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**IMPLICIT IDENTITY CODING FROM OWN- AND OTHER-RACE FACES: BRAIN
TEMPORAL DYNAMICS IN ADULTS AND CHILDREN**

**ELABORAZIONE IMPLICITA DELL'IDENTITÀ DEI VOLTI DELLA PROPRIA E
DI ALTRE ETNIE: DINAMICHE TEMPORALI NEURALI IN ADULTI E BAMBINI**

Candidato: Luana Serafini

Relatore (Tutor): Prof.ssa Francesca Pesciarelli

Coordinatore del Corso di Dottorato: Prof. Sandro Rubichi

Per mio babbo

Per Giulio, Matteo e Alessandro

SUMMARY

Human faces are a special class of stimuli which we are experts at extracting relevant information from, such as gender, race, emotion, and identity. Face individuation, despite requiring the complex ability to discriminate idiosyncratic features, can be performed within milliseconds from seeing a face. Although we are experts at face individuation, this expertise is reduced for racial outgroup faces. Other-race faces are individuated less accurately and more slowly than own-race faces, a phenomenon known as the Other-Race Effect (ORE). The ORE has received little attention in childhood and its neural time course has never been investigated in its implicit and unconscious form in either adults or children. In this work, I focused on the *implicit* (i.e., outside of voluntary control) and *unconscious* (i.e., outside of awareness) impact of face racial belonging on face individuation. Specifically, I investigated how and when face individuation occurs for supraliminal and subliminal own- and other-race faces when identity and race processing is not explicitly requested or accessed. To this end, I conducted two studies using the priming paradigm combined with electroencephalographic (EEG) recording and Event-Related Potentials (ERPs) analysis.

In Study 1, adults performed a priming paradigm while their electro-cortical activity was recorded. Participants were instructed to classify fully visible "target" faces, either Caucasian (own race) or Asian (other race), according to gender. Each target face was immediately preceded by a same-identity or a different-identity "prime" face, always sharing its race and gender. Critically, the prime face was either shown unmasked, i.e., visible, or masked, i.e., not visible. When the prime was visible, a priming effect, i.e., a facilitation of the target processing following an identical prime, emerged at the N100 ERP stage, for own- more than for other-race faces, and was present across later stages (N200, P300), more prominently for other- than own-race faces. When the prime was not visible, a priming effect emerged at

the P300 stage, more prominent for other- than own-race faces. Differences could indicate different individuation of own- and other-race faces shown consciously and unconsciously.

In Study 2, school-aged children performed a priming paradigm while their electro-cortical activity was recorded. The paradigm was the same as in adults, but the prime was only presented masked (not visible). A priming effect emerged at the N100 ERP stage, irrespective of face race, and a race effect emerged at the N200 stage, irrespective of prime identity. The lack of face race influence on the priming effects could suggest comparable unconscious individuation of own- and other-race faces in school-aged children.

As a study in progress, I am investigating the implicit neural face individuation in adults using a newly available paradigm, the frequency-sweep "oddball" fast periodic visual stimulation (FPVS), combined with electro-cortical activity recording and Steady State Visual Evoked Potentials (SSVEPs) analysis. In this paradigm, identical faces are periodically presented at decreasing frequency rates (20 to 5 Hz), whilst identity changes are introduced at a stable slower "oddball" frequency rate. If face individuation occurs, the neural response should synchronize to the oddball frequency. I expect this synchronization to emerge at different frequencies for Caucasian (own race) and Asian (other race) faces.

Overall, this work provides original results that aim at elucidating the neural characterization of the implicit and unconscious impact of face racial belonging on face individuation in adults (Study 1, study in progress) and children (Study 2). Results help shed light on theoretical aspects of the ORE.

RIASSUNTO

Il volto umano è uno stimolo speciale da cui siamo esperti a estrarre informazioni, come il genere, la razza, le emozioni e l'identità. La discriminazione dell'identità, nonostante richieda la complessa capacità di discernere caratteristiche idiosincratiche del volto, avviene in pochi millisecondi. Tuttavia, questa capacità è ridotta per volti appartenenti a razze diverse dalla propria. In genere, siamo più lenti e meno accurati a discriminare l'identità di volti di altre razze rispetto a volti della nostra, un fenomeno denominato "other-race" effect (ORE). L'ORE è stato poco studiato nei bambini, e il decorso temporale neurale dell'ORE nella sua forma implicita e inconscia non è mai stato esaminato in adulti o bambini. La presente tesi indaga come la razza influenza la discriminazione dell'identità a livello *implicito* (i.e., in assenza di controllo consapevole) e *inconscio* (i.e., in assenza di consapevolezza). In particolare, ho esaminato come e quando avviene la discriminazione dell'identità in volti supraliminali e subliminali della propria e dell'altra razza quando l'elaborazione di identità e razza non sono esplicitamente richieste. Allo scopo, ho condotto due studi utilizzando un paradigma di priming combinato con la registrazione dell'attività elettroencefalografica (EEG) e dei Potenziali Evento-Relati (ERPs).

Nello Studio 1, ai partecipanti adulti è stato chiesto di classificare volti "target", caucasici (propria razza) o asiatici (altra razza), in base al genere. Ogni volto target era preceduto da un volto "prime" della sua stessa identità o di diversa identità, ma del suo stesso genere e razza. Il volto prime era mostrato non mascherato (visibile) o mascherato (non visibile). Quando il prime era visibile, un effetto di priming, i.e., facilitazione dell'elaborazione del target preceduto da un prime identico, è emerso sulla componente N100, in misura maggiore per la propria che per l'altra razza, e su componenti più tardive (N200, P300), in misura maggiore per l'altra che per la propria razza. Quando il prime non era visibile, l'effetto di priming è emerso sulla P300, maggiormente per l'altra che per la propria razza. Tali risultati

suggeriscono una diversa discriminazione dell'identità in volti della propria e dell'altra razza elaborati consciamente e inconsciamente.

Nello Studio 2, bambini in età scolare hanno svolto lo stesso compito, ma a differenza degli adulti, il prime compariva solo mascherato (non visibile). Un effetto di priming è emerso sulla componente N100, indipendentemente dalla razza, e un effetto della razza è emerso sulla N200, indipendentemente dall'identità del prime. Tali risultati suggeriscono una simile discriminazione inconscia dell'identità dei volti della propria e dell'altra etnia nei bambini in età scolare.

In uno studio in corso, indago la discriminazione implicita dell'identità negli adulti utilizzando un nuovo paradigma, il frequency-sweep "oddball" fast periodic visual stimulation (FPVS), combinato con la registrazione EEG e degli Steady State Visual Evoked Potentials (SSVEPs). In questo compito, volti identici sono ripetuti periodicamente a una frequenza decrescente (20-5Hz) e cambi di identità appaiono sempre alla stessa frequenza "oddball" più lenta. La discriminazione dell'identità comporta una sincronizzazione della risposta neurale alla frequenza di presentazione degli oddball. Prevedo che la sincronizzazione emerga a diverse frequenze per volti caucasiaci (propria razza) e asiatici (altra razza).

In breve, la presente tesi fornisce risultati originali volti a chiarire i correlati neurali dell'influenza della razza sulla discriminazione dell'identità a livello implicito e inconscio in adulti (Studio 1, Studio in corso) e bambini (Studio 2). I risultati aiutano a far luce su aspetti teorici dell'ORE.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

INTRODUCTION

Chapter 1. THE "OTHER-RACE" EFFECT FOR FACE PROCESSING

1.1. Human face: a special stimulus for specialized perceivers

Human faces permeate our visual environment since birth (Oruc et al., 2019; Sugden et al., 2014). Most of the information about a person is displayed on the human face. Information can be relatively invariant, like identity, race, sex, age, and attractiveness; or it can quickly change, like emotion, speech content, intention, and health condition (Bruce & Young, 1986; Sheehan & Nachman, 2014; Todorov, 2017). Extracting information from human faces is complex - even invariant information needs to be extracted despite varying face conditions, like illumination, expression, age, and viewpoint - but it is pivotal to our social functioning and survival. Owing to its characteristics, i.e., pervasiveness, multidimensionality, and social informativeness, the human face has been widely employed to investigate vision and social phenomena.

What most renders the human face "special" is the *necessity* to distinguish a huge number of its exemplars. Face individuation (or "individual face recognition", or "face identity recognition", or "face individualization") refers to the ability to discriminate and recognize individual faces based on distinct features (e.g., Retter et al., 2021). Empirically, face individuation was mainly tested using unfamiliar faces, i.e., faces for which only visual experience exists, which observers were asked to encode and later recognize among new faces, or to match with a subsequent or simultaneously presented face.

1

Human adults are typically experts at individuating human faces. Indeed, they appeared to be able to individuate unfamiliar faces with high accuracy (70-80%, at worse) (e.g., Busigny & Rossion, 2010; Estudillo & Bindemann, 2014; Herzmann et al., 2008; Sergent, 1984), within few hundred milliseconds from seeing the faces (e.g., Caharel et al., 2009; Jacques et al., 2007; Retter et al., 2021; see Rossion & Jacques, 2011, for a review) and automatically or without intentionality (Caharel et al., 2009; Liu-Shuang et al., 2014; Retter et al., 2021; Yan et al., 2017; Zimmermann et al., 2019).

The ability to individuate faces is present early in development. Newborn babies can recognize unfamiliar faces after familiarization (de Haan et al., 2001; Turati et al., 2008; 2006). However, this capacity remains suboptimal, i.e., less accurate and fast, until late childhood or adolescence (e.g., Bruce et al., 2000; Carey, 1992; Carey et al., 1980; Croydon et al., 2014; de Heering et al., 2012; Germine et al., 2011; Megreya & Bindemann, 2015; Mondloch et al., 2003).

In this thesis, I focus on the identity and race dimensions of the human face. Specifically, I investigate the capacity to individuate faces as a function of race in neurotypical adults and children.

1.2.   A flaw in face individuation ability: the case of the "other-race" effect

A well-known exception to human's face individuation expertise is the individuation of human faces belonging to racial groups other than one's own. Malpass and Kravitz (1969) have been the first to empirically demonstrate decreased recognition performance for other-race faces as compared with own-race faces. Since then, this phenomenon has been known as the "other-race effect" (ORE) (or "cross-race effect", CRE, or "own-race bias", ORB) and it has been replicated across face individuation tasks and racial groups (see Meissner & Brigham, 2001; Serafini & Pesciarelli, 2022 for reviews).

Typically, the effect reflects a cross-over interaction between observer's race and face race in recognition accuracy. But it was also found as a response time disadvantage for other-than own-race faces (Chance & Goldstein, 1987; Michel, Rossion et al., 2006; Valentine, 1991), in perceptual matching tasks (Lindsay et al., 1991; Malpass et al., 1988; Sangrigoli & de Schonen, 2004a; Walker & Hewstone, 2006a; b; Walker & Tanaka, 2003), and as an imperfect cross-racial effect (Anthony et al., 1992; Meissner & Brigham, 2001).

In the real world, poor individuation ability for other-race faces has important consequences. Phenomenologically, it translates into the illusion that other-race faces look all alike (Feingold, 1914). Misidentification of a person due to the ORE can discourage social interactions in social contexts (McKone et al., 2021), contribute to wrongful convictions in forensic contexts (Scheck et al., 2000; Smith et al., 2004; Wells & Olson, 2001; Wilson et al., 2013), and produce spurious identity matchings in security contexts (e.g., Birhane, 2022).

Related to the ORE there are other perceptual and social phenomena deriving from the prepotent presence of race information on faces. Human adults are typically faster and better at race-categorizing other-race faces than own-race faces. This "other-race categorization advantage" (ORCA) (Caldara et al., 2004; Levin, 1996; 2000; Valentine & Endo, 1992; Zhao & Bentin, 2008) has been regarded as complementary to the ORE, and the two are thought to share some theoretical ground (Levin, 1996; 2000; Valentine & Endo, 1992; Hugenberg et al., 2010). Mere exposure to other-race faces is thought to trigger social categorization, i.e., the assignment of faces to racial ingroup and outgroup (e.g., Dixon & Maddox, 2005). Social categorization is thought to be necessary and sufficient to generate implicit racial biases, such as prejudice and stereotype. Racial prejudice refers to a negative evaluation of racial outgroup members (McConahay & Hough, 1976), and racial stereotype refers to mental representations of culturally shared beliefs about racial outgroup members (Dovidio et al., 1986).

Besides race, other face dimensions were found to produce similar individuation deficits. The "other-age effect" (e.g., Anastasi & Rhodes, 2005; 2006; Kuefner et al., 2008; Lamont et al., 2005), the "other-sex effect" (Wright & Sladden, 2003) and the "other-species effect" (Pascalis et al., 2002), refer to phenomena of reduced individuation performance for faces of other age, sex, or species than one's own, respectively. These effects could partially share some mechanisms with the ORE (e.g., Levin, 1996; 2000; Rodin, 1987).

In this thesis, I focus on the other-race effect, but the findings could be informative also for other related effects.

1.2.1. Accounts of the other-race effect

Despite nearly fifty years of replication, the primary mechanism of the other-race effect has proved difficult to isolate (see Young et al., 2012 for a review). The other-race effect has been traditionally explained by two streams of thought: the perceptual expertise account, and the socio-cognitive account. Perceptual/representational difficulties, for the former account, and attentional/motivational biases, for the latter account, are thought to lead to a less efficient encoding and/or retrieval of other-race faces, thus to poorer memory and discrimination for those faces. Hybrid accounts recently attempted to reconcile the traditional perspectives and suggested that perceptual and socio-cognitive mechanisms could co-act to produce the ORE.

1.2.1.1. Perceptual expertise accounts

The perceptual expertise accounts assume that lack of visual experience with other-race faces during development would cause faces of one's race and faces of other races to be differently *perceived* (Michel, Caldara et al., 2006; Rhodes et al., 1989; Tanaka et al., 2004) or *represented* in memory (Valentine, 1991; 2001). Specifically, own-race faces would be processed more holistically (i.e., as integrated wholes) or they would be represented more distinctively in memory, as compared with other-race faces. Arguing that perception *needs* the

matching of incoming visual stimulus to an internal representation to fully occur, perceptual and representational differences could be reconciled in a single mechanism (Rossion & Michel, 2011).

1.2.1.1.1. Holistic perception account

Human faces are perceived holistically. Holistic face perception refers to the fact that the processing of single facial features (e.g., eyes, mouth) and spatial configurations of features (e.g., the spacing between the eyes, spacing between nose and mouth) occurs *interdependently*, so that if a change occurs in one or more of these face aspects (e.g., if the nose is changed) then all the rest will be perceived as different from the original (e.g., Farah et al., 1998; Homa et al., 1976; Mermelstein et al., 1979; Sergent, 1984; Tanaka & Farah, 1993; Tanaka & Sengco, 1997; Young et al., 1987). Empirically, this processing mode results in the so-called "composite-face illusion" (Young et al., 1987). When the top half of a face is aligned with the bottom halves of different faces, we fail to appreciate the sameness of the top half, because the unattended bottom half influences the processing of the attended top half. Our vision is tricked into seeing a different top half for each combination. This illusion vanishes when the top halves and bottom halves are misaligned. This processing mode is functional: face processing is reduced to a single representation (i.e., a whole) with all features encoded at once.

One hypothesis is that the ORE may be due to decreased holistic face processing of other-race faces (Rhodes et al., 1989; Tanaka et al, 2004; Michel, Caldara et al., 2006; Michel Rossion et al., 2006). There is evidence that own-race faces are perceived more holistically than other-race faces, as demonstrated by no "part-whole advantage" (i.e., the advantage for processing features embedded in the whole face rather than presented in isolation; Tanaka & Farah, 1993) for other-race faces (Tanaka et al., 2004; Michel, Caldara et al., 2006), or no or reduced composite-face effect (i.e., difference in accuracy between aligned and misaligned composite faces) for other-race faces (Michel, Rossion et al., 2006). There is also evidence of

increased holistic processing of other-race faces, and decreased ORE, as a function of reported or newly gained interracial contact (Hancock & Rhodes, 2008; McKone et al., 2007).

1.2.1.1.2. Multidimensional face-space account

The face-space is a psychological multidimensional memory-space in which encountered faces would be located as points or vectors (Valentine, 1991). The dimensions of the face-space reflect the dimensions for which faces vary (e.g., eye color from dark to light, spacing between the eyes from large to narrow). Faces would be normally distributed along each dimension and the origin of each dimension would be set on its central tendency. Thus, the center of the face-space would represent a face prototype, the "norm" (see also "norm-based coding"; Rhodes et al., 1987), to which incoming face stimuli would be compared. Distinctive faces would be located far from the center; typical faces would be located near the center. The face prototype and the dimensions of the space would constantly tune to experienced faces to optimize their individuation.

According to the face-space model (Valentine, 2001), the ORE would be caused by a sub-optimal fit of other-race faces in the face-space. If experience is absent or reduced for other-race faces, the dimensions of the face-space themselves or their scale would be inadequate to encode other-race faces. Other-race faces would be represented all equally dissimilar from the template and densely clustered in the periphery of the space. Face encoding and retrieval could be more prone to errors given this distribution: a precise encoding of individual exemplars could be more difficult and multiple exemplars could be activated by an individual face at retrieval (e.g., Byatt & Rhodes, 2004). Evidence of a different distinctiveness effect (i.e., better individuation performance for atypical than typical faces) (Chiroro & Valentine, 1995) or a different adaptation effect (Jaquet et al., 2007) for other-race faces support a different representation of own- and other-race faces in face-space.

1.2.1.1.3. Experience-Based Holistic (EBH) account

The experience-based holistic account of the ORE (Rossion & Michel, 2011) argues that perception and representation cannot be disentangled because perception requires the matching of perceptual information to internal representations to happen in full. Thus, what would be holistic in the first place is the internal face prototype, and an incoming face would need to be matched to this template to be holistically processed (Rossion, 2009; Rossion & Boremanse, 2008). An incoming other-race face would not match the holistic template; thus, it would not be holistically processed. Other-race faces would be processed and encoded analytically, requiring more resources. As for the face-space model, the visual experience would have a key role in tuning the internal face prototype.

1.2.1.2. Socio-cognitive accounts

As an alternative to the perceptual expertise accounts, the socio-cognitive accounts of the ORE hold that the perceptual system *can* expertly process and represent the identity of other-race faces, but it *does* not because of socio-cognitive factors. Social categorization (i.e., the classification of faces as belonging to an ingroup or outgroup) (Bernstein et al., 2007; Shriver et al., 2008) would cause either *attentional* biases towards identity-specifying features (e.g., eye color) for ingroup faces and category-specifying features (e.g., skin color) for outgroup faces (Levin, 1996, 2000), or *motivation* to process identity-specifying information only for ingroup members (Berger, 1969; Galper, 1973; Rodin, 1987).

1.2.1.2.1. Feature-selection account

Social categorization consists in assigning people an ingroup or outgroup status (e.g., for a woman, a man would be a gender outgroup member) (e.g., Liberman et al., 2017). Consequences are the tendency to think individually about the ingroup and categorically about

the outgroup (e.g., Brewer, 1988); and greater perceived homogeneity of the outgroup as compared with the ingroup (Judd & Park, 1988).

Transferring this knowledge to face perception, the feature-selection account of the ORE (Levin, 1996, 2000) argues that assigning other-race faces to the outgroup would lead observers to think categorically about them, causing attention to be directed to race-specifying features (e.g., skin tone) at the expense of identity-specifying features (i.e., the eyes), and to perceive them as more homogeneous (i.e., the "they-all-look-alike" phenomenon). Supporting this account, other-race faces appeared to be race-categorized faster than own-race faces, as tested with visual search tasks or race categorization tasks, and the amount of this categorization advantage showed to predict the amount of ORE (Ge et al., 2009; Levin, 1996; 2000; Levin & Angelone, 2001; Susa et al., 2010).

1.2.1.2.2. Cognitive disregard account

Perceivers allocate less processing resources to stimuli that they deem irrelevant (e.g., Taylor, 1998). Rapidly extracted social category information (e.g., Cloutier et al., 2005) could signal that some faces are not worth processing at the individual level, because the processing at the categorical level has previously proved to be sufficient for an effective interaction.

One possible explanation of the ORE is that observers would not be motivated to encode the identity of other-race faces (Berger, 1969; Galper, 1973; Rodin, 1987). The lack of motivation could owe to racial prejudice (i.e., negative attitude towards racial outgroup) or to mere social categorization (i.e., classification of faces into ingroup and outgroup). Consistent with this account, eye-tracking studies showed less fixation to other-race faces, which correlated with the amount of ORE (Goldinger et al., 2009). Further, enhancing motivation to encode other-race faces, e.g., by explicit instructions or by showing facial expressions, could reduce or eliminate the ORE (Hugenberg et al., 2007; Johnson & Fredrickson, 2005)).

1.2.1.3. Hybrid accounts

Integrative, or "hybrid" accounts have tried to explain the ORE in both perceptual and socio-cognitive terms. Sporer's (2001) ingroup-outgroup model (IOM) proposed that *social categorization,* instead of visual experience, could determine qualitatively different processing styles. Ingroup faces would be holistically processed; outgroup faces would be analytically processed (Tanaka et al., 2004, Michel, Caldara et al., 2006). Adding to processing differences, categorizing a face as an outgroup would signal that the face is not worth being deeply processed (Rodin, 1987), or cause attention to category-specifying features at the expense of identity-specifying features (Levin, 1996; 2000). Consistent with this account, there is evidence that labeling racially ambiguous faces as ingroup favors holistic processing, whereas labeling racially ambiguous faces as outgroup disrupts holistic processing (Corneille et al., 2006); and that categorizing own-race faces as outgroup (e.g., other-university) would cause less holistic processing (Hugenberg & Corneille, 2009).

The categorization-individuation model (CIM) (Hugenberg et al., 2010; Hugenberg & Sacco, 2008) states that *motivation* would be the key factor leading to a shift in perceiver's attention to the costly extraction of identity-specifying features both in own- and other-race faces. As a basis, perceivers would extract category information from all faces, producing a within-category homogeneity effect. This effect would be greater for other-race faces, but present also for own-race faces under certain circumstances. Visual experience, on the other hand, could facilitate identity-specifying features extraction and detection, but *only* if perceivers are motivated to use their expertise.

Last, the dual-process model (Meissner et al., 2005), based on the dual-process memory framework (Tulving, 1985), suggests that the ORE is due to the use of different *memory-related processes*. Other-race faces would be encoded and retrieved via less costly familiarity-based processes (i.e., no encoding/retrieval of contextual details); own-race faces would be encoded

and retrieved via more costly recollection-based processes (i.e., encoding/retrieval of contextual details). Consistently, more false alarms were found for other-race faces recognition (Meissner & Brigham, 2001), associated with familiarity-based; more confusion of encoding (familiarization or test phase) context for other-race faces (Marcon et al., 2009); or less "remember" (recollection-based) judgments in remember-know tasks (Meissner et al., 2005).

1.3.   Development of the other-race effect

The ORE is thought to emerge during the first year of life (see Sugden & Marquis, 2017 for a meta-analytic review of the ORE in infants). Individuation is tested by exposing infants to an unfamiliar face, and later measuring the novelty preference for a novel face coupled with the exposed face. The ORE is demonstrated by absent or reduced novelty preference for other-race faces compared with own-race faces.

Studies showed that the ORE is absent at 3 months of age, present only for some other-race face categories at 6 months of age, and present for multiple other-race face categories at 9 months of age, across multiple racial groups (Kelly et al., 2007; 2009). Contrasting with this evidence, some studies reported an ORE at 3-4 months of age across racial groups (Chien et al., 2016; Hsu & Chien, 2011; Hayden et al., 2007; Sangrigoli & De Schonen, 2004b), some limitedly to female faces (Tham et al., 2015; 2019). Of these, some showed that the ORE was present for multiple other-race face categories at 4 months of age, for multiple or only some other-race face categories at 6 months of age, and absent at 9 months of age, in Asian observers (Hsu & Chien, 2011; Chien et al., 2016). Thus, whereas there is consensus that the first year of life marks the emergence of the ORE, its developmental pattern and timing is debated.

After the first year of life, evidence for the ORE is mixed (see Table 1.1). In childhood, individuation was tested using the same procedures as in adults, from more demanding old/new recognition memory tasks to less demanding perceptual matching tasks.

Table 1.1. Behavioral other-race effect (ORE) for face individuation in childhood.

Study	2	3	4	5	6	7	8	9	10	11	12	13	14	adult
Feinman & Entwisle, 1976					G	G	G			G				
Chance et al., 1982					R	R			G	G	G	G	G	
Pezdek et al., 2003			G	G			G						G	G
Sangrigoli & de Schonen, 2004a	G	G	G	G										
Corenblum & Meissner, 2006							G	G	G	G	G	G	G	G
Walker & Hewstone, 2006a									G	G	G	G	G	
Goodman et al., 2007				R	R	R	G	G	G	G	G	G	G	G
de Heering et al., 2010				G	G	G	G	G	G					
Anzures et al., 2014				G	G	G	G	G	G					
Chien et al., 2014			G	G	G	G	G	G	G					
Ding et al., 2014							R	R	R	R	R	R	R	
Macchi Cassia et al., 2014	G	G	G											
Suhrke et al., 2014	G	G												
Kehn et al., 2014				G	G	G	G	G	G	G	G	G	G	G
Hu et al., 2014		R	R	R	R	R								R
Suhrke et al., 2015			G	G										
Yi et al., 2016		R	R	R	R	R	R	R	R	R				
Zhou et al., 2016	R	R	R	R	R	R	R	R	R	R	R	R	R	
Tham et al., 2017				G	G							G	G	
Chien et al., 2018				R	R	R	R	R	R	R		G		G
Golarai et al., 2021							G	G	G	G	G	G	G	G
Hanley et al., 2020					G	G	G	G	G	G	G	G	G	G
Anzures et al., 2022				G	G	G	G	G	G		G	G	G	G

Note. Green color code indicated the presence of an ORE, red the absence of an ORE, white the absence of investigation. Studies are ordered by year of publication.

Studies showed an ORE at 3 years of age across racial groups (Macchi Cassia et al., 2014; Sangrigoli & de Schonen, 2004a; Suhrke et al., 2014; but see Zhou et al., 2016). However, between 4 and 7 years of age studies yielded the most mixed findings. In this age range, some reported an ORE across racial groups (Anzures et al., 2014; 2022; Corenblum & Meissner, 2006; Chien et al., 2014; 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, 2004a; Suhrke et al., 2015; Tham et al., 2017) and others failed (Chance et al., 1982; Chien et al., 2018; Ding et al., 2014; Hu et al., 2014; Goodman et al., 2007; Yi et al., 2016; Zhou et al., 2016). The ORE was then reliably found from 11 years old on (but see Ding et al., 2014; Zhou et al., 2016). Further, the trajectory of the ORE throughout

childhood appeared 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; Sangrigoli & de Schonen, 2004a; Chien et al., 2018; Golarai et al., 2021). Thus, so far it is not clear if the ORE is present also during childhood, and, if present, if it is adult-like or still developing.

1.3.1. Accounts of the development of the other-race effect

The most prominent model of the emergence of the ORE is the perceptual narrowing hypothesis (Nelson, 2001; Scott et al., 2007, for reviews see: Flom, 2014; Maurer & Werker, 2014), but an alternative perceptual *learning* hypothesis has recently been formulated (Chien et al., 2016). Recent years have also witnessed the emergence of other models considering the contribution of attentional, linguistic, or emotional factors to the specialization of the perceptual systems (Markant & Scott, 2018; Timeo et al., 2017; see also Quinn et al., 2019).

1.3.1.1. Perceptual expertise accounts

Perceptual-expertise accounts of the emergence of the ORE include both perceptual narrowing and learning hypotheses. The perceptual narrowing hypothesis (Nelson, 2001; Scott et al., 2007) holds that at first infants can efficiently process all face categories, but progressive experience with only a few of them determines a *decrease* in the ability to individuate less experienced faces (e.g., other-race faces); the perceptual learning hypothesis (Chien et al., 2016) holds that at first infants cannot optimally process faces, but progressive experience with few face categories determines an *increase* in the ability to individuate more experienced faces (e.g., own-race faces).

The perceptual narrowing is supported by reduced individuation for an increasing number of other-race face categories between 3 and 9 months of age (Kelly et al., 2007; 2009); perceptual learning is supported by increasing individuation abilities mostly for own-race faces

12

between 3 and 9 months of age, specifically evident in the increasing capacity to discriminate finer variations (e.g., detect eye changes) in own-race faces only (Hsu & Chien, 2011; Chien et al., 2016).

For both hypotheses, experience plays a key role. Supporting this role, experience with other-race faces (via one-hour individuation training) between 6 and 9 months of age could prevent the ORE from emerging in Caucasian 9-month-olds (Heron-Delaney et al., 2011). Once the ORE has been established, experience (three weeks exposure to a video showing faces) could eliminate the ORE in Caucasian 8-10-month-olds (Anzures et al., 2012). Further, minimal experience (i.e., showing 3 exemplars) with other-race faces could eliminate the ORE in Caucasian 3-month-olds (Sangrigoli & De Schonen, 2004b) and experience with other-race faces (through adoption) from 2 to 26 months of age could eliminate the ORE in Asian 6- to 14-year-olds (de Heering et al., 2010).

Visual experience beyond the first year of life also showed a consistent impact on the ORE. Experience with other-race faces (through adoption) from 3 to 9 years of age produced a reversal of the ORE in Asian adults (Sangrigoli et al., 2005) and reported contact between 5 and 12 years old (McKone et al., 2019), or more broadly before 18 years old (Singh et al., 2021), predicted the ORE in adults.

1.3.1.2. Emerging accounts

Recently, non-purely perceptual accounts were proposed for the emergence of the ORE.

The interactive model of attentional and perceptual face learning (I-MAP; Markant & Scott, 2018) holds that the ORE would emerge through repeated interactions between developing *attention* and perceptual learning systems. Newborn's bottom-up attention orienting to faces (e.g., Johnson et al., 1991) is predicted to promote efficient processing abilities for familiar faces by 6 months of age. Contingent to the development of endogenous selective attention, efficient processing of familiar faces would lead to top-down selective

attention biases, which would favor the generalization of processing abilities to unfamiliar faces by 9 months of age.

The neuro-linguistic rewiring hypothesis (Timeo et al., 2017) holds that the ORE would emerge through perceptual processes but later evolve through the influence of categorization and linguistic labeling (i.e., assignment of unique labels to own-race faces and categorical labels to other-race faces) on those processes. Face individuation, or the chunking of continuous stimulus information on identity boundaries, would initially rely on perceptual processes, and later on categorization processes (i.e., the assignment of visual stimuli to categories). Culture would shape categorization through linguistic labels.

Chapter 2. THE NEUROSCIENCE OF THE "OTHER-RACE" EFFECT

2.1. *Where* in the brain does the ORE occur?

Functional neuroimaging techniques allowed to investigate the neural bases of the ORE. The functional magnetic resonance imaging (fMRI) in adults and children, and the functional near-infrared spectroscopy (fNIRS) in infants and children, allowed for a high-resolution spatial investigation of the brain areas differentially responding to own- and other-race faces. Both techniques detect transient hemodynamic responses triggered by neuronal activity, by taking advantage of the magnetic properties of deoxyhemoglobin (i.e., hemoglobin not bound to oxygen) (Ogawa et al., 1990), or of differences in the absorption of red and near-infrared light between oxygenated and de-oxygenated blood (Jöbsis, 1997; Meek et al., 1998), respectively. Evidence from functional neuroimaging allowed to understand the contribution of visual, emotional, and cognitive processes to the ORE, and the way they interact based on known structural and functional properties of the brain. This evidence is even more important in development since neuroimaging measures can detect differences that behavioral measures may not detect due to the limited behavioral repertoires of infants and children.

2.1.1. Brain areas involved in the ORE in adulthood: fMRI evidence

In adults, fMRI investigations of the ORE divide into studies focused on high-level visual processing differences between own- and other-race faces, and studies focused on socio-cognitive and socio-affective responses to own- and other-race faces (see Ficco et al., 2022; Natu & O'Toole, 2013 for reviews). The former research line targeted well-established face-selective brain regions, especially those showing involvement in face individuation (Duchaine and Yovel, 2015; Haxby et al., 2000; Rossion, 2008; Rossion, 2014; Rossion, Caldara et al.,

2003; Steeves et al., 2009), whereas the latter research line targeted brain regions involved in memory, social cognition, and emotion, some of which belong to the extended face system (Gobbini & Haxby, 2007).

Face-selectivity is defined as a significantly greater response to faces than to non-face objects (Kanwisher et al., 1997; McCarthy et al. 1997). Areas that reliably showed this property were traditionally the "occipital face area" (OFA) in the lateral inferior occipital gyrus (Haxby et al. 1999, Gauthier et al. 2000), the "fusiform face area" (FFA) in the middle fusiform gyrus (Hoffman & Haxby, 2000; Kanwisher et al., 1997; McCarthy et al., 1997), and the pSTS-FA in the posterior superior temporal sulcus (Kanwisher et al. 1997, Hoffman & Haxby, 2000). These areas form the core face system, responsible for the visual processing of faces (Haxby et al., 2000). Among these areas, the FFA and OFA are thought to be involved in face identity recognition, but the role of each is debated (Haxby et al., 2000; Rossion, 2014; Rossion, Caldara et al., 2003).

Both FFA and OFA typically showed greater activity for own- than other-race faces. The impact of face race on the FFA was reported across multiple racial groups (Brosch et al., 2013; Feng et al., 2011; Golby et al., 2001; Hughes et al., 2019; Kim et al., 2006; Natu et al., 2011) and the amount of differential responding to own- and other-race faces predicted the behavioral ORE (Golby et al., 2001). Some studies suggested that the effect could owe to differential perceptual experience with own- and other-race faces. Specifically, the effect was found for unfamiliar but not for familiar faces (Kim et al., 2006), and the right FFA showed a neural composite face effect only for own-race faces (Brown et al., 2017), suggesting holistic processing for own- but not for other-race faces. However, racial bias and social categorization also appeared to influence the FFA response to own- and other-race faces. One study found the FFA race effect only in individuals showing stronger implicit racial bias (Brosch et al., 2013) and other studies found that the FFA responded more to own-*group* than other-group faces

when adding orthogonal group memberships (e.g., sport teams) to racial distinctions (Van Bavel et al., 2008; 2011).

However, some findings suggested the involvement of areas other than FFA in race-related visual processing differences (Natu et al., 2011; Ng et al., 2006). Consistently, a few studies also found greater activity to own- than other-race faces in the OFA (Brosch et al., 2013; Feng et al., 2011; Natu et al., 2011; Ng et al., 2006). Altogether, these findings have been interpreted as indicating greater involvement of high-level visual areas when processing own- than other-race faces. This could owe to differential experience with own- and other-race faces, but also to socio-cognitive factors.

Some brain areas are not face-selective but are functionally connected to areas of the core face system. As such, they were included in an extended face system (Gobbini & Haxby, 2007; Haxby et al., 2000). They contribute to face processing by informing face perception with emotion significance, episodic and semantic memory, mental state and intention knowledge relative to faces.

Among these areas, the amygdala typically showed greater activity for other- than own-race faces (e.g., Cunningham et al., 2004; Ronquillo et al., 2007). However, this occurred limited to some conditions, such as the processing of unfamiliar faces (Phelps et al., 2000), the perceptual encoding but not the verbal encoding of faces (Lieberman et al., 2005), or the task-relevance of race (Hart et al., 2000). The effect was mostly associated to threat responses elicited by racial outgroup faces, or Black faces specifically (Lieberman et al., 2005). However, considering the sensitivity of the amygdala also to novelty (Dubois et al., 1999; Gobbini & Haxby, 2006; Natu & O'Toole, 2011), the effect could rather indicate a lack of familiarity for racial outgroup faces.

Other neural correlates of the ORE could be the anterior cingulate cortex (ACC) (Cunningham et al., 2004; Greer et al., 2012), the dorsolateral prefrontal cortex (dlPFC)

(Cunningham et al., 2004; Greer et al., 2012; Van Bavel et al., 2008), the hippocampus and parahippocampal area (Cunningham et al., 2004; Greer et al., 2012), which are related to person processing and conflict resolution. These areas possibly reflect the inhibition of prejudice towards other-race faces. Altogether these findings revealed the neural bases of socio-cognitive and socio-affective dimensions of the ORE.

2.1.2. Brain areas involved in the ORE in development: fNIRS and fMRI evidence

In infants, knowledge of the neural basis of the ORE is limited to a few fNIRS studies (Kelsey et al., 2019; Timeo, Brigadoi et al., 2019; Ujiie et al., 2020). Timeo et al. (2019) reported that Caucasian 5- and 9-month-olds showed greater overall activation when passively viewing (African) other-race faces than own-race faces. The effect showed a statistically marginal increase and a change in localization from 5 to 9 months of age. Keyser et al. (2019) showed that Caucasian 9-month-olds showed activity in the temporal cortex (i.e., right and left STC) when passively viewing own-race pupillary changes; and activity in the frontal cortex (dlPFC) when passively viewing (Asian) other-race pupillary changes (Keyser et al., 2019). Last, Ujiie et al. (2020) found that Asian 8- to 9-month-olds showed activity in the left temporal region for matching audio-visual stimuli and in the bilateral temporal region for the McGurk effect, but exclusively for own-race faces. Together, these studies showed that a neural ORE is likely present at around 9 months of age. From 5 to 9 months of age the neural ORE could possibly increase, but it might be that the ORE is to some extent already present at 5.

In children, few fNIRS (Ding et al., 2014; Zhou et al., 2016) and fMRI (Golarai et al., 2021; Telzer et al., 2013) studies were performed. In a first study, Asian 7- to 13-year-olds showed greater neural activity in frontal (right MFG/IFG) and occipital (left cuneus) brain areas when recognizing (Caucasian) other-race faces than own-race faces (Ding et al., 2014). In a different study, Asian 3- to 13-year-olds showed stronger causal connections within the frontal area when recognizing (Caucasian) other-race than own-race faces; while stronger

causal connections between occipital and frontal areas and within the occipital area when recognizing own- than other-race faces (Zhou et al., 2016). Using the fMRI, Golarai et al. (2021) found greater activation in the FFA to own- than (African American) other-race faces in Caucasian 7- to 16-year-olds and adults during a one-back task. On the other hand, amygdala activation did not differ between African American and Caucasian faces in 4- to 14-year-olds of various racial backgrounds but started differing after 14 years of age (Telzer et al., 2013). In addition, all studies reported a modification of the neural ORE with age, typically driven by an increasing neural response to own-race faces across development. Together, these studies suggest that a neural ORE is present during childhood and that the magnitude and spatial extent of this neural ORE changes through childhood.

Overall, these investigations offered new perspectives on the development of the ORE. But the evidence is still poor and comparisons among infants, children, and adults are complicated because different techniques (i.e., fMRI, fNIRS), stimuli (multisensory or dynamic in infants, static in children and adults) and tasks (typically passive viewing in infants and active tasks in children and adults) were used across age ranges.

In this thesis, I focus on *when* the neural ORE occurs, i.e., on the neural time course of the ORE from face appearance to response generation.

2.2. *When* in the brain does the ORE occur? [1]

The Event-Related Potential (ERP) technique, alongside behavioral manipulations, allowed investigating the neural time course of the ORE. ERPs consist of the electrical field recorded from scalp electrodes, generated by populations of neurons in response to an event (e.g., the appearance of a face). This technique can detail, with millisecond temporal resolution,

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[1] The content of this chapter has been adapted from the article: Serafini, L., & Pesciarelli, F. (2022). Neural timing of the other-race effect across the lifespan: A review. *Psychophysiology, e14203*. https://doi.org/10.1111/psyp.14203

the continuum of the neural events generated by own- and other-race faces and ending with a specific response to the face. The ERP waveform can be decomposed into ERP components, related to partially distinct cognitive processes.

While behavioral measures, e.g., accuracy and response times, reflect the outcome of the operations involved in processing a face, the ERP technique indirectly reflects these operations (Luck, 2005). Thus, the investigation of the impact of face race on ERP components allowed to indirectly test the contribution of the various – perceptual, attentional, motivational, and evaluative – processes, and their temporal unfolding, to the ORE. This is particularly important considering that the ORE has been conceptualized as a complex phenomenon, in which multiple operations interact.

2.2.1. Neural timing of the ORE in adulthood: ERP evidence

In adults, ERP investigations of the ORE also divide into two partially distinct research lines. One research line focused on the impact of face race on face processing and paralleled the fMRI research line focused on high-level visual processing. The other research line focused on the time course of racial perception, i.e., when in the time course of stimulus processing faces were perceptually distinguished or differentially attended to as a function of racial belonging, which paralleled the fMRI research line focused on socio-cognitive and socio-affective responses.

The first line focused on ERP components that showed involvement in face processing, with a focus on face-selective components (Bentin et al., 1996; Kaufmann & Schweinberger, 2008; Rossion, Joyce et al., 2003; Scott, Tanaka, et al., 2006; Scott et al., 2008; Tanaka et al., 2006). The second line focused on ERP components generally associated with early attentional effects (Hillyard & Münte, 1984; Luck & Hillyard, 1994; Ritter et al., 1983; Wijers et al., 1989) working memory and evaluative processes (Cacioppo et al., 1993; Ito et al., 1998; Bartholow et al., 2001).

A third research line more recently emerged and focused on the impact of face race on ERP effects associated with long-term memory processes.

2.2.1.1. ERP correlates of race impact on face perception

The time course of face processing in human adults involve multiple stages, partially reflected in multiple ERP components, ordered by appearance: P100 (early vision/attention), N170 (structural encoding), P200 (configuration processing) and N250 (accessing individual representations). Of these, the N170 more reliably showed face-selectivity, i.e., preferentially responded to face than non-face stimuli (e.g., Bentin et al., 1996; Carmel & Bentin, 2002; Eimer, 2000; Rossion et al., 2000).

The extract processing stage reflected by each of these components is not clear, but some hypotheses were proposed. The P100 likely contributes to early visual processing informed by low-level visual features (e.g., Halgren, 2000; Rebai et al., 2001; Rossion, Joyce et al., 2003; Schendan et al., 1998) and holistic processing (Itier & Taylor, 2002; 2004a; Jacques & Rossion, 2007; Marzi & Viggiano, 2007). The N170 is thought to index the initial structural encoding of the face (Bentin et al., 1996; Eimer, 2000; Jacques & Rossion, 2010), but also showed the ability to code face identity (but see e.g., Tanaka & Pierce, 2009). The P200 likely reflects the processing of metric distances between the facial features (Halit et al., 2000; Kaufmann & Schweinberger, 2012; Latinus & Taylor, 2006; Mercure et al., 2008). Last, the N250 is thought to index visual expertise at the individual level (Scott, Tanaka, et al., 2006), specifically the activation of pre-existing individual level perceptual representations of faces and objects (Pierce et al., 2011).

The N170, a negative-going deflection peaking about 170 ms post-stimulus at occipito-temporal (right-lateralized) scalp location, has been the most investigated. Evidence for a modulation of the N170 by face race is mixed (see Serafini & Pesciarelli, 2022 for a review). Inconsistency pertains to the presence/absence of a race effect, and the direction of the effect,

and involves both amplitude and latency measures. Overall, despite some findings of cross-racial interaction effects (Vizioli, Rousselet, et al., 2010; Wiese et al., 2014), the N170 race effect showed variable effects as a function of a racial group and face racial categories. Specifically, a race effect was more reliably found in Caucasian than Asian observers (e.g., Balas & Nelson, 2010; Brebner et al., 2011; Chen et al., 2013; Gonzalez & Schnyer, 2019; Hahn et al., 2012; Liu et al., 2014; Lv et al., 2015; Montalan et al., 2013; Ran, Zhang et al., 2014; Tong et al., 2014; Volpert-Esmond et al., 2018; Walker et al., 2008), and, in Caucasian observers, between Black and own-race faces than between Asian and own-race faces (e.g., Herzmann et al., 2018). Task goals could account for some mixed results, especially when comparing Asian with Caucasian faces in Caucasian observers (e.g., Wiese, 2013; but see Anzures & Mildort, 2021; Caldara et al., 2004).

When an N170 race effect was found, it more typically manifested as larger amplitude to other- than own-race faces (e.g., Stahl et al., 2008; 2010; Wiese et al., 2014) and delayed latency for other- than own-race faces (Anzures & Mildort, 2021; Gajewski et al., 2008; Hahn et al., 2012; Liu et al., 2014; Ran, Zhang et al., 2014; Stahl et al., 2008; 2010; Tong et al., 2014; Wiese, 2013; Wiese et al., 2009; but see Balas & Nelson, 2010; Gajewski et al., 2008; Herzmann et al., 2011). These findings were interpreted as indexing a disruption of configural face processing by other-race faces at the structural face encoding stage, somehow similar to the N170 face inversion effect (i.e., larger and delayed N170 for inverted as compared to upright faces) (Goffaux et al., 2003; Latinus & Taylor, 2006; Liu et al., 2002; Rossion et al., 2000). Accordingly, the N170 inversion effect was also more pronounced for own- than other-race faces (Caharel et al., 2011; Gajewsky et al., 2008; Vizioli, Foreman et al., 2010; Wiese, 2013; but see Cassidy et al., 2014; Chen et al., 2013; Colombatto & McCarthy, 2017; Montalan et al., 2013; Wiese et al., 2009; Zhou et al., 2015).

22

Importantly, one study found a neural repetition suppression (i.e., reduced activity for repeated stimuli) in the N170 time window for own- but not for other-race faces in both Asian and Caucasian groups, suggesting that the neural population of the N170 could code for the identity of own- but not of other-race faces (Vizioli, Rousselet, et al., 2010). Fewer studies found larger N170 to own- than other-race faces (e.g., Cassidy et al., 2014; Gajewski et al., 2008; Ito & Urland, 2005; Proverbio et al., 2020; Senholzi & Ito, 2013; Wiese, 2013). This finding has been interpreted as an effect of visual experience, consistent with the idea that the N170 could be an index of domain-general perceptual expertise (Rossion et al., 2002; Scott, Shannon, et al., 2006; Tanaka & Curran, 2001). However, experience inconsistently affected the N170 race effect (Stahl et al., 2008; Tanaka & Pierce, 2009; Walker et al., 2008; Wiese et al., 2014).

Preceding the N170, the P100, a positive-going deflection peaking at about 100 ms after stimulus onset over occipital areas, also showed mixed evidence for a modulation by face race. As for the N170, inconsistencies regarded both the presence/absence of the effect and the direction of the effect. When an effect was found, it seemed not to reflect an "own" vs. "other" race effect, but rather be specific to a racial group, i.e., Caucasian (e.g., Herzmann et al., 2011; Wang et al., 2020) and to a class of other-race faces i.e., Asian (e.g., Herzmann, 2016; Herzmann et al., 2018). In this condition, the P100 typically showed larger amplitudes to own- than other-race faces (but see Anzures & Mildort, 2021; Stahl et al., 2010). On the other hand, the P100 typically did not respond differently to own-race and Black other-race faces in Caucasians (Brebner et al., 2011; Caharel e al., 2011; Cassidy et al., 2014; Colombatto & McCarthy, 2017; Herzmann, 2016; Herzmann et al., 2018; Senholzi & Ito, 2013). When it occurred, the effect was typically the opposite, i.e., larger amplitude to Black than own-race faces (Hanh et al., 2012; He et al., 2009; Fishman et al., 2012; but see Hehman et al., 2011 for the opposite effect).

Overall, it was suggested that the presence/absence of the P100 race effect could owe to the use of color or greyscale images, respectively, but this showed not always to be the case (see Brebner et al., 2011; Herzmann et al., 2011; Herzmann, 2016; Senholzi & Ito, 2013; Stahl et al., 2010; Wang et al., 2020; Wiese, 2013). The typical effect could be interpreted as reflecting a different processing style for own- and other-race faces at this early visual processing stage. Consistently, a featural processing bias was found for Caucasian as compared to Asian faces in Caucasian observers (Wang et al., 2020), and face manipulations intended to disrupt configural/holistic processing impacted the P100 amplitude more so for own- than for other-race faces (Colombatto & McCarthy, 2017; Hanh et al., 2012; but see Caharel et al., 2011; Cassidy et al., 2014; Chen et al., 2013; Wiese, 2013; Vizioli, Foreman et al., 2010 for null findings). Alternatively, a P100 race effect could be interpreted as reflecting differential attention or motivation towards own- and other-race faces, given that the P100 is modulated by spatial attention (Eason et al., 1969; Gazzaniga et al., 2002; Hillyard & Anllo-Vento, 1998; Hillyard et al., 1998) and arousal (Vogel & Luck, 2000). This could mainly be true for Caucasian observers processing Black faces, due to higher vigilance (see Ito & Bartholow, 2009; Kubota & Ito, 2007), arousal and prejudice (Phelps et al., 2000; Cunningham et al., 2004; Lieberman et al., 2005; for a review, see Eberhardt, 2005) associated with this racial group.

Following the N170 component, the P200, a positive-going deflection, maximal at 200-250 ms after stimulus onset over lateral occipito-temporal sites, typically showed larger amplitudes to own- than other-race faces (Chen et al., 2013; Lucas et al., 2011; Stahl et al., 2008; 2010; Tanaka & Pierce, 2009; Wang et al., 2020; Wiese, 2012; 2013; Wiese et al., 2014; Wiese & Schweinberger, 2018; but see Anzures & Mildort, 2021; Ran, Chen et al., 2014), with some exceptions (see Hahn et al., 2012; Herzmann et al., 2011; Tüttenberg & Wiese, 2019; Vizioli, Foreman, et al., 2010; Yong et al., 2020 for null findings). The effect was more consistent between Caucasian and Asian faces in Caucasian observers, whereas poor evidence

exists for an effect in Asian observers and towards other-race face categories (e.g., Black faces). The effect has been interpreted as reflecting greater or more effective configural or featural processing for own-race faces (Halit et al., 2000; Kaufmann & Schweinberger, 2012; Latinus & Taylor, 2006; Mercure et al., 2008), and greater perceived typicality relative to a prototype for own-race faces (Halit et al., 2000). Experience affected the P200 race effects (Stahl et al., 2008; Wiese et al., 2014) more on the right hemisphere, whereas task goals (i.e., the focus on race rather than on identity) affected the P200 race effects (Stahl et al., 2010; Tanaka & Pierce, 2009) more on the left hemisphere (Stahl et al., 2010; Wiese, 2013).

Following the P200, the N250 component, a negative-going deflection peaking between 200 and 300 ms post-stimulus at occipito-temporal sites, typically showed larger amplitude to other- than own-race faces (Balas & Nelson, 2010; Brebner et al., 2011; Herzmann et al., 2011; 2018; Herzmann, 2016; Liu et al., 2014; Sun et al., 2014; Wiese et al., 2014; Wiese & Schweinberger, 2018). But fewer studies found the opposite effect (Balas & Nelson, 2010; Herrmann et al., 2007; Tüttenberg & Wiese, 2019), and others failed to find an effect (Lv et al., 2015; Vizioli, Foreman, et al., 2010; Wiese, 2012; Zhou et al., 2015). The N250 race effect was generally found across racial groups, i.e., Asian, Caucasian, (e.g., Sun et al., 2014; Wiese et al., 2014) and across multiple other-race face classes (e.g., Herzmann, 2016). The effect has been ascribed to increased individuation difficulties or processing effort for other- relative to own-race faces (Schweinberger, 2011). It was proposed that such difficulties arise because observers are "forced" to focus on face identity. However, the effect was observed also when perceivers focused on face race (Herzmann, 2016; Sun et al., 2014), face age (Brebner et al., 2011), or face orientation (Balas & Nelson, 2010). The opposite effect, i.e., larger amplitudes to own-race faces (found only in Caucasians) is in line with effects of individual-level training with objects (Scott, Tanaka, et al., 2006; Scott et al., 2008) and face familiarity (Andrews et al., 2017; Gosling & Eimer, 2011; Pierce et al., 2011). Consistently,

the N250 increased after an individuation training with other-race faces (Tanaka & Pierce, 2009).

Altogether, these findings suggest that face race effects encompass the time course of face processing. Whereas early perceptual stages (P100, N170) showed more ambiguous findings, and suggested possible cultural or face race related effects, later perceptual/representational stages (P200, N250) showed more reliable findings and suggested perceptual and representational differences between racial ingroup and outgroup faces. These results more directly support perceptual expertise accounts of the ORE. However, they could also be interpreted as indicating more individuation for other-race faces, because of attentional or motivational factors, in line with socio-cognitive accounts. Here, importantly no evidence exists in the Black population.

2.2.1.2. ERP correlates of racial perception

Racial perception is the capacity to perceptually distinguish faces based on their racial belonging. The neural time course of racial perception has been examined by focusing on components indexing selective attention, working memory, and evaluation processes. The fronto-centrally distributed N100, P200 and N200 components have been associated with early selective attention processes (Hillyard & Munte, 1984; Luck & Hillyard, 1994; Ritter et al., 1983; Wijers et al., 1989). The N100 and P200 were further linked with an automatic vigilance effect (Carretié et al., 2001; Näätänen 1992), whereas the N200 was further linked with depth of encoding (Ito & Bartholow, 2009). On the other hand, the P300 component was associated with arousal and attention to motivationally significant events (Nieuwenhuis et al., 2005; Polich & Kok, 1995) and, in oddball procedures, to updates of working memory (Donchin, 1981).

The N100, an early negative-going component peaking between 50 and 150 ms post-stimulus onset, typically showed larger amplitudes to other- than own-race faces (Ito & Urland,

2003; 2005; James et al., 2001; Kubota & Ito, 2007; Lipp et al., 2011; Zhou et al., 2020; but see Ito & Urland, 2005; James et al., 2001 for an opposite effect; Hehman et al., 2011; Spencer et al., 2018; Willadsen-Jensen & Ito, 2006; 2008; 2015 for null findings). This effect was ascribed to an early attention capture or vigilance to faces of other racial groups (Carretié et al., 2001; Näätänen 1992). Of note, the effect likely indicates an implicit and automatic process, given that it occurred also in the absence of an explicit race categorization, and a more stimulus-driven process, given that it occurred irrespective of the racial context (Ito & Urland, 2003).

However, the effect did not manifest as an interaction in cross-racial studies (e.g., Lipp et al., 2011) and showed specificity to Black faces both in Asian and Caucasian perceivers (e.g., Ito & Urland, 2003; Kubota & Ito, 2007; Zhou et al., 2020). Evidence was more nuanced for N100 race effects between Asian and White faces in both Asian and White racial groups (e.g., Willadsen-Jensen & Ito, 2006; 2008). The greater N100 amplitude to faces of racial outgroups, and to Black faces specifically, could be due to other-race faces being perceived as more threatening or distinctive than own-race faces (Felmingham et al., 2003; Vanderploeg et al., 1987; Weinstein, 1995). Importantly, the lack of a repetition suppression effect (i.e., decreased amplitude) for same-race sequences compared with alternated-race sequences for other-race faces (Black or Caucasian) in Asian observers (Zhou et al., 2020), suggested that implicit race encoding might instead not occur at this processing stage. Each individual other-race face could capture attention irrespective of their perceptual grouping into racial categories (Zhou et al., 2020).

Following the N100, the P200, a positive-going component peaking between 150 and 300 ms post-stimulus onset, typically showed larger amplitude for other- than own-race faces (Dickter & Bartholow, 2007; Dickter & Kittel, 2012; Fishman et al., 2012; He et al., 2009; Ito & Urland, 2003; 2005; Ito & Tomelleri, 2017; Kubota & Ito, 2007; 2017; Lipp et al., 2011; Volpert-Esmond & Bartholow, 2019; Volpert-Esmond et al., 2017; Wiese, 2012; Willadsen-

Jensen & Ito, 2006; 2008; 2015; Yong et al., 2020; Zhou et al., 2020), with only a few studies reporting no race effect (Brebner et al., 2011; Hehman et al., 2011; James et al., 2001; Spencer et al., 2018; Wang et al., 2020).

Like the N100 race effect, this effect was ascribed to an early attention capture or vigilance to other-race faces, through the activation of threat or distinctiveness responses. Unlike the N100 race effect, the effect was found across multiple racial groups, i.e., White, Black, and Asian, and for multiple other-race face categories, i.e., White, Black, Asian (e.g., Dickter & Bartholow, 2007; Lipp et al., 2011; Willadsen-Jensen & Ito, 2006; 2008; Zhou et al., 2020), suggesting an ingroup-outgroup rather than a race-specific effect. The effect was generally found irrespective of the focus on race and irrespective of the racial context (e.g., Ito & Urland, 2003; 2005; Willadsen-Jensen & Ito, 2006; 2008; but see Lipp et al., 2011). Further, Zhou et al. (2020) found a repetition suppression effect (decreased amplitude) for same-race sequences compared to alternated-race sequences on the P200 in both Caucasian and Asian observers for their respective other-race (and Black) but not for their respective own-race faces. This effect suggests that race in other-race faces is implicitly encoded at this processing stage.

Following the P200, the N200, a negative-going component peaking at about 250 ms post-stimulus onset, typically showed the opposite effect, i.e., larger amplitude for own- than other-race faces (Brebner et al., 2011; Dickter & Bartholow, 2007; 2010; He et al., 2009; Hehman et al., 2011; Ito & Tomelleri, 2017; Ito & Urland, 2003; 2005; James et al., 2001; Kubota & Ito, 2007; 2017; Lipp et al., 2011; Lucas et al., 2011; Spencer et al., 2018; Willadsen-Jensen & Ito, 2006; 2008; 2015; Zhou et al., 2020; but see Proverbio & De Gabriele, 2019), with few exceptions (Fishman et al., 2012; Gonzalez & Schnyer, 2019; Proverbio et al., 2020; Wang et al., 2020; Wiese, 2012). This effect was interpreted as indicating that racial ingroup faces eventually attract more attention and are processed more deeply than racial outgroup faces. This re-direction of attention would be automatic and spontaneous and could owe to

greater familiarity or relevance of own-race faces (Bentin & Deouell, 2000; Tanaka et al., 2006).

The effect was observed in multiple ingroups (Asian, Caucasian, Black) and for more own-race face classes (Asian, Caucasian, Black) (e.g., Dickter & Bartholow, 2007; Willadsen-Jensen & Ito, 2006; 2008). But it more consistently showed when comparing own-race with Black other-race faces (see He et al., 2009; Zhou et al., 2020). Specifically, Zhou et al. (2020) found a repetition suppression effect (i.e., decreased amplitude) for same-race sequences as compared to alternated-race sequences on the N200 only for own-race face sequences when they were compared with sequences of alternating own- and Black other-race faces. The result was ascribed to the association of Black faces to threat (Correll et al., 2002; Payne, 2001; Plant et al., 2011; Trawalter et al., 2008; Wilson et al., 2017), which might have increased the sense of ethnic identity and improved racial categorization of own-race faces (see Zhou et al., 2020). The effect was typically found irrespective of the focus on race, but it sometimes interacted with the racial context in line with the involvement of the N200 in conflict-monitoring processes (see Botvinick et al., 2001; Nieuwenhuis et al., 2003; van Veen & Carter, 2002).

Last, the P300 (also referred to as the "Late Positive Potential, LPP" or "Late Positive Component, LPC") is a late positive-going component peaking after 300 ms from stimulus onset and generally distributed over centro-parietal and centro-frontal sites (Donchin, 1981; Polich, 2007). The P300 typically showed larger amplitude to other- than own-race faces (Brebner et al., 2011; Dickter & Bartholow, 2007; Gonzalez & Schnyer, 2019; James et al., 2001; Liu et al., 2014; Lv et al., 2015; Ran, Zhang et al., 2014; Yan Shan et al., 2018; Stahl et al., 2010; Sun et al., 2014; but see: He et al., 2009; Ito & Urland, 2003), with some exceptions (Kubota & Ito, 2007; Proverbio & De Gabriele, 2019; Proverbio et al., 2020; Wang et al., 2020; Yong et al., 2020). Further, an interaction effect between context and target race was typically reported, with the incongruent race (relative to the context) eliciting larger amplitudes

irrespective of its belonging to the ingroup or outgroup (Ito & Urland, 2003; 2005; Lipp et al., 2011; Willadsen-Jensen & Ito, 2006; 2008).

The race effect was observed in multiple racial groups (Asian, Caucasian, Black) for multiple other-race categories (Asian, Caucasian, Black) (e.g., Dickter & Bartholow, 2007; Sun et al., 2014), and it was interpreted as reflecting race categorization through more motivated attention or arousal directed to other- than own-race faces (Nieuwenhuis et al., 2005; Polich & Kok, 1995). More specifically, it could index the easiness of extraction of race from faces, given that it was progressively larger to faces with a context-congruent race, racially ambiguous faces, and faces with a context-incongruent race in an oddball procedure (Willadsen-Jensen & Ito, 2006). On the other hand, the interaction effect between racial target and context is in line with the typical "oddball" effect observed for the P300 and could indicate that race is spontaneously incorporated in working memory. However, the effect did not interact with the race of the faces (with some exceptions, see Ito & Urland, 2005), suggesting similar working memory update processes for own- and other-race faces.

Altogether, these findings suggest that race is encoded by the brain at successive stages. Whereas attention is first captured by other-race faces (N100, P200 effects), it is soon redirected to own-race faces (N200 effect) to allow deeper processing. The easiness of race encoding could be reflected on a later P300 component. This evidence more directly supports a socio-cognitive model of the ORE, wherein racial categorization precedes and interferes with individuation (here, deeper processing). However, the N200 effect could indicate greater individuation of own-race faces in general, and earlier attentional effects (N100, P200) could not be related to successive individuation performance, in line with perceptual expertise accounts.

2.2.2. Neural timing of the ORE in development: ERP evidence

2.2.2.1. ERP evidence in infants (5 to 9 months of age)

The impact of face race was tested on some ERP components involved in face processing in infants, ordered by their temporal appearance: N290, P400, negative central component (Nc), and slow-wave activity (SLW). The N290 and the P400 were considered precursors of the adult's face-sensitive N170 component, owing to the N290's sensitivity to faces (Conte et al., 2020; Guy et al., 2018; Halit et al., 2003; 2004; Kouider et al., 2013; McCleery et al., 2009; Xie & Richards, 2016) and the P400's sensitivity to face inversion (Haan et al., 2002; Halit et al., 2003) and familiarity with faces (Scott, Shannon et al., 2006; Scott & Nelson, 2006). The Nc and the SLW reflected higher-order domain-general processing.

The N290, an early negative-going deflection peaking at about 290 ms post-stimulus onset at posterior scalp areas, showed a larger amplitude to own- than (Black) other-race faces in Caucasian 9-month-olds in one ERP study (Balas et al., 2011). However, another ERP study (Vogel et al., 2012) showed no N290 race effect in Caucasian 9-month-old or 5-month-old between own- and (African American) other-race faces. Differences in the procedure, stimuli, and task complexity likely account for the different results. In the former study, infants passively viewed synthetic faces which showed combinations of Black and White skin tone and Black and White face structure; in the latter study, infants passively viewed emotional female faces primed by an emotionally congruent or incongruent sound. The effect could index greater familiarity or salience of own-race faces (Haan et al., 2002; Halit et al., 2003; Righi et al., 2014; Scott, Shannon et al., 2006; Scott & Monesson, 2010; Scott & Nelson, 2006) and it is consistent with a behavioral ORE in 6- to 9-month-olds (Anzures et al., 2010; 2011; Kelly et al., 2007; 2009). However, evidence is so far limited to a single racial ingroup (Caucasian) and a single other-race class (Black).

The P400, a mid-latency positive-going deflection peaking at about 400 ms following stimulus onset at lateral posterior electrode sites, also showed larger amplitude to own- than (African American) other-race faces in Caucasian 9-month-olds but not in 5-month-olds in one ERP study (Vogel et al., 2012). However, Balas et al. (2011) found no P400 race effect in Caucasian 9-month-olds. As for the N290, differences in the procedure, stimuli, and task complexity likely account for the different results. The effect was found when infants passively viewed emotional (happy or sad) female faces that were preceded by an emotionally congruent or incongruent (crying or laughing) sound, but it was not found when infants passively viewed synthetic faces which showed combinations of Black and White skin tone and Black and White face structure. As for the N290, the effect could index greater familiarity and salience of own-race faces (Haan et al., 2002; Halit et al., 2003; Scott, Shannon et al., 2006; Scott & Nelson, 2006) and it is consistent with a behavioral ORE in 6- to 9-month-olds but not earlier (Anzures et al., 2010; 2011; Kelly et al., 2007; 2009). This neural pattern supports a perceptual narrowing hypothesis of the development of the ORE (Nelson, 2001; Scott et al., 2007). However, the lack of an effect in 5-month-olds could also owe to the use of multisensory stimuli (faces preceded by sound) (see Minar & Lewkowicz, 2018).

Going a step forward, Vogel et al. (2012) also found that in 5-month-olds the emotional incongruence between face and sound was caught by the Nc component for both own- and other-race faces, while in 9-month-olds it was caught by the P400, exclusively for own-race faces. These findings provided tentative evidence that perceptual narrowing (here, for emotion encoding) could result from an interaction of attentional (the Nc) and perceptual (the P400) systems, consistent with emerging accounts of the ORE (Markant & Scott, 2018). However, evidence for P400 race effects is limited to a single racial ingroup (Caucasian) and a single other-race face class (African American).

Despite the investigation, no sensitivity to race was found for the Nc (Vogel et al., 2012) or the SLW (Balas et al., 2011).

2.2.2.1. ERP evidence in children (3 to 10 years of age)

The impact of face race in children was studied on a few ERP components, the P100, N170, and N400. The P100 and the N170 showed some sensitivity to face stimuli from childhood on (e.g., Taylor et al., 2001; Kuefner et al., 2010). The N400 was instead associated with semantic categorization for face stimuli (Kutas & Federmeier, 2011).

The P100, larger and delayed as compared with adults (Taylor et al., 1999, 2001, 2004; Itier & Taylor, 2004a,b; Kuefner et al., 2010), showed larger amplitudes to other- than own-race faces in Caucasian 5- to 7-year-olds, 8- to 10-year-olds and adults as they viewed Asian and Caucasian faces while detecting an occasionally grey picture background (Anzures et al., 2022). The effect could index (i) greater effort and more processing resources dedicated to the early processing of other-race faces (see Mercure et al., 2008); (ii) attention or motivation differences towards own- and other-race faces (Herzmann et al., 2011). Overall, this neural ORE is consistent with a behavioral ORE at the same age ranges (Anzures et al., 2014; Macchi Cassia et al., 2014; Sangrigoli & de Schonen, 2004a; Suhrke et al., 2014; de Heering et al., 2010; Pezdek et al., 2003; Tham et al., 2017).

In addition, the lack of age modulation on the P100 race effect argues for a stable ORE from childhood to adulthood, in line with behavioral findings (Anzures et al., 2014; Corenblum & Meissner, 2006; de Heering et al., 2010; Pezdek et al., 2003; Sangrigoli & de Schonen, 2004a; Tham et al., 2017). However, the effects of idiosyncratic differences on the P100 latency depict a more complex scenario: the latency to own-race faces decreased with age in children with greater implicit racial bias favoring the other race, while it was stable in children with greater own-race implicit bias. This could suggest that for children with implicit bias favoring the other race the attentional bias to own-race faces could evolve with age. However,

evidence for P100 race effects is limited to a single racial ingroup (Caucasian) and a single other-race class (Asian).

The N400, a mid-latency negative going deflection peaking between 200 and 600 ms post-stimulus onset over centro-parietal and frontal sites, showed some evidence of a face race sensitivity, in the form of larger N400 amplitude to racially incongruent than racially congruent pairs of faces (Timeo, Mento et al., 2019). The effect was found in Caucasian 3- and 5-year-olds and adults as they watched a centrally- displayed video while face pairs appeared bilaterally. Face pairs were either identical, different but belonging to the same racial group, i.e., both Asian or both Caucasian, or belonging to different racial groups, i.e., one Asian, one Caucasian.

This finding suggests that preschoolers can perceptually categorize faces according to race, in line with behavioral evidence for a race perceptual categorization ability from 6 months of age (Quinn et al., 2016; Sangrigoli & De Schonen, 2004b). This finding is consistent with the role of N400 in the semantic categorization of face stimuli (Kutas & Federmeier, 2011). In addition, in children the magnitude of the effect positively correlated with the use of linguistic race labels by the parents or the child, suggesting that implicit race categorization in children may develop with the capacity to produce and understand race labels. This evidence supports emerging accounts of the ORE (Timeo et al., 2017), since it implies that labeling can impact categorization, so that both could affect perceptual processes.

Despite the investigation (Anzures et al., 2022; Timeo, Mento et al., 2019), no modulation as a function of race was found for the N170.

THE PRESENT THESIS

This thesis focuses on the phenomenon of the other-race effect (ORE) and takes a *lifespan* perspective on the phenomenon: the ORE is comprehensively defined both in its mature form and in its possible developmental forms and trajectories.

This thesis's project is motivated by some limitations of the extant empirical literature on the ORE, both in the adult and developmental populations.

In adults, an important shortcoming of the scientific literature on the ORE relates to the use of explicit tasks. The ORE has been traditionally examined using recognition memory tasks, involving the familiarization with unfamiliar faces followed by a recognition memory test, or using perceptual matching tasks, involving the presentation of an unfamiliar face and the request to match this face to another face. In these tasks, attention and intention are directed to process and report the identity of the faces. By using explicit tasks, some variability of non-interest (i.e., noise) is introduced above the phenomenon of interest. Obtained results can pertain to encoding procedures (e.g., the number of faces presented at familiarization, the time between familiarization and test), or presentation procedures (e.g., presenting target and to-be-matched faces simultaneously or subsequently), but also to reporting procedures (e.g., the internal criterion to bias the response, the motor capacity). These variables render the comparison across studies difficult and the characterization of the phenomenon in its more "obligatory" or spontaneous form challenging. Some studies in adults took an *implicit* (i.e., non-intentional) approach to study the ORE. They did so by using implicit paradigms, like the priming procedure (e.g., Herrmann et al., 2007; Herzmann, 2016) or the neural adaptation technique (Vizioli, Rousselet et al., 2010; Hughes et al., 2019; Zhou et al., 2020). In the priming procedure, the processing of a "target" stimulus is facilitated by the immediately preceding presentation of an identical or semantically (or evaluatively) related "prime" stimulus (Tulving

& Schacter, 1990). This paradigm can tackle implicit memory, because memory of the prime stimulus is implicitly measured through the influence it exerts on the target stimulus, without the need for an explicit report. On the other hand, the neural adaptation technique takes advantage of the suppression of the neural activity due to repeating the same or related stimuli, to infer that the brain coded for the common aspects of the presented stimuli (see Grill-Spector et al., 2006 for a review). Related to the neural adaptation, the so-called fMRI-adaptation technique (Grill-Spector & Malach, 2001), takes advantage of the *release* from adaptation due to the presentation of a stimulus differing from preceding stimuli, to infer that the brain could discriminate the new stimulus. Of note, the measurement of the neural activity *per se* can be regarded as a form of implicit investigation because neural differences can be investigated for task-irrelevant dimensions. With this respect, brain imaging and electrophysiological literature on the ORE are rich of examples.

A step forward to investigate the spontaneous and implicit occurrence of the ORE is to examine the phenomenon in the absence of awareness. To date, no study in the adult population examined the *unconscious* occurrence of the ORE. This approach is made possible by the knowledge provided by previous evidence that faces and face dimensions can be automatically (Caharel et al., 2009; Liu-Shuang et al., 2014; Retter et al., 2021; Yan et al., 2017; Zimmermann et al., 2019) and unconsciously (e.g., Henson et al., 2008) processed. Thus, we can capitalize on this human capacity to investigate possible race-related differences at this level.

The first research question **(Q1)** that I aim to address in this thesis is: is there a difference between the implicit and unconscious processing of faces depending on their belonging to the own or to another race? My hypothesis **(H1)** is that indeed there should be differences. This hypothesis is based on the theoretical accounts of the ORE, especially the ones involving the key role of perceptual/representational processes, but to some extent also

the ones involving social categorization and attention, which suggest that the phenomenon should occur also in the absence of intention and awareness. To address this question, I conducted a study **(Study 1)**, in which I used a masked and unmasked priming paradigm combined with EEG/ERP recording in young adults. In this experimental context, participants saw faces of their own race and faces of another race. My hypothesis would be met if different priming effects as a function of the own or the other race were to be found at the behavioral or neural level.

In development, it is relevant to distinguish between the literature on infancy and childhood. In infancy, the ORE has been necessarily examined in its implicit form since infants cannot provide explicit reports. In this population, the ORE was investigated at the behavioral level via novelty preference indexed by the infant's gaze, and at the neural level using passive viewing tasks. In children, however, the ORE was typically investigated using explicit paradigms, and specifically using tasks common to adults. By using these tasks results were inconsistent. Additionally, neural investigations of the ORE in children are scarce. Of these, only some used implicit procedures (Anzures et al., 2022; Timeo, Mento et al., 2019). Thus, my approach could be particularly informative in children because by using: (i) the EEG, we can look at differences that may not appear in behavior due to lower sensitivity; (ii) an implicit and unconscious paradigm we can obviate difficulties due to the task, which so far produced contrasting results. In the child population, the research question **(Q2)** that I address in this thesis is: is there a difference between the implicit and unconscious processing of faces depending on their belonging to the own or to another race *in children*? My hypothesis **(H2)** is twofold. According to the extant knowledge, two results can emerge: (i) there is a difference if the ORE is adult-like or mature enough in children; (ii) there is no difference if the ORE is still immature in children. To address this question, I conducted a study **(Study 2)**, in which I used a masked priming paradigm combined with the EEG/ERP recording in 6- to 7-year-old

children. The hypothesis of a difference would be met if different priming effects as a function of the own or the other race were to be found at the behavioral or neural level; the hypothesis of no difference would be met (or at least supported by) if similar priming effects irrespective of face race were to be found at the behavioral or neural level.

Overall, the general aim of this thesis is to isolate implicit and unconscious processes of race, at both behavioral and neural levels.

Chapter 3. STUDY 1: ELECTROPHYSIOLOGICAL CORRELATES OF UNCONSCIOUS PROCESSES OF RACE

3.1. Introduction[2]

The present investigation focused on two different accounts of the ORE: The experienced based holistic account, EBH (Rossion & Michel, 2011), and the socio-cognitive account (Galper, 1973) (see Chapter 1.2.1). Specifically, it aimed to shed light on this theoretical debate by investigating the brain mechanisms and the temporal course of the implicit/automatic own- and other-race face processing. For this purpose, the masked priming manipulation has been used, a manipulation that allows investigating the unconscious processing of a stimulus (Cheesman & Merikle, 1986; Forster et al., 1987; Kinoshita & Lupker, 2003; Marcel, 1983). In this paradigm, the prime stimuli are displayed very briefly and are then obscured/masked either by a series of letters or symbols or directly by the target stimuli. Participants generally report not having seen the prime stimulus and respond to the target faster and more accurately when prime-target are identical or semantically related (e.g., dog - dog / cat – dog) compared to when they are not (e.g., shoe - dog). Although the mechanisms underlying these unconscious effects are under debate (De Wit & Kinoshita, 2015; Rohaut et al., 2016), consensus exists that the masked priming paradigm reflects implicit/automatic mechanisms of stimulus processing (Marcel, 1983). We, therefore, preferred this paradigm to other experimental designs since it is a suitable tool for exploring the brain mechanisms involved in the unconscious processing of the face and the stages involved in the activation of race information (Henson et al., 2008; Kiefer & Brendel, 2006; Leo & Pesciarelli, 2018; Pesciarelli et al., 2016; Pesciarelli et al., 2011). Specifically, if any differences were to be found

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between own-race and other-race face priming effects (same vs. different prime-target pairs), these effects could not be explained by strategic processing. This could rule out a stream of the socio-cognitive account of the ORE arguing for a strategically/intentionally deeper processing of own-race faces (e.g. Galper, 1973; Berger, 1969; Malpass, 1990). For instance, it is hypothesized that due to racial attitudes or low interest, observers would not be motivated to process or to pay attention to other-race faces. On the contrary, these effects could only be explained as automatic and implicit effects. Since the prime is thought to pre-activate representations in long-term memory which facilitate their later access by the target, differences in priming effects between own-race and other-race faces could reflect less precise and/or less accessible memory representations of other-race than own-race faces, in line with an EBH account. In this vein, different priming effects for own-race and other-race faces could fit with the EBH account. However, some theories within the socio-cognitive framework could also be plausible. For instance, social factors such as social categorization (i.e., the classification of social stimuli as ingroup and outgroup) and attentional factors, such as attention capture could also occur automatically (e.g., Devine, 1989; Crisp & Hewstone, 2007), and thus could also explain different priming effects as a function of race.

To our knowledge, the neural mechanisms underlying race processing have never been explored comparing face stimuli presented above and below threshold. Event-related potentials (ERPs) are particularly suitable because they provide a continuous measurement between the target stimulus and the response, allowing to isolate the effect of a single experimental manipulation at a specific processing stage. Previous ERP studies have concentrated on various ERP waveforms that seem to distinguish own- from other-race face processing (as discussed above in Chapter 2.2.1). To evaluate whether race processing is unconsciously activated, we used the masked priming paradigm. The primes were faces that differed in their race, Caucasian (own-race) or Asian (other-race). The prime stimulus was presented very briefly (33 ms). In

the masked manipulation the prime face was preceded and followed by a scrambled face; while in the unmasked manipulation, these scrambled faces were replaced by a black screen, making the prime stimulus fully visible. The prime stimulus was then followed by a Caucasian (own-race) or Asian (other-race) target face. The face stimuli on each pair were of the same gender and race. RTs and EEG were recorded.

If our hypothesis that race is processed outside of people's awareness is correct, we expect race to be processed also in the masked manipulation. Moreover, considering that participants are instructed to attend to gender and not explicitly to race, we can also evaluate responses to index the degree to which the information related to race is implicitly processed. The present research investigated the time course of the implicit processing of the face, analyzing the early (P100 and N100) and late (N200 and P300) ERP components, in particular examining how the roles of race and priming (intended as a same/different situation), can interact in different stages of face processing. In specific, race (own vs. other) was expected to interact with priming (same: identical faces vs. different: non-identical faces [but of the same gender and race]) under masked and unmasked conditions in a gender-classification task if face identity is processed to a larger degree in faces of the own-race than in faces of the other-race. In this case, we expected a selective (or stronger) identity/priming effect in the own-race condition but not (or weaker) in the other-race condition. If this interaction between race and identity/priming is independent of the participant's awareness of the faces, the interaction should be found regardless of masking. Besides, this interaction should be found in early ERP components if it relies on early (sensory) processing stages. Few researchers have explored the temporal course of the race effect (Caldara et al., 2004; Ito & Urland, 2005; Vizioli, Foreman et al., 2010; Beyersmann et al., 2011) and, to the best of our knowledge, none by comparing stimuli proposed above and below threshold. Based on the literature, we hypothesized a masked and unmasked "other race" effect in all the components analyzed and a masked and

41

unmasked priming effect in the late ones. Nevertheless, considering the not consistent data in the literature and the novel approach taken in the present study, it was possible that, for some of the considered ERP components, the priming and race effects could appear in additional time windows.

3.2. Method

3.2.1. Ethics statement

This study was carried out following the recommendations of the "Italian Association of Psychology" (AIP) Ethical Guidelines (Codice Etico: www.aipass.org/node/11560), was reviewed and received formal approval by the local Ethical Committee of the School of Psychology of the University of Padua, Italy. Participants were informed of their rights and gave written informed consent for participation in the study, according to the Declaration of Helsinki. All study procedures met the ethical guidelines for the protection of human participants, including adherence to the legal requirements of the Country.

3.2.2. Participants

Thirty-five students at the University of Modena and Reggio Emilia with Caucasian ethnic backgrounds (18 women; age range: 19-27 yrs, M=22 yrs) participated in the experiment. All participants were right-handed (L.Q. = + 88, Decile R.7) as assessed with an Italian version of the Edinburgh Handedness Inventory (Oldfield, 1971). Participants had no history of neurological or mental disorders and had normal or corrected-to-normal visual acuity. The criteria for considering participants as Caucasians are: born in western countries, white-skinned and with Caucasian parents, and no Asian (the ethnic group not belonging to their own) relatives or close friends.

3.2.3. Stimuli

88 pictures of faces were used, 44 Caucasian and 44 Asian faces, 50% of each female; each picture was displayed four times, for a total of 352 stimuli. Face pictures were selected from the FERET database (FERET Facial Image Database Release 2, Phillips et al., 1998). Asian pictures rather than African-American have been used given that Asian and Caucasian pictures have similar luminance and contrast. However, they were imported into Adobe Photoshop, luminance was controlled within each racial group (Asian = 121 mean luminance, Caucasian = 123 mean luminance; $p > .1$). The background and all of the details of the face (as ears, hair, and neck) were hidden (covered) using a black oval passe-partout. Two separate surveys to control race and gender reliability of the experimental face stimuli were each presented to 60 participants. In the race survey it was asked to rate the extent to which each face was associated with a Caucasian or Asian face, while in the gender survey to rate the extent to which each face was associated with a male or female. For both surveys, a seven-point Likert scale has been used (half of the participants saw: 1 -Asian/Male and 7 - Caucasian/Female, the other half saw a reversed scale). The final rating assigned to each face was calculated by combining the ratings obtained with both directions of the rating scale. All experimental face stimuli emerged to be prototypical of both race and gender. The overall average for Asian faces was 1.09 (SD = 0.12, range 1-2), for Caucasian faces was 6.95 (SD = 0.1, range 6-7), for Male faces was 1.01 (SD = 0.05, range 1-2), and for Female faces was 6.97 (SD = 0.12, range 6-7).

Two types of prime-target pair faces were used: Same face pairs (prime-target were identical faces), and Different face pairs (prime-target were different faces). Prime-target pairs were half Asian (other-race) and half Caucasian (own-race) faces. The face stimuli on each pair belonged to the same gender and race. Four are the resulting conditions: 1. Other-race Same; 2. Other-race Different; 3. Own-race Same; 4. Own-race Different. The prime was 25%

smaller than the target to avoid any perceptual overlapping. In the present work, we used a masked and unmasked priming paradigm highly similar to that employed by Pesciarelli, et al. (Pesciarelli et al., 2019, see Method section), with the difference that in the present study we presented human faces as prime-target pairs instead of words. In each trial of the masked condition, the prime face was preceded and followed by masking stimuli. In each trial of the unmasked condition, the masking stimuli were replaced by a black screen of the same duration of the mask. Participants performed eight blocks of 88 trials each, resulting in a total of 704 trials (44 trials per condition). To avoid revealing the presence of the prime stimulus the first blocks were masked and the last four unmasked. Within each block, the four conditions (Other-race Same; Other-race Different; Own-race Same; Own-race Different) appeared in randomized order and with the same probability. The critical stimuli on which ERP data were compared were the target faces of each trial. Prime-target pairs were randomized before presentation. Before the experiment, participants took part in a short training session with 16 prime-target pairs (8 masked and 8 unmasked, half Caucasian and half Asian) formed by stimuli different from the experimental ones. The masking stimulus consisted of a scrambled picture of a face with the same luminance and contrast of the prime and target and the same dimensions and visual angle of the target.

3.2.4. Design and Procedure

Participants were seated comfortably in a darkened sound-attenuated room. An example of the stimulus presentation procedure is illustrated in Figure 3.1.
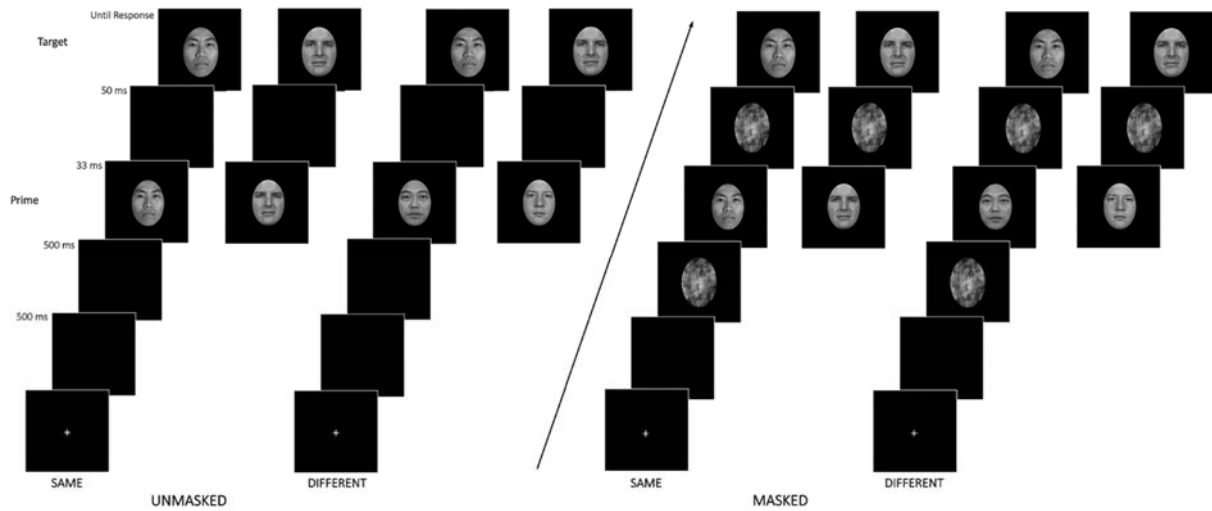
Figure 3.1. Schematic depiction of the unmasked and masked procedures used in the present experiment.

As in Pesciarelli et al. (2019, see Method section), all stimuli were presented in the center of a 17″ CRT monitor synchronous with the screen refresh [Philips 107B; refresh rate = 60 Hz (16.67 ms)] that was positioned at eye level approximately 70 cm in front of the participant, such that each target and mask stimulus subtended 11.3° of visual angle. The prime stimulus was 25% smaller (visual angle 8.5°) than the target stimulus, to avoid any perceptual overlapping. Stimuli were displayed against a black background. E-Prime software (Version 2; Psychology Software Tools, Pittsburgh, PA) was used for stimulus presentation and behavioral response collection. The test computer was an ACPI multiprocessor PC with a D CPU 2.80 GHz Intel Pentium processor, Radeon X550 video card. Priority settings were optimized to ensure accurate display durations. Each trial began with a fixation cross (+) presented in the middle of the screen and stayed there until participants pressed a button to start the trial. Then a black screen was displayed for 500 ms and replaced by a 500 ms forward mask consisting of a scrambled picture of a face. The forward mask was replaced by the prime stimulus for 33 ms at the same location on the screen. The use of a 33 ms prime stimulus duration was expected to make masking effective and to prevent participants from consciously perceiving the primes. The prime was then immediately followed by a 50 ms backward mask

consisting of a scrambled face. Then the target face appeared and remained on the screen until a response was made. Each response was followed by a 1000 ms blank screen. The use of prolonged forward and backward mask durations was expected to make masking even more effective preventing participants from consciously perceiving the primes and avoiding selection bias. In the unmasked condition, the masking stimuli were replaced by a black screen of the same duration as the mask. This manipulation made the prime stimulus fully visible, above threshold.

The task of the participants was to decide, as quickly and accurately as possible, whether the target was a female or a male face (gender task). Participants responded by pressing one of two buttons, which were counterbalanced (left and right) across participants. This implicit task (to attend to gender and not explicitly to race) has been used to assess responses as a function of race to index the degree to which race is automatically processed.

An objective measure of prime visibility was obtained after the experiment for the masked condition. Participants were informed of the presence of the prime behind the masks and had to perform a gender task on masked prime faces that could be either a female or a male. They received a practice session to ensure that they understood the prime visibility task. Participants were also requested to make the best guess when they felt not confident about the correct response. Data of no participants had to be excluded from the analysis because the identification rate did not exceed the confidence interval of chance performance (accuracy greater than 70%). The gender task on the masked primes confirmed that our masking method rendered the primes largely invisible, as the average accuracy was close to chance [mean percentage correct = 55% (SD=.10, range 35-70%)]. Accuracy was distributed around the chance level of 50%, which is expected by mere guessing. This objective prime visibility measure overcomes the limitations of subjective self-report measure in which participants

report not having seen the stimuli but may have experienced it consciously (Pesciarelli et al., 2019).

3.2.5. EEG recording and analysis

As in Pesciarelli et al. (2019, see Method section), EEG was amplified and recorded with the BioSemi Active-Two System from 30 active electrodes placed on the scalp according to the International 10– 10 System. Besides, four electrodes were placed around the eyes for eye-movement monitoring (two at the external ocular canthi and two below the eyes) and two electrodes were placed over the left and right mastoids. Two additional electrodes were placed close to Cz, the Common Mode Sense [CMS] active electrode and the Driven Right Leg [DRL] passive electrode, which were used to form the feedback loop that drives the average potential of the participant as close as possible to the ADbox reference potential. EEG and EOG signals were amplified and digitized continuously with a sampling rate of 512 Hz. Brain Vision Analyzer (Brain Products, Gilching, Germany) was used to perform off-line signal processing analyses. EEG signal was bandpass filtered between 0.1–80 Hz and referenced off-line to the average activity of the two mastoids. Artifact activity was rejected using a semiautomated procedure, with artifacts identified by the following criteria: Gradient, with 25 μV maximal allowed voltage step; Max-Min with 200 ms maximal allowed absolute difference; Low activity, with 0.5 μV/50 ms lowest allowed activity. Data with excessive blinks were adaptively corrected using ICA. 1000-msec epochs containing the ERP elicited by the target face were extracted, starting with 200 ms before the onset of the face. A 200 ms pre-stimulus baseline was used in all analyses. Segments including artifacts due to activity exceeding ±100 μV in amplitude were also rejected. The lost data (due to artifacts) of the 35 participants were equal to 4,7%. Overall, averaged ERPs included: in the masked manipulation, an average of 69.8 trails for the Other-race same, 70.1 for the Other-race different, 73.3 for the Own-race same, 73.4 for the Own-race different conditions and in the unmasked manipulation, an average of

71.5 trails per the Other-race same; 71.2 Other-race different; 71.7 Own-race same; 72.9 Own-race different conditions. The averaged ERPs were low-pass filtered at 30 Hz. Based on visual inspection of grand average ERP waveforms and in line with our previous studies and previous literature (Herrmann et al., 2005; Jiang et al., 2009; Pesciarelli et al., 2016; Pickering & Schweinberger, 2003; Wynn et al., 2008), the following components were identified for target onset at frontal (F3, Fz, F4), central (C3, Cz, C4), and parietal (P3, Pz, P4) scalp sites: P100 from 70 to 130 ms after target onset; N100 from 100 to 200 ms after target onset; N200 from 230 to 400 ms after target onset; P300 from 400 to 700 ms after target onset. For each ERP component amplitude was measured as mean activity within the respective time window. The N170 component, a core marker of face processing (see Chapter 2.2.1), could not be identified, possibly owing to the attenuation of the activity at temporo-parietal sites due to the use of an average mastoid reference.

3.2.6. Statistical analyses

Behavioral and ERP analyses were carried out only on trials with correct responses. Individual reaction times (RTs) exceeding ±2 SD were eliminated (4.4%). The mean response times (RTs) of correct responses per condition were submitted to analyses of variance (ANOVAs) with Masking (unmasked, masked), Race (other-race, own-race), Identity (Same, Different), as within-subject factors. ERP effects time-locked to the onset of the target were evaluated considering 6 clusters of electrodes representing the mean amplitude of three electrodes in close position: Anterior (F3, Fz, F4), Central (C3, Cz, C4), Posterior (P3, Pz, P4), Left (F3, C3, P3), Midline (Fz, Cz, Pz), Right (F4, C4, P4). ANOVAs were conducted on mean ERP amplitudes with Masking (unmasked, masked), Race (other-race, own-race), Identity (same, different), Longitude (anterior, central, posterior), and Latitude (left, midline, right) as within-subject factors. When appropriate, degrees of freedom were adjusted according to the method of Greenhouse-Geisser; only corrected significance levels are reported. 90%

confidence intervals for the effect sizes are reported (Steiger, 2004). The level of significance testing was p = .05. The main effects of Masking, Identity, and Electrode position are not central to the questions under study. Therefore, they are reported and not discussed since we discuss only the main effects and interactions of interest to the study. Significant ERP effects on Longitude and Latitude factors are not reported.

3.3. Results

3.3.1. Behavioral results

Figure 3.2 and Table 3.1 show the mean RTs to face targets preceded by same and different face primes.

Figure 3.2. Mean reaction times to target faces separately for the unmasked (left panel) and masked (right panel) procedures as a function of prime-target identity (same vs different) and race (other-race vs own-race). Error bars represent standard errors of the mean.

Participants were not able to identify the primes. The omnibus ANOVA performed on the RTs showed a significant main effect of Masking [$F(1, 34) = 28.06$, $p < .001$, $\eta_p^2 = .45$, 90% CI = .23, .59] revealing faster RTs for the unmasked than masked manipulation; a

significant main effect of Race [$F(1, 34) = 8.12$, $p < .01$, $\eta_p^2 = .19$, 90% CI = .03, .37] revealing faster RTs for own-race faces than other-race faces; a significant main effect of Identity [$F(1, 34) = 80.86$, $p < .001$, $\eta_p^2 = .70$, 90% CI = .54, .78] revealing faster RTs for the Same than Different condition; and a Masking x Identity interaction [$F(1, 34) = 13.98$, $p < .0001$, $\eta_p^2 = .29$, 90% CI = .09, .46], revealing a larger priming effect in the unmasked than masked condition, regardless of race. No other effects reached significance (ps > .1). The omnibus ANOVA conducted on the accuracy did not reveal any significant effects (all ps > .05), probably because performance was near ceiling, with all conditions averaging between 95-97% correct.

Table 3.1. Mean and standard deviation (SD) of response times (RTs) to target faces as a function of Masking (unmasked, masked), Race (own-race, other-race) and Identity (same, different).

Conditions	Response times (RTs)	
	M (ms)	SD (ms)
Unmasked		
Own-race Same	604.27	100.51
Own-race Different	636.34	108.91
Other-race Same	613.80	105.07
Other-race Different	645.06	114.88
Masked		
Own-race Same	654.21	101.98
Own-race Different	666.15	106.94
Other-race Same	666.27	101.19
Other-race Different	681.48	100.22

3.3.2. ERP results

Grand-averaged ERPs elicited by the different experimental conditions are represented in Figures 3.3, 3.4, 3.5, and 3.6. Visual inspection revealed that, in all components, the magnitude of the effects was maximal at the Cz electrode, thus, for an easier visualization of our results, we show only the Cz electrode.
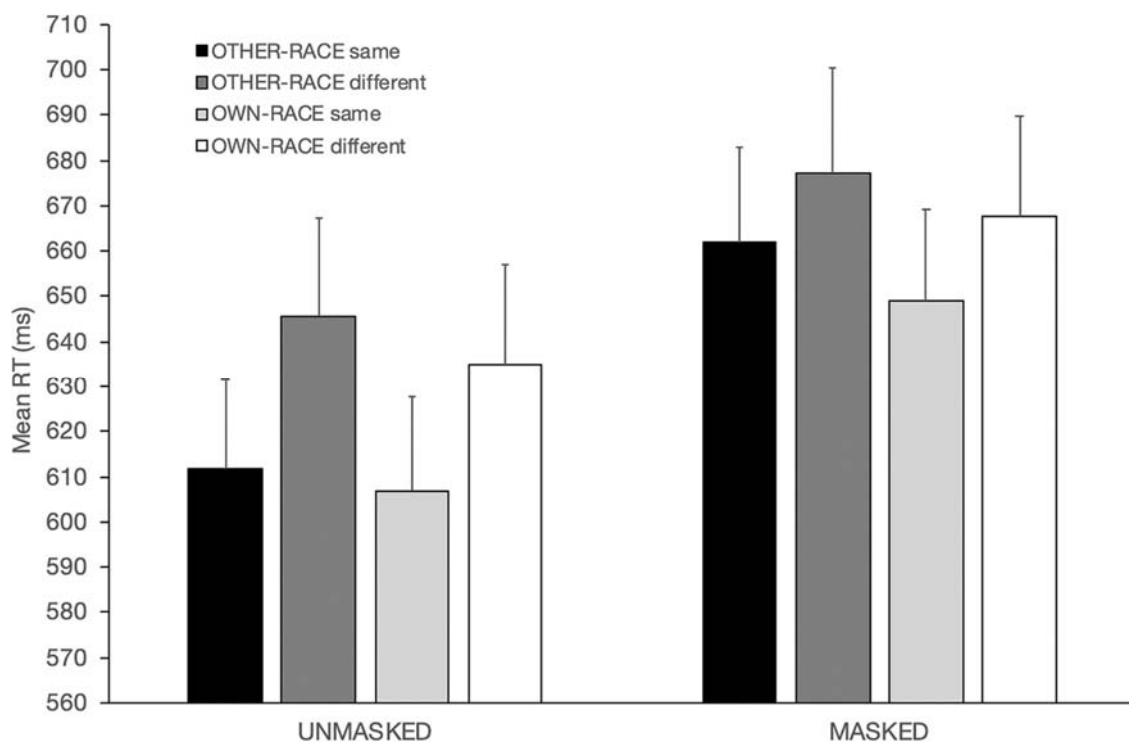
RACE EFFECTS
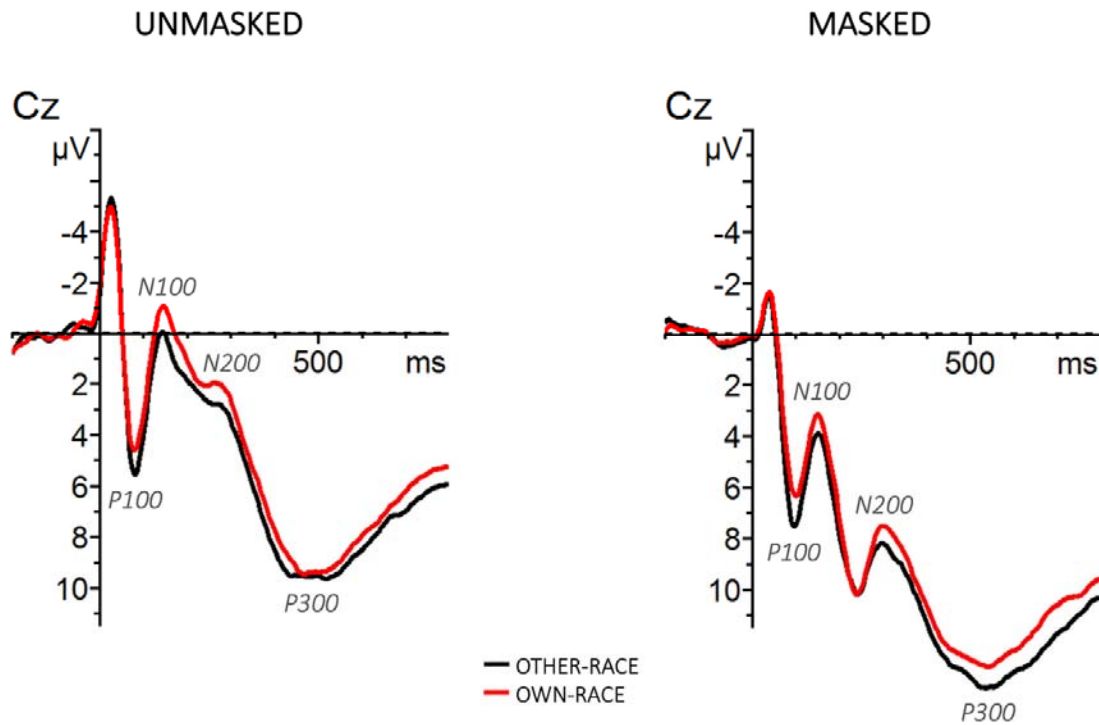
Figure 3.3. Grand-averaged ERP waveforms elicited by target faces separately for the unmasked (left panel) and masked (right panel) procedures as a function of race (other-race vs own-race).

PRIMING EFFECTS
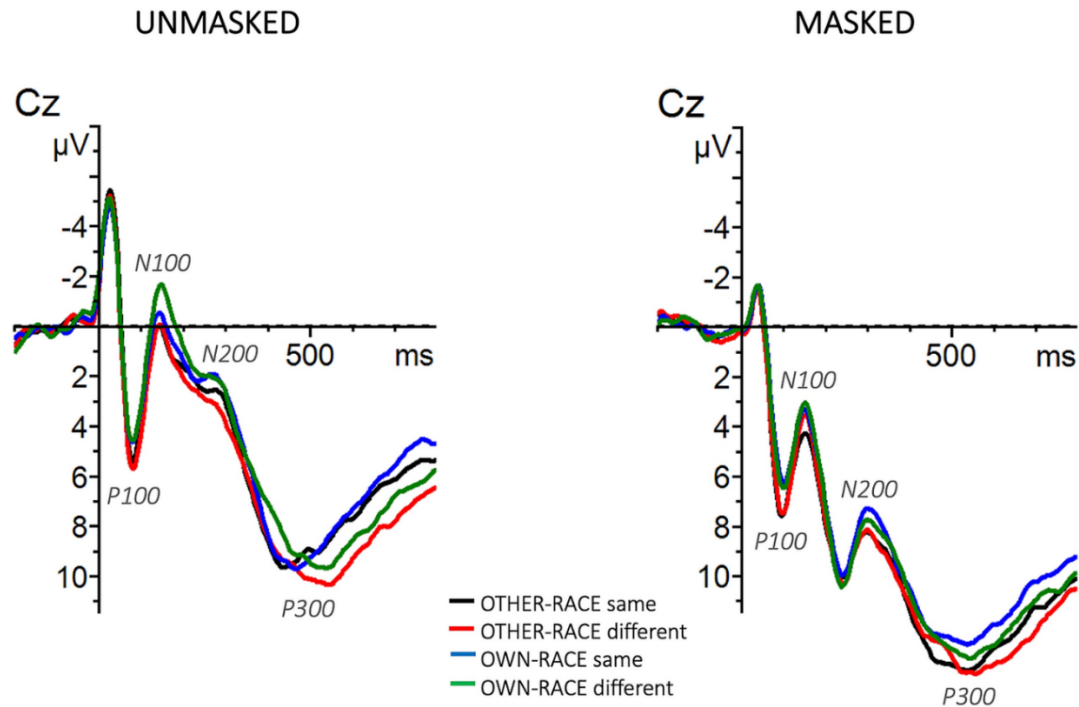
Figure 3.4. Grand-averaged ERP waveforms elicited by target faces separately for the unmasked (left panel) and masked (right panel) procedures as a function of prime-target identity (same vs different) and race (other-race vs own-race).
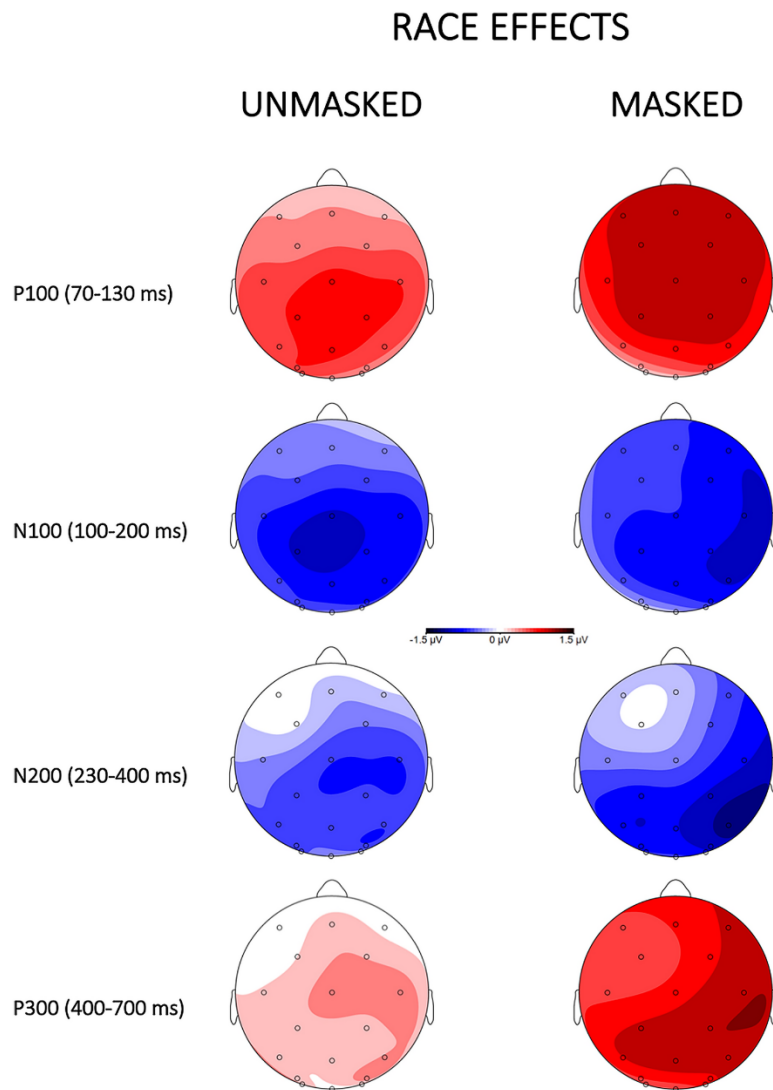
Figure 3.5. Topographical scalp distributions for target faces separately for the unmasked (left panel) and masked (right panel) procedures as a function of race (other-race vs own-race) in the four critical time windows, created by subtracting other from own-race conditions.

PRIMING EFFECTS

	UNMASKED		MASKED	
	OTHER-RACE	OWN-RACE	OTHER-RACE	OWN-RACE
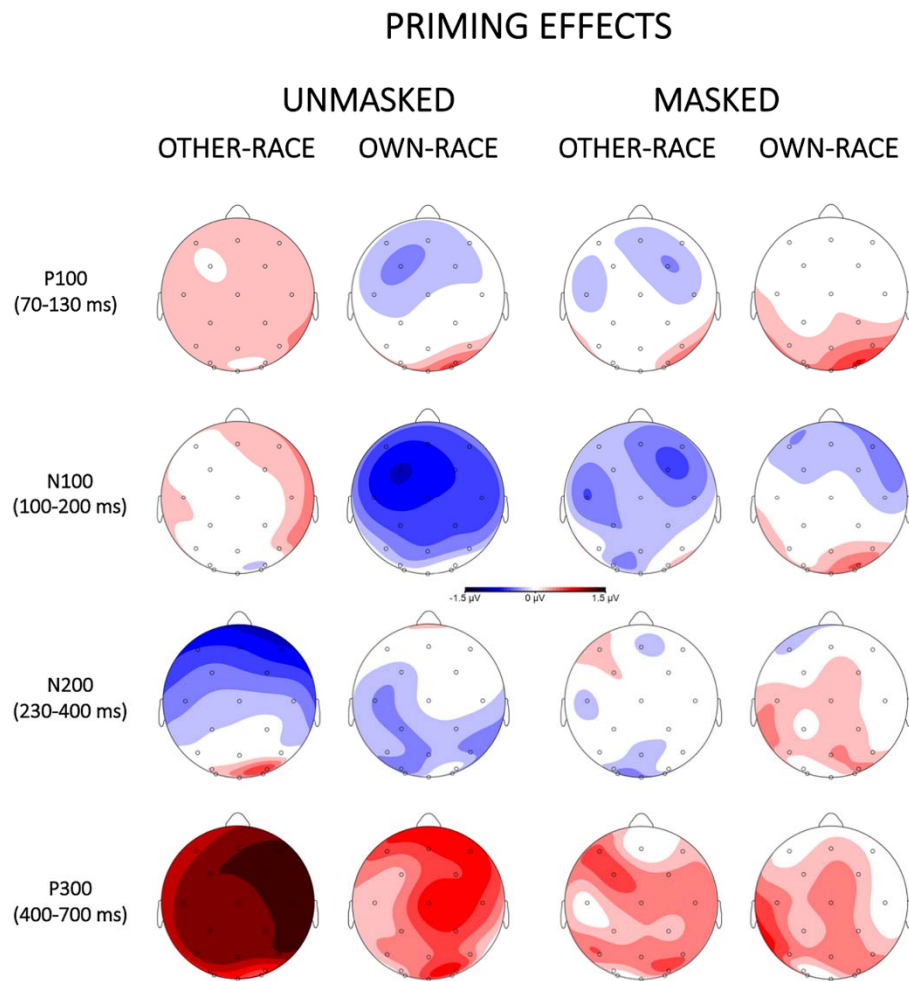
Figure 3.6. Topographical scalp distributions for target face separately for the unmasked (left panel) and masked (right panel) procedures as a function of prime-target identity (same vs different) and race (other-race vs own-race) in the four critical time windows, created by subtracting same other-race and own-race conditions from different other-race and own-race ones, respectively.

3.3.2.1. P100

The omnibus ANOVA yielded significant main effects of Masking [$F(1, 34) = 7.97$, $p < .01$, $\eta_p^2 = .19$, 90% CI = .03, .36], with more positive waveforms for the masked ($\mu V = 4.57$, SE = 0.54, 95% CI = 3.47, 5.67) than for the unmasked condition ($\mu V = 3.14$, SE = 0.54, 95% CI = 2.04, 4.24), of Race [$F(1, 34) = 48.24$, $p < .001$, $\eta_p^2 = .59$, 90% CI = .39, .69], indicating a more positive brain response for other-race ($\mu V = 4.25$, SE = 0.48, 95% CI = 3.27, 5.23) than own-race faces ($\mu V = 3.46$, SE = 0.48, 95% CI = 2.48, 4.44). No other main effects and interactions of interest to the study reached significance ($ps > .1$).

3.3.2.2. N100

The P100 was followed by a negative waveform identified as an N100 component. The omnibus ANOVA revealed a main effect of Masking [$F(1, 34) = 24.23$, $p < .001$, $\eta_p^2 = .42$, 90% CI = .2, .56], with more negative waveforms for the unmasked ($\mu V = 1.79$, SE = 0.51, 95% CI = 0.75, 2.83) than for the masked ($\mu V = 4.26$, SE = 0.51, 95% CI = 3.22, 5.30) condition, and a main effect of Race [$F(1, 34) = 40.05$, $p < .001$, $\eta_p^2 = .54$, 90% CI = .33, .66], with more negative waveforms for the own-race ($\mu V = 2.65$, SE = 0.45, 95% CI = 1.74, 3.56) than for the other-race ($\mu V = 3.40$, SE = 0.45, 95% CI = 2.49, 4.31) condition. The ANOVA also showed a Masking x Race x Identity interaction [$F(1, 34) = 12.04$, $p < .001$, $\eta_p^2 = .26$, 90% CI = .07, .43], showing a priming effect (more negative waveforms for different than same conditions) for own-race faces (different $\mu V = 1.12$, SE = 0.53, 95% CI = 0.04, 2.20; same $\mu V = 1.73$, SE = 0.53, 95% CI = 0.65, 2.81) and not for other-race faces (different $\mu V = 2.29$, SE = 0.53, 95% CI = 1.21, 3.37; same $\mu V = 2.0$, SE = 0.53, 95% CI = 0.92, 3.08) and only in the unmasked condition. No other main effects and interactions of interest to the study reached significance ($ps > .1$).

3.3.2.3. N200

The omnibus ANOVA showed significant main effects of Masking [$F(1, 34) = 33.15$, $p < .001$, $\eta_p^2 = .49$, 90% CI = .28, .62], with more negative waveforms for the unmasked ($\mu V = 5.07$, SE = 0.69, 95% CI = 3.67, 6.47) than for the masked ($\mu V = 8.40$, SE = 0.69, 95% CI = 7.0, 9.8) condition, and of Race [$F(1, 34) = 16.78$, $p < .001$, $\eta_p^2 = .33$, 90% CI = .12, .49], with more negative waveforms for the own-race ($\mu V = 6.44$, SE = 0.63, 95% CI = 5.16, 7.72) than for the other-race ($\mu V = 7.03$, SE = 0.63, 95% CI = 5.75, 8.31) condition. The ANOVA also showed the following significant interactions: Latitude x Masking x Race [$F(1.92, 65.15) = 3.21$, $p < .05$, $\eta_p^2 = .09$, 90% CI = 0, .19], Longitude x Masking x Identity [$F(1.19, 40.39) = 4.59$, $p < .05$, $\eta_p^2 = .12$, 90% CI = .01, .27], and Latitude x Longitude x Masking x Race x

Identity [$F(3.71, 126.02) = 3.72$, $p < .01$, $\eta_p^2 = .10$, 90% CI = .02, .17]. To further explore these interactions, the unmasked and masked conditions were analyzed separately. The analysis of the unmasked condition showed a significant main effect of Race [$F(1, 34) = 5.23$, $p < .05$, $\eta_p^2 = .13$, 90% CI = .01, .31], with more negative brain response to own-race ($\mu V = 4.94$, SE = 0.76, 95% CI = 3.40, 6.48) than to other-race ($\mu V = 5.44$, SE = 0.76, 95% CI = 3.90, 6.98) faces, a significant Longitude x Race interaction [$F(1.6, 54.58) = 7.31$, $p < .001$, $\eta_p^2 = .18$, 90% CI = .04, .31], indicating a race effect more pronounced in the centro-parietal area (anterior: own-race $\mu V = 1.15$, SE = 0.85, 95% CI = -0.58, 2.88, other-race $\mu V = 1.36$, SE = 0.85, 95% CI = -0.37, 3.09; central: own-race $\mu V = 4.44$, SE = 0.85, 95% CI = 2.71, 6.17, other-race $\mu V = 5.07$, SE = 0.85, 95% CI = 3.34, 6.80; parietal: own-race $\mu V = 9.24$, SE = 0.85, 95% CI = 7.51, 10.97, other-race $\mu V = 9.89$, SE = 0.85, 95% CI = 8.16, 11.62), and a significant Latitude x Longitude x Race x Identity interaction [$F(2.9, 98.53) = 3.29$, $p < .05$, $\eta_p^2 = .09$, 90% CI = .01, .17] indicating an unmasked priming effect for the other-race condition in the anterior-left-midline area (anterior-left: different $\mu V = 1.43$, SE = 0.89, 95% CI = -0.38, 3.24, same $\mu V = 0.74$, SE = 0.89, 95% CI = -1.07, 2.55; anterior-midline: different $\mu V = 1.29$, SE = 0.89, 95% CI = -0.52, 3.10, same $\mu V = 0.57$, SE = 0.89, 95% CI = -1.24, 2.38). In the masked condition emerged a more negative waveforms for the own-race ($\mu V = 8.07$, SE = 0.59, 95% CI = 6.87, 9.27) than for the other-race ($\mu V = 8.74$, SE = 0.59, 95% CI = 7.54, 9.94) race, as suggested by a significant main effect of Race [$F(1, 34) = 11.10$, $p < .01$, $\eta_p^2 = .25$, 90% CI = .06, .42]. Moreover, the analysis showed a significant Latitude x Race interaction [$F(1.7, 57.72) = 10.03$, $p < .001$, $\eta_p^2 = .23$, 90% CI = .08, .36], indicating a race effect more pronounced in the right area (left: own-race $\mu V = 7.69$, SE = 0.6, 95% CI = 6.47, 8.91, other-race $\mu V = 8.22$, SE = 0.6, 95% CI = 7, 9.44; midline: own-race $\mu V = 8.72$, SE = 0.6, 95% CI = 7.5, 9.94, other-race $\mu V = 9.27$, SE = 0.6, 95% CI = 8.05, 10.49; right: own-race $\mu V = 7.8$, SE = 0.6, 95% CI = 6.58,

9.02, other-race $\mu V = 8.72$, SE = 0.6, 95% CI = 7.5, 9.94). No other main effects and interactions of interest to the study reached significance (ps > .1).

3.3.2.4 P300

The omnibus ANOVA revealed a significant main effect of Masking [$F(1, 34) = 28.77$, $p < .01$, $\eta_p^2 = .46$, 90% CI = .24, .6], with more positive waveforms for the masked ($\mu V = 10.51$, SE = 0.73, 95% CI = 9.03, 11.99) than for the unmasked ($\mu V = 7.48$, SE = 0.73, 95% CI = 6, 8.96) condition, of Race [$F(1, 34) = 16.63$, $p < .001$, $\eta_p^2 = .33$, 90% CI = .12, .49], with more positive waveforms for other-race ($\mu V = 9.29$, SE = 0.67, 95% CI = 7.93, 10.65) than for the own-race ($\mu V = 8.70$, SE = 0.67, 95% CI = 7.34, 10.06) condition, and of Identity [$F(1, 34) = 11.36$, $p < .01$, $\eta_p^2 = .25$, 90% CI = .06, .42], indicating a more positive brain response for the different ($\mu V = 9.25$, SE = 0.67, 95% CI = 7.89, 10.61) than the same ($\mu V = 8.74$, SE = 0.67, 95% CI = 7.38, 10.10) condition. The ANOVA also showed a Latitude x Race interaction [$F(1.9, 63.51) = 4.04$, $p < .02$, $\eta_p^2 = .11$, 90% CI = .01, .22], indicating a race effect more pronounced in the right hemisphere (left: own-race $\mu V = 8.14$, SE = 0.69, 95% CI = 6.74, 9.54, other-race $\mu V = 8.61$, SE = 0.69, 95% CI = 7.21, 10.01; midline: own-race $\mu V = 9.26$, SE = 0.69, 95% CI = 7.86, 10.66, other-race $\mu V = 9.86$, SE = 0.69, 95% CI = 8.46, 11.26; right: own-race $\mu V = 8.72$, SE = 0.69, 95% CI = 7.32, 10.12, other-race $\mu V = 9.39$, SE = 0.69, 95% CI = 7.99, 10.79), and a Masking x Race x Identity interaction [$F(1, 34) = 5.10$, $p < .05$, $\eta_p^2 = .13$, 90% CI = .01, .3], indicating a larger priming effect (more positive waveforms for different than same conditions) for other-race than own-race stimuli more pronounced in the unmasked (other-race: different $\mu V = 8.24$, SE = 0.75, 95% CI = 6.72, 9.76; same $\mu V = 6.98$, SE = 0.75, 95% CI = 5.46, 8.50; own-race: different $\mu V = 7.52$, SE = 0.75, 95% CI = 6, 9.04; same $\mu V = 7.17$, SE = 0.75, 95% CI = 5.65, 8.69) than masked (other-race: different $\mu V = 11.01$, SE = 0.75, 95% CI = 9.49, 12.53; same $\mu V = 10.92$, SE = 0.75, 95% CI = 9.40, 12.44; own-race: different $\mu V = 10.22$, SE = 0.75, 95% CI = 8.7, 11.74; same $\mu V = 9.90$, SE = 0.75, 95% CI =

8.38, 11.42) condition. No other interactions of interest to the study reached significance (ps > .1).

3.4. Discussion

The purpose of our study was to investigate the neural mechanisms underlying race processing, and whether and to which extent these processes occurred outside of people's awareness. In the present work, participants had to report the gender of the face target ignoring the face prime that was displayed masked or unmasked. In line with the literature, the behavioral findings of the present study highlighted a race effect: slower reaction times for other-race faces than for own-race faces, regardless of masking (e.g., Slone et al., 2000). Moreover, race effects were seen on all ERP components analyzed (P100, N100, N200, and P300), in both the unmasked and masked conditions. The ERP findings showed rather early race effects: a larger P100 amplitude for other-race compared to own-race faces (Herrmann et al., 2005), and a more negative N100 waveform for own-race than for other-race faces. These findings are in line with the literature (He et al., 2009; Ito & Urland, 2003; 2005; Vizioli, Foreman et al., 2010) and seem to highlight that people are able, in the earliest stages of face processing, to distinguish between a face belonging to their own or other ethnic groups. These effects on the P100 and N100 agree with previous ERP evidence suggesting that information related to race is available very early before perceptual processes are concluded. We also found an N200 race modulation, with more negative amplitudes for own-race faces than other-race faces. These N100 and N200 enhanced negativities for own-race faces can be interpreted, as suggested by previous works, as a reflection of an automatic shifting of attention to ingroup (own-race) faces for a more in deep analysis following early greater attention to outgroup (other-race) members in the P100 (Ito & Urland, 2003; 2005; Dehaene et al., 2007; Willadsen-Jensen & Ito, 2008). In our study, the race also modulated the amplitude of a later component

57

such as the P300. The analyses on the P300 showed a larger positivity for other-race than own-race faces, confirming the data present in the literature on the involvement of this component for faces belonging to another race or belonging to a different social category (Kubota & Ito, 2007; Ito & Urland, 2005; Ito & Bartholow, 2009). It is worth noting that in our research an implicit task (to attend to gender and not explicitly to race) has been used, this means that all our race effects reported above occurred regardless of whether the participants were explicitly classifying the faces in terms of race, thus, all our results index implicit and automatic processing of race.

While race effects were seen in all ERP components analyzed (P100, N100, N200, and P300) and regardless of masking, priming effects as a function of race, were seen on the N100, N200, and P300 components, and only in the latter in the masked condition. It is worth noting that, the first waveforms to be modulated by the interaction between prime and target as a function of race, was the N100, being larger when the stimuli were different than same for own-race faces and only in the unmasked condition. This N100 unmasked priming effect, suggests an automatic brain mechanism underlying an early recognition of faces and seems in accordance with previous N100 findings that have been suggesting that information relative to race is available early in face processing, even before perceptual processing is complete (Ito & Urland, 2005; but see Ito & Urland, 2003). Given that, this early component has been related to the automatic allocation of attention in response to attention-grabbing stimuli (Luck & Hillyard, 1994), our early N100 priming effect for own-race stimuli can be interpreted as a reflection of initially greater attention to stimuli that did match (e.g., for identity) the preceding context of more familiar (own-race) stimuli. Or it could be interpreted as individuation-related features being more effectively processed for own-race than other-race faces in early processing stages, since the N100 was sensitive to the incongruency between a target and its prime in own-race but not in other-race faces. Moreover, we also found an unmasked priming

effect on the N200 component, with larger negativity for same than different trials for other-race and not for own-race faces. This priming effect (larger negativity for same stimuli) is in line with many repetition and semantic priming studies where a larger N200 amplitude for repeated and semantically congruent stimuli has been found (e.g., Du et al., 2014; Pickering & Schweinberger, 2003). The fact that this priming effect is present only for other-race faces can be interpreted as reflecting a more in-depth processing of unfamiliar (outgroup) stimuli. It could reflect a facilitated processing of other-race target faces by the pre-activation of their memory representation at this processing stage, since this representation could be difficult to access or less precise as compared to the one for own-race faces. Thus, it could index a more difficult processing of other-race faces.

The last component affected by priming was the P300. Interestingly, the P300 was the only component where a priming effect as a function of race was found not only in the unmasked condition but also in the masked condition and both for own-race and other-race faces. This enhanced P300 observed for different relative to same targets in both masked and unmasked conditions might indicate an automatic and implicit brain mechanism underlying the recognition and identification of faces. Interestingly to note, the priming effect was larger for other-race faces and more pronounced in the unmasked condition, showing a facilitated processing of stimuli that matched a pre-existing memory representation (own-race) and a more in-depth processing of unfamiliar (outgroup) stimuli (started in the N200 time window). In other words, greater difficulty to process faces belonging to other-race. It is worthy of note that, although the N100 and the N200 were not sensitive to the relation between the prime and the target face as a function of race in the masked condition, the P300 component did change as a function of the preceding prime face in both unmasked and masked conditions. The P300 is thought to reflect the updating of information in working memory (Donchin & Coles, 1988; Johnson, 1986). Accordingly, our findings have thus been taken as evidence that working

memory processes were affected by social category information in a context in which race categorization was occurring implicitly (gender task) and the stimuli were presented below threshold. Overall, the P300 effect in the masked condition showed that the race of a face could be processed automatically and unconsciously, i.e., outside of conscious awareness.

Our results indicate that at the earlier stage (P100) of processing, effects were mainly accountable to race properties of the stimulus, regardless of the more complex relation between the prime and the target stimulus. While later stages (N100, N200, P300) are sensitive to these latter effects. Taken together our findings further confirm that race information is present remarkably early in face processing. More importantly, we provided for the first time evidence that these effects occur even without conscious inferences. Indeed, our P300 masked priming modulation on face targets preceded by face primes in both other-race and own-race conditions can only be attributable to participants having not consciously processed the face primes, confirming and extending the hypothesis that the activation of race information is automatic and occurs very early in time.

Conclusively, our results cannot fit with a strand of the Socio-cognitive theory arguing for a strategically or intentionally deeper processing of own-race faces (e.g. Berger, 1969; Galper, 1973) because our race priming effects occurred automatically and even without conscious inferences. On the contrary, our results fit with the EBH account of the ORE, because they seem to reflect a different accessibility or matching difficulty between incoming visual information and memory representations between other-race and own-race faces in Caucasian observers. Our results could also be interpreted from other Socio-cognitive points of view. For instance, it is possible that participants automatically categorized own-race faces as ingroup and other-race faces as outgroup, and that different priming effects for different races were a result of the automatic processing of identity-specifying features in own-race faces and race-specifying features in other-race faces (Levin, 1996; 2000). This could explain situations in

which the priming effect present for own- but not for other-race faces, since the effect is based on identity repetition. This account is also in line with early ERP effects that we observed for face race (e.g., on the P100 and N100), which could be interpreted as reflecting rapid social categorization. However, greater priming effects for other-race faces (see e.g., N200 priming effects) are difficult to interpret within this framework, because since identity here is not task relevant, there would be no motivation for the observer to put more effort and go deeper (to the individual level) in the processing of other-race faces. Finally, these effects could also be explained as a matter of differences in attention capture: own-race faces could automatically capture more attention than other-race faces, but own-race faces would eventually be attended to more than other-race faces. This could be reflected by the pattern of the P100, N100, and N200 sensitivity to own- and other-race faces. The effects of priming as a function of race could be interpreted as more attention being allocated to changes of identity between target and prime face in own-race than in other-race faces. However, the account could not explain the opposite effects.

To our knowledge, none of the studies examined the brain correlates and the temporal characteristics of implicit race processing by comparing face stimuli above and below threshold. Our study adds further evidence that race information influences face processing, but unlike works already present in the literature, our data clearly highlights how this influence is immediate and automatic. Our research suggests that race information grabs attention automatically and quickly, at early processing stages. Overall, the data from this study seems to support the hypothesis for which race processing is a rather early process, also found in conditions of unconsciousness. To note, the present research was limited to Caucasian participants and the ORE was observed in a specific context (Asian faces vs Caucasian faces). Future studies should further investigate whether our research can be generalized to faces of other races and other ethnic samples.

Chapter 4. STUDY 2: ERP CORRELATES OF IMPLICIT PROCESSING OF OWN- AND OTHER-RACE FACES IN CHILDREN

4.1. Introduction

Whereas in the adult and infant populations the ORE has been reliably found, in the child population the ORE proved more elusive, and its neural substrate received only partial investigation. Behavioral studies yielded mixed findings, mostly between 4 and 7 years of age (see Chapter 1.3), leaving 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 and fMRI studies revealed a *neural* ORE in children, which consistently increased with age (see Chapter 2.1.2). 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. In this study, Anzures et al. (2022) examined early (P100, N170) ERP effects and found larger P100 amplitudes to other- than own-race faces, with no difference between 5-7-, 8-10-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 further insights into its implicit and unconscious (i.e., non-strategic) functioning, we adopted the same paradigm that we used with adult participants

(Study 1), but including only the masked condition. 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 study to address the ERP correlates of the implicit and unconscious ORE in children. Here, 6- to 7-year-old children performed the masked priming paradigm. 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 as compared to non-identical 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.

In adults (Study 1), race affected all examined ERP stages (P100, N100, N200, 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, owing to the prevalent evidence for an increasing ORE from childhood to adulthood. However, we also expected priming, race, and interaction effects at different stages as compared with adults, considering the mixed literature, no prior similar investigation in children, and the unprecedented approach.

4.2. Method

4.2.1. Ethics statement

The experiment was approved by the local Ethical Committee of the School of Psychology of the University of Padua, Italy, and it was run in accordance with the "Italian Association of Psychology" (AIP) Ethical Guidelines (Codice Etico:

www.aipass.org/node/11560) and the Declaration of Helsinki. Both parents or caregivers provided informed consent for the participation of their child/children and received no monetary compensation.

4.2.2. Participants

Nineteen 6- to 7-year-old children of Caucasian ethnic background (8 females; M age = 6.31 yrs, SD = 0.48 yrs; twins = 2 pairs) participated in the study. An additional two 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. Participants were all first- or second-graders of primary schools in Modena, Italy. They were recruited through the collaboration of local schools and advertisements at the University of Modena and Reggio Emilia. Fifteen children were right-handed and four ambidextrous, as assessed with an Italian version of the Edinburgh Handedness Inventory (Oldfield, 1971). All had normal or corrected-to-normal visual acuity. All children reported no history of neurological or psychiatric disorders, but one, who reported a 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 two months: n = 4, or two years: n = 2); among these, one participant also reported a life-long contact with an Asian nursemaid.

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, 2021). With a sample size of 19 participants and an alpha level set to 0.05, our analyses yielded 80% power to detect effects as small as $\eta_p^2 = 0.33$, and 50% power to detect effects as small as $\eta_p^2 = 0.19$. We consider that effects bigger than $\eta_p^2 = 0.33$ could be

plausible for the main effects (Race, Identity) [in adults, using same stimuli and paradigm, we observed a η_p^2 range of 0.25 – 0.54 for main effects (Study 1), but in children, using similar stimuli and a different design, Anzures et al. (2022) observed a $\eta_p^2 = 0.07$ for the main effect of race]. However, they seem less plausible for an interaction (Race x Identity) effect [for which η_p^2 range was equal to 0.10 – 0.26 in adults (Study 1)]. Thus, we deem that our study could be informative for main effects but could be underpowered for interaction effects.

Considering the limited sample size, to help discern absence of evidence from evidence of absence for statistically non-significant 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 section "4.2.5. Statistical analyses" below). This analysis was not performed in adults (Study 1). Critically, no study so far investigated the neural time course of own- and other-race face processing in children, thus our study provides the first evidence with this respect. Effect sizes and confidence intervals can be useful to conduct future meta-analyses.

4.2.3. Stimuli

88 pictures of adult faces, 44 Caucasian and 44 Asian, 50% of each female, were used in the experiment. All face stimuli were previously used in Study 1. They were previously selected to be prototypical of both race and gender, as rated by adult samples (see details in Chapter 3.2.3), but were further rated for race and gender reliability by two samples of age-matched Caucasian children [for the race survey: n = 48 (23 females, age range = 5-7 yrs, M = 6.40 yrs, SD = 0.54 yrs); for the gender survey: n = 36 (18 females, age range = 5-7 yrs, M = 6.42 yrs, SD = 0.55 yrs)]. In the race survey, participants rated how much each face was associated with a Caucasian or an Asian face; in the gender survey, they rated how much each face was associated with a female or a male face. Both surveys consisted of a seven-point Likert scale ranging from 1 – Caucasian/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 Caucasian 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 Caucasian faces did not differ for gender reliability (the task-relevant dimension) (female faces: M Asian = 2.12, SD = 1.16; M Caucasian = 1.56, SD = 1.24; male faces: M Asian = 6.67, SD = 0.57; M Caucasian = 6.95, SD = 0.05; ps > .10).

As in Study 1, face stimuli appeared as prime and target stimuli in the priming paradigm. Specifically, prime-target pairs were either Same-face pairs (prime and target were identical faces) or Different-face pairs (prime and target were different faces), half of each Caucasian (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: 1. Own-race Same; 2. Own-race Different; 3. Other-race Same; 4. Other-race Different. In the present experiment, differently from Study 1, only a masked (and not an additional unmasked) priming condition was used. Thus, a masking stimulus (i.e., a scrambled picture of a face) preceded and followed the prime face in each trial.

Across the whole experiment, each face was repeated four times as the target (twice preceded by an identical prime, twice preceded by a different prime) and four times as the prime (twice followed by an identical target, 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 Caucasian, 50% female for each category, were used in a practice block preceding the experiment. These faces were not used in the main experiment.

4.2.4. 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 the child for the entire duration of the experiment and provided occasional support. An example of the stimulus presentation procedure is illustrated in Figure 4.1.
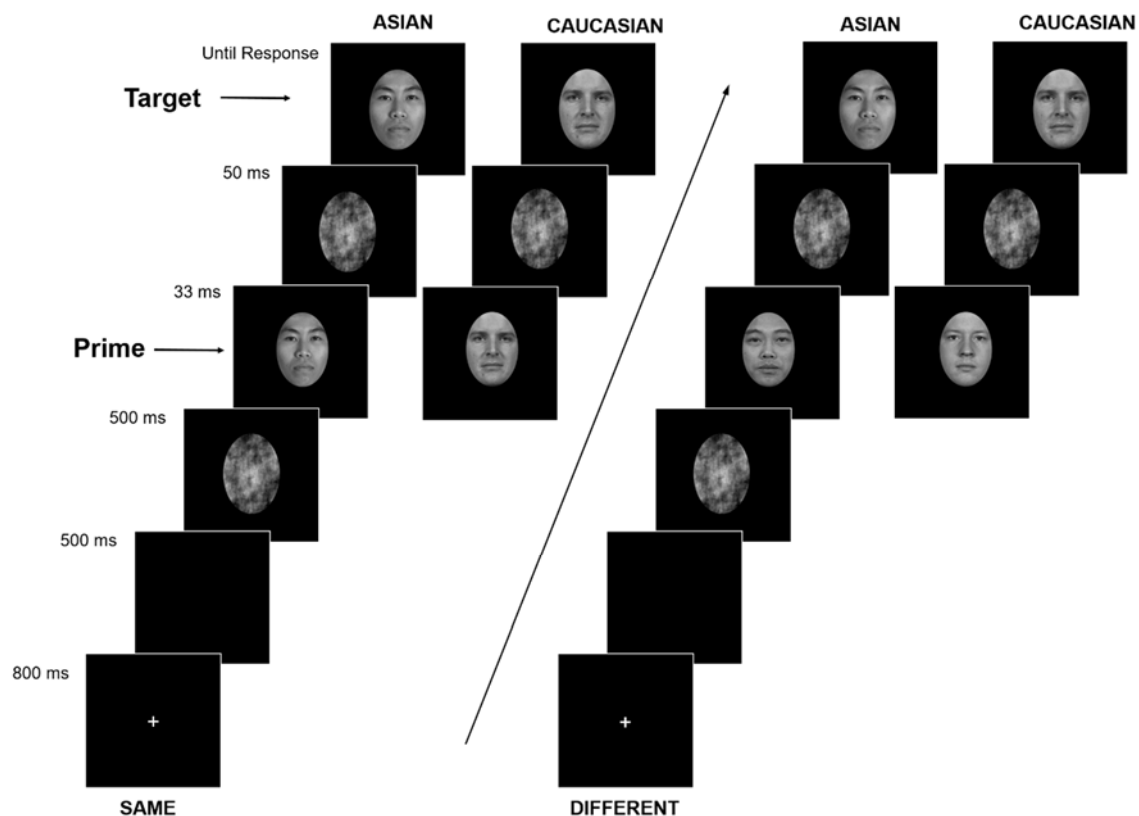
Figure 4.1. Schematic depiction of the masked priming procedure used in the present experiment.

Experimental setup and stimulus presentation was the same as in Study 1 (see "Method" section of Study 1, i.e., Chapter 3.2.4, 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 the 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 it 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 were expected to make masking effective and to prevent participants from consciously perceiving the primes.

Participants were asked to indicate, as quickly and accurately as possible, whether each target face was a female or a male face. They responded by pressing one of two keyboard keys, "c" or "m", with their left or right index, 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". Data of no participant had 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 thirty-five adult participants (see Study 1). As adults performed a gender categorization task on the *prime* faces, 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.

4.2.5. EEG recording and analysis

As in Study 1, 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 four electrodes were used, two were placed over the left and right mastoids and two 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 two additional electrodes

placed close to Cz, the Common Mode Sense [CMS] and the Driven Right Leg [DRL] electrode. EEG and EOG signals were recorded with a sampling rate of 512 Hz. EEG signal was analyzed off-line using BrainVision Analyzer (Version 2.2.0; Brain Products, Gilching, Germany). EEG signal was band-pass filtered between 0.1 and 30 Hz (instead of between 0.1 – 80 Hz as in Study 1) using a zero-phase IIR Butterworth band-pass frequency filter (12dB/oct roll-off, 3dB cutoff frequencies, two-pass). A notch filter at 50 Hz was applied only to subjects that showed power line noise. EEG signal was referenced off-line 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 4 non-noisy nearby channels. A maximum of 2 channels was interpolated per participant (representing the 6.67% of the channels). EEG signal was corrected for eye movements using a restricted infomax ICA (Bell & Sejnowski,1997), using a meaned slope detection algorithm (Gratton et al., 1983). 1000ms epochs time-locked to the target face were extracted and baseline corrected using a 200 ms pre-stimulus baseline. Epochs were rejected if they contained portions of the signal with voltage steps > 75µV, absolute voltage difference in 200ms > 200µV, activity in 50ms < 0.5µV, and voltage > ±120 µV (see Solomon et al., 2012) (note, more stringent criteria were used in Study 1). 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); Own-race Different = 52.37 (SD = 11.01; range = 33-73); Other-race Same = 47.68 (SD = 14.66; range = 25-74); Other-race Different = 47.95 (SD = 12.10; range = 27-68)]. ERP components were identified for target onset at frontal (F3, Fz, F4), central (C3, Cz, C4), and parietal (P3, Pz, P4) scalp sites, as in Study 1. Based on visual inspection of the grand average ERP waveform and in line with previous literature (Bayet et al., 2021; 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; N200

from 360 to 450 ms; P300 from 450 to 800 ms. For each ERP component amplitude was measured as mean activity within the respective time window. As for Study 1, the N170 component could not be identified, possibly owing to the attenuation of the activity at temporo-parietal sites due to the use of an average mastoid reference.

4.2.6. Statistical analyses

Statistical analyses were performed in JASP (JASP Team, 2022). Behavioral analyses were carried out on individual trials with response times > 200 ms and < 3500 ms (as in Roch et al., 2020) representing the 96.54% of trials, to avoid anticipatory and late responses. Analyses of response times (RTs) and ERP analyses were carried out only on trials with correct responses. Response accuracy, calculated as the percentage of correct responses, and response times (RTs), calculated as the mean of the individual reaction times (RTs) in milliseconds, were submitted to repeated-measure analyses of variance (ANOVAs) with two within-subject factors: Race (other-race, own-race) and Identity (same, different). ERP effects time-locked to the onset of the target face were evaluated at Anterior (F3, Fz, F4), Central (C3, Cz, C4), Posterior (P3, Pz, P4), Left (F3, C3, P3), Midline (Fz, Cz, Pz) and Right (F4, C4, P4) locations. Mean ERP amplitudes were submitted to repeated-measure ANOVAs with four within-subject factors: Race (other-race, own-race), Identity (same, different), Latitude (left, midline, right), and Longitude (anterior, central, posterior). Greenhouse-Geisser correction for degrees of freedom was applied for sphericity violation. Post-hoc repeated measure t-tests were performed for single-level comparisons, with Holm-Bonferroni corrected p-values. Only corrected p-values were reported. The level of significance testing was $p = 0.05$. 90% confidence intervals 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 not reported. To complement the ANOVA results, with the aim of disambiguating between evidence of absence and absence of evidence for null results, we conducted Bayesian repeated

measures ANOVAs. We kept defaults priors for ANOVA design (Cauchy distribution with a scale parameter of r = 0.5 for fixed effects, and 1 for random effects). We interpreted BF_{incl} between 1 and 0.33 as absence of evidence for either the null or the alternative model, and BF_{incl} below 0.33 as evidence for the absence of an effect (see e.g., Keysers et al., 2020).

4.3. Results

4.3.1. Behavioral results

Figure 4.2 shows the mean RTs and percent correct responses to target faces preceded by same and different prime faces. See Table 4.1 for mean and SD values per condition.
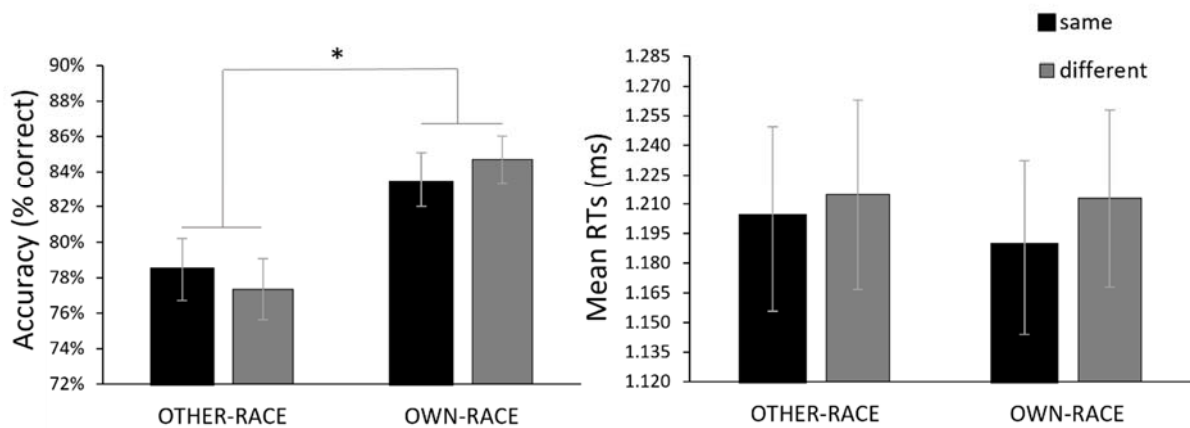
Figure 4.2. Mean response time (RTs) (right panel) and % correct responses (left panel) to target faces as a function of Race (own-race, other-race) and Identity (same, different). Error bars represent standard errors (SE) of the means. Statistically significant differences are marked by an asterisk.

The omnibus ANOVA performed on percentage of correct responses only revealed a significant main effect of Race [$F(1,18) = 20.38$, $p <.001$, $\eta_p^2 = 0.53$, 90% CI = 0.23, 0.68], indicating that children performed better at categorizing Caucasian (own-race) than Asian (other-race) target faces for the gender dimension; and a tendency for a Race x Identity interaction which did not reach significance level [$F(1,18) = 3.27$, $p = 0.09$, $\eta_p^2 = 0.15$, 90% CI = 0, 0.38]. Despite the tendency, post-hoc paired sample t-tests revealed better performance for Caucasian than Asian target faces irrespective of the prime. The main effect of Identity was

non-significant [$F(1,18) = 0.02$, $p = 0.89$, $\eta_p^2 = 0.001$, 90% CI = 0, 0.07]. A complementary Bayesian ANOVA comparing the models with the Identity or the Identity x Race effects to the next simpler models without these effects showed evidence for the absence of an Identity effect ($BF_{incl} = 0.24$), but inconclusive evidence for the presence or absence of an interaction effect ($BF_{incl} = 0.53$). The omnibus ANOVA performed on mean RTs showed no significant main effect of Race [$F(1,18) = 0.20$, $p = 0.66$, $\eta_p^2 = 0.01$, 90% CI = 0, 0.17], Identity [$F(1,18) = 2.00$, $p = 0.17$, $\eta_p^2 = 0.10$, 90% CI = 0, 0.32] or Race x Identity interaction [$F(1,18) = 0.20$, $p = 0.66$, $\eta_p^2 = 0.01$, 90% CI = 0, 0.17], with a complementary Bayesian ANOVA showing evidence for the absence of a Race effect ($BF_{incl} = 0.26$), but inconclusive evidence for the presence/absence of the Identity or the interaction effect ($BF_{incl} = 0.41$ and 0.34, respectively).

Hence, children performed better at gender-categorizing Caucasian own- than Asian other-race faces but took the same time to generate their response. Thus, in speed-accuracy trade-off, an other-race effect for gender categorization emerged in children. The masked priming procedure elicited no clear behavioral effects in terms of response time and accuracy. In addition, behavioral data offered no clear support for the presence or absence of a modulation of the priming by race or vice versa.

Table 4.1. Mean and standard deviation (SD) of response times (RTs) and percentage of correct responses to target faces as a function of Race (own-race, other-race) and Identity (same, different).

	Response times (RTs)	
Conditions	*M (ms)*	*SD (ms)*
Own-race Same	1188.94	189.81
Own-race Different	1212.90	196.47
Other-race Same	1203.81	199.88
Other-race Different	1214.80	210.02
	Accuracy (% correct)	
Conditions	*M (%)*	*SD (%)*
Own-race Same	83.36	7.58
Own-race Different	84.71	5.83
Other-race Same	78.43	7.80
Other-race Different	77.34	7.50

4.3.2. ERP results

Grand-averaged ERP waveforms elicited by the target faces in the different experimental conditions are represented in Figures 4.3 and 4.4.
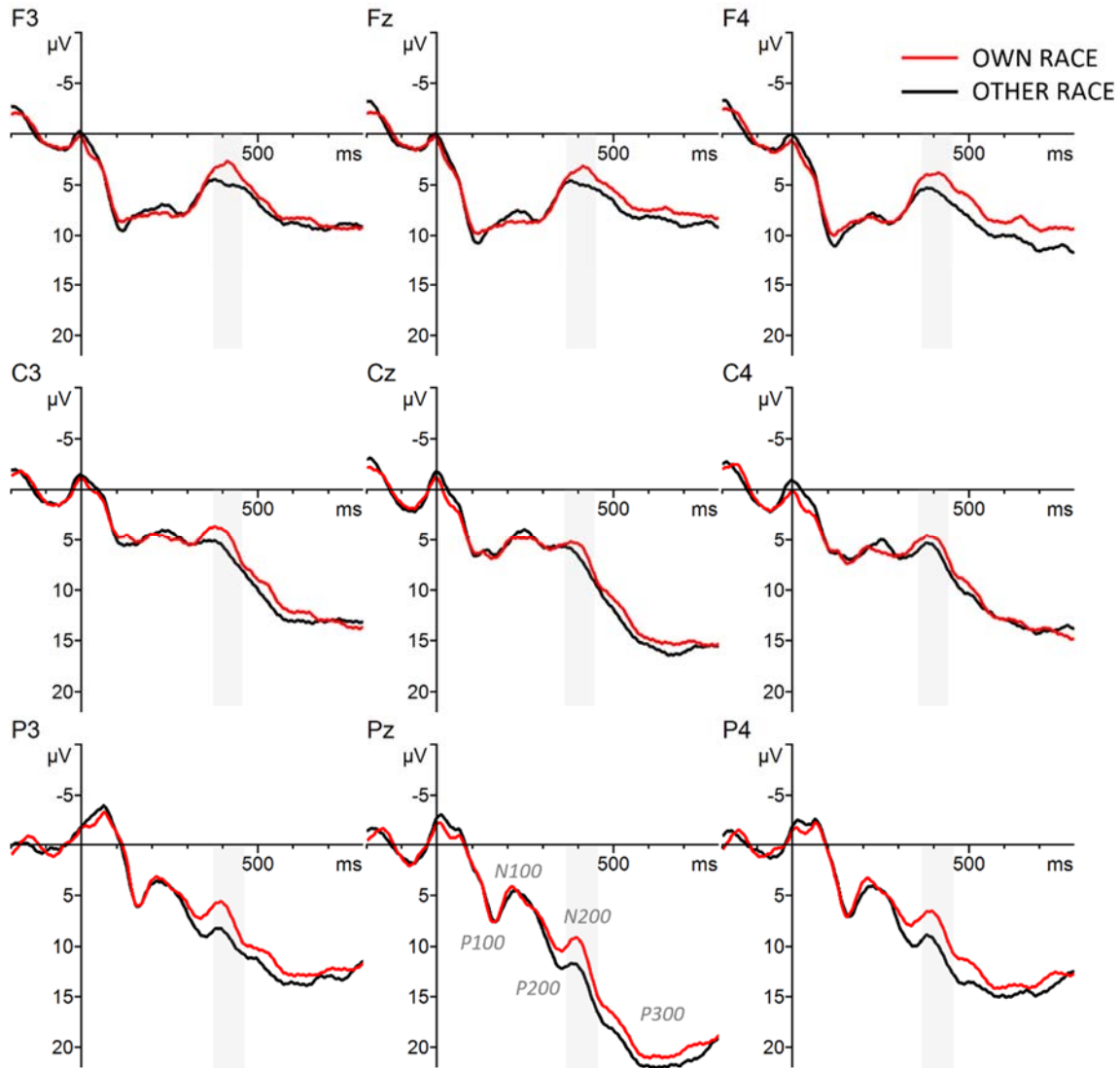
Figure 4.3. Grand-averaged ERP waveforms elicited by OWN- (in red) and OTHER- (in black) RACE target faces in (n=19) 6- to 7-year-olds in the context of a masked priming paradigm. Shaded in grey is the time window of the N200 ERP component (360-450ms), which revealed a significant effect of race. Target onset coincides with the intersection between the y axis and the x axis. Displayed waveforms are low-pass filtered to 20Hz for display purposes.
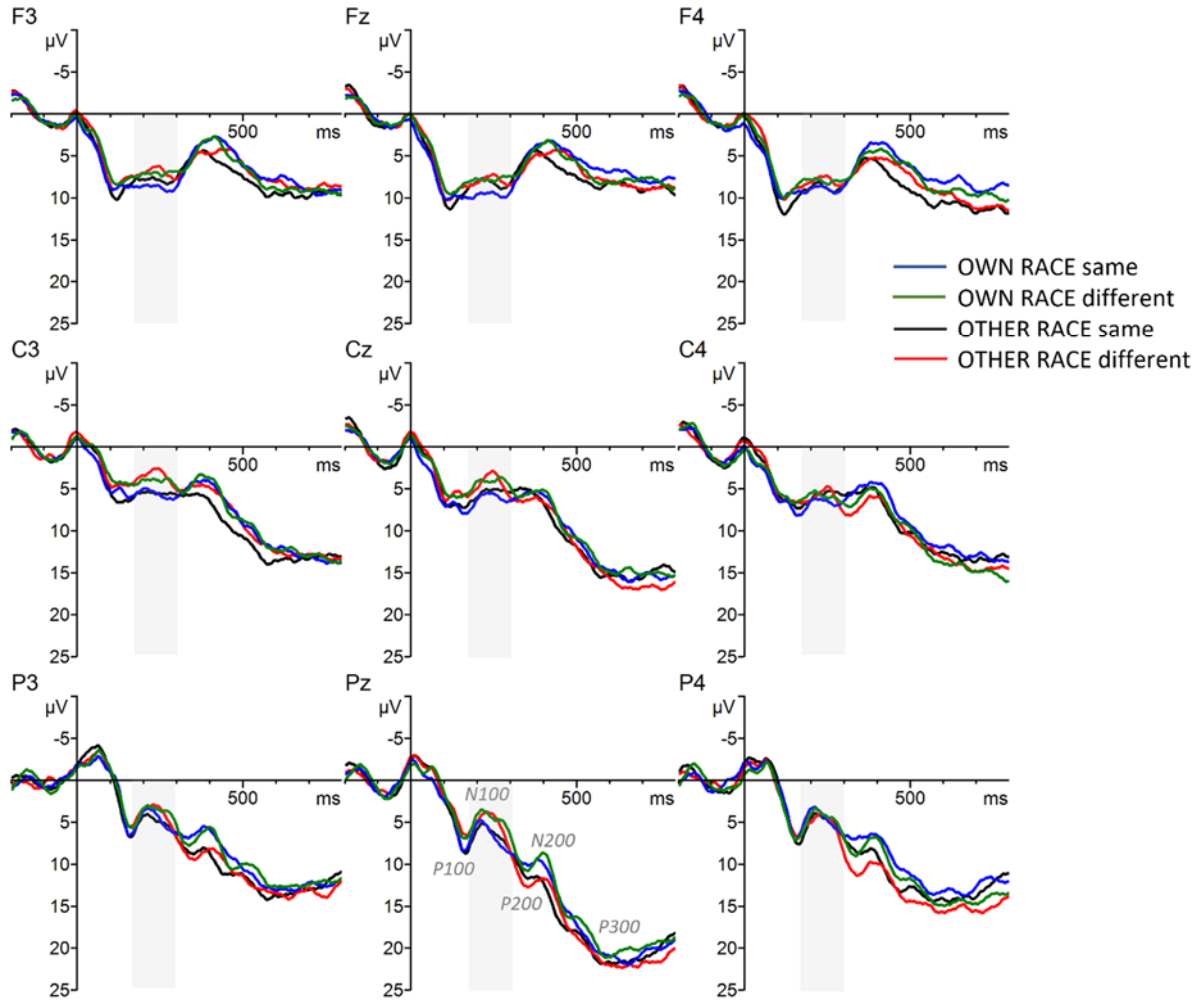
Figure 4.4. Grand-averaged ERP waveforms elicited by OWN- and OTHER- RACE target faces preceded by SAME and DIFFERENT prime faces (Identity condition) in (n=19) 6- to 7-year-olds in the context of a masked priming paradigm. Target onset coincides with the intersection between the y axis and the x axis. Shaded in grey is the time window corresponding to the N100 ERP component (180-300ms), for which a significant effect of Identity (i.e., priming) was found. Displayed waveforms are low-pass filtered to 20Hz for display purposes.

4.3.2.1. P100

The omnibus ANOVA performed on the P100 amplitude showed a trend for a main effect of Identity, which did not reach significance level [$F(1,18) = 3.10$, $p = 0.09$, $\eta_p^2 = 0.15$, 90% CI = 0, 0.37], indicating more positive amplitudes to target faces preceded by same (μV = 6.52, SE = 1.02, 95% CI = 4.40, 8.65) as compared to 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 to 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

75

interest to the study reached significance [Race: $F(1,18) = 0.12$, $\eta_p^2 = 0.007$, 90% CI = 0, 0.15; Race x Identity: $F(1,18) = 0.006$, $\eta_p^2 = 3.2223e\text{-}4$, 90% CI = 0, 0.02] (all ps >.10). A complementary Bayesian ANOVA showed evidence for the absence of the main effect of Race or Race x Identity interaction ($BF_{incl} = 0.10$ and 0.12, respectively). Hence, face race did not affect the P100 amplitude, nor it influenced 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.

4.3.2.2. N100

The omnibus ANOVA on the successive N100 amplitude showed a significant main effect of Identity [$F(1,18) = 4.90$, $p = 0.04$, $\eta_p^2 = 0.21$, 90% CI = 0.005, 0.44], indicating more negative amplitudes to target faces preceded by different ($\mu V = 5.53$, SE = 1.11, 95% CI = 3.20, 7.85) than same ($\mu V = 6.61$, SD = 1.11, 95% CI = 4.28,8.93) prime faces. The effect was characterized by a trend for the Identity and Latitude interaction of Identity and Latitude, which did not reach statistical significance level [$F(1.27,22.79) = 2.82$, $p = 0.099$, $\eta_p^2 = 0.13$, 90% CI = 0, 0.33], indicating more negative amplitudes to target faces preceded by different prime faces in the left ($\mu V = 4.81$, SE = 1.15, 95% CI = 2.42, 7.20) than target faces preceded by same prime faces in the middle region ($\mu V = 7.03$, SE = 1.15, 95% CI = 4.64, 9.42) ($p = 0.03$). No other effect of interest to the study reached significance [Race: $F(1,18) = 0.05$, $\eta_p^2 = 0.003$, 90% CI = 0, 0.11; Race x Identity: $F(1,18) = 0.28$, $\eta_p^2 = 0.02$, 90% CI = 0, 0.19] (all ps > .10). A complementary Bayesian ANOVA showed evidence for the absence of a main effect of Race or Race x Identity interaction ($BF_{incl} = 0.10$ and 0.15, respectively). Thus, target faces elicited greater N100 amplitudes when primed by a different-identity as compared to the same-identity face, irrespective of the racial belonging. This neural priming effect confirmed that the masked priming procedure was effective.

4.3.2.3. P200

The omnibus ANOVA on the P200 amplitude showed no statistically significant effect of interest to the study [Race: $F(1,18) = 0.54$, $\eta_p^2 = 0.03$, 90% CI = 0, 0.22; Identity: $F(1,18) = 1.65$, $\eta_p^2 = 0.08$, 90% CI = 0, 0.30; Identity x Race: $F(1,18) = 0.19$, $\eta_p^2 = 0.01$, 90% CI = 0, 0.17] (all ps >.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 evidence for the absence of an Identity x Race interaction ($BF_{incl} = 0.17$). 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.

4.3.2.4. N200

The omnibus ANOVA on the N200 amplitude revealed a significant main effect of Race [$F(1,18) = 4.88$, $p = 0.04$, $\eta_p^2 = 0.21$, 90% CI = 0.005, 0.44], indicating more negative amplitudes for Caucasian (own-race) ($\mu V = 5.69$, SE = 1.11, 95% CI = 3.39, 7.99) than Asian (other-race) ($\mu V = 7.39$, SE = 1.11, 95% CI = 5.09, 9.69) target faces. No other effect of interest to the study reached significance level [Identity: $F(1,18) = 0.03$, $\eta_p^2 = 0.002$, 90% CI = 0, 0.09; Identity x Race: $F(1,18) = 0.18$, $\eta_p^2 = 0.01$, 90% CI = 0, 0.17] (all ps > .10). A complementary Bayesian ANOVA showed evidence for the absence of the main effect of Identity or Identity x Race interaction ($BF_{incl} = 0.08$ and 0.17, respectively). Hence, Caucasian own-race faces elicited larger N200 amplitudes as compared to Asian other-race faces, irrespective of the priming.

4.3.2.5. P300

The omnibus ANOVA on the P300 amplitude revealed no significant effect of interest to the study [Race: $F(1,18) = 0.98$, $\eta_p^2 = 0.05$, 90% CI = 0, 0.26; Identity [$F(1,18) = 0.10$, $\eta_p^2 = 0.006$, 90% CI = 0, 0.14, 90% CI = 0, 0.14; Race x Identity: $F(1,18) = 0.09$, $\eta_p^2 = 0.005$, 90%

CI = 0, 0.14] (all ps > .10). A complementary Bayesian ANOVA showed evidence for the absence of an Identity or an Identity x Race interaction effect (BF_{incl} = 0.09 and 0.12, respectively), but 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 any effect of priming was different according to the face race. Evidence was inconclusive for the presence/absence of a race effect on the P300 amplitude.

4.4. Discussion

This study is the first after Anzures et al. (2022) to investigate the time course of the neural ORE 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 Caucasian 6- to 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/non-identical 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 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 a behavioral level, investigations provided contrasting evidence for an ORE, with the largest incongruency for the age range between 4 and 7 years old (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 a fNIRS study, Asian 7- to 13-year-olds showed greater neural activity in frontal (right MFG/IFG) and

occipital (left cuneus) brain areas when recognizing other-race (Caucasian) 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 (Caucasian) than own-race faces, but stronger causal connections between occipital and frontal areas and within the occipital area when recognizing own- than other-race faces (Zhou et al., 2016). In an fMRI study, Caucasian 12- to 16-year-olds and adults, but not 7- to 11-year-olds, showed greater activation in the fusiform face area (FFA) to own- than other-race (African American) faces while performing a one-back task (Golarai et al., 2021). In the only ERP study, Caucasian 5- to 10-year-olds showed larger P100 amplitudes to other-race (Asian) than own-race faces, when faces were implicitly processed (task of detecting 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- to-7-years-old children. This effect manifested as an increased amplitude of the N200 component for own- than 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, 2022 for a review), and it replicates the effect we found in adults using the same paradigm and stimuli (Study 1). The N200 race effect has been generally interpreted as reflecting greater attention allocation to own- than 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 lead to deeper processing of own-race faces. Of note, this occurred even though race was task-irrelevant, as also 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- than other-race target faces by gender, as we observed in this study. This "other-race" effect for the gender categorization is known in literature and 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., 2022). Differential perceptual experience with own- and other-race faces or the overlap of phenotypic (or stereotypic) cues between race and gender categories (e.g., female faces sharing more phenotypic cues with Caucasian 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. 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 than greyscale 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. Overall, the N200 race effect confirms that face race is implicitly encoded by the child'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- to 7-year-old children. A priming effect, i.e., a differential responding to the same target when preceded by identical as compared with non-identical 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 180-300 ms from target onset, with larger amplitude to target faces preceded by different than 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 non-consciously 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 same paradigm and stimuli (Study 1). However, in Study 1 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- to-7-year-old children could be similar, rather supporting behavioral evidence showing no ORE at this age range.

Another important aspect which 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 across childhood (Sangrigoli & de Schonen, 2004a) 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 FFA 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 present study) to adulthood (Study 1). 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, P300), whilst in children the effect was limited to the N200 time window. This result, together with the results from Anzures et al. (2022), suggest that in children race might exert a limited early (attentional, perceptual) impact, whilst in adults it might exert a broader impact, possibly spanning more cognitive processes. Second, in adults (Study 1) 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- than own-race faces. We interpreted this seemingly counterintuitive finding 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 present 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- to 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, while individual other-race faces would be more densely clustered together. Since masked priming has been attributed, among other mechanisms, to the pre-activation of the target representation by the prime (for the prime's dimensions that can be activated unconsciously) (Marcel, 1983; Schnyer et al., 2002), a modulation by race could

82

indicate that the activation of the identity representation differed. Our findings could suggest that in 6- to 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; Nishimura et al., 2009) in childhood. However, these findings could also fit alternative accounts of the ORE. Referring to socio-cognitive models, they could indicate that ingroup and outgroup faces are automatically and unconsciously processed at a comparable depth in 6- to 7-year-olds (Rodin, 1987); or that attention is automatically directed to the identity of own- and other-race faces alike in 6- to 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 the sample are the limited size and the inclusion of a single racial group (Caucasian). Both limitations are due to the difficulty of recruiting children for EEG experiments. The use of a small sample size could impact the interpretation of the null findings: the lack of an interaction between race and priming could owe to low power rather than absence of an effect. However, results from additional Bayesian analyses support the absence of the interaction effect. Similarly, the use of a single racial sample could undermine the generalizability of the effect across racial groups. Results may be specific to Caucasian perceivers or be driven by differences between Asian and Caucasian face stimuli besides their racial belonging. However, our review of the ERP correlates of the ORE (Serafini & Pesciarelli, 2022) showed typically converging evidence from cross-racial and non-cross-racial studies, also for the N200 race effect, suggesting that is it unlikely to be the case. 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 was obtained from adults using same stimuli and procedure (Study 1). Last, the finding of an ORE for gender categorization, beside its interest, raises the possibility that our N200 result is due to difficulty alone. While this is possible because the N200 has been also associated with task difficulty (Senkowski & Hermann, 2002) and conflict monitoring (e.g., Dickter & Bartholow, 2010), we deem that it unlikely because our effect (larger amplitude in the easier condition, i.e., own race) is opposite in direction as compared with typically reported effects.

Overall, our results provide a preliminary insight about 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-race and other-race faces in 6- to 7-year-old children. Altogether, our findings seem to suggest that the ORE in 6- to 7-year-old children could be still 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.

GENERAL DISCUSSION

The broader aim of the present thesis was to acquire knowledge about the implicit or spontaneous occurrence of the phenomenon of the other-race effect (ORE) for face processing. This thesis focused on the ORE in its developmental and mature form. Here, a novel approach was adopted to investigate the ORE, providing evidence for the phenomenon at an implicit (i.e., without intentionality) and unconscious (i.e., without awareness) level. Previous studies suggested that (own-race) faces can be processed for identity automatically/implicitly (Caharel et al., 2009; Liu-Shuang et al., 2014; Retter et al., 2021; Yan et al., 2017; Zimmermann et al., 2019) and unconsciously (e.g., Henson et al., 2008). Here, we investigated if and how the implicit and unconscious processing of face identity differs between faces of the own and the other race.

To this aim, we used the unmasked and, critically, the *masked* priming paradigm combined with EEG recording. This method was preferred to other methods because, (i) the unmasked condition (i.e., visible prime) allowed to examine if identity processing differed between own- and other-race faces at an implicit level (task focused on target gender); (ii) the masked condition (i.e., non-visible prime), further allowed to see if identity processing differed between own- and other-race faces at an unconscious level. Of note, the identity and the race dimensions of the faces were readily available on the target faces, but a facilitation of the target processing could only occur if the identity of the *prime* face was implicitly, and unconsciously, processed. Further, a difference in this facilitation effect between own- and other-race faces could only occur if race implicitly and unconsciously affected face identity processing.

The EEG was used in combination with behavioral measures, given that it is more sensitive than response time and accuracy measures. Indeed, the EEG provides a continuous measure from face presentation to response generation at the millisecond resolution and in

addition, can provide information about the underlying mechanisms, given that the continuous EEG signal can be parceled into ERP components, which are partially associated to different cognitive/affective processes.

Using this approach, we investigated the ORE both in adults (Study 1) and in 6- to 7-year-old children (Study 2). Our results, summarized in Box 1 and 2, allowed us to respond to our research questions at least partially.

Box 1. Summary of the results from Study 1.

IN ADULTS (Study 1), we found:

At the behavioral level:
- a race effect on the response times, showing faster responses to gender-categorize own- than other-race target faces
- a priming effect, showing faster responses to same than different prime-target pairs

At the neural level:
- an effect of face race (Asian vs. Caucasian) on all ERP components analyzed (P100, N100, N200, P300)
- a priming effect as a function of face race on the N100, N200 and P300, in the unmasked condition, on the P300 exclusively, in the masked condition
- specifically, <u>race affected the priming effects</u> in this manner:
    - in the unmasked condition: the priming effect on the N100 was found exclusively for own-race faces, on the N200 in the anterior-left-midline area exclusively for other-race faces, and on the P300 more prominently for other- than own-race faces
    - in the masked condition: the priming effect on the P300 was more prominent for other- than own-race faces
    - on the P300, the effect of race on the priming was more pronounced in the unmasked compared with the masked condition

Box 2. Summary of the results from Study 2.

IN CHILDREN (Study 2)*, we found:

At the behavioral level:
- a race effect on the accuracy, showing more accurate responses to gender-categorize own- than other-race target faces

At the neural level:
- an effect of face race (Asian vs. Caucasian) on the N200 ERP component
- a priming effect on the N100 ERP component

But, we did <u>not</u> find:
- a race impact on the priming effect on any ERP component examined (P100, N100, P200, N200, P300)

*Note, in this study only the masked condition was used.

In the adult population, the results broadly agreed with our hypothesis. Indeed, we found different priming effects as a function of race at the neural level. At the behavioral level, we did not find interactions between race and priming effects, suggesting that the neural measure was more sensitive than behavioral measures. From our results it is not possible to definitively isolate the mechanisms at the basis of the ORE. However, they are more easily interpretable within the perceptual expertise account, as they can indicate that the prime's identity is activated differently for own- and other-race faces. This could be due to perceptual or representational differences, such as reduced holistic perception (Rhodes et al., 1989; Tanaka et al, 2004; Michel Caldara et al., 2006; Michel, Rossion et al., 2006) or less distinct representation in memory (Valentine, 2001; Valentine et al., 2016) for other- than own-race faces, or both combined (Rossion & Michel, 2011). Specifically, the finding of an exclusive or more prominent neural priming effect for own-race faces (N100) could index an easier or more efficient activation of identity from own- race faces, which could determine stronger priming effects; oppositely, the finding of an exclusive or more prominent neural priming effect for other-race faces (N200, P300) could index a more difficult activation of identity from other-race faces, which could produce stronger priming effects. Results are also interpretable within a stream of the socio-cognitive account (Levin, 1996; 2000). Specifically, they could be interpreted in terms of attention differences or social categorization effects, but the finding of exclusive or more prominent neural priming effect for other-race faces (N200, P300) is less explicable within this account since perceivers should not have been motivated by the task to focus more on the identity of other-race faces.

In the child population, our hypothesis was twofold. Previous evidence was mixed both pertaining the presence of the ORE in childhood, specifically in the age range from 4 to 7 years old, and its developmental trajectory. Based on this evidence, we could find either a difference in the priming effect for own- and other-race faces, suggesting an adult-like ORE, or no or less

difference, suggesting a still immature ORE. Our findings offered preliminary proof in favor of the hypothesis that the ORE is still immature in childhood, since they showed no impact of face race on the priming effect neither at the behavioral nor at the neural level.

Main effects of race are also important to discuss in children, because, to the best of our knowledge, they provide the first evidence of the neural time course of face race processing in children, after the studies from Anzures et al. (2022) and Timeo, Mento et al. (2019). We found an N200 race effect, showing larger amplitude to own- than other-race faces, which indicates that race can exert an implicit impact on the child's brain. This effect possibly caused more accuracy in classifying own- than other-race faces by gender. The effect is in line with the direction of the effect in adults (see Serafini & Pesciarelli, 2022 for a review) and suggest deeper processing of own- race than other-race faces driven by selective attention.

Together the results from this thesis corroborate and expand previous knowledge on the ORE, by showing implicit and unconscious neural effects related to identity processing as a function of the racial belonging of the face.

STRENGTHS AND LIMITATIONS

The main strength of this thesis is that, to the best of our knowledge, it provides (i) the first evidence of the ORE at the *implicit and unconscious* processing level in adults and children, and (ii) the first comprehensive *neural* evidence of the ORE in children.

The use of the masked and unmasked priming procedure combined with the EEG recording allowed to tackle a complex research question and provided interpretable results. All our conclusions are based on the effective functioning of the priming procedure. In the last thirty years, a large debate surrounded the possibility of obtaining real priming effects when the prime is unconsciously perceived (Holender, 1986; Kinoshita & Lupker, 2003; Marcel, 1983). Several studies have provided credibility and reliability to this effect. These studies showed that unconscious priming can occur under certain circumstances, including a fast presentation of the prime (60-30 ms), the use of backward and forward masking, and the use of an objective measure of prime visibility (e.g., Beyersmann et al., 2019; Grainger & Holcomb, 2009; Holcomb & Grainger, 2006, 2007; Kiefer & Spitzer, 2000; Zhang & Damian, 2019). Using this foresight, many studies in the word recognition domain (Bowers et al., 1998; De Wit & Kinoshita, 2015; Dehaene et al., 2001; Peressotti et al., 2012; Pesciarelli et al., 2007) and in the face processing domain (Henson et al., 2008) used this paradigm to investigate the extraction of word or face properties occurring at the absence of awareness. Here, we used this paradigm as a tool to investigate the extraction of identity as a function of face race at the absence of awareness.

As a general limitation of this thesis, we aimed to study differences between own- and other-race faces, considering only a single own-race (i.e., Caucasian) and a single other-race (i.e., Asian) face category. This can be problematic because results could owe to low-level differences between the two conditions instead of high-level race distinctions. This is mainly

true for early visual components, such as the P100 and N100. In this thesis, low-level stimulus differences were minimized by converting color face stimuli to greyscale, by applying an oval pass-partout to the faces, and by checking luminance and contrast differences between the faces. In addition, most of our findings related to a later component, the P300, which should be less sensitive to low-level features. But we cannot totally exclude a possible influence of low-level features. Another concern of this sample choice is that, even assuming that the effects were high-level, they could reflect specific responses of Caucasians towards Asians, and could not generalize to all racial ingroups and outgroups. We recently reviewed the literature on the ERP correlates of the ORE across the lifespan (Serafini & Pesciarelli, 2022). In this review, we found some consistency between the effects found in cross-racial and non-cross-racial studies. Based on this evidence, our findings would likely agree with the ones we could obtain by including multiple own-race or multiple other-race face categories. This does not exclude the possibility that some results are specific to Caucasian observers or Asian faces, as the literature also suggests that this can occur for the race effect on some components.

This thesis also presents limitations that are specific to Study 1 or 2. These are mentioned in each discussion section, but here it is worth covering an important limitation of Study 2, which is the small sample size. This is important mostly because we base our interpretations on null findings. Null findings can occur for two reasons: either there was no effect, or there was not enough power to detect an effect. A sensitivity power analysis was performed a posteriori to determine the minimum effect size we could detect with 80% power. The effect size that resulted was realistic for the main effects, but less for the interaction effects according to the available literature. However, additional Bayes Factor analyses showed more evidence in favor of the absence of an effect. Thus, we can be more confident that the lack of a result is due to the actual absence of an effect. These results would need to be replicated to be fully confirmed.

ONGOING AND FUTURE DIRECTIONS

As an ongoing project, I am investigating differences in the implicit face individuation between own- and other-race faces in adults using a newly available paradigm, the frequency-sweep "oddball" fast periodic visual stimulation (FPVS), combined with EEG recording and Steady State Visual Evoked Potentials (SSVEPs) analysis.

This approach presents two main novelties as compared with the approach adopted in Study 1 and 2. First, whereas all projects use the EEG as a measure of the neural activity, Study 1 and 2 are based on the analysis of the ERPs, whilst the present project is based on the analysis of the SSVEPs (Regan, 1966). Like ERPs, SSVEPs are neural responses to events or stimulations; but, whereas the ERPs require the stimulations to be separated by a relatively long temporal interval to allow a return to baseline, SSVEPs are oscillatory periodic neural responses synchronized to a fast and constant stimulation frequency. Second, in Study 1 and 2, we used the priming paradigm, whereas in the present study we use the "oddball" fast periodic visual stimulation (FPVS) paradigm (Liu-Shuang et al., 2014).

In the context of face individuation studies, this paradigm consists in presenting same-identity unfamiliar faces (i.e., the "base") at a fast constant frequency F (i.e., 6 Hz) and in introducing different-identity unfamiliar faces (i.e., the "oddball") every *nth* base face, i.e., at a frequency of F/*n* (e.g., every 5th base, 1.2 Hz). This rapid visual stimulation should entrain a neural synchronization (i.e., SSVEPs) at the rate of stimulus presentation (i.e., the base rate). If the brain discriminates the facial identities, the oddball stimuli should also trigger a neural synchronization at the rate of the oddball presentation. Thus, the neural synchronization to the oddball frequency represents an implicit measure of individuation (i.e., facial identity discrimination). The mechanism at the basis of this effect could be a combination of neural adaptation, due to the repetition of the base, and release from adaptation, due to the identity

change. The extent of the neural synchronization is measured as the amplitude of the peak at the stimulation frequency and its harmonics (i.e., 2F, 3F, etc.) in the frequency domain of the EEG.

In this project, we used a variant of the "oddball" FPVS, called "frequency-sweep" oddball FPVS (Retter et al., 2021). In this variant, instead of presenting the base at a single frequency (typically, 6 Hz), the base is presented at progressively decreasing frequencies within the same stimulation sequence, in a number of steps from very high (e.g., 40 Hz or 25 ms presentation) to very low (e.g., 3 Hz or 333 ms presentation) frequencies. Identity changes are introduced at a stable lower "oddball" frequency (e.g., 1 Hz) (see Figure 5.1). Retter et al. (2021) used this approach to investigate the minimal and the optimal frequency (or stimulus presentation time) at which the visual system can discriminate face identity. They reported that for own-race faces the minimal frequency for face individuation could be 20 Hz and the optimal could be 6 Hz.
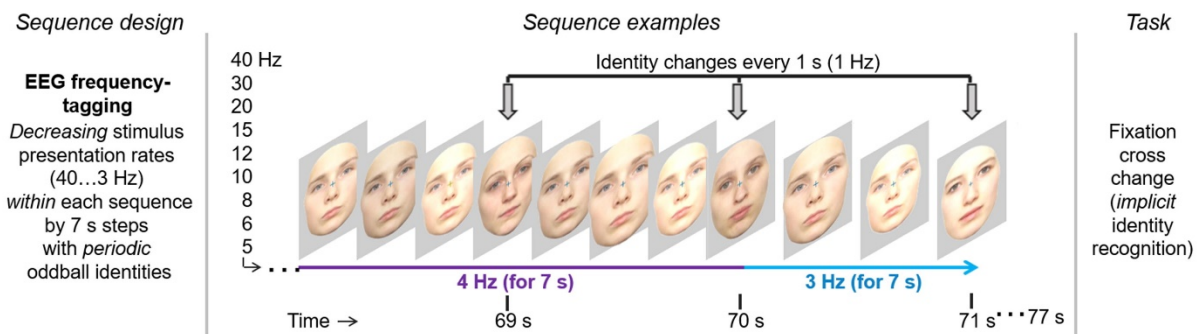
Figure 5.1. Example of a frequency-sweep oddball FPVS. Adapted from Retter et al., (2021).

In the present project, we aimed at examining if individuation of own- and other-race faces occurs differently depending on the stimulation frequency (or presentation time). Considering the literature on the ORE, suggesting decreased identity discrimination for other-race faces (e.g., Vizioli, Rousselet et al., 2010), we expected a decreased neural synchronization for other- as compared with own-race faces. Further, considering that memory

for other-race faces "suffers" more than memory for own-race faces of the constraints imposed on processing time (Marcon et al., 2009; Zhou et al., 2018), it seems possible that face individuation would take more time and processing effort for other- than own-race faces. If this is the case, we expected face individuation to occur at higher frequencies for own- as compared with other-race faces. To test this hypothesis, we used the same procedure as Retter et al. (2021) but comparing own- and other-race faces and using a frequency sweep between 20 Hz and 5 Hz, instead of 40 Hz to 3 Hz. We limited the frequency range since this was the range which showed significant and increasing face individuation in Retter et al. (2021) for Caucasian faces, and we expected the individuation response to other-race faces to fall within this frequency range as well. Data collection and analysis is still in progress.

The use of the oddball FPVS presents some advantages as compared with the more traditional ERP approach. First, responses of interest can be isolated unambiguously from the the rest (noise), whereas ERP results depend on procedural choices, such as time-window for the components, activity measured as baseline-to-peak, or peak-to-peak. Second, this method has a high signal to noise ratio (SNR) such that oddball FPVS responses can be obtained with as few as four sequences of 60 seconds each. It also presents some advantages specific to our research question. The oddball FPVS paradigm allows to implicitly investigate face individuation, because face individuation is inferred from the synchronization of the neural response to the oddball frequency. In our priming paradigm, face individuation was instead inferred from the influence an identical as compared with an non-identical prime face had on the target face at the behavioral or neural level. The FPVS approach present the advantage of measuring face individuation directly from brain activity with an impeccable signal to noise ratio.

Possible future directions are the application of the oddball FPVS to study individuation of own- and other-race faces in children. This paradigm is particularly suitable to investigate

the ORE in this population because of its high SNR. This allows: (i) faster recording time which can be important to test children because of their lower compliance; (ii) higher power to detect the signal of interest among the noise, which in children is typically high, mainly due to movement effects.

This technique also presents interesting similarities with the priming procedure, such as a possible shared neural mechanism (i.e., neural adaptation) or the possibility that fast presentation works as a masking procedure preventing conscious perception, which could be further exploited.

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