

available at www.sciencedirect.comwww.elsevier.com/locate/brainres

**BRAIN
RESEARCH**

Research Report
The importance of skin color and facial structure in perceiving and remembering others: An electrophysiological study

 Joanne L. Brebner^a, Olav Krigolson^b, Todd C. Handy^c,
 Susanne Quadflieg^a, David J. Turk^{a,*}
^aSchool of Psychology, University of Aberdeen, King's College, Aberdeen AB24 2UB, Scotland, UK^bDepartment of Psychology, Dalhousie University, Nova Scotia, Canada^cDepartment of Psychology, University of British Columbia, Vancouver, BC, Canada

ARTICLE INFO

Article history:

Accepted 27 February 2011

Available online 5 March 2011

Keywords:

Race

Face processing

Social cognition

ERP

Own-race bias

Memory

ABSTRACT

The own-race bias (ORB) is a well-documented recognition advantage for own-race (OR) over cross-race (CR) faces, the origin of which remains unclear. In the current study, event-related potentials (ERPs) were recorded while Caucasian participants age-categorized Black and White faces which were digitally altered to display either a race congruent or incongruent facial structure. The results of a subsequent surprise memory test indicated that regardless of facial structure participants recognized White faces better than Black faces. Additional analyses revealed that temporally-early ERP components associated with face-specific perceptual processing (N170) and the individuation of facial exemplars (N250) were selectively sensitive to skin color. In addition, the N200 (a component that has been linked to increased attention and depth of encoding afforded to in-group and OR faces) was modulated by color and structure, and correlated with subsequent memory performance. However, the LPP component associated with the cognitive evaluation of perceptual input was influenced by racial differences in facial structure alone. These findings suggest that racial differences in skin color and facial structure are detected during the encoding of unfamiliar faces, and that the categorization of conspecifics as members of our social in-group on the basis of their skin color may be a determining factor in our ability to subsequently remember them.

© 2011 Elsevier B.V. All rights reserved.

1. Introduction

Many of us can identify an almost unlimited number of relatives, friends, celebrities, or acquaintances based on their facial appearance alone, in fact, “face perception may be the most developed visual perceptual skill in humans” (Haxby et al., 2000, p. 223). It appears, however, that even this highly developed skill is not without its limitations. Most notably, perceivers tend to be more accurate at recognizing own-race

(OR) compared to cross-race (CR) faces (e.g., Corenblum & Meissner, 2006; Kelly et al., 2007; Malpass & Kravitz, 1969; Meissner & Brigham, 2001; Pezdek et al., 2003; Sangrigoli & de Schonen, 2004). Although there is little disagreement about the existence of an own-race bias (ORB), its underlying mechanisms are still poorly understood. What is it about the characteristics of OR faces that dissociates their processing relative to CR faces?

According to perceptual-expertise accounts, perceivers have more contact with people from their own racial group

* Corresponding author. Fax: +44 1224 273426.

E-mail address: david.j.turk@abdn.ac.uk (D.J. Turk).

resulting in the development of finely tuned mechanisms along OR dimensions. This perceptual expertise facilitates exemplar individuation and enhances subsequent recognition accuracy for OR faces (e.g., [Chiroro & Valentine, 1995](#); [Tanaka et al., 2004](#); [Valentine, 1991](#); [Valentine & Endo, 1992](#); [Wright et al., 2003](#)). One such dimension of perceptual expertise is reflected in the ability to employ holistic, configural encoding of OR faces, whereas CR faces tend to be processed in a more piecemeal manner ([Fallshore & Schooler, 1995](#); [Hayward et al., 2008](#); [Michel, Caldara & Rossion, 2006](#); [Michel, Rossion et al., 2006](#); [Rhodes et al., 1989](#); [Tanaka et al., 2004](#)), suggesting that OR faces are encoded in a more holistic manner than are CR faces.

However there is also evidence that the ORB may be influenced by factors other than the ability to engage in expert, holistic encoding. Social cognitive models suggest that when different race-specific features (i.e., skin color, hairstyle, etc.) are detected, they indicate social (in/out) group membership. For cross-race faces this results in an impoverished perceptual representation centred on category membership (i.e., out-group) rather than on individual identity, and thus leads to deleterious memory performance ([Levin, 2000](#)). In support of this idea, it has been shown that ambiguous-race face stimuli are recognized more accurately when race-specific features signal that the face is of a racial in-group rather than out-group member ([MacLin & Malpass, 2001, 2003](#)). Evidence suggests that this may be due to differences in the extent to which perceivers employ holistic encoding (i.e., perceptual expertise), on ambiguous-race exemplars when they are considered as in- versus outgroup members ([Michel et al., 2007](#); but see [Rhodes et al., 2010](#) for conflicting evidence). According to [Levin \(2000\)](#) it is not that perceivers cannot utilize perceptual expertise to encode individuating aspects of CR faces, it is just that they do not do so. These social categorization accounts can also be applied to differences in the way in which OR faces are processed. For example, when perceivers consider own-race faces to represent members of social out-groups (i.e., belonging to a different university, having a different personality type or economic status) a recognition deficit empirically similar to the ORB can also be observed ([Bernstein et al., 2007](#); [Shriver et al., 2008](#)). These findings suggest that it is the categorization of exemplars on the basis of social group (i.e. in-group versus out-group) that shapes perceptual encoding and subsequent memory. Thus the ORB appears to be influenced by the extraction of race-categorizing features (i.e., skin color), which in turn attenuate perceptual expertise.

What these data imply is that when perceiving members of other racial (or social) groups, both categorical markers (or features) and configural properties may be utilized in determining the nature of the encoding process. One aim of the current investigation therefore was to explore how the extraction of categorical and structural information affects the ORB in memory.

A second theme of the current investigation was to chart the timecourse of the extraction of categorical and structural markers of race during face processing. Previous research has focused on several electrophysiological components that appear to differentiate own from other race face processing. The N170 is a well-defined ERP component which tends to be maximal over right occipito-temporal electrode locations

([Bentin et al., 1996](#)) and is linked to face-specific structural encoding ([Eimer, 2000](#)), and perceptual expertise ([Rossion et al., 2002](#); for a review see [Rossion & Jacques, 2008](#)). Given that perceptual expertise has been offered as a mechanism to account for the ORB, one might expect race-related differences in N170 to emerge. While the majority of studies have observed a modulation of N170 as a function of target race, the relationship between race and amplitude is equivocal. Several studies have reported increased negativity in N170 amplitude towards CR relative to OR faces ([Herrmann et al., 2007](#); [Stahl et al., 2008](#); [Walker et al., 2008](#)), whereas others have found the opposite pattern (i.e., decreased N170s for CR relative to OR faces; [Ito & Urland, 2005](#)) or have failed to detect any differences in this component to OR and CR exemplars ([Caldara et al., 2004](#); [Caldara et al., 2003](#); [James et al., 2001](#)). In this study we sought to evaluate the contribution of skin color and facial structure to the N170 component.

A second ERP component concerned with fine-grained perceptual encoding and exemplar individuation is the N250, observed in the same occipitotemporal locations. This component has been argued to index exemplar learning ([Tanaka et al., 2006](#)), through the ability to utilize perceptual expertise in face encoding ([Scott et al., 2006](#)). However, recent research has demonstrated that the N250 is sensitive to racial differences in both skin color and facial structure ([Balas & Nelson, 2010](#)), implying that both elements may contribute to the encoding of information pertinent to individuate exemplars.

In addition, race-related ERP modulations have also been observed approximately 200 ms following stimulus onset in components associated with attention and categorization which may reflect social cognitive processes. For example, the N200 component recorded from frontal and central midline sites was repeatedly found to be more negative for OR than CR faces ([Dickter & Bartholow, 2007](#); [Ito et al., 2004](#); [Ito & Urland, 2003](#); [2005](#); [James et al., 2001](#); [Kubota & Ito, 2007](#); [Walker et al., 2008](#); [Willadsen-Jensen & Ito, 2006, 2008](#)). This component has been argued to represent a bias in attention toward faces containing in-group cues ([Ito & Urland, 2003](#)), and a concomitant increases in the depth of the encoding process ([Kubota & Ito, 2007](#)). Data from Ito and colleagues also suggests a race-specific modulation of the posterior P200 component (also referred to as the vertex positive potential), with more positive amplitudes to CR than OR faces ([Ito & Urland, 2003](#); [2005](#); [Kubota & Ito, 2007](#); [Willadsen-Jensen & Ito, 2006](#)). This component has been argued to reflect the detection of and attention towards out-group cues ([Dickter & Bartholow, 2007](#); [Ito & Urland, 2003, 2005](#)). In the current study we wanted to explore the extent to which color or structure information signaled categorical status.

Finally a Late Positive Potential (LPP), maximal at parietal and central midline electrode sites (e.g., Pz and Cz), has also been associated with the processing of racial differences in faces ([Dickter & Bartholow, 2007](#); [Stahl et al., 2010](#)) and is suggested to be modulated by task demands ([Stahl et al., 2010](#)) or a perceiver's racial attitude to CR individuals ([Ito et al., 2004](#)), perhaps reflecting cognitive processes associated with aspects of racial prejudice. We sought therefore to determine the extent to which racial differences in skin color or facial structure would inform on the level of prejudicial processing indexed by the LPP component.

While much has been learned about differences in the processing of faces of own- and other-race origins using naturalistic color faces (Dickter & Bartholow, 2007; Golby et al., 2001; Ito & Urland, 2005; Kubota & Ito, 2007; Michel, Caldara & Rossion, 2006; Michel, Rossion et al., 2006; Stahl et al., 2008; Turk et al., 2005), others have sought to minimize the effects of color and contrast differences by employing achromatic stimuli (Caldara et al., 2003, 2004; Hayward et al., 2008; Michel et al., 2007; Tanaka et al., 2004; Vizioli et al., 2010; Wiese et al., 2009). However, given that both skin color and facial structure convey important information about race, it is surprising that relatively few studies have attempted to manipulate these factors independently of one another. Indeed when explicitly controlled for, color and structure do appear to provide independent contributions to the ORB in memory (Bar-Haim et al., 2009), and its neural signature (Balas & Nelson, 2010), and so a better understanding of the influence of these elements of the face appears crucial to understanding the person perception process.

We therefore recorded ERPs while a group of Caucasian participants viewed unfamiliar faces. Importantly, to investigate the contribution of skin color and structural properties to memory and ERP effects, target photographs were digitally manipulated such that they contained one of four possible color/structure combinations: Black color/Black structure, Black color/White structure, White color/Black structure, or White color/White structure. In order to capture the natural and spontaneous processes applied to the perception of own- and other-race individuals, participants were asked to make relative age judgments on each exemplar and were then subjected to a surprise memory test. The central issue of investigation was the degree to which racial differences in skin color and facial structure contribute to the own-race bias in memory, and the extent to which these factors would also modulate electrophysiological markers of race such as the N170, N250, P200, N200, and LPP components.

2. Results

2.1. Behavioral data

Recognition memory data (i.e., hits & false alarms) were converted into measures of accuracy (d') and response bias (C ; see Table 1) according to signal detection algorithms (Green & Swets, 1966; see also Stahl et al., 2010). These two measures were analyzed in

separate 2 (skin color: Black or White) \times 2 (facial structure: Black or White) repeated measures ANOVAs. Comparison of d' revealed a significant main effect of skin color [$F(1,16)=14.41$, $p<0.005$, $\eta^2=0.474$], with accuracy for faces with Black skin color lower ($d'=0.517$) than for faces with White skin color ($d'=0.997$). However, we observed no significant main effect of facial structure [$F(1,16)=0.31$, $p=0.59$], and no color \times structure interaction [$F(1,16)=0.82$, $p=0.38$]. Analysis of the response bias (C) data revealed a similar pattern of results with a marginally significant main effect of skin color [$F(1,16)=3.87$, $p=0.067$, $\eta^2=0.20$] reflecting a more liberal response criterion for faces with Black skin color ($C=.047$), compared to those with white pigmentation ($C=0.254$). However, there was no significant main effect of facial structure on response bias [$F(1,16)=0.01$, $p=0.93$] and no significant color \times structure interaction [$F(1,16)=0.12$, $p=0.74$]. This pattern of a liberal response criteria leading to a “mirror effect” in the high numbers of hits and false alarms to CR faces is a characteristic finding in the literature (Glanzer & Adams, 1990; see Meissner & Brigham, 2001 for a review).

2.2. Electroencephalographic data

Interrogation of the ERP data focused a priori on five components of interest—two previously associated with perceptual aspects of face processing, the posterior lateral N170 and N250 (e.g., Rossion & Jacques, 2008; Tanaka et al., 2006), two components previously associated with differences in attention associated with race, the P200 and N200 (Ito et al., 2004; Ito & Urland, 2003; 2005; James et al., 2001; Kubota & Ito, 2007; Walker et al., 2008; Willadsen-Jensen & Ito, 2006), and one component, the LPP (also referred to as the P300) associated with more general, postperceptual stimulus categorization and evaluation (e.g., Dickter & Bartholow, 2007; Ito et al., 2004).

In determining what electrode sites to analyze, these components all have canonical scalp sites where they are typically maximal, the N170 and N250 over lateral posterior temporal locations—P9/10 or T5/T6 (e.g., Rossion & Jacques, 2008; Tanaka et al., 2006). The N200 has been previously reported along midline electrode sites, in frontal locations (Dickter & Bartholow, 2007), whereas the P200 is generally reported central midline locations (Dickter & Bartholow, 2007). The LPP component has been observed over midline parietal- and central locations, Pz/Cz (e.g., Cacioppo et al., 1993; Schupp et al., 2000). For each component we confirmed that it was indeed maximal at these canonical sites, and thus we restricted analysis of each component to these component-specific locations as noted in the results below.

Table 1 – Recognition performance (top) and electrophysiological response (bottom) across each structure/color combination (BB = Black Col/Black Str; BW = Black Col/White Str; WB = White Col/Black Str; WW = White Col/White Str). Figures in parentheses represent one standard error of the mean.

Memory performance	Face Type			
	BCol/BStr	BCol/WStr	WCol/BStr	WCol/WStr
Proportion hits	0.59 (0.03)	0.57 (0.04)	0.57 (0.05)	0.61 (0.04)
FA	0.39 (0.04)	0.39 (0.03)	0.29 (0.05)	0.26 (.05)
C	0.03 (0.10)	0.06 (0.09)	0.26 (0.15)	0.25 (.11)
d'	0.53 (0.07)	0.50 (0.08)	0.92 (0.15)	1.07 (.15)

Analyses themselves were based on separate repeated-measures ANOVAs with factors of skin color (Black or White) and facial structure (Black or White) and, where appropriate, electrode location. All analyses were based on the mean voltage over a specific time window centered on the peak amplitude of the given component in the grand-averaged waveforms (see Handy, 2005), scaled to a baseline of –200 to 0 ms relative to event onset.

2.3. Perceptual components

The N170 and N250 both appeared to manifest an increased negativity for Black relative to White faces, an effect that did not appear to interact with the structure of the faces. This basic pattern was confirmed statistically. The N170 component was analyzed at lateral posterior temporal electrode sites P9 & P10 from 143 to 163 ms following stimulus onset. The analysis revealed a main effect of skin color [$F(1,16)=4.96$, $p<0.05$, $\eta^2=0.236$], with more negative amplitudes for faces with Black than White skin color (see Fig. 2). There was also a main effect of location [$F(1,16)=14.23$, $p<0.01$, $\eta^2=0.471$], with greater negativity in P10 than P9. However we observed no significant effect of structure [$F(1,16)=1.73$, $p=0.21$, $\eta^2=0.098$], and no significant 2- or 3-way interactions (all $ps>0.2$).

The N250 component was also analyzed at P9 and P10 between 240 and 260 ms (see Fig. 2). This analysis also revealed a main effect of skin color [$F(1,16)=9.1$, $p<0.01$, $\eta^2=0.362$], showing a similar pattern of increased negativity to Black compared to White skin color as observed in the N170 component. However, we observed no significant main effect of structure [$F(1,16)=3.33$, $p=0.09$, $\eta^2=0.172$] or electrode location [$F(1,16)=0.04$, $p=0.85$, $\eta^2=0.002$], and no significant 2- or 3-way interactions (all $ps>0.35$).

2.4. Categorization components

2.4.1. P200

The P200 component was maximal at Cz between 125 and 155 ms (see Fig. 2). Analysis of mean peak amplitudes revealed no significant main effect of color [$F(1,16)=0$, $p=0.97$] or structure [$F(1,16)=1.78$, $p=0.2$], and no significant color \times structure interaction [$F(1,16)=0.16$, $p=0.70$].

2.4.2. N200

Analysis of the N200 component was centred on the location of maximal activation at Fz between 220 and 270 ms (see Fig. 2). This analysis revealed a significant main effect of skin color [$F(1,16)=13.73$, $p<0.01$, $\eta^2=0.462$], with more negative responses to OR than CR exemplars. We also observed a significant main effect of facial structure [$F(1,16)=5.24$, $p<0.05$,

$\eta^2=0.247$], with more negative amplitudes to OR than CR exemplars, but there was no significant color \times structure interaction [$F(1,16)=3.80$, $p=0.41$].

2.5. Post-perceptual effects

The LPP was analyzed at midline central and parietal electrode sites (i.e. Cz & Pz), between 450 and 700 ms post-stimulus. This analysis revealed a significant main effect of facial structure [$F(1,16)=12.20$, $p<0.005$, $\eta^2=0.433$], such that faces with Black facial structure had a greater positive amplitude than faces with White facial structure (see Fig. 3). We also observed a significant main effect of electrode location [$F(1,16)=19.08$, $p<0.001$, $\eta^2=0.544$] with increased positive amplitude in parietal relative to central electrode sites. However, there was no significant main effect of skin color [$F(1,16)=2.07$, $p>0.1$] and no significant 2- or 3-way interactions (all $ps>0.41$).

2.6. Control analysis

Given that we found main effects of facial color in the early ERP components associated with perceptual processing, we also performed a control analysis to examine whether this effect may simply have been driven by low-level differences in image intensities rather than an actual effect of processing facial color (Balas & Nelson, 2010; Vizioli et al., 2010). Specifically, the lateral occipital P1 ERP component modulates in amplitude with the intensity or brightness of a stimulus, such that the greater the overall luminance of a stimulus, the larger the amplitude of the P1 (e.g., Handy & Khoe, 2005). Given this response property of the P1, it can be assumed that if the N170 and N250 in the current data were simply reflecting differences in image intensity associated with White vs. Black faces, then the P1 amplitude should be larger for the former relative to the latter. However, examining mean P1 amplitude at O1 and O2 electrode sites (see Fig. 4) revealed no significant main effect of color [$F(1,16)=0.853$, $p=0.37$], or structure [$F(1,16)=0.508$, $p=0.49$]. All two-way and three-way interactions also failed to reach the required statistical threshold. This finding provides support for our assumption that the data pattern observed in the N170 and N250 components is not driven by low-level, global image properties present in the faces.

2.7. Correlations between the magnitude of the color–structure bias in ERP and memory

The analysis of the ERP data demonstrated that several ERP components appeared to differentiate the processing of faces on the basis of skin color (N170, N250, N200), whereas others showed a structural dissociation in recorded amplitude (N200, LPP). In order to determine whether color or structure mediated biases in the generation of electrophysiological responses were related to similar differences in memory performance we computed the difference in memory accuracy (d') as a function of skin color (White–Black) and as a function of facial structure (White–Black). We also computed the difference in electrophysiological signal for skin color and structure in a similar way. Bivariate Pearson correlations were then computed for a priori contrasts in which significant color



Fig. 1 – Examples of morphed face stimuli used in the study.

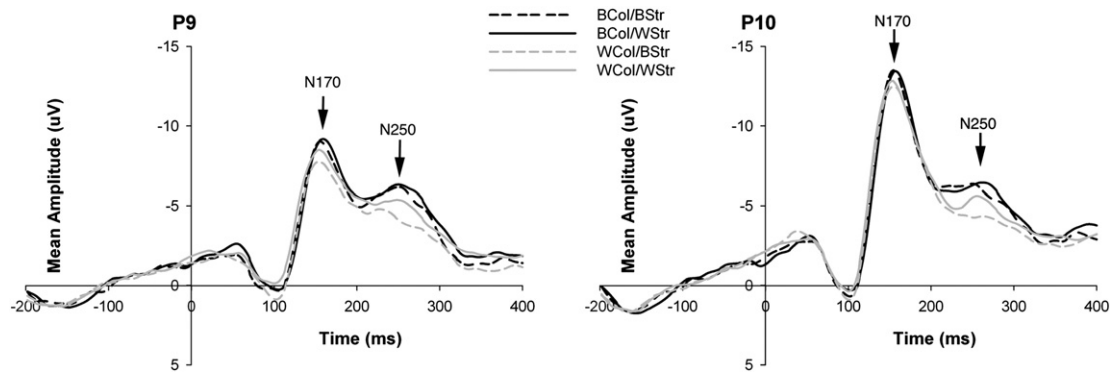


Fig. 2 – Grand-averaged ERP waveforms for the N170 and N250 components in P9 and P10 electrodes for each face type. Black lines represent Black skin color; gray lines represent White skin color. Dotted lines represent Black face structure; solid lines represent White face structure.

or structure effects had been observed in the EEG signal. Specifically we computed the correlation between color effects in memory performance and ERP amplitude for the N170, N250, N200 components, and the correlation between structure effects in memory and at the amplitude of the N200 and LPP components. We observed no significant correlation between color related differences in memory performance and N170 amplitude [$r(17)=0.112, p=0.56$], or N250 amplitude [$r(17)=-0.217, p=0.25$]. However we did observe a marginally significant correlation between color related differences in memory and N200 amplitude [$r(17)=-0.472, p=0.056$], suggesting that as differences in amplitude between OR and CR color increased, the ORB to faces with OR skin color also increased. Apriori correlations between structural biases in memory and ERP components showing a structural differentiation showed no significant correlation in N200 [$r(17)=-0.058, p=0.82$], or in LPP [$r(17)=0.008, p=0.62$].

3. Discussion

The current investigation sought to investigate the neurocognitive processes factors delineating OR and CR face processing. Our findings suggest that for Caucasian perceivers skin color is a critical, yet hitherto unexplored, factor in determining the likely recognition of others, whereas facial structure appears to have much less impact upon the ORB in memory. This color-indexed memorial advantage in memory was also echoed in the electroencephalographic signal, with the N170, N250 and N200 components showing modulations as a function of skin color. Furthermore, we observed a negative trend between the magnitude of the skin color memory bias and the amplitude difference between White and Black skin faces in the N200. Taken together, these findings highlight the important role played by skin color in the differential processing of conspecifics.

3.1. N170 and N250

Previous research has suggested that differences in low-level image properties such as contrast or luminance are detected

in early perceptual ERP components (Hillyard et al., 1998; Johannes et al., 1995; Luck, 2005), and that this may affect later face processing components such as the N170 (see Vizioli et al., 2010 for a discussion of this). In the current study we found no differences in the P1 component (sensitive to differences in global low-level image properties) as a function of skin color, suggesting that N170 amplitudes were not influenced by low-level, global stimulus properties.

While the N170 has been argued to reflect holistic, structural encoding processes (Jacques & Rossion, 2010), we observed a significant increase in the negativity of the N170 component to faces with CR skin color (see also Herrmann et al., 2007; Ito & Urland, 2005; Stahl et al., 2008). This same skin color modulation in N170 amplitude was also reported by Balas and Nelson (2010), and suggests that the categorization of conspecifics on the basis of skin color may influence the degree to which structural encoding is employed during face processing (Levin, 2000; Sporer, 2001). One possible explanation of this increased negativity to CR color cues is that for the current task, the use of color to signal race may lead to a more feature-based processing strategy associated with CR faces (Fallshore & Schooler, 1995), thus affecting configural processes associated with the N170 component. Face inversion is thought to similarly disrupt configural processing and is also associated with increased negative amplitudes in the N170 component compared with upright faces (Itier & Taylor, 2002; Latinus & Taylor, 2006). In addition, Itier & Taylor (2002) also observed increased N170 to contrast reversed upright faces, suggesting that the processing of surface information modulates N170 amplitude in the absence of any structural differences in the array.

Observed differences in ERP as a function of skin color were also evident in the N250 component, which has been previously thought to reflect the structural encoding of faces (Maurer et al., 2002) and is also associated with exemplar familiarity and perceptual expertise (Scott et al., 2006; Tanaka & Pierce, 2009). As with the N170 effects, we interpret this as evidence that race-defining features such as skin color appear to influence the holistic encoding and individuation of faces (Balas & Nelson, 2010).

Interestingly, previous studies on task-unrelated processing of faces on the basis of other categories (e.g., age or gender) failed

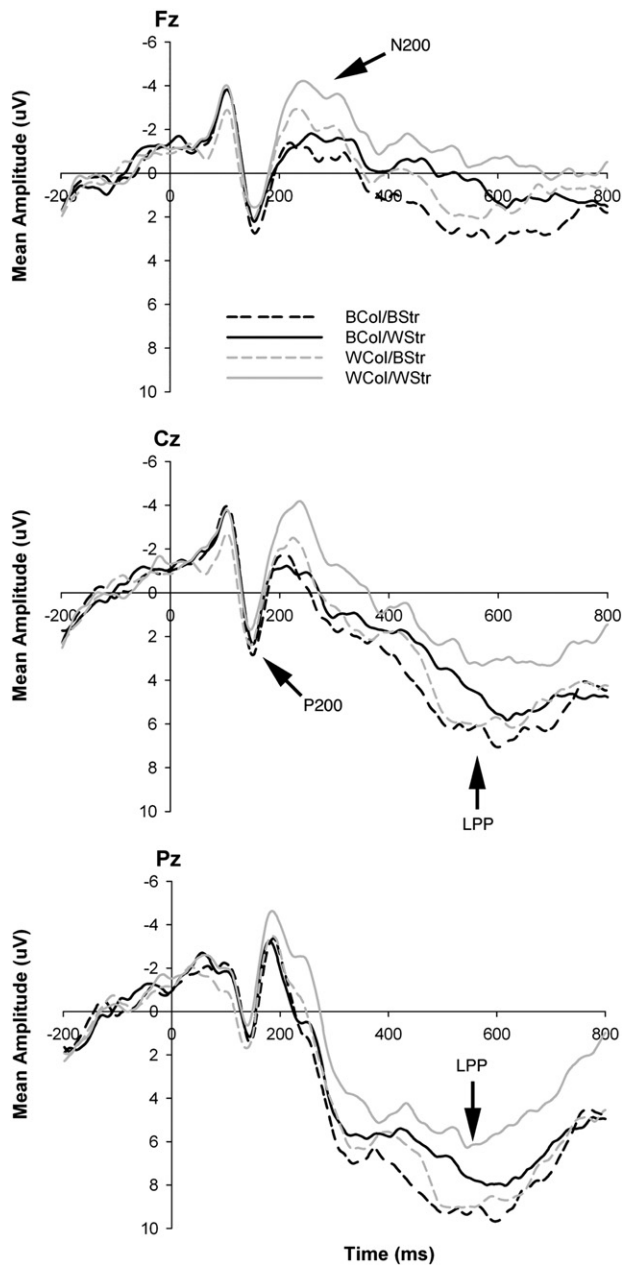


Fig. 3 – Grand-averaged ERP waveforms representing N200 component (top), the P200 component (middle) and the LPP component (bottom) at midline posterior and central electrode sites for each face type. Black lines represent Black skin color; gray lines represent White skin color. Dotted lines represent Black face structure; solid lines represent White face structure.

to show modulation of face processing ERP components in the N170 and N250 timeframe (Mouchetant-Rostaing & Giard, 2003; Mouchetant-Rostaing et al., 2000). It therefore seems that category membership delineated on grounds of race has a greater impact on face processing than other types of category-specifying information such as age or gender.

In an attempt to control for the effects of contrast and luminance on the processing of own versus other race faces, numerous studies have utilized grayscale images (e.g., Caldara

et al., 2003, 2004; Hayward et al., 2008; Michel et al., 2007; Tanaka et al., 2004; Vizioli et al., 2010; Wiese et al., 2009). While this methodology has led to significant advances in our understanding of racial differences in face processing, the current findings highlight the important role played by skin color in delineating faces on the basis of race, suggesting that by neglecting this vital feature, we are likely to underestimate the impact of skin color on face processing (Balas & Nelson, 2010).

3.2. P200 and N200

In addition to ERP components associated with perceptual processing we also examined race mediated ERP components associated with differences in attention to OR and CR faces. Two attentional ERP components have been identified as reflecting the detection of facial distinctiveness (P200; Ito & Urland, 2003, 2005; Kubota & Ito, 2007) and increased attention related to depth of processing and exemplar individuation (N200; Dickter & Bartholow, 2007), and has been shown to differentiate OR and CR face processing (Ito et al., 2004; Ito & Urland, 2003; James et al., 2001; Tanaka et al., 2004; Walker & Tanaka, 2003). In the current study we also observed the largest increase in N200 to faces with OR skin color, suggesting that the implicit categorization of faces as in-group members through skin color cues led to greater attention and processing afforded to the faces. However, we also observed an effect of facial structure in this component such that faces with OR structure led to increased N200 compared to those with CR structure. This may reflect the extent to which structural encoding and exemplar individuation is subsequently applied to faces categorized as in-group or out-group on the basis of skin color. Of note here also is the fact that differences in amplitude in this component to faces with OR or CR skin color appears to track with the magnitude of the ORB observed.

Previous studies have observed increases in the P200 amplitude to CR compared to OR faces (Dickter & Bartholow, 2007; Kubota & Ito, 2007), however in the current study we found no significant color or structure modulation in this component. Kubota & Ito (2007) demonstrated that the P200 could be modulated by both explicit racial categorization and explicit detection of negative facial expressions (i.e. anger) relative to neutral expressions. Thus they argue that the P200 reflects the detection of distinctiveness or threat from the face. In the current study we utilized neutral facial expressions and did not require explicit categorization of faces on the basis of race. This difference in our methodology may well account for the absence of P200 effects observed. Thus it may be that this component represents neural processes associated with explicit processing of out-group cues (but see Dickter and Bartholow, 2007 for an alternative viewpoint).

3.3. Late positive potential (LPP)

We also found that the LPP component, previously associated with cognitive processes, perhaps reflecting racial prejudice (Dickter & Bartholow, 2007; Ito et al., 2004), was sensitive to differences in the structural composition of faces, with increased positive amplitude to faces with CR relative to OR structure. Together with the structural modulation observed

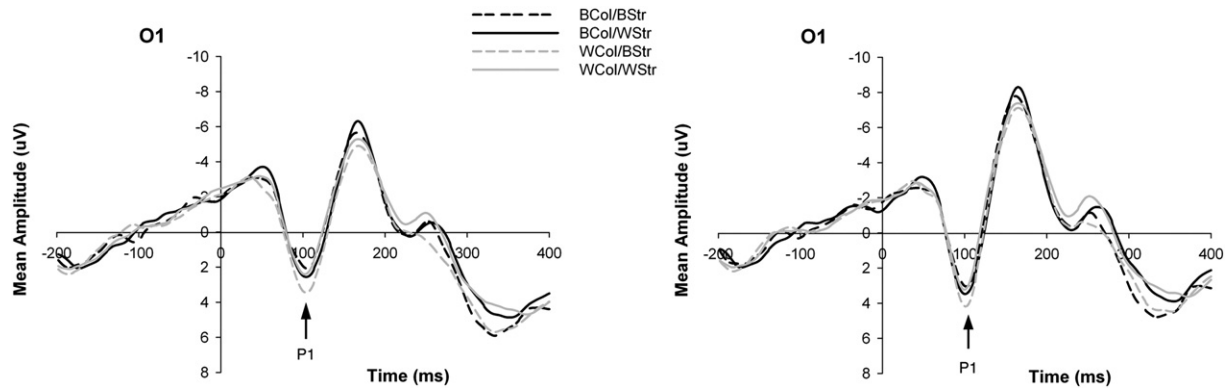


Fig. 4 – Grand-averaged ERP waveforms for the P1 component at O1 and O2 electrodes for each face type. Black lines represent Black skin color; gray lines represent White skin color. Dotted lines represent Black face structure; solid lines represent White face structure.

in the N200 component, this finding in the LPP is important for two reasons. First, it demonstrates that structural properties of faces from different racial groups are separately encoded. Second, that while perceivers do extract race-related structural information, it appears to have little impact on the observed memory bias, which instead tracks with skin color.

What our data suggest is that early perceptual processing of OR and CR faces is dominated by the extraction of color information in the N170. This color preference is extended to the later perceptual component occurring at approximately 250 ms (posterior N250), and is also observed in the N200 component previously identified to reflect increased attention to in-group members, and which appears to correlate with memory performance. At this timepoint in N200 we begin to see evidence that structural differences are also beginning to influence face encoding, but only as a secondary source of information. In later cognitive ERP components (peaking around 600 ms) we observed a significant modulation on the grounds of facial structure. It has been suggested that the early categorization of others as out-group members on the basis of skin color reduces the motivation for perceivers to engage in holistic, structural encoding processes, even when OR structural information is present in the array (Bernstein et al., 2007; Shriver et al., 2008). The current study however suggests that in fact it may be the early detection of in-group status on the basis of skin color that increases the motivation to attend and process the faces of others and thus facilitates the resultant memory advantage.

3.4. Previous research

Two recent studies in which the impact of skin color and facial structure were contrasted produced somewhat different results than the current data set. Bar-Haim et al. (2009) generated sets of color images of Caucasian and Black faces in which an original pair of photographs was modified by computing skin color information from 16 locations around the face on one image and applying this pigmentation to the other-race image using filters and color-curve adjustment software. This enabled them to create sets of four possible combinations of racial color and structure information.

Participants were instructed to memorize sixteen images from each color–structure combination, and main effects of both color and structure were observed in recognition accuracy. These were qualified in a color by structure interaction in which faces with OR color and structure were better remembered than all other combinations. The authors concluded that while color influenced the recognition process, it was secondary to the extraction of structural information.

Similarly Balas & Nelson (2010) used 200 computer-generated images in which color and structure combinations were manipulated. They recorded electrophysiological responses while participants attempted to memorize upright and inverted faces, and found an ORB only when the faces were inverted. While this study demonstrated an effect of skin color on the N170 and N250, the absence of an ORB for upright exemplars makes this difficult to interpret. It may be that the instruction to memorize the faces prompted participants to focus on individuating information in the faces, thus reducing the ORB (Hugenberg et al., 2007). This methodological difference may also account for why Balas & Nelson found that structural information modulated the N250 component, while it failed to do so in the current study.

In the current investigation we generated images using natural surface pigmentation warped onto the structure of CR exemplars. These images were presented in an upright orientation, and to promote more typical encoding processes, participants were asked to determine the relative age of the presented face but were not instructed to memorize it. Under these encoding conditions color information had a significant impact on memory for unfamiliar faces. Our interpretation of these data is that while not focusing on race in the task per se, categorical processing of conspecifics on the basis of skin color information occurred automatically (Ito & Urland, 2005) and resulted in differences in the quality of the encoding process reflected in modulation of face-specific ERP components previously thought to represent holistic, structural encoding.

3.5. Limitations of the current research

One major limitation of the current study is the fact that we recruited only Caucasian participants. While this perceiver

group is typical for several previous electrophysiological investigations of the own-race bias (Balas & Nelson, 2010; Caldara et al., 2003; Ito & Urland, 2003, 2005; Ito et al., 2004; Stahl et al., 2010), the absence of a second perceiver group may reduce the scope of our findings (Balas & Nelson, 2010; Dickter & Bartholow, 2007; Vizioli et al., 2010). One important function of using multiple perceiver groups is to determine whether data patterns reflect the impact of stimulus properties (e.g., low-level properties such as luminance, contrast, or color) or a more specific alignment of aspects of the image that reflect race, and the ethnicity of the perceiver group (Balas & Nelson, 2010; Dickter & Bartholow, 2007). Since natural pigmentation was used in the current investigation it is likely that the faces did differ in low-level properties such as luminance, contrast and color. However, analysis of the P1 data in the current study suggests that the observed effects were not due to low-level global stimulus properties, but may well represent the alignment of perceiver group and stimulus category membership.

A second benefit of testing different racial cohorts on the current paradigm would be to determine the relative importance of color or structure to each perceiver group. That is, while the current study shows that color cues are important when Caucasian participants view Black versus White faces, the same may not be true when viewing other racial groups such as Asians, or color cues may be less important when non-Caucasian participants view faces. Golby et al. (2001) tested Caucasian and African American participants and showed that while both sets of observers exhibited patterns of memory and neural activation consistent with an own-race advantage, the Caucasian participants showed a larger ORB, and larger fusiform gyrus activity to OR versus CR faces than the African American perceivers. The extent to which color and structure contribute to the ORB in other, non-Caucasian perceivers may provide a useful avenue for future research in this area. In the context of methodological issues in studying the own-race bias, what our results and those of recent experiments (Balas & Nelson, 2010; Bar-Haim et al., 2009) clearly illustrate is that it is difficult to interpret the determinants of racial biases in memory if color or structural information is absent from the array.

It could also be argued that because Black and White faces differ more in terms of their color than their structural properties, and that our findings are the result of our color manipulation being more powerful than our structural manipulation in delineating race. As such it is possible that where skin color differences between racial groups are less marked (e.g., Caucasian versus Asian faces) that memorial and electrophysiological markers might track more with structural variation than color. This may be an interesting avenue for future research on the determinants of racial memory bias, but further highlights the need to include both color and structural information in the array to be processed.

Finally, in the current investigation we presented fifty-six faces of each color structure combination during the encoding phase. While this provided us with sufficient numbers of trials to determine the effect of color and structure on the electroencephalographic response averaged across all face-types, as well as the resultant memory bias, it has only permitted a rudimentary analysis of the relationship between these two variables. Given the small numbers of encoding trials and the generally high levels of remembering it is unsurprising that only

a marginal correlation between ERP and memory emerged in the N200 component. While such a relationship would support memory differences resulting from the detection of ingroup characteristics reflected in the N200, we would not want to overstate the importance of this finding. While the use of correlation has been used to explore the relationship between brain activity and memory performance (see also Vizioli et al., 2010), an alternative approach would be to examine differences in the ERP elicited at encoding to subsequently remembered versus forgotten items—the DM effect (Paller et al., 1987; Wagner et al., 1999). This would give a better indication on the relationship between ERP components and memory performance. Given the small number of trials in the current investigation this analysis has not been possible, but could be a profitable line of inquiry in future research.

The current study therefore supports a broader view of the factors that affect racial face processing along the lines of the social categorization model. This account argues that the cross-race deficit lies in a tendency to utilize color information to categorically process others. Specifically, that faces containing OR cues (i.e., skin color) are processed in terms of their in-group status. In-group faces are afforded increased attentional resources and are likely to be encoded in a manner that fosters exemplar individuation and, as a result, are more likely to be remembered. Similar categorization effects favoring in-group members can be observed when ambiguous race faces are perceived to be CR rather than OR (Shutts & Kinzler, 2007), and when OR faces are perceived to belong to a social in- versus out-groups (Shriver et al., 2008). Taken together, these findings suggest that categorizing conspecifics on the basis of a race-defining feature (e.g., skin color) influences the degree to which perceptual expertise is recruited during encoding and the likelihood they will be later remembered (Sporer, 2001). As such social categorization appears to be a key determinant in the ORB.

In summary, this study explored the encoding and subsequent recognition of unfamiliar faces as a function of skin color or facial structure. We observed significant memorial advantages in Caucasian perceivers for faces with White relative to Black skin color irrespective of facial structure. This color effect was mirrored in the early modulation of perceptual ERP components. While structural differences were observed in later ERP components associated with the detection of in-group status and racial prejudice, this appears not to have influenced memory performance.

Thus we conclude that social categorization on the basis of skin color cues is a significant factor in determining the own-race bias in memory. Consequently, it is important that future research into the ORB utilizes color images, as when this feature of racial identity is present in the array, it appears to provide an attenuating factor in both the neural signature of face processing and the resultant mnemonic bias.

4. Experimental procedures

4.1. Participants

Seventeen right-handed Caucasian students (8 male, 9 female), aged between 18 and 35 (mean age = 21 years) from the

University of Aberdeen participated for course credit. All had normal or corrected-to-normal vision, and had no history of neurological disorders.

4.2. Stimuli

One hundred and sixty-eight male faces (84 white and 84 black) were collated from the internet (e.g., Minear & Park, 2004), and from other sources. The faces measured $10.2^\circ \times 10.2^\circ$ of visual angle and were depicted in frontal pose displaying neutral facial expressions. Each white face was paired with a black face on the basis of having similar hairstyles, degree of head tilt, and approximate age to create 84 face pairs. Using Gryphon Morph 2.5 PPC, numerous points of reference (e.g. face outline, eye shape and centre, nose and mouth shape, hairline, etc.) on each face were marked. The faces within each pair were then warped with one another, a process which applies the surface information (i.e. skin, eye and hair color, luminance, contrast) from one face to the spatial configuration of the other face. In doing so, two new faces were created per face pair, one with the featural configuration of the Black face but with surface information from the White face (from here-on-in referred to as skin color) and another with the featural configuration of the White face but with Black skin color (see Fig. 1 for examples). These changes are global changes, but may also lead to small perturbations in the perceived shape of individual features resulting from preserved shading information in the warped surface detail. We created 84 sets of faces, each of which contained one with Black skin and Black facial structure (BCol/BStr), one with Black skin color and White structure (BCol/WStr), one with White skin and Black structure (WCol/BStr), and one with both White skin and White structure (WCol/WStr). These sets of faces were further divided into 56 sets used for encoding and 28 used as foils in the subsequent memory test. The 56 sets of four images used at encoding were then further divided into four equal blocks each containing only one face from each set. These four blocks contained equal numbers of each of the different face types. As such, no two faces from the same set of four morph images were ever presented together. The images comprising the encoding and foil sets were counterbalanced across participants

4.3. Procedure

Each trial comprised the central presentation of a fixation cross which remained on screen for 500 ms, followed by a face which remained onscreen for 1000 ms. The interstimulus interval varied randomly between 2000 and 3000 ms. There were 224 trials during the encoding phase of the experiment (56 per condition), comprising of 56 full face sets. As such, each individual color and structure information was presented twice during encoding. Participants were not explicitly asked about their experiences during the task, but none spontaneously reported seeing repetitions of color or structure information. Participants were required to make a relative age judgment (i.e., whether the individual was under or over 21 years of age). To simplify this, participants (who were university students) were given the example that the face could be of an undergraduate or postgraduate student. Responses to each face were made by way of a button press. This task was to ensure that participants were attending to the faces, but were not explicitly processing race information. The order of trials was

randomized within each block of trials, and block order was counterbalanced across participants.

While the main focus of interest within this study was to examine participants' sensitivity to color and structural information when viewing faces, we also collected recognition memory scores during a surprise memory test in order to see how color and structural information influences the ORB. To prevent explicit encoding of the faces, participants were only informed about this task following completion of the encoding phase. In this memory test, each of the 224 faces previously encountered during encoding and 112 previously unseen items (28 of each face type) were presented in the centre of the screen. Each face remained on screen until the participant responded with an "Old" (i.e., previously seen) or "New" (i.e., previously unseen) response via button press. In each trial a fixation cross appeared for 500 ms, followed by a centrally presented face. An interstimulus interval of 500 ms preceded the each trial.

4.4. Electroencephalographic recording

Scalp potentials were recorded from 64 Ag-AgCl active electrodes via a Biosemi ActiveTwo ERP system. Continuous electroencephalographic (EEG) was recorded with a bandpass of 0.1 to 30 Hz at a sampling rate of 512 samples per second. Vertical and horizontal eye movements were recorded using four additional electrodes placed on the outer canthus of each eye, and one above and one below the right eye, and two additional electrodes were used to record from the left mastoid and nose. All recorded voltages at analog-to-digital conversion for each electrode site were made relative to a common mode voltage based on the ActiveTwo's CMS/DRL feedback loop. Offline, all scalp electrodes were referenced to an electrode on the tip of the nose. Computerized artifact rejection was then used to eliminate trials with detectable eye movements, blinks, muscle potentials or amplifier blocking. This resulted in a maximum loss of 28% of trials (leaving a minimum of 40 trials per condition). For each participant, EEG time-locked to the remaining events of interest was epoched into 1000 ms segments, beginning 200 ms before stimulus onset. These epochs were then signal-averaged within each condition and baseline corrected. The single-subject average waveforms were then used to generate grand average waveforms for display and analysis.

Acknowledgments

This research was supported by a grant to DJT from the British Academy. The authors would also like to thank Dr. Jennifer Eberhardt for providing some of the face stimuli, and three anonymous reviewers for their helpful comments.

REFERENCES

- Balas, B., Nelson, C.A., 2010. The role of face shape and pigmentation in other race face perception: an electrophysiological study. *Neuropsychologia* 48, 498–506.
 Bar-Haim, Y., Sidel, T., Yovel, G., 2009. The role of skin colour in face recognition. *Perception* 38, 145–148.

- Bentin, S., Allison, T., Puce, A., Perez, E., McCarthy, G., 1996. Electrophysiological studies of face perception in humans. *J. Cogn. Neurosci.* 8, 551–565.
- Bernstein, M.J., Young, S.G., Hugenberg, K., 2007. The cross category effect: mere social categorization is sufficient to elicit an own-group bias in face recognition. *Psychol. Sci.* 18, 706–712.
- Cacioppo, J.T., Crites, S.L., Berntson, G.G., Coles, M.G.H., 1993. If attitudes affect how stimuli are processed, should they not affect the event-related brain potential. *Psychol. Sci.* 4, 108–112.
- Caldara, R., Rossion, B., Bovet, P., Hauert, C.A., 2004. Event related potentials and time course of the “other-race” face classification advantage. *NeuroReport* 15, 905–910.
- Caldara, R., Thut, G., Servoir, P., Michel, C.M., Bovet, P., Renault, B., 2003. Face versus non-face object perception and the “other-race” effect: a spatiotemporal event-related potential study. *Clin. Neurophysiol.* 114, 515–528.
- Chiroro, P., Valentine, T., 1995. An investigation of the contact hypothesis of the own-race bias in face recognition. *Q. J. Exp. Psychol. Hum. Exp. Psychol.* 48A, 879–894.
- Corenblum, B., Meissner, C.A., 2006. Recognition of ingroup and outgroup children and adults. *J. Exp. Child Psychol.* 93, 187–206.
- Dickter, C.L., Bartholow, B.D., 2007. Racial in-group and out-group attention biases revealed by event-related brain potentials. *Soc. Cogn. Affect. Neurosci.* 2, 189–198.
- Eimer, M., 2000. The face-specific N170 component reflects late stages in the structural encoding of faces. *NeuroReport* 11, 2319–2324.
- Fallshore, M., Schooler, J.W., 1995. Verbal vulnerability of perceptual expertise. *J. Exp. Psychol. Learn. Mem. Cogn.* 21, 1608–1623.
- Glanzer, M., Adams, J.K., 1990. The mirror effect in recognition memory: data and theory. *J. Exp. Psychol. Learn. Mem. Cogn.* 16, 5–16.
- Golby, A.J., Gabrieli, J.D.E., Chiao, J.Y., Eberhardt, J.L., 2001. Differential responses in the fusiform region to same-race and other-race faces. *Nat. Neurosci.* 4, 845–850.
- Green, D.M., Swets, J.A., 1966. Signal detection theory and psychophysics. Wiley, New York.
- Handy, T.C., 2005. Basic principles of ERP quantification. In: Handy, T.C. (Ed.), *Event-Related Potentials: A Methods Handbook*. MIT Press, Cambridge, MA, pp. 33–55.
- Handy, T.C., Khoe, W., 2005. Attention and sensory gain control—a peripheral visual process? *J. Cogn. Neurosci.* 17, 1936–1949.
- Hayward, W.G., Rhodes, G., Schwaninger, A., 2008. An own-race advantage for components as well as configurations in face recognition. *Cognition* 106, 1017–1027.
- Haxby, J.V., Hoffman, E.A., Gobbini, M.A., 2000. The distributed human neural system for face perception. *Trends Cogn. Sci.* 4, 223–233.
- Herrmann, M.J., Schreppe, T., Jager, D., Koehler, S., Ehls, A.C., Fallgatter, A.J., 2007. The other-race effect for face perception: an event-related potential study. *J. Neural Transm.* 114, 951–957.
- Hillyard, S.A., Teder-Sa’leja’rvi, W.A., Münte, T.F., 1998. Temporal dynamics of early perceptual processing. *Curr. Opin. Neurobiol.* 202–210.
- Hugenberg, K., Miller, J., Claypool, H., 2007. Categorization and individuation in the cross-race recognition deficit: toward a solution to an insidious problem. *J. Exp. Soc. Psychol.* 43, 334–340.
- Ito, T.A., Thompson, E., Cacioppo, J.T., 2004. Tracking the timecourse of social perception: the effects of racial cues on event-related brain potentials. *Pers. Soc. Psychol. Bull.* 30, 1267–1280.
- Itier, R.J., Taylor, M.J., 2002. Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: a repetition study using ERPs. *Neuroimage* 15, 353–372.
- Ito, T.A., Urland, G.R., 2003. Race and gender on the brain: electrocortical measures of attention to race and gender of multiply categorizable individuals. *J. Pers. Soc. Psychol.* 85, 616–626.
- Ito, T.A., Urland, G.R., 2005. The influence of processing objectives on the perception of faces: an ERP study of race and gender perception. *Cogn. Affect. Behav. Neurosci.* 5, 21–36.
- Jacques, C., Rossion, B., 2010. Misaligning face halves increases and delays the N170 specifically for upright faces: implications for the nature of early face representations. *Brain Res.* 1318, 96–109.
- James, M.S., Johnstone, S.J., Hayward, W.G., 2001. Event-related potentials, configural encoding, and feature-based encoding in face recognition. *J. Psychophysiol.* 15, 275–285.
- Johannes, S., Munte, T.F., Heinze, H.J., Mangun, G.R., 1995. Luminance and spatial attention effects on early visual processing. *Cogn. Brain Res.* 2, 189–205.
- Kelly, D.J., Quinn, P.C., Slater, A.M., Lee, K., Gibson, A., Smith, M., et al., 2007. The other-race effect develops during infancy: evidence of perceptual narrowing. *Psychol. Sci.* 18, 1084–1089.
- Kubota, J.T., Ito, T.A., 2007. Multiple cues in social perception: the time course of processing race and facial expression. *J. Exp. Soc. Psychol.* 43, 738–752.
- Latinus, M., Taylor, M.J., 2006. Face processing stages: impact of difficulty and the separation of effects. *Brain Res.* 1123, 179–187.
- 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. *J. Exp. Psychol. Gen.* 129, 559–574.
- Luck, S.J., 2005. In: *An introduction to the event-related potential technique*. Cambridge, MIT, Cambridge, MA.
- MacLin, O.H., Malpass, R.S., 2001. Racial categorization of faces: the ambiguous race face effect. *Psychol. Public Policy Law* 7, 98–118.
- MacLin, O.H., Malpass, R.S., 2003. The ambiguous-race face illusion. *Perception* 32, 249–252.
- Malpass, R.S., Kravitz, J., 1969. Recognition for faces of own- and cross-race. *J. Pers. Soc. Psychol.* 13, 330–334.
- Maurer, D., Le Grand, R., Mondloch, C.J., 2002. The many faces of configural processing. *Trends Cogn. Sci.* 6, 255–260.
- Meissner, C.A., Brigham, J.C., 2001. Thirty years of investigating the own-race bias in memory for faces: a meta-analytic review. *Psychol. Public Policy Law* 7, 3–35.
- Michel, C., Caldara, R., Rossion, B., 2006. Same-race faces are perceived more holistically than other race faces. *Vis. Cogn.* 14, 55–73.
- Michel, C., Rossion, B., Han, J., Chung, C.-S., Caldara, R., 2006. Holistic processing is finely tuned for faces of one’s own race. *Psychol. Sci.* 17, 608–615.
- Michel, C., Corneille, O., Rossion, B., 2007. Race categorization modulates holistic face encoding. *Cogn. Sci.* 31, 911–924.
- Minear, M., Park, D.C., 2004. A lifespan database of adult facial stimuli. *Behav. Res. Meth. Instrum. Comput.* 36, 630–633.
- Mouchetant-Rostaing, Y., Giard, M.H., Bentin, S., Aguera, P.E., Pernier, J., 2000. Neurophysiological correlates of face gender processing in humans. *Eur. J. Neurosci.* 12, 303–310.
- Mouchetant-Rostaing, Y., Giard, M.H., 2003. Electrophysiological correlates of age and gender perception on human faces. *J. Cogn. Neurosci.* 15, 900–910.
- Paller, K.A., Kutas, M., Mayes, A., 1987. Neural correlates of encoding in an incidental learning paradigm. *Electroencephalogr. Clin. Neurophysiol.* 67, 360–371.
- Pezdek, K., Blandon-Gitlin, I., Moore, C., 2003. Children’s face recognition memory: more evidence for the cross-race effect. *J. Appl. Psychol.* 88, 760–763.
- Rhodes, G., Lie, H.C., Ewing, L.A., Evangelista, E., Tanaka, J.W., 2010. Does perceived race affect discrimination and recognition of ambiguous-race faces? A test of the socio-cognitive hypothesis. *J. Exp. Psychol. Learn. Mem. Cogn.* 36, 217–223.
- Rhodes, G., Tan, S., Brake, S., Taylor, K., 1989. Expertise and configural coding in face recognition. *Br. J. Psychol.* 80, 313–331.

- Rossion, B., Gauthier, I., Goffaux, V., Tarr, M.J., Crommelinck, M., 2002. Expertise training with novel objects leads to left lateralized face-like electrophysiological responses. *Psychol. Sci.* 13, 250–257.
- Rossion, B., Jacques, C., 2008. Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170. *Neuroimage* 39, 1959–1979.
- Sangrigoli, S., de Schonen, S., 2004. Recognition of own-race and other-race faces by three month-old infants. *J. Child Psychol. Psychiatry* 45, 1219–1227.
- Schupp, H.T., Cuthbert, B.N., Bradley, M.M., Cacioppo, J.T., Ito, T.A., Lang, P.J., 2000. Affective picture processing: the late positive potential is modulated by motivational relevance. *Psychophysiology* 37, 257–261.
- Scott, L.S., Tanaka, J.W., Sheinberg, D.L., Curran, T., 2006. A reevaluation of the electrophysiological correlates of expert object processing. *J. Cogn. Neurosci.* 18, 1453–1465.
- Shriver, E.R., Young, S.G., Hugenberg, K., Bernstein, M.J., Lanter, J.R., 2008. Class, race, and the face: social context modulates the cross-race effect in face recognition. *Pers. Soc. Psychol. Bull.* 34, 260–274.
- Shutts, K., Kinzler, K.D., 2007. An ambiguous-race illusion in children's face memory. *Psychol. Sci.* 18, 763–767.
- Sporer, S., 2001. Recognizing faces of other ethnic groups: an integration of theories. *Psychol. Public Policy Law* 7, 36–97.
- Stahl, J., Wiese, H., Schweinberger, S.R., 2008. Expertise and own-race bias in face processing: an event-related potential study. *NeuroReport* 19, 583–587.
- Stahl, J., Wiese, H., Schweinberger, S.R., 2010. Learning task affects ERP correlates of the own-race bias, but not recognition memory performance. *Neuropsychologia* 48, 2027–2040.
- Tanaka, J.W., Curran, T., Porterfield, A.L., Collins, D., 2006. Activation of preexisting and acquired face representations: the N250 event-related potential as an index of face familiarity. *J. Cogn. Neurosci.* 18, 1488–1497.
- Tanaka, J.W., Kiefer, M., Bukach, C.M., 2004. A holistic account of the own-race effect in face recognition: evidence from a crosscultural study. *Cognition* 93, B1–B9.
- Tanaka, J.W., Pierce, L.J., 2009. The neural plasticity of other-race face recognition. *Cogn. Affect. Behav. Neurosci.* 9, 122–131.
- Turk, D.J., Handy, T.C., Gazzaniga, M.S., 2005. Can perceptual expertise account for the own-race bias in face recognition? A split-brain study. *Cogn. Neuropsychol.* 22, 877–883.
- Valentine, T., 1991. Representation and process in face recognition. In: Watt, R. (Ed.), *Pattern recognition by Man and Machine*. (Vol. 14 in 'Vision and Visual Dysfunction' series edited by J. Cronly-Dillon). Macmillan Press, London.
- Valentine, T., Endo, M., 1992. Towards an exemplar model of face processing: the effects of race and distinctiveness. *Q. J. Exp. Psychol.* 44A, 671–703.
- Vizioli, L., Foreman, K., Rousselet, G.A., Caldara, R., 2010. Inverting faces elicits sensitivity to race on the N170 component: a cross-cultural study. *J. Vis.* 10, 1–23.
- Wagner, A.D., Koutstaal, W., Schacter, D.L., 1999. When encoding yields remembering: insights from event-related neuroimaging. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 354, 1307–1324.
- Walker, P.M., Silvert, L., Hewstone, M., Nobre, A.C., 2008. Social contact and other-race face processing in the human brain. *Soc. Cogn. Affect. Neurosci.* 3, 16–25.
- Walker, P.M., Tanaka, J.W., 2003. A perceptual encoding advantage for own- versus other-race faces. *Perception* 32, 1117–1125.
- Wiese, H., Stahl, J., Schweinberger, S.R., 2009. Configural processing of other-race faces is delayed but not decreased. *Biol. Psychol.* 81, 103–109.
- Willadsen-Jensen, E.C., Ito, T.A., 2006. Ambiguity and the timecourse of racial perception. *Soc. Cogn.* 2006, 580–606.
- 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 & Intergroup Relations* 11, 182–200.
- Wright, D.B., Boyd, C.E., Tredoux, C.G., 2003. Inter-racial contact and the own race bias for face recognition in South Africa and England. *Appl. Cogn. Psychol.* 17, 365–373.