, 9*(1). https://doi.org/10.1038/s41598-019-54394-6 17743.

Ujiie, Y., Kanazawa, S., & Yamaguchi, M. K. (2020). The other-race-effect on audiovisual speech integration in infants: A NIRS study. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.00971 971.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *Quarterly Journal of Experimental Psychology A, 43*(2), 161–204. https://doi.org/10.1080/14640749108400966.

Valentine, T., Lewis, M. B., & Hills, P. J. (2016). Face-space: A unifying concept in face recognition research. *Quarterly Journal of Experimental Psychology, 69*(10), 1996–2019. https://doi.org/10.1080/17470218.2014.990392.

Van Voorhis, S., & Hillyard, S. A. (1977). Visual evoked potentials and selective attention to points in space. *Perception & Psychophysics, 22*(1), 54–62. https://doi.org/10.3758/BF03206080.

Vogel, M., Monesson, A., & Scott, L. S. (2012). Building biases in infancy: The influence of race on face and voice emotion matching. *Developmental Science, 15*(3), 359–372. https://doi.org/10.1111/j.1467-7687.2012.01138.x.

Volpert-Esmond, H. I., & Bartholow, B. D. (2019). Explicit categorization goals affect attention related processing of race and gender during person construal. *Journal of Experimental Social Psychology, 85*. https://doi.org/10.1016/j.jesp.2019.103839 103839.

Wijers, A. A., Mulder, G., Okita, T., Mulder, L. J. M., & Scheffers, M. K. (1989). Attention to color: An analysis of selection, controlled search, and motor activation, using event-related potentials. *Psychophysiology, 26*(1), 89–109. https://doi.org/10.1111/j.1469-8986.1989.tb03137.x.

Willadsen-Jensen, E. C., & Ito, T. A. (2006). Ambiguity and the timecourse of racial perception. *Social Cognition, 24*(5), 580–606. https://doi.org/10.1521/soco.2006.24.5.580.

Willadsen-Jensen, E. C., & Ito, T. A. (2008). A foot in both worlds: Asian Americans' perceptions of Asian, White, and racially ambiguous faces. *Group Processes and Intergroup Relations, 11*(2), 182–200. https://doi.org/10.1177/1368430207088037.

Wilson, J. P., Hugenberg, K., & Bernstein, M. J. (2013). The cross-race effect and eyewitness identification: How to improve recognition and reduce decision errors in eyewitness situations: CRE and eyewitness identification. *Social Issues and Policy Review, 7*(1), 83–113. https://doi.org/10.1111/j.1751-2409.2012.01044.x.

Yi, L., Quinn, P. C., Fan, Y., Huang, D., Feng, C., Joseph, L., Li, J., & Lee, K. (2016). Children with autism spectrum disorder scan own-race faces differently from other-race faces. *Journal of Experimental Child Psychology, 141*, 177–186. https://doi.org/10.1016/j.jecp.2015.09.011.

Zhao, L., & Bentin, S. (2008). Own- and other-race categorization of faces by race, gender, and age. *Psychonomic Bulletin & Review, 15*(6), 1093–1099. https://doi.org/10.3758/PBR.15.6.1093.

Zhou, G., Liu, J., Ding, X. P., Fu, G., & Lee, K. (2016). Development of effective connectivity during own- and other-race face processing: A Granger causality analysis. *Frontiers in Human Neuroscience, 10*. https://doi.org/10.3389/fnhum.2016.00474 474.

Zhou, Y., Gao, T., Zhang, T., Li, W., Wu, T., Han, X., & Han, S. (2020). Neural dynamics of racial categorization predicts racial bias in face recognition and altruism. *Nature Human Behaviour, 4*(1), 69–87. https://doi.org/10.1038/s41562-019-0743-y.