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Learning to perceive race: the development of different styles in processing own- and other-race faces.

Direttore della Scuola : Ch.ma Prof. ssa Francesca Peressotti ____________________

Supervisore :Ch.ma Prof.ssa Teresa Farroni ____________________

Dottoranda : Susanna Timeo

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ABSTRACT

The face is a key element in interpersonal relationships. Even just looking at a face we can get much information about our partner, such as sex, age and ethnicity. It has been shown that the latter feature has a great influence on the type of processing that is made up of a face and leads to poorer memory for faces of ethnic groups other than one's own (Other Race Effect-ORE). In this project I aim to investigate the perception of faces of different ethnic groups in relation to the more general framing systems of information processing (global / local or holistic / analytical): specifically, I wanted to find out if the ORE can be attributed to a more large model of perception and cognition. In my discussion I investigated the perception of the faces of other ethnic groups from both the behavioral and neural point of view. In my research project I have adopted a developmental perspective, comparing the development of the neural basis of ethnicity of infants and adults.

In Chapter 1 I have summarized the literature on the ORE and the perception of faces of different ethnic groups, with particular attention to the different styles of processing involved and their respective neural activations. In Chapter 2, the ORE and the perception of ethnicity have been described with a developmental perspective, focusing on results with infants of a few months old. In Chapter 3, I have exposed my own studies that aimed to a better understanding of the relation between different elaboration styles and the perception of faces of other ethnic groups. Study 1 investigated in more detail the relationship between the styles of processing (holistic / analytical) and ORE. Studies 2 and 3 have been taken in order to understand how contextual aspects, such as the simultaneous presentation of multiple faces and the coexistence of different ethnic groups, are capable to induce, on the one hand, a different recognition performance (Study 2) and, on the other hand, different scanning and attention patterns on faces of other ethnic groups (Study 3). In the last part of the discussion studies that have investigated the neural basis of perception of ethnicity through

the use of near-infrared spectroscopy have been presented. In the first two experiments (Studies 4 and 5), I have studied the link between neural activation for processing styles (holistic / analytical) and neural activation to the faces of different ethnicities in adults.

Finally, in the last study (Study 6) I have investigated the perception of ethnicity with a developmental perspective. I have, in fact, tested a group of infants of 5 months and 9 months to answer questions about when and how it changes the brain activation to the faces of another ethnic group. Finally, in the last chapter I have discussed the findings in the frame of the development of the social brain, integrating the results of my studies within the broader theoretical currents on the ORE and the perception of ethnicity.

RIASSUNTO

Il volto è l'elemento chiave nei rapporti interpersonali. Anche solo osservando un volto possiamo ottenere molte informazioni sul nostro interlocutore, come il sesso, l'età e l'etnia. Si è visto che quest'ultima caratteristica influisce molto sul tipo di elaborazione che viene fatta di un volto e porta ad un peggiore ricordo per i volti di etnie diverse dalla propria (Other-Race Effect-ORE). Il presente progetto ha indagato la percezione dei volti di diverse etnie in relazione del più generale framing dei sistemi di elaborazione di informazioni (globale/locale o olistica/analitica): nello specifico si è voluto capire se l'ORE possa essere ricondotto ad un più ampio modello percettivo e cognitivo. Nella mia trattazione ho investigato la percezione dei volti di altre etnie sia dal punto di vista comportamentale che da quello neurale. Nel mio progetto di ricerca ho adottato un'ottica evolutiva, comparando lo sviluppo delle basi neurali dell'etnia di infanti e adulti.

Nel Capitolo 1 viene riassunta la letteratura riguardante l'ORE e la percezione dei volti di diverse etnie con particolare attenzione ai diversi stili di elaborazione coinvolti e alle rispettive attivazioni neurali. Nel Capitolo 2, invece, l'ORE e la percezione dell'etnia vengono descritti in prospettiva evolutiva, concentrandosi sui risultati con infanti di pochi mesi di vita. Nel Capitolo 3 sono esposti gli studi da me condotti che hanno mirato a comprendere maggiormente la relazione tra gli stili percettivi e l'elaborazione di volti di altre etnie. Lo Studio 1 ha indagato in maniera più approfondita la relazione tra gli stili di elaborazione (olistico/analitico) e l'ORE. Gli Studi 2 e 3 hanno cercato di comprendere come aspetti più contestuali, come la presentazione simultanea di più volti e la compresenza di diverse etnie, possano portare, da un lato, ad una diversa performance riconoscitiva (Studio 2) e, dall'altro, ad un diverso pattern di scannerizzazione e di attenzione verso i volti di altre etnie (Studio 3). Nell'ultima parte della trattazione, infine, vengono esposti gli studi che hanno indagato le basi

neurali della percezione dell'etnia attraverso l'utilizzo della spettroscopia nel vicino infrarosso. In due primi esperimenti (Studi 4 e 5), ho studiato il legame tra l'attivazione neurale per stili di elaborazione (olistico/analitico) e l'attivazione neurale per i volti di diverse etnie. Infine, negli ultimi due studi (Studio 6 e 7) ho investigato la percezione dell'etnia in prospettiva evolutiva. Ho, infatti, testato un gruppo di infanti di 5 mesi (Studio6) e di 9 mesi (Studio 7) per rispondere ai quesiti su quando e come cambia l'attivazione cerebrale per i volti di un'altra etnia. In conclusione, l'ultimo capitolo discute i risultati in un'ottica di evoluzione del cervello sociale, integrando i risultati dei miei studi all'interno delle più ampie correnti teoriche sull'ORE e sulla percezione dell'etnia.

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Introduction

The face is the most complex, informative and socially relevant stimulus that each person has to deal with in her life. We interact with faces of different people every day. Faces are composed by 43 muscles and, as they move, they can interact in a variety of ways. They can form dozens of emotions, hundreds of expression, hundreds of thousands of words. In this dissertation I have focused the attention on one side of face-to-face interaction, that is perception. Although face perception could be seen as a partial and not exhaustive component of our everyday experience it is the very first and essential part to establish contact with other human beings. Even when they are still, faces can give us a lot of information, as the age, gender, race of the interlocutor, and can foster or inhibit our wish of interaction.

Specifically, in my research I focused the attention on a particular group of face, namely, other-race faces. As our world is increasingly becoming a mixture of different ethnicities and cultures, it is always more frequent to encounter people of other ethnic groups. However, too often, problems of social harmony and integration arise everywhere. In the domain of interethnic relationships, social psychologists have for long time highlighted phenomena as stereotype and prejudice (for a review see Fiske, Gilbert & Lindzey, 2010) that end up to undermine social peaceful cohesion. Differences in relating to other ethnic groups, however, seem to start way much earlier than that, and even at perceptual level we are not able to treat everyone equally (Meissner & Brigham, 2001). Studying the mechanisms that can bias the perception of the ethnicity, may help researchers to minimize the differences between own and other races at the very beginning of the interethnic relationship.

Moreover, Italy has been a recent destination of migrations and in the past few years, sons and daughters of immigrants started to attend schools, facing Italian children with problems of intercultural difference. At school age children already hold stereotypes for different ethnic groups (Castelli, De Amicis, & Sherman, 2007) and these biases may prevent a peaceful cohesion and integration of immigrants. This calls for the need to go backwards in the developmental timeline to understand how intercultural relationships are established. In effect, biases in the perception of ethnicity become stable in the first few months of life (Kelly et al, 2007b;2009), and is, therefore, really important to investigate this issue with a developmental perspective. Knowing how these biases appear and evolve may not only be a progress for theoretical knowledge, but could have important repercussions for applied intervention. Indeed, the earlier we can intervene on a developing system the more we can reeducate it toward a more adaptive behavior for our society.

Chapter 1
A face different from me:
other-race face perception

Face is a general label for a broad category of stimuli. Under this umbrella different groups of faces can be sampled together depending on various characteristics. Faces can belong to humans, but also to animals; also within the human group, faces differ based on fixed characteristic as age, gender and race and, even on more ephemeral ones, as expressions. Moreover, our own face falls every time inside just one of those fixed groups: for example, if Maria is a 15 years old Italian girl, her face will be young (group based on age), feminine (gender) and Caucasian (ethnicity). Interestingly, for each of those antithetically formed groups (e.g. male-female), a bias in the recognition and perception of the outgroup faces has been found (Meissner & Brigham, 2001; Palmer, Brewer & Horry, 2013; Rhodes & Anastasi, 2012; Scherf & Scott, 2012; Sporer, 2001a; Wiese, Komes & Schweinberger, 2013). In our example, Maria would remember worse faces of old and not Caucasian men. The first discovered and more famous of these biases is the other-race effect (ORE), also called cross-race effect (CRE) or own-race bias (ORB), which consists in a better recognition performance for faces of the one's own racial group compared to faces of other racial groups. Research on this phenomenon has been carried out for more than forty years (Malpass & Kravitz, 1969) and its reliability and stability has been confirmed by numerous studies (for reviews see Brigham & Malpass, 1985; Chance & Goldstein, 1979; Meissner & Brigham, 2001). The causes of this bias are still argument of debate but probably more than one factor is involved and contributes to this multifaceted phenomenon. The very first type of explanation could be ascribed to an objective different face homogeneity within the different ethnic groups

(Malpass & Kravitz, 1969). The ORE cannot be attributed to greater physiognomic similarity among specific ethnic groups, given that, the other-race effect has been found among Caucasian, African, Hispanic and Asian participants (Gross, 2009; Meissner & Brigham, 2001; Sporer, 2001a; Wright, Boyd & Tredoux, 2003). Early on, researchers have shifted their attention to the psychological mechanisms guiding the bias; this led to a flourishing of theories stressing the importance of different perceptual and cognitive factors (for a review see Hugenberg Young, Bernstein & Sacco, 2010).

1.1 Bias Explanations: From perceptual to Cognitive Factors

1.1.1 Interracial contact and expertise.

A first set of explanations has focused the attention on the perceptual expertise and interracial contact as possible causes of the bias (e.g. Chance and Goldstein, 1979, 1981; Chiroro & Valentine, 1995; Furl, Phillips & O'Toole, 2002; Rhodes, Brake, Taylor & Tan, 1989; Wright et al., 2003). The general idea behind these theories is that people are usually more exposed to faces of their own ethnic group and hence become experts in processing and remembering their characteristics.

Indeed, results with children adopted by parents of a different ethnic group (De Heering, De Liedekerke, Deboni & Rossion, 2010; Sangrigoli, Pallier, Argenti, Ventureyra & de Schonen, 2005) or with people who live in an other-race environment (Chiroro & Valentine, 1995; Wright et al., 2003) support explanations of the other-race effect based on perceptual expertise and interracial contact. In effect, developmental studies show that growing up in a different-race context induces people in some cases to eliminate (De Heering et al., 2010) or even to reverse the other-race effect (Sangrigoli et al., 2005). Along similar lines, the adult literature suggests that the superior recognition for own-race faces, although present in all groups, may be more evident among Caucasian participants (see Meissner & Brigham, 2001), presumably because people of other ethnic groups often have much more experience with Caucasians people, than vice versa. For instance, Chiroro and Valentine (1995) found a stronger own-race bias among African individuals who had a low contact rate with Caucasian people, compared to those who had a higher contact rate, lending support to the claim that recognition ability is, at least in part, driven by perceptual experience.

Nevertheless, many authors have questioned the effects of perceptual expertise (Hugenberg et al., 2010; Ng & Lindsay, 1994; Young, Hugenberg, Bernstein & Sacco, 2012). Some studies have failed to find a correlation between contact and the ORE (Ng & Lindsay, 1994; Luce, 1974) and in their meta-analysis Meissner and Brigham (2001) found that only 2% of the variance in the bias could be attributed to the experience with other-race faces. Thus, although experience with other-race faces may affect the recognition ability of adults to some degree, the magnitude of its contribution seems to be rather modest.

Finally, there are some variations of the bias that cannot easily be accounted by differential perceptual experience alone. For example, MacLin and Malpass (2001) added racial markers (e.g. Hispanic vs. African hairstyle) to race-ambiguous (Hispanic-Black) faces. Although faces were identical except for the racial marker (hair) surrounding the face, Hispanic participants recognized the ambiguous faces better in the presence of a typically Hispanic than in the presence of an African hairstyle.

To summarize, although this line of research has shown some link between experience and ORE, the perceptual expertise cannot be the only predictor for the same-race recognition advantage.

1.1.2 Differential encoding: categorical vs. individuating.

Along with the expertise hypothesis, other social-cognitive theories have been advanced to account for the ORE (for a review see Young et al., 2012). All these theories rely on the phenomenon of categorization as the basic cause of the other-race recognition deficit (see also Hugenberg et al., 2010). The unifying idea is that categorizing a faces as belonging to an outgroup inhibits further elaboration of its characteristics as an individual. This will then result in worse encoding and mnemonic performance for that face. In a series of studies, Levin (1996, 2000; Levin & Angelone, 2002) has proven that race is perceived in a categorical (rather than continuous) way and that race provides a basis for grouping faces. He found that categorical perception is stronger for morphed face continua that cross racial-boundaries compared to morphed face continua within the same racial group (Levin & Angelone, 2002). The author (Levin 1996, 2000) proposed a model according to which race detection and categorization are the primary process of face elaboration: race is considered a powerful visual cue and the analysis of this characteristic drains attentive and mnemonic resources from the elaboration of other facial features (see also Anthony, Copper & Mullen, 1992). Levin (1996) tested this hypothesis with an attentional task, finding that Caucasian participants detected an African face faster among many Caucasian faces than a Caucasian face among many African faces. Together with other evidence (e.g., Levin, 2000; Levin, 1996), these results suggest that, when processing faces of other races, people focus on race cues at the expense of more individualizing features.

Other social-cognitive theories have focused more explicitly on motivational factors. These models generally rely on the idea that people have a limited amount of cognitive resources and should allocate them to the most relevant targets. As a result, in-group faces should foster a deeper type of elaboration, (Sporer, 2001a,b), whereas out-group faces are subject to cognitive disregard because they are perceived as socially less relevant (Rodin, 1987).

This second group of theories has shown how much race is an important feature for categorizing a face and how this categorization leads, subsequently, to a different perceptual and cognitive treatment of this stimulus, depending of in-group-outgroup processes. In these theories, however, the influence of perceptual experience is no more taken into account, because the motivational and social variables are considered stronger than the pure expertise.

1.1.3 A theoretical integration.

Recently, Hugenberg and collaborators (Hugenberg, Wilson, See & Young, 2013; Hugenberg et al., 2010) have proposed a new model, the categorization-individuation model, trying to connect the three main factors identified in the other-race effect phenomenon, namely perception, categorization and motivation. The authors recognize the important role of perceptual expertise in the other-race recognition deficit, however, in their perspective, intercultural contact will be beneficial only to the degree to which it allows people to learn to individuate outgroup members. Hence, not all kinds of exposure are connected with better face recognition abilities; instead an active and motivated experience with a group of faces is needed to acquire (or maintain) the capacity to remember them.

The central factor remains, nevertheless, the categorization process that, according to the authors, is the initial stage of the categorization individuation model and considered automatic and unavoidable (Hugenberg et al., 2010). In this perspective, however, is not only the race that elicits categorization but any type of socially relevant identity can play an important role in creating in-group and out-group clusters, with the resulting homogenization of the latter. This claim is consistent with the findings on other-age (for review see Rhodes & Anastasi, 2012; Wiese et al., 2013) and other-gender biases (see Palmer et al., 2013; Scherf & Scott, 2012) and supports the idea that ORE is part of a more general phenomenon of in-group-outgroup differentiation (see also Sporer, 2001a,b). Indeed, in the third step of the model, the categorization process culminates in fostering or reducing the motivation to process a particular face at a deep level perceptual encoding. In the case of race, then, people are usually more willing to individuate faces of their own race, while they are less motivated to enhance the encoding process for faces of other races (Hugenberg et al., 2010). Nevertheless, when a particular situation stresses another social identity or group belonging, the bias may shift. In line with this idea, a recent study by Hehman and colleagues (Hehman, Mania & Gaertner, 2010) has shown that, depending on the type of group categorization, people showed different types of memory biases. When faces were spatially grouped by race categories, participants showed the typical other-race effect; but when faces were spatially grouped according to university affiliation, participants remembered the faces of their own university better than those of an outgroup university, regardless of race (Hehman et al., 2010). Many other studies have shown that the encoding of and memory for a particular target face depend greatly on the affiliation of this face to the in-group or outgroup (see Hugenberg et al., 2010). Taken together, these results provide converging evidence in favor of the categorization-individuation model .

Although this model has successfully integrated apparently incompatible results for the other-race effect in the adult literature, it is somewhat difficult to reconcile with the developmental perspective. Along with other social-cognitive theories, this model has been criticized for not accounting for the early emergence of the other-race effect (i.e. when experience is very low as in the infant stage, Scherf & Scott, 2012).

1.2 Proximal Causes: face encoding strategies.

Whether the ultimate cause of the ORE is the lack of experience, motivation or an inter-group categorization phenomenon, it affects, beyond doubt, the memory mechanisms. Another line of research has investigated the biases occurring during different phases of this mnemonic process. Under this broad umbrella we find different theories concerning both the encoding processes and the strategies of face representation in memory (for review see Young et al., 2012).

The first group of theories focused the attention on face encoding strategies as possible predictors of the recognition disparity. Researchers, in effect, demonstrated that people not only recognize better own-race faces compared other-race faces, but they can also discriminate them better in the first place, when the faces are presented one after another (Marcon, Meissner, Frueh, Susa & MacLin, 2010; Walker & Hewstone, 2006; Walker & Tanaka, 2003) or simultaneously (Megreya, White & Burton, 2011). These results led the experimenters to think that there should be some bias in the mechanisms that supports the encoding process.

The face, more than any other stimulus, is known to be perceived in an holistic way, in the sense that all facial features are integrated in the global configuration (Galton, 1883; Sergent, 1984; Young, Hellawell & Hay, 1987; for a review see Bruyer, 2011; McKone & Robbins, 2011). Despite some different operationalization of the holistic/configural construct there are some acknowledged tasks, used to investigate the holistic perception: they are the inversion, the part-whole and the composite face task (see Tanaka & Gordon, 2011). In the inversion task a face is put upside-down. This change disrupts face configuration and has been proven to cause a serious impairment in its recognition (Yin, 1969). In the part-whole recognition task (Tanaka & Farah, 1993), some features (as nose or mouth) are extrapolated from a previously seen face and presented or in isolation (featural recognition), or upon another face configuration (holistic recognition): researchers demonstrated that a facial feature is recognized better when inserted within the holistic configuration (see also Tanaka & Sengco, 1997). Finally, in the composite face task (Young et al., 1987), two previously seen faces are horizontally cut in two halves (top- and bottom-half). These two parts are then re-aligned together in different mixes and can belong or not to the same face. There are two versions of this task: in the naming version, for each composite face, participants have to match the identity of just one of the two halves to the faces seen previously. In the "same-different" version two composite faces are presented simultaneously. In this case participants have to compare only the top or bottom halves and say if they match or not. In both cases people have to ignore the irrelevant half, but they actually cannot. In fact, even when a face-half is the same, it is perceived as different when aligned with different halves: the explanation of this phenomenon is that the perception of the configuration is stronger than the perception of just one part. In effect, if the two halves are misaligned or if the composite face is inverted, and, then, the configuration is disrupted, the interference of the irrelevant half disappears (for a review see Rossion, 2013). In face perception literature, all these findings are used as proofs of the holistic perception of faces.

For other–race faces, instead, people seem to employ a different style of elaboration: specifically, people use a more featural processing for faces of other races compared to faces of their own race. This conclusion was obtained testing the other-race face perception with all three holistic recognition tasks. The inversion effect was found to be larger for own-race faces (Hancock & Rhodes, 2008; Rhodes et al., 1989). Moreover, the whole recognition advantage in the part-whole task (Michel, Caldara & Rossion, 2006; Mondloch et al., 2010; Tanaka, Kiefer & Bukach, 2004) and the composite face effect (Michel, Rossion, Han, Chung & Caldara, 2006) were present only for own-race face in Caucasian participants.

Knowing that faces are usually perceived holistically (see Bruyer, 2011), this phenomenon can be seen as a disadvantage for the encoding of other-race faces. The analytical elaboration style could, then, be linked to a worse memory performance (DeGutis, Mercado, Wilmer & Rosenblatt, 2013; Hancock & Rhodes, 2008; Wiese, Kaufmann & Schweinberger, 2014), but it can also be considered the effect of a more remote cause, as the lack of exposure or other socio-cognitive factors. In fact, the configural elaboration style is modulated also by categorization mechanisms as the perceived race of the face (Michel, Corneille & Rossion, 2010) and, also within the same-race sample, by the in-group outgroup differentiation (Hugenberg & Corneille, 2009). Altogether, these findings seem to indicate that the ORE is linked to a disparity in the encoding phase in the first place more than in other phases of memory process (see Megreya et al., 2011).

Some other theories, however, focused their attention on differences in the face representation system (see Byatt & Rhodes, 2004; Goldstein & Chance, 1980; Rhodes et al., 1989): these theories suggest that there is an irreconcilable difference between other-race faces and our internal face prototype. This discrepancy may impede us to code properly these stimuli, ultimately resulting in a recognition disparity. The most famous of these models is the Multidimensional Space Framework (MDS, Byatt & Rhodes, 2004; Valentine, 1991). According to Valentine (1991), each face we encounter is stored in our memory, as in a multidimensional space. It occupies a specific position in this space according to its rate on the different dimensions, as length or hair color. The subsequent recognition of that face is allowed by tracking its coordinates on our mental face space. Our experience with faces will allow us to shape and fill in this face space region with many points as the faces we encounter. The dimensions we use to classify faces will be the ones that help us to best discriminate those face. Moreover there will be a central clustering to the prototype face, because the vast majority of faces will fall near the prototype of the group and just a few will be really different and fall far from the space center. Because the vast majority of face we encounter will be own-race faces, our face space will be adjusted to the distinctive characteristics of those face. When we store other-race faces, then, they will fall far from the face space prototype and will be clustered all really close to each other, because the dimension we use are not suitable to distinguish them. The worse recognition performance, then, will be an effect of this other-race faces overlapping in our mental face space.

Recently Rossion and Michel (2011) proposed an holistic account for the other race effect, which is linked to the expertise hypothesis, and seems to reconcile theories that focus on encoding disparities (Levin, 2000; Megreya et al., 2011; Sporer 2001a,b) with the ones focusing on the face representation system (Byatt & Rhodes, 2004; Goldstein & Chance, 1980; Valentine, 1991). Their experience-based holistic model (EBH) hypothesize that repeated exposure to own races faces creates an “holistic” internalized representation of faces, that helps the observer to well encode the multiple faces that she encounters. Because other-race faces deviate too much from this holistic model, they are processed feature by feature, but this encoding strategy does not reach the level of accuracy of the holistic strategy. This model is in line with Valentine’s face-space model, because assumes that people hold a prototypic representation that only fits own-race characteristics. Moreover it can also explain Levin’s (1996, 2000) findings of an other-race categorization advantage: in effect, because we possess a solid internalized representation only for own-race faces, other-race faces will pop-up quicker as exceptions to our expectations. Anyway, this model rejects the socio-cognitive and motivational accounts (see Hugenberg et al., 2010; Young et al. 2012), because it believes that those variables, even if important, do not constitute the foundation of the ORE.

Despite those findings, the holistic account for the ORE is still a matter of debate. Some other researchers do not think that there is a qualitative difference between the encoding of own- and other race faces (see Hayward, Crookes & Rhodes, 2013). The first issue is that the other-race holistic impairment does not seem to be universal. For Asian, participants, for example, the race bias was only partially demonstrated (Michel et al., 2006b) but the majority of the studies do not find it (see Crookes, Favelle & Hayward, 2013). This results can be attributed, in part, to a more extensive exposition to Caucasian faces (Tanaka et al., 2004; Michel et al., 2006a) and to a more general holistic predisposition for Asian people (Kitayama, Duffy, Kawamura & Larsen, 2003). A recent study specifically tested these hypotheses

(Crookes et al., 2013). Asian participants, living in an own-race predominant environment were tested on a part-whole advantage task with upright and inverted faces of own and other race. They showed holistic processing for both races, but only for the upright faces. Because Asian participants did not show a greater holistic encoding in general, but selectively for faces in their right orientation, the researchers hypothesized that Asian people may use more face-specific mechanisms and may be tolerant of a wider range of faces.

As a second issue, other studies have found a better encoding for own-race faces both for the configuration and for the features (Hayward, Rhodes & Schwaninger, 2008; Rhodes, Hayward & Winkler, 2006). Third, other studies found an holistic encoding for both own-and other-race faces (Bukach, Cottle, Ubiwa, & Miller, 2012; Harrison, Gauthier, Hayward & Richler, 2014; Zhao, Hayward & Bülthoff, 2014). Finally, the holistic encoding strategies has an ambiguous link with the recognition effect with some studies finding the relationships (DeGutis et al., 2013; Hancock & Rhodes, 2008; Wiese et al., 2014) and others that did not find it (Michel et al., 2006a; Michel et al., 2006b).

A recent review of the holistic processing of own- and other-race faces (Hayward et al., 2013) revealed a confused situation with very incongruent findings. The authors linked this blur to the inconsistent use of the terms holistic and configural and to the discrepancy of different tasks (as part-whole vs composite face). A study, just published, (Zhao et al., 2014b) used different tasks to asses face processing (recognition, holistic, configural, featural) trying to disentangle this ambiguity. They used the part-whole task to test the holistic perception, a blurred face to test the configural perception and a scrambled face to test featural perception. They found an ORE only for recognition and for the configural task. These results might suggest an impairment of just this type of encoding, which regards more the relationship between the elements of the face, instead of the whole holistic perception.

Also studies with the eye-tracker technique have brought mixed evidence of different scanning behavior between own- and other-race faces. Some studies, in effect, found a discrepancy just between observers of different ethnic groups (Blais, Jack, Scheepers, Fiset & Caldara, 2008). Caucasian participants seem to pay more attention at the eye region whether Asian participants to the nose region. These results led also the researchers to hypothesize different features to be diagnostic for different ethnic groups, in line with the multidimensional face space of Valentine (1991). In effect some studies found that directing participants' attention to different own- and other-race face regions helps other race face recognition (Hills & Lewis, 2006; 2011; Hills & Pake, 2013): specifically Caucasian faces where recognized better when fixated on the eyes and African faces where recognized better when fixated on the nose. Anyway, other studies actually found differences in the way people scan own- and other-race faces. It has been found that own-race faces are scanned more accurately and more in the eye and forehead regions whereas other-race faces are scanned more on the mouse and nose and induce a wider pupil dilation (Fu, Hu, Wang, Quinn & Lee, 2012; Goldinger, He & Papesh, 2009; Wu, Laeng & Magnussen, 2012).

To summarize the ORE in recognition seems to be linked to a disparity in the early encoding phase. Anyway it is still a matter of debate whether this is a qualitative (featural/configural) or a quantitative (deeper elaboration) discrepancy and how it is exhibited in the scanning habits.

1.3 Neural underpinnings of race perception

Researchers have also found differences in the neural activations for own- and other-race faces, which are generally accounted as the neural other-race effect (NORE). In their review, Ito and Bartholow (2009) traced a complete picture of the neural activation related to ethnicity, starting from perception, through categorization and stereotype activation, till behavior regulation. At different steps correspond different active areas: for example, the anterior cingulate cortex (ACC) and the pre-frontal cortex (PFC), regions connected to conflict monitoring and control, are found to be more active when viewing other-race faces (Cunningham et al., 2004; Ito & Bartholow, 2009). The explanation of this finding is that people try to repress stereotypes or negative evaluations when viewing other-race people. Anyway, to the interest of the present dissertation, the focus will be on the neural bases of the first part of other-race face contact, that is perception.

Face perception is processed by a cortical network that includes the fusiform gyrus (FG) and the inferior occipital gyrus (IOG) that serve for individual identification, the nucleus accumbens and orbitofrontal cortex (OFC) for the evaluation of attractiveness, the superior temporal sulcus (STS) which is sensitive to face movements and the amygdala and insula for facial expressions of emotion (see Haxby & Gobbini, 2011; Ishai, 2008).

One of the most studied brain area in face perception, nevertheless, is a part of the fusiform gyrus, called the fusiform face area (FFA) (for a review see Kanwisher & Yovel, 2006). There is considerable debate about the purpose of this area. The main two perspectives claim, respectively, that the FFA is domain-dependent and is specialized for face-like stimuli or that FFA is process dependent and specialized for fine grade discrimination and within-category individuation (see McKone & Robbins, 2011). Moreover, the FG and the IOG have been connected with the holistic processing of faces (Schiltz & Rossion, 2006). Ultimately, the functioning of this brain area is interesting and it seems connected to the processing of own-race faces. In effect, comparing activation for own and other-race faces in the FFA, fMRI studies found a larger activation for own-race faces (Feng et al.,2011; Golby, Gabrieli, Chiao & Eberhardt, 2001; Lieberman, Hariri, Jarcho, Eisenberger & Bookheimer, 2005; Wei, et al., 2014). This result seems to outline a better encoding processing for these face. Moreover, left FFA activation and face recognition performance were found to be positively correlated (Golby et al., 2001).

Also another area, located in the occipital gyrus, responds remarkably to faces compared to objects: this is the occipital face area (OFA). The OFA is linked to the early stages of face encoding, is essential to accurate face perception and seems to be linked more to the perception of face parts (for a review see Pitcher, Walsh & Duchaine, 2011). Other studies have found larger activation for own-race faces in the OFA (Feng et al., 2011) or in other areas of the inferior/middle occipital cortex in race categorization tasks (Feng et al., 2011; Natu, Raboy & O'Toole, 2011; Ng, Ciaramitaro, Anstis, Boynton & Fine, 2006). A recent study (Liu et al., 2014) found that, for other-race faces, both the FFA and the OFA activated more on the recognition than on the categorization task, while the STS activation for own race faces was greater in the categorization than in the recognition task. All these findings underline a broader network of face selective areas, which respond differently depending on the race and on the task.

On the other side, the electrophysiological correlate of early face perception is the N170 component (Eimer, 2000). This ERP (event-related potential) has been alternatively linked to a general greater expertise with faces compared to non-face stimuli (Eimer, 2000) or to the specific configural encoding of faces (Jacques & Rossion, 2009). In support of the second hypothesis, studies with a source analysis technique have linked the N170 to the FFA, which is also believed to be related to holistic processing (Herrmann, Ehlis, Muehlberger & Fallgatter, 2005). Depending on different models on the role of the N170, predictions about the effect of race on this component are different. In the first case, the N170 would be generally tuned to face and race should not have an effect on it. In the second case, because own- and other-race faces are processed differently, the N170 would vary depending on the race of the face. The results on race modulation of this component are mixed, giving alternatively right to the first

(Caldara, Rossion, Bovet & Hauert, 2004; Caldara et al., 2003; Tanaka & Pierce, 2009) or second hypothesis (Stahl, Wiese & Schweinberger, 2008; Walker, Silvert, Hewstone & Nobre, 2007). A recent study has found a race-dependent modulation of the N170 only for inverted faces (Vizioli, Foreman, Rousselet & Caldara, 2010). Generally, for inverted faces, the N170 has been found to be larger than usual and delayed in time: this ERP components, however, was significantly larger for inverted own- than other-race faces. This result has been interpreted as a finer racial differentiation at the early stage of perception, but more research is needed to clarify the entire picture.

Summarizing, some studies have identified neural networks involving ventro-lateral occipital areas (FFA, OFA) that differentiate faces by race. On a temporal point of view the N170, an ERP related to face perception and to face selective regions, seems also to be somehow modulated by race. Ultimately, the role of these brain activations is still under debate and more research is needed to shed light into the process of race perception and its neural bases.

1.4 Conclusion

The literature on the ORE has a long tradition in the psychological research (see Meissner & Brigham, 2001). Past theoretical debates on the causes of this phenomenon has brought to the acknowledgment of both expertise and motivation as important factor involved in this process (see Hugenberg et al., 2010).

More recent studies have highlighted the link between the mnemonic effect and the perceptual processes (Walker & Tanaka, 2003). The most famous distinction has ascribed the encoding deficit of other-race faces to the lack of holistic perception for those faces (see Rossion & Michel, 2011). However, this model has been put into question (Hayward et al.,

2013) and deeper investigation is needed to disentangle the differences in perception between own- and other-race face.

Finally, investigating the underpinning of race perception, researchers have found different activations in brain areas, usually related to face perception, as the FFA, the OFA and the STS. However, still few neuroimaging studies has been conducted on the perception of other-race faces and many issues about the different perceptual strategies or cognitive processes involved have not yet been addressed.

Chapter 2
Starting the same, going to separate ways: the development of Other Race Effects

The other-race effect appears surprisingly early in life: already at 3 months of age infants show both a preference for (Hayden, Bhatt, Joseph & Tanaka, 2007; Kelly et al., 2005; 2007a) and a better recognition of (Sangrigoli & De Schonen, 2004) own-race faces. This bias becomes more stable between 6 and 9 months of age (Fassbender et al., 2012; Kelly et al., 2007b). The symmetry of the ORE was also tested with different ethnic groups: the bias has been found among Asian infants of 6 and 9 months of age (Kelly et al., 2009) and among 3 months-old African infants (Bar-Haim, Ziv, Lamy and Hodes, 2006) bringing new support for the universality of the ORE.

2.1 Looking for the primary causes: experience or motivation

2.1.1. Perceptual narrowing and cross-racial expertise.

The findings of an other-race effect at such early stage of development led scientists to argue for a perceptual explanation of the bias (Kelly 2007b; 2009; Scott, Pascalis & Nelson, 2007; Slater et al., 2010). The perceptual narrowing model is, still nowadays, one of the best domain-general explanations to account for the development of the other-race effect and of other perceptual biases during infancy (Scott et al., 2007; Slater et al., 2010). The common idea behind this perspective is that, because of repeated experience with certain stimuli, humans become experts in some domain, but loose gradually the ability to distinguish other types of targets. In effect, beyond face discrimination, infants showed own-group biases also for linguistic discrimination, inter-sensual modality perception (face and voice matching) and even metrical structure in music (see Scott et al., 2007). It seems that during the first year of life humans gradually lose the ability to discriminate a large variety of stimuli, including facial characteristics, linguistic sounds or music components (Scott et al., 2007), to become attuned to those differentiations that are relevant to their own group or culture.

These results seem difficult to reconcile with adult theories of the other-race effect involving more cognitive and motivational factors (see Hugenberg et al., 2010; Sporer, 2001a,b). It is difficult to believe that infants at just 3 months of age could make distinctions based on factors other than perception and experience. Even if motivation could still play a significant role in directing the attention of young infants (see Scherf & Scott, 2012) it is a process connected with the instinctual sense of survivor, far away from the in-group favoritism found in adults. Moreover a study has investigated the link between the other-race effect and the categorization of stimuli in infants of 6 and 9 months of age (Anzures, Quinn, Pascalis, Slater & Lee, 2010). The authors found that the other-race effect was present in both age groups, but the ability to categorize faces on the basis of race was exhibited only by the 9 months old group (Anzures et al., 2010). This seems to support the idea that perception precedes categorization in the establishment of the other-race effect.

Some studies also tested the contact hypothesis in infants, trying to find a direct link between experience and other-race perception. Bar-Haim and colleagues (2006) compared three groups of 3 months old infants, namely Caucasian infants living in a Caucasian context, African infants living in an African context and African infants living in a Caucasian context. Results showed that only infants living in a context matching their ethnic group showed a preference for own-race faces. The authors interpret these results as the effect of the exposure to a prototypical face on the ORE.

Moreover, a recent study showed that early deprivation of other-race experience in infancy leads to a lower emotion expression recognition and to a greater amygdala activity in response to other-race faces in later childhood (Telzer et al, 2013). The authors concluded that “the heightened amygdala response observed [...] may suggest that out-group faces are both relatively novel and particularly salient” (Telzer et al, 2013, p. 13487). These results, then, seem to find a direct effect of early experience on preference and on discrimination abilities for other-race faces.

Finally also perceptual training studies provide support for the perceptual narrowing hypothesis (Anzures et al., 2012; Heron-Delaney et al., 2011; Spangler et al., 2012) showing that even rather short sessions of exposure to other-race faces, are able to eliminate the discrimination bias; surprisingly, this holds even for 9 month old infants that had previously displayed the ORE (Anzures et al., 2012).

Despite the considerable support for perceptual expertise as a cause of ORE, findings are not fully compatible and leave many questions open. In particular, it is unclear which kind of experience is needed to reach expertise in recognition. Is it mere exposure sufficient or need additional factors to be present? If so, which ones? Are only perceptual variables involved or may more cognitive processes play an additional role, as suggested by Hugenberg et al. (2010).

Moreover, it is unclear how long the perceptual exposure has to last in order to have an impact; the idea that ORE may be caused by predominant and prolonged exposure with own-race faces clashes with studies demonstrating that a short perceptual training ,also for adults, improves recognition performance for other-race faces (see also Young et al., 2012).

Summarizing, perceptual exposure and expertise can surely play an important role in helping discrimination abilities for a group of stimuli; however, the definition of perceptual expertise seems to be too vague and it does not describe the processes taking place during the experience, that should, in turn, account for the recognition improvement.

2.1.2 Categorization and motivation.

Despite of the predominant focus on perceptual narrowing, other developmental studies have investigated the type of experience needed to foster expertise for a wide range of stimuli, including objects (Scott, 2011), non-human figures (Gauthier, Williams, Tarr & Tanaka, 1998) or other-species faces (Scott & Monesson, 2009). These studies took, again, categorization effects into account, differentiating between the individual and the categorical level of training. For instance, Scott and Monesson (2009) found that the other-species bias could be eliminated in infants of 9 months of age, only when the babies were trained to associate individual names to different monkey faces, but not when they were trained to associate these same faces with the categorical label of "monkeys". These results are quite consistent with Tanaka and Pearce (2009) observations on adults. These authors trained Caucasian participants to distinguish African and Hispanic faces. The faces of one group, Hispanic or African depending on the condition, were presented linked with their category label (e.g. "African American"), whereas the faces of the other group were linked to different individual names (e.g. "Joe", "Bob"). Only the training connecting faces with individual labels improved the recognition performance of the participants.

Together Scott and Monesson's (2009) and Tanaka and Pearce's (2009) studies suggest that the ability to discriminate faces of outgroup members (including other species) only improves through experiences that fosters the individual level of knowledge, whereas the mere exposure to such stimuli at the category level is insufficient. Labeling and categorization seem to work jointly by directing attentive and cognitive resources towards different features. These results suggest that social and cultural factors may exert a remarkable influence on people's recognition ability. For instance, the verbal behavior of caregivers, referring to outgroup members either with individuating labels such as names or with categorical labels, may, to a large degree, determine whether children will learn to differentiate people from other groups. From a more functionalist perspective, Scherf and Scott (2012) have recently argued that the presence and evolution of these face-discrimination biases are due to the demands of different developmental tasks that babies need to accomplish. In the first year of life, infants will logically pay attention primarily to their caregivers because they are the source of their sustenance and well-being. In this case, caregiver's characteristics such as race, gender and age will be those best elaborated and remembered. In subsequent years, when the primary objective is to establish relationships with peers, the authors predict a reorientation of attention to same age faces, with a strengthening of the same-age bias. This theory then suggests that motivational factors are the best predictor of the other-race effect.

Taken together, these different models and theories go beyond a purely perceptual explanation of ORE, starting to depict a multifaceted scenario, where various factors play different and complementary, roles in building a complex phenomenon. In this framework, clear analogies emerge to the socio-cognitive literature on adults (Hugenberg et al., 2010), although the transition from a perceptual discrimination to a more cognitive and categorical one is not yet well established.

2.2 Developing two parallel encoding strategies?

A parallel question to the adult research is whether infants display different elaboration strategies for own- and other-race faces. In the adult literature, in effect, the recognition bias has been several times attributed to the difference in face perception at the encoding stage (Rossion & Michel, 2011).

To address this issue, a first introduction to infants' face processing is necessary. In effect, in the adult literature a rich line of research has demonstrated that face is processed more holistically compared to objects (Galton, 1883; Sergent, 1984; Young et al., 1987; for a review see Bruyer, 2011). A parallel line of research has investigated the presence of this holistic face perception in the very first months of life. This research question was addressed with different tasks, evaluating various aspects of holistic perception (Tanaka & Farah, 1993). The recognition of the first order relationships (the features that characterize the stimulus as a face) has been demonstrated already at birth, because infants prefer the face-like stimuli compared to other stimuli with the same complexity (Morton & Johnson, 1991; Valenza, Simion, Macchi Cassia, & Umiltà, 1996). Also the reliability on second order relationships was proven at birth with the face inversion effect (Turati, Macchi Cassia, Simion & Leo, 2006). Finally, the holistic perception, operationalized as the connection between all the elements of the face into a complex unit, was found to appear, between 3 and 4 months of age (Cashon & Cohen, 2003; Cashon & Cohen, 2004; Turati, Di Giorgio, Bardi & Simion, 2010). Cashon and Cohen (2003; 2004) used an habituation-switch procedure to test the holistic face perception. The researchers habituated infants to two upright or inverted faces and, subsequently, tested them for novelty effects: in the test phase they presented a familiar face, a novel face and a switched face, which was composed by the outer shape of one habituation face and the internal elements of the other habituation face. The switched face would be seen as familiar if the infant focuses on the single elements (analytical elaboration) or as new if the infant looks at the configuration (holistic elaboration). With this procedure the authors found that 3 months-old infants processed both upright and inverted faces analytically and that 4 months-old infants processed both upright and inverted faces holistically. Only at 7 months infants demonstrated a specific holistic processing only for upright faces (Cohen & Cashon, 2001).

Using a composite-face task to test for holistic face processing, Turati and colleagues (2010) found that 3 months-old infants could discriminate faces only in the misaligned condition, i.e. when the two halves of the composite face are separated and the configuration does not interference in face processing. For the newborn group, instead, they did not find differences in any condition. The authors took this result as a proof of a holistic face processing starting from 3 months of age, because infants, at that age, could discriminate the faces only when the configural information did not interfere in their processing (misaligned condition).

Only one study, to date, has specifically investigated the processing differences for own- and other-race faces in infants. In their experiment Ferguson and collaborators (Ferguson, Kulkofsky, Cashon & Casasola, 2009) tested 4 and 8 months-old infants on a habituation-switch procedure (Cohen & Cashon, 2001). The infants were divided in two conditions, depending on the habituation faces: in one case they were two own-race faces while, in the other, they were two other-race faces. Subsequently, they were tested for a novelty effect with some switched faces (internal parts of an habituation face and external contour of the other habituation face), to look for face holistic perception. Results showed that 4 months-old infants used an holistic encoding strategy for both own- and other-race faces but, starting at about 8 months of age, they maintained a holistic elaboration only for faces of their own race. In this sense the processing style of own- and other-race faces seems to follow a narrowing pattern to reach an adult-like performance (Rossion & Michel, 2011).

Moreover, eye-tracking studies with infants have found scanning differences between own- and other-race faces (Gaither, Pauker & Johnson, 2012; Liu et al., 2011, Wheeler et al., 2011; Xiao, Xiao, Quinn, Anzures & Lee, 2013). In correspondence to the adult literature (Blais et al., 2008; Fu, Hu, Wang, Quinn & Lee, 2012; Goldinger et al., 2009; Wu et al., 2012), also infants' studies found both effects connected to the ethnic group of participants (Liu et al., 2011; Wheeler et al., 2011) and to the different scanning between own- and other-race faces (Xiao et al., 2013).

Caucasian infants showed an increased visual scanning on the eye-region for own-race faces (Wheeler et al., 2011) whereas Asian participants showed a decrease in the visual scanning on the nose region for other-race faces (Liu et al., 2011). These findings are in line with the theories that suggest the presence of different diagnostic feature for different ethnic groups (Hills & Lewis, 2006; 2011).

One recent study, anyway, have found different scanning strategies for own- and other-race faces (Xiao et al., 2013). Caucasian infants, at 9 months of age, looked longer at the eyes of Caucasian faces and more at the mouth of African faces. This result is also in line with the findings in the adult literature (Fu et al., 2012; Goldinger et al., 2009; Wu et al., 2012)

In general, the scenario of the other-race perception is still puzzled and somehow incongruent, but there is growing evidence of a differential processing and scanning of own- and other-race faces.

2.3 Development of separate neural bases for other race faces

Neural correlates of face perception have been extensively studied in the adult population (Haxby & Gobbini, 2011; Kanwisher, McDermott & Chun, 1997; Ishai, 2008). Also infant neuroimaging studies have been carried out in order to investigate the development of this preferential perception.

The first studies used the EEG technique and compared face vs object perception (de Haan & Nelson, 1997; 1999). Results demonstrated that faces elicited a greater P400 component. The authors hypothesized the P400 to be a precursor of the adult N170 face-related component. Moreover, greater activation was found in the right hemisphere for faces, compared to objects. This asymmetry, has been subsequently explained in terms of a more configural processing for faces (Otsuka et al., 2007).

Other ERP studies have investigated the differences in face perception by comparing the activation for upright and inverted faces in 3, 6 and 12 months-old infants (de Haan, Johnson & Halit, 2003; Halit, De Haan & Johnson, 2003). Moreover, to test for human face specificity, they compared human and monkey faces. Results showed that upright faces, compared to the inverted ones, elicit ah higher P400 and N290 since 6 months of age. These two components have been thought to be, together, precursors of the face specific N170 adult component (Eimer, 2000; Halit et al., 2003). However, these ERPs become specific for human faces at 12 months (Halit et al., 2003) while at 6 months they respond indistinctly for human and monkey upright faces (de Haan et al., 2003). This finding gives some first indication about the neural bases of the perceptual narrowing phenomenon in face recognition. In effect, the other-species bias is similar to the other-race effect, and consists in a better recognition of faces of the one's own species (Scott & Monesson, 2009). Halit and collaborators (2003) have demonstrated that the brain starts to differentiate faces depending on the species, between 6 and 12 months of age. This development in the neural activation is consistent with the development of the corresponding behavioral bias in face recognition (Scott & Monesson, 2009).

Another neuroimaging technique, that has been extensively used in infants research, is the functional near-infrared spectroscopy (fNIRS, see Otsuka, 2014; Lloyd-Fox, Blasi & Elwell, 2010). This technique uses near-infrared light to assess relative changes in the oxygenated- (HbO), deoxygenated-hemoglobin (HbR), and total-hemoglobin (HbT) concentrations from the superficial layer of the cortex (for a more exhaustive description see section "Functional near-infrared spectroscopy" in Chapter 3). FNIRS is less sensitive to movements and it is a non-invasive technique to be used with infant participants (Lloyd-Fox et al., 2010).

The first two studies, that used the fNIRS to investigate the neural correlates of face perception on the infant brain, compared faces to non-face stimuli with the same spatial frequencies and color distribution (Blasi et al., 2007; Csibra et al., 2004). Both studies tested the occipital areas in 4 months-old participants and found differences in the activation for faces, compared to non-face stimuli. Although Csibra and collaborators (2004) initially found a decrease in the hemodynamic response of oxyhemoglobin (HbO), the follow-up study of Blasi and collaborators (2007) found an increase in HbO for faces compared to non-face stimuli. The different result obtained in these two studies has been explained as a difference in the depth of cortical signal acquisition, due to different source-detector separation used in the two experiments (see Otsuka, 2014).

Other neuroimaging studies have investigated face perception in infants' temporal cortex. Otsuka and collaborators (2007) compared the neural responses for upright and inverted face in 5-to-8 months-old infants. They found greater activation for upright faces than for inverted faces in the right temporal lobe. This result is in line with previous EEG studies, showing greater activity for faces in the right hemisphere (de Haan & Nelson, 1997; 1999) and has been explained as the ability of infants to process upright faces configurally compared to inverted faces (Otsuka et al., 2007). Subsequent fNIRS studies have generally confirmed the right hemisphere predominance for face perception (see Otsuka, 2014).

The neural underpinnings of other-race face perception have been investigated, in the infant population, only by one study (Balas, Westerlund, Hung & Nelson III, 2011). The authors used the EEG technique to compare brain responses to own- and other-race faces in a group of 9 months-old infants. Results revealed that only own-race faces elicited the N290 component, while no difference was found on the P400 component. The authors explained this last finding as an insensitivity, for the P400, to category distinction. However the different N290 activation demonstrated that, at 9 months of age, the brain responds differently to faces based on their ethnicity.

Another study has investigated the neural bases of race discrimination with the fNIRS technique in a group of children (7-13 years-old, Ding, Fu & Lee, 2014). The authors have found higher activation for other-race faces in the right middle frontal gyrus, inferior frontal gyrus and the left cuneus. With the increased age, however, own-race faces elicited modestly greater HbO activation than other-race faces. Finally, this study provided the first insight of functional connectivity between these frontal and occipital areas.

Summarizing, the development of the neural responses to own- and other-race faces has been scarcely investigated. Moreover, studies with infants and children used different paradigms and techniques and have brought mixed evidence of different brain activation depending on face racial cues. More research is, therefore, needed to outline a complete and coherent developmental path of the neural activation connected to ethnicity.

2.4 Conclusion

Researchers have, since long time, investigated infants' face perception. Nevertheless, differences among own- and other-race faces have been taken into account relatively recently (Sangrigoli & De Schonen, 2004). The presence of this bias has been, by now, acknowledged and different type of explanations has been proposed, from perceptual narrowing to motivational factors (Scherf & Scott, 2012; Scott et al., 2007). However, less research has been addressed to the development of different types of face encoding (Ferguson et al., 2009), which has been largely linked to the recognition bias in the adult research (Rossion & Michel, 2011). Finally, the neural responses to own- and other-race faces have been investigated only by two studies (Balas et al., 2011; Ding et al., 2014) and little is known about the neural underpinnings of this bias in infancy.

Chapter 3
Different strategies for different faces: analyzing the relationship between race and elaboration styles

Literature has, since long time, highlighted a recognition deficit for other-race faces (Meissner & Brigham, 2001) which starts to appear very early in the developmental time-line (Sangrigoli & De Schonen, 2004). Moreover, this effect has been connected to different face encoding strategies (Rossion & Michel, 2011). The processing effect, is, however, unclear (Hayward et al., 2013) and more research is needed to understand its contribution to the ORE.

In the present dissertation, I have focused the attention on the processing differences linked to own- and other race faces at various level of investigation, from behavioral to neuroimaging studies, from adult to infant participants.

In the first three studies, I have taken into account the behavioral link between different perceptual strategies recognition performances. In the first study, the relationship between more general global and local processing styles and other-race face recognition was investigated. In the second and third study, the influence of contextual factors in face perception on subsequent face recognition was assessed.

In the last four studies, instead, the investigation of perceptual differences in other-race faces was investigated at the neural level. Activation for own- and other-race faces was compared with the activation for different encoding strategies. Moreover, the development of different neural activation for other-race faces was tested comparing adults' and infants' samples.

3.1 Study 1:

The influence of processing styles on cross-race recognition

In the first study, it was investigated the relationship between the style of elaboration and the other-race face recognition. In the literature of face recognition, the Other-Race Effect (ORE) is a well-established bias towards a better recognition of own-race faces (Malpass & Kravitz, 1969). On the other side, the literature about the styles of face elaboration has found a more holistic processing of own-race faces compared to other-race faces (Rossion & Michel, 2011). If we think that one of the main characteristics of face perception compared to object perception is its holistic elaboration (see Bruyer, 2011), the poorer recognition for other-race faces may reflect the differential style of encoding.

The link between the style of elaboration and face recognition has not yet been disentangled with some studies finding a correlation (DeGutis et al., 2013; Hancock & Rhodes, 2008; Wiese et al., 2014) and others not (Michel et al., 2006a; Michel et al., 2006b). To my knowledge only one study has investigated the influence of a general induced processing style and other-race face recognition (Weston, Perfect, Schooler & Dennis, 2008). In their study, the authors used the Navon task to induce a global or local processing style, which are predicted to be linked, respectively, with the holistic and analytical face elaboration strategies. The Navon task (Navon, 1977) is a task used to assess or induce global and local processing and is formed by composite letter, which are large letters composed by small letters (see Figure 14). These types of stimuli can be processed at the global level (focusing attention on the large letters) or at the local level (focusing the attention on the small letters). After the Navon task, the authors assessed recognition performance for own- and other-race faces but did not find an effect of the processing condition. They did, actually, find an effect of the holistic or analytical encoding when they operationalized them as a request to focus on the personality, for the holistic condition, and on the eyes, for the analytical condition. In this case, they found a better recognition for own-race faces in the holistic condition and a better recognition for other-race faces in the analytical condition.

However, the methodology that the authors used in their study was rather complex and mixed together multiple elements. In effect, they used two steps of holistic and analytical manipulation: one before the face encoding and one between face encoding and recognition. In the first part, there were only two conditions, holistic and analytical, induced, respectively, in the first experiment by the Navon task and, in the second, by the instruction on how to look at faces. Then, after face presentation, participants were assigned to one of four conditions: a holistic Navon, an analytical Navon, a verbalization or a control reading task. All these condition where randomized during different trials so that participants went through all the conditions. This procedure, itself, could have created carry-over effects, possibly causing interactive outcomes or reducing of the effects of manipulation altogether.

Moreover, face presentation was somehow particular. In fact, in the first phase, faces were presented simultaneously in a three-quarter pose, while, during the recognition, participants were presented with two-alternative forced choice trials. Given this complexity, I have decided to run a similar study with a simpler methodology. Also in the present study a Navon task was used to induce global and local processing, that are supposed to be linked to the holistic and analytical face elaboration. This task was used only before the face encoding phase and frontal looking faces were presented individually, both in the encoding and in the recognition phases.

It was hypothesized to find, as for the study of Weston and collaborators (2008), a general ORE, with a better recognition for own-race faces. Moreover, the holistic condition was expected to improve the recognition of own-race faces whether the analytical condition was expected to improve the recognition of other-race faces. These expectations are based on the hypothesis that each group of faces better fits a style of elaboration. Therefore, it was hypothesized to find a greater ORE in the holistic than in the analytical condition.

3.1.2 Method

Participants. Seventy-one Caucasian participants (35 male; mean age 33.2 years) took part in the experiment. Only 4 were left-handed; 66.2% held a bachelor degree.

Material. For the Navon task, 26 composite letters were created, so that global letters (6.2° X 7.8°) were made out of local letters (0.47 X 0.67). All the stimuli were composed by different letters at the local and global level.

For the recognition task 40 faces were taken from the Minear and Park (2004) database. The images were full frontal faces, displayed in full color and with the same gray background. All extraneous features (e.g. make-up or jewelry) were removed; all the clothing was equalized and black colored using Adobe Photoshop. The faces were half male and half female, aged between 18 and 30: half of each was ethnically Black and half were ethnically White. The pictures had a grey background and were enclosed in a rectangle with a visual angle of 22.16° X 16.13°.

For the distractor task, 10 anagrams, of 5 letters each, were created. Also a decision task was created. The decision the participants had to take was about the custody of a child between two grandmothers. A small table was created with 2 positive and 2 negative characteristics for both, with a mixed order. Participants were asked " To which grandma would you give the custody of the child?" and "Which of the two grandma do you think is most authoritative?". This last task was used as a pretest for another experiment. For the present study, it simply worked as a distractor task, in order to increase the time between the encoding and the test phase of the recognition task.

At the end, participants' attitudes towards other ethnic groups were assessed. An adapted version of the interethnic ideology scale was used (Ryan, Hunt, Weible, Peterson &

Casas, 2007), which assesses the multicultural versus the colorblind ideology. It is composed of 8 statements and each one represents a strategy of intergroup-relationship management. Participants were asked to rate the extent to which they thought that each strategy would or would not improve relations between groups on a scale from 1 (it does not improve relations between groups at all) to 7 (it improves relations between groups a lot). Four strategies reflected a multicultural perspective (e.g. “Emphasizing the importance of appreciating group differences between ethnic groups”) and 4 items reflected a colorblind perspective (e.g. “Recognizing that all people are basically the same regardless of their ethnicity”).

Also an intergroup anxiety scale was used (Voci & Hewstone, 2003). Participants were asked “In a hypothetical situation in Italy, how would you feel if you were the only Italian among a group of immigrant strangers?”. They had to rate to which extent, on a scale from 1 (not at all) to 5 (a lot), they would feel 5 emotions (awkward, self-conscious, happy, confident, relaxed).

Procedure. The procedure started with the Navon task. Compound letters were presented on the center of the screen for 2 s each. Participants were divided into two conditions: holistic and analytical. In the holistic condition, they had to say out loud the large letter that they saw on the screen whereas in the analytical condition they had to say out loud the small letter. For each letter the experimenter took note if the answer of the participant was correct.

Subsequently, participants were presented with an old/new recognition task. They saw 20 faces individually, each for 2s. Then, the distractor task (anagram and decision making task) was administered. After that, they performed the recognition: they were presented with 40 faces, 20 seen previously and 20 new. For each face they had to say if they had seen it before or not. Again the experimenter took note of the answer.

3.1.2 Results

Recognition Bias. The d-prime, a measure of recognition, was calculated for each ethnic group of faces. The d-prime is the difference between the Hit rates (the correct "yes" answer when the target is present) minus the False Alarms (FA, the incorrect "yes" answer when the target was absent), and it is calculated using the formula,

$$(d') = z(Hit) - z(FA)$$

with Z as the z-scores, with Hit and FA calculated as proportions (see Macmillan & Creelman, 2004).

Following Wixted & Lee (2008), these hit and false alarm rates were corrected with the $1{-}1/2N$ and $1/2N$ formulas respectively, with N being the maximum number of hits or false alarms. This resulted in minimum and maximum d-prime values of 0.05 and 0.095, respectively.

The recognition of Caucasian and African faces was significantly different, paired t-test $t(70) = 7.95$, $p<.001$ with higher recognition for the Caucasian group. This result is in line with the well-established ORE.

Recognition as a function of target race and analytic vs. holistic processing. The ORE index was calculated as the d-prime for Caucasian minus the d-prime for African faces. An independent t-test with the Navon group (holistic/analytical) as the between participants variable revealed no effect of the condition , $t(69) = -1.60$, $p = .115$.

However, many participants showed poor performance on the Navon task and, hence, it was unlikely that analytical vs holistic processing had been effectively primed in these participants. When only the participants that did not make mistakes in the Navon task (N= 47) where taken into account , then, the same analysis became significant, $t(45) = -2.16$, $p = .036$ (see Figure 1). In this case, a higher recognition bias is observed in the holistic than in the analytical condition.

Nevertheless, one sample t-tests against zero (the value corresponding to the absence of the recognition bias) revealed the presence of the ORE in both holistic, $t(21) = 5.75$, p <.001, and analytical condition, $t(21) = 2.76$, p =.011 (Figure 1).

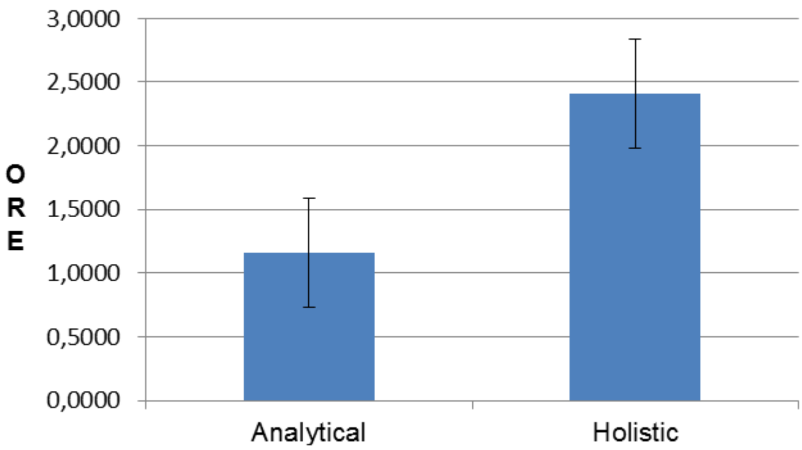

Figure 1. The ORE, calculated as the d-prime for the own-race minus the d-prime for other-race faces, is higher in the holistic condition, compared to the analytical. In both cases the ORE is different from zero, implicating an own-race recognition advantage

Influence of other-race attitudes. The reliability of the interethnic ideology scale was tested for the separate factors: multicultural and colorblind. For both sub-scales the reliability was low (alpha for multicultural .34 alpha for colorblind .57). Two items of the colorblind scale "Recognizing that all people are basically the same regardless of their ethnicity" and "Recognizing that all people are created equally regardless of their ethnicity" were averaged together (alpha .70). The reliability of the intergroup anxiety scale was good (alpha .81), so a unique variable was created. None of these variable showed a correlation with the ORE or with the d-prime values for the separate ethnic groups.

3.1.3 Discussion.

In this study, the influence of a general global or local processing style on the ORE was tested. A previous study has brought support for the hypothesis of a larger ORE in the global processing condition (Weston et al., 2008), but this study was flawed by multiple priming procedure. Here a similar result was found with a different and simplified methodology. In effect, this study found a greater ORE for the holistic than for the analytical condition, but the ORE was still significantly positive, so that this manipulation could only mitigate but not eliminate the bias. Nevertheless, this finding provides support to the link between the elaboration style of a face at encoding and recognition. This is in line with the hypothesis that the different elaboration strategies used for own- and other-race faces are one possible cause of the recognition discrepancy. Moreover, it supports the hypothesis of the correspondence between global and local processing and the holistic and analytical elaboration styles.

The major limitation of the study is that this result was found only for participants who performed the Navon task correctly. On one side, this distinction could be used as a proof of the success of the manipulation, but on the other side as the weakness of this task to produce and maintain the effect. This last issue was also addressed in the work of Weston and collaborators (2008).

Another limitation was the lack of a control group. In effect, it is not known if it is the holistic condition that enhances the ORE or the analytical condition that mitigates it. Further research is needed to address this issue.

Despite these limits, this study underlines the importance of face perception mechanisms on memory and identification phenomena. Therefore, further research on the elaboration differences between own- and other-race faces is needed to comprehend the bases of their recognition disparity.

3.2. Study 2 and 3

Effects of multiple face presentation on scanning behavior and recognition performance.

In the following two studies I have investigate more in depth the relationship between the encoding conditions and the ORE. The ORE was first discovered and studied was the eyewitness research. Studies in this field have extensively analyzed which elements of the recognition process (e.g. the line-up procedure) may influence the recognition of other-race faces (see Meissner &Brigham, 2001). These studies have led to the construction of precise guidelines to improve the identification procedure (see Lindsay, Brigham, Brimacombe & Wells, 2002). Recently, a study (Zhao et al., 2014a) has evoked renew interest in this question showing that, presenting rigidly moving faces or faces with multiple views, the ORE disappeared. This results was linked to the induction of a more analytical elaboration of the faces.

In Study 2 and 3 I have investigated how the simultaneous presentation of own- and other-race faces may impact their subsequent recognition. In effect, Levin (1996, 2000) has showed that the poor recognition of other-race faces goes hand in hand with a categorization advantage. The categorization advantage has been studied using detection tasks that have evidenced a pop-out effect of other-race faces when they are mixed together with own-race faces. Thus, other-race faces are detected faster than own-race faces, when presented in a intermixed context. This phenomenon could also cause to pay more attention to other-race faces in a multiracial presentation context and help to remember them better. Some support for this hypothesis could come from the comparison of two similar studies, differing in the type of face presentation. These studies have investigated the effects of in-group and out-group contrast on the ORE. The authors created an in-group, composed by both own- and other-race people, based on the university affiliation, and tested the effect of this new grouping variable on the recognition of faces. In the first study (Shriver, Young, Hugenberg, Bernstein & Lanter, 2008), the authors presented faces individually on different backgrounds, related to different groups. In the second study (Hehman et al., 2010), faces were presented simultaneously and grouped together based on the university affiliation. In the first study, the authors have demonstrated an effect of the university, but own-race faces were always recognized better. In the second experiment, instead, in the same university condition, other-race and same-race recognition was the same. In this sense, the mixed presentation procedure could have facilitated the other-race face recognition.

Moreover, in a multiple face presentation paradigm, also the position of faces becomes important. The Spatial Agency Bias (SAB), has demonstrated the preference of the left-to-right scanning direction (Chatterjee, Maher & Heilman, 1995). This bias is linked to the writing and reading direction, so that this preference reverses for languages with a right-to-left direction (Maass & Russo, 2003). Recent studies, moreover, have demonstrated a memory effect related to this spatial bias, so that elements on the left of the visual hemi-field are remembered better (Bettinsoli, Maass, Suitner & Timeo, in prep.).

Joining together these effects I expected to find a comparable recognition for own- and other-race faces when they are presented together and to find a main effect of position, so that faces on the left on the visual field are recognized better.

3.2.1 Study 2

3.2.1.1 Method

Participants. Overall, 135 people entered the Survey Monkey questionnaire, but only 97 participants completed the entire survey. Participants were randomly assigned to 12 conditions with different face presentation and recognition orders: the number of participants for each order was unbalanced, thereby introducing a potential bias, so 6 participants were randomly selected from each order condition to counterbalance this control variable (6 was the number of participants in the condition with the smallest number of participants).

The responses of 72 participants were analyzed (16 male; mean age = 26 years; 65 right-handed). All but one were native Italian speakers and only one selected Spanish as native language. They were asked if they knew other languages, to control for the knowledge of right-to-left languages: only one person reported some knowledge of Arabian. Because the responses of this participant did not differ from the mean, this participant was maintained in the sample for the statistical analyses.

Material. For the recognition task 24 faces were taken from the Minear and Park (2004) database. The images were full frontal faces, displayed in full color and with the same grey background. All extraneous features (e.g. make-up or jewelry) were removed; clothing was standardized such that all t-shirts were colored black using Adobe Photoshop. The faces were half male and half female, aged between 18 and 30: half of them were ethnically African and half Caucasian. For the presentation, was created a grid with four rows and six columns for a total of twenty-four faces. Faces were positioned in a chessboard arrangement, so that faces were never close to other faces of the same ethnic group. Six versions of this grid by moving the columns were created so that, at the end, each column was presented in all positions from far left to far right. For the recognition task, all originally seen photos were presented together with 20 filler images taken from the same collection and prepared according to the same criteria. All images were presented individually at the center of the screen. Also for the recognition, two random orders of faces were created. Based on the combination between the number of grid orders and recognition orders, there were twelve order conditions.

Procedure. SurveyMonkey was used to run the experiment, so each participant responded on her/his computer. After reading a description of the experiment and giving their consent, participants first viewed one of the six grids of 24 faces, for a total of 30 s. Subsequently, they performed the recognition task: they were presented with 44 faces, 24 of which had been seen previously and 20 were new. For each face they had to say if they had seen it in the grid or not, by pressing a “yes” or “no” button with the mouse. At the end of the study, participants were debriefed and thanked for their participation.

3.2.1.2 Results

A general d-prime (d’) index was calculated for each ethnic group of faces as

$$(d') = z(H) - z(FA)$$

with Z as the z-scores and H as the number of hits and FA the number of False Alarms, proportioned to one.

Following Wixted & Lee (2008), these hit and false alarm rates were corrected with the $1-1/2N$ and $1/2N$ formulas respectively. This resulted in minimum and maximum *d*-prime values of 0.05 and 0.095 for the FA index (N=10) and 0.042 and 0.958 for the H index (N=12), respectively. The recognition of Caucasian and African faces was not significantly different, paired t-test $t(68) = 1.16$, p = n.s. (Figure 2).

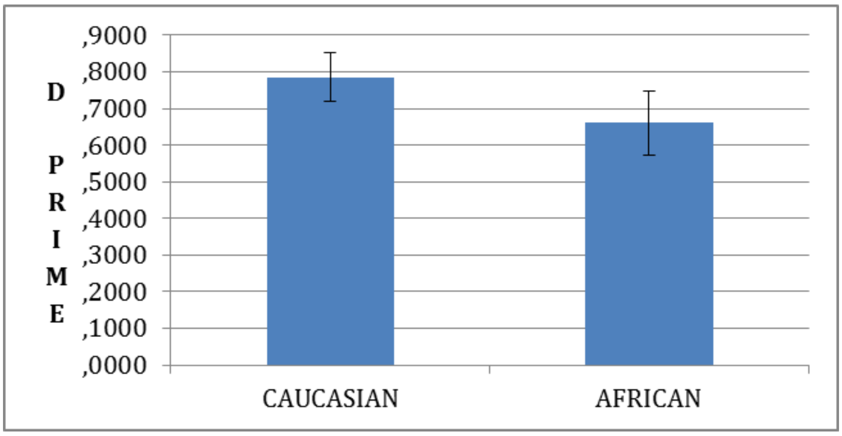

Figure 2 D-prime as a function of race.

Subsequently, the two main indexes of signal detection theory were analyzed separately: the Hit rates (that were affected by the position of the face in the space) and the

False Alarms (FA, that were, by definition, unaffected by position as they were not distributed in space along the left-right axis). For the FA, a paired t-test revealed an effect of race, $t(68) = -4.22$, $p < .001$, with the African faces inducing more FA (Figure 3).

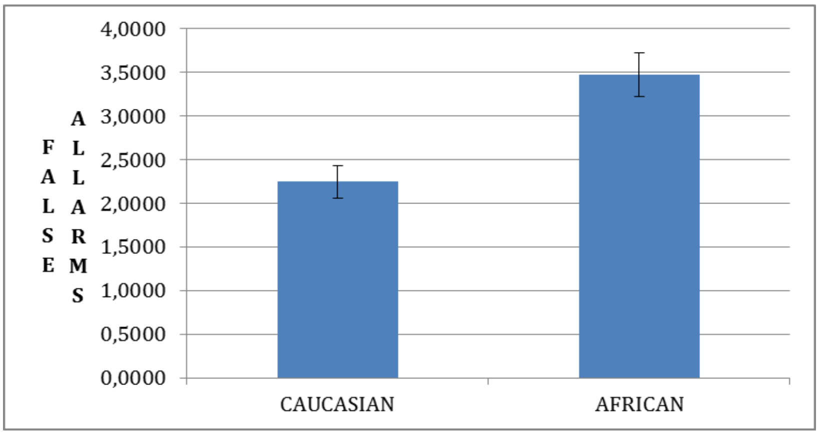

Figure 3 False alarms as a function of race

For the Hit rate, a 2 Race (Caucasian-African) X 3 Position of the Face (Left-Center-Right) repeated-measures ANOVA was run. There was a main effect of Race $F(1, 69)=14.602$, $p < .001$, $\eta^2_p = .175$, with a greater number of hits for African (M = 2.262 out of 4) than for Caucasian faces (M= 1.919 out of 4). The Position had only a marginal linear effect $F(2, 69) = 3.052$, $p = .085$, $\eta^2_p = .042$; there was no interaction between the two variables (see Figure 4).

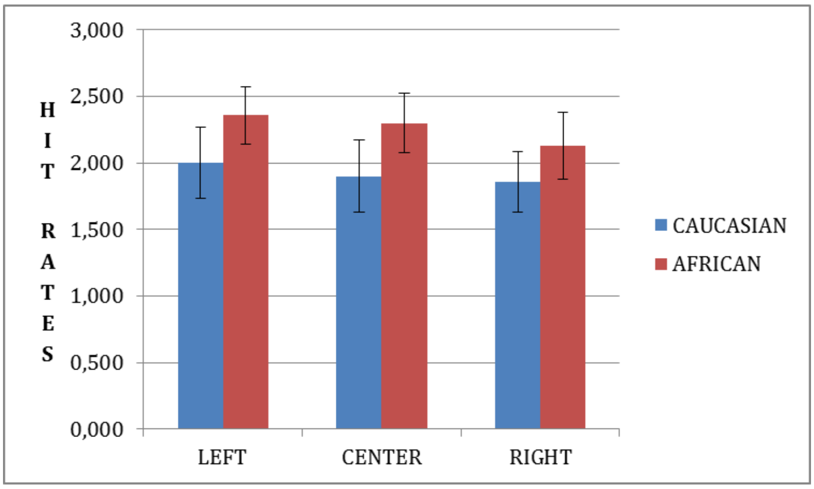

Figure 4 Distribution of hit rates based on the race and position of the face.

To investigate the Race effect in greater detail, a one-sample t-test was run on the total number of hits for Caucasian (M = 5.757) and African faces (M= 6.786 out of 12). Only the African group revealed an above-chance recognition performance on hits, $t(69) = 3.230$, $p= .002$, whereas the recognition of Caucasian faces was not different from chance (M=6), $t(69) = -1.007$, $p=$ n.s. (see Figure 5).

Finally, was calculated the c index as the recognition criterion. The formula for c is

$$C = -\frac{Z(H) + Z(FA)}{2}$$

The criterion measures the bias toward responding "yes" or "no" in the recognition task. If c is equal to zero, it means there is no bias. If it is negative there is a liberal tendency and participants respond "yes" more often, whereas if c is positive participants are conservative and have a tendency to answer "no". A one-sample t-test against zero revealed that, for both ethnic groups, participants are conservative, Caucasian $t(68) = 8.617$, $p<.001$ and African $t(69) = 2.517$, $p= .014$. However, participants were more conservative for Caucasian (M= 4.38) than for African faces (M= .131), $t(69) = 5.417$, $p< .001$.

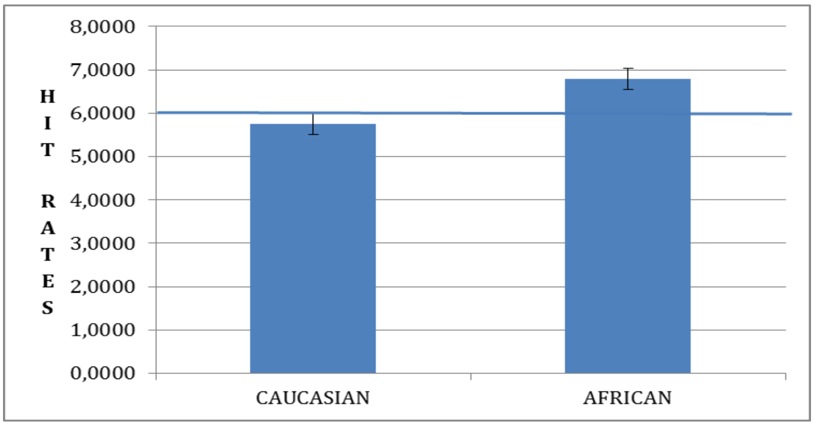

Figure 5 Hit Rates for Caucasian and African faces compared to the chance.

3.2.1.3 Discussion

Looking at the overall recognition performance (d-prime), there was no difference between own- and other-race faces, suggesting, as expected, the absence of an ORE. Moreover, a separate look at Hits and False Alarms offers an account for the effect of the presentation format. FA rates, that are, by definition, not influenced by the multiple format, show a greater number of mistakes for the other-race faces, as already shown in the literature (see Meissner & Brigham, 2001). For the hit rates, an analysis considering both ethnicity and spatial position revealed that recognition accuracy decreases in a linear fashion from left to right. It also showed better performance for other-race faces, in line with the hypothesis of a greater attention directed to other-race faces when presented together with same-race faces. However, this finding may also be accounted by a more liberal tendency to respond to other-race faces, as showed previously (Levine, 1996). In effect, both groups yielded a conservative criterion compared to zero, but participants were more conservative for own-race faces, thus applying a stricter decision criterion for faces of their own race. To better discriminate between these two types of explanations, an eye-tracking study was conducted, where I investigated differences in the scanning patterns for own- and other-race faces, which may influence the recognition performance. Thus, if better recognition of other-race faces is due to the greater attention to these faces in a mixed display, rather than due to a simple response bias, then this greater attention, revealed with eyetracking methodology, should mediate differential recognition of other- (vs. own-) race faces.

3.2.2 Study 3

This study investigated more in depth the relationship between the presentation format and the ORE, by analyzing the gaze behavior during face presentation. Different from the previous study, only two faces were presented at the same time. For this study, I relied upon the same theoretical bases of Study 2. For the recognition, I expected to find no ORE effect in general and more hit rates for the other-race group.

Moreover, in this study I have investigated the gaze behavior during both face encoding and recognition. Previous eye-tracking studies have found mixed results, with some studies finding differences only related to the ethnicity of the participants (see Blais et al., 2008). The differences found for own- and other-race faces were connected to a more accurate scanning in the eye and forehead regions for own-race faces, but more scanning on the mouth and nose for other-race faces (Goldinger et al., 2009; Wu et al., 2012). I therefore, expected to find, also in this case, longer fixations in the eye region for own-race faces and longer fixations on the mouth region for other-race faces. Concerning the differences connected to the pop-out effect hypothesis, I expected to find a faster orienting of attention and longer fixations towards other-race faces. Finally, concerning the effect of position, I expected to find a faster orienting of attention to the faces on the left visual hemi-field, as previously demonstrated (Bettinsoli et al., in prep.). Finally, I hypothesize the gaze behavior difference between own- and other-race faces to predict the memory for those faces. The gaze behavior indexes (the time to fixate the target and the length of fixation) are, therefore, expected to be correlated with the recognition performance.

3.2.2.1 Method

Participants. Initially, 38 Caucasian students of the University of Padova with normal or corrected to normal sight were tested. Because of poor eye calibration the data of 6 participants were not considered, reducing the final sample to 32 participants (18 females; 28 right-handed; mean age = 23.32 years). Thirty-one participants were Italian native speakers while one participant was Croatian native speaker, but with excellent knowledge of Italian. None of the participants knew any right-to-left languages. Nineteen people held a bachelor degree while the rest had a second level school diploma. As far as the political affiliation is concerned, 20 people self-defined as left wing, 2 as central, 3 as right wing and 7 people stated not to have any political affiliation. As far as religious beliefs are concerned, only 14 people were religious, while the rest were atheists. No participant had African relatives, two people had (or have had) African partners and 22 people declared to have (or have had) African acquaintances. Because the responses of this participant did not differ from the mean, this participant was maintained in the sample for the statistical analyses.

Materials. The faces were taken from the Minear and Park (2004) database as in the previous experiments. For the presentation, 8 face pairs were created (with one face on the left and one on the right side of the screen) for a total of 16 faces presented. Each face was included in a rectangle with a visual angle of 10.29° X 7.63° at 60 cm. The distance between the internal edge of each rectangle and the center of the screen measured 1.43°. The pairs were always of the same gender (both males or both females), but varied in ethnicity (Caucasian and African) and position (left or right): one pair of two Caucasian faces, one pair of two African faces, one pair with a Caucasian face on the left and an African face on the right, and one pair with an African face on the left and a Caucasian face on the right were created. Every couple had a male and a female version, resulting in a total of 8 versions. For the presentation four sequences were created, in which the faces within each pair were changed, so that the specific characteristics of one faces could not interact with the face disposition. Each of these sequences was then counterbalanced to avoid order effects.

For the recognition task the faces of the presentation phase plus 16 filler faces were shown one at a time. Each face was presented full screen and was included in a rectangle with a visual angle of 23.54° X 18.46°. Also for the recognition, two orders of faces were created.

In order to distract the participants between the presentation and the recognition task, they were presented with the translated version of the Analysis-Holism Scale (AHS) developed by Choi and collaborators (Choi, Koo & Choi, 2007), which tests people's predisposition to holistic or analytical thinking. The scale was composed of a total of 24 items divided in 4 subscales. Participants had to give their opinion about different statements on a scale from 1 (completely disagree) to 7 (completely agree). The '*causality*' subscale investigates the beliefs about the interdependence or independence of the events and comprises items, like "Everything in the universe is somehow related to each other". The '*attitude toward contradiction*' scale assesses people opinions about how to deal with different points of view or attitudes and comprises items like "When disagreement exists among people, they should search for ways to compromise and embrace everyone's opinions" or "Choosing a middle ground in an argument should be avoided". The third scale, '*perception of change*', investigates people's beliefs about of whether things tend to remain always the same or, instead, change constantly. Item examples of this scale are "Current situations can change at any time" or "An individual who is currently honest will stay honest in the future". The last scale, '*Locus of attention*', assesses the tendency to look at particulars or at the global shape or configuration and is composed by items like "It is more important to pay attention to the whole than its parts" or "It is more important to pay attention to the whole context rather than the details".

Procedure. After giving their consent, participants were seated 60 cm away from a 17'' LCD screen. The experiment started with face pair presentation. Each pair was presented for 3 s and the inter stimulus trial was 1 s. In order to test the influence of a central fixation point on the direction of the first fixation, two conditions of this task were created: in one case the inter-stimulus trial consisted in a white screen, whereas, in the other, there was a central fixation cross. After the presentation, participants filled in the holistic/analytical thinking scale and the personal information. At the end they were presented with a sequence of thirty-two faces and had to perform the recognition task. Each face was presented individually and participants had to say out loud if they had previously seen it or not. The experimenter took note of their answers.

Eye-tracking apparatus and data analysis. Eye movements were collected with a Tobii T120 eye-tracking (Tobii Technology, Stockholm, Sweden). The eye-tracker is a system based on infrared tracking combined with hyperacuity image processing. Tobii T120 is integrated into a 17'' TFT display with a resolution of 1280 X 1024 pixels. There are five near-infrared light emitting diodes (NIR-LEDs) and a high resolution camera with a charge couple device (CCD) sensor. The camera samples pupil location and pupil size at the rate of 120 Hz. For the present experiment, binocular registration was used. The accuracy of eye position tracking is 0.4 and the spatial resolution is 0.16. The freedom of head movement and the tracker field of view is 30 X 22 X 30. Before each session a 9-point calibration procedure was used. The calibration was run before stimulus presentation in the first phase and, again, before the recognition task.

Data were recorded with Tobii-Studio (2.1.14.) software. Different AOIs (Area of interest) were created for the faces in the presentation and recognition tasks. In the presentation task, for each face of the pair, a face area (2.64% of the total screen) was created. Also for the recognition task, for each image, a face area (13.98%), an eye area (2.33%), a nose area (0.85%), and a mouth area (1.17%) were computed. The output indexes of the Tobii studio were obtained for every AOI of each image and used for subsequent analyses. The indexes used were: time to first fixation, the duration of the first fixation, and the total fixation length.

3.2.2.2 Results

Recognition. A d-prime index was calculated for both the Caucasian and African group of faces, with the formula used in the previous experiment (see description in Study 1). A paired t-test on the two indexes revealed no significant effect of ethnicity, $t(31) = 0.931$, p= n.s.

A paired t-test on the False Alarm (FA) rates for the Caucasian and African groups was performed. The FA were significantly greater for the African (M= 2.37) than for the Caucasian group (M= 1.56 out of 8), $t(31) = 2.290$, $p= .029$ (see *Figure 6*). Results were not affected by the contact with African people.

To assess whether the spatial position of the face had an influence on recognition, a 2 Ethnicity (Caucasian-African) X 2 Position (left-right) X 2 Gender of participant (male-female) ANOVA was run on the hit rates in which the first two variables were within-subjects factors. The ethnicity had a significant effect, $F(1, 30)= 4.467$, $p= .043$, $\eta^2_p = .130$, with hit rates being slightly higher for the African group (M= 2.806) than for the Caucasian one (M= 2.518 out of 4). This result is in line with the finding of the previous experiment (see *Figure 6*).

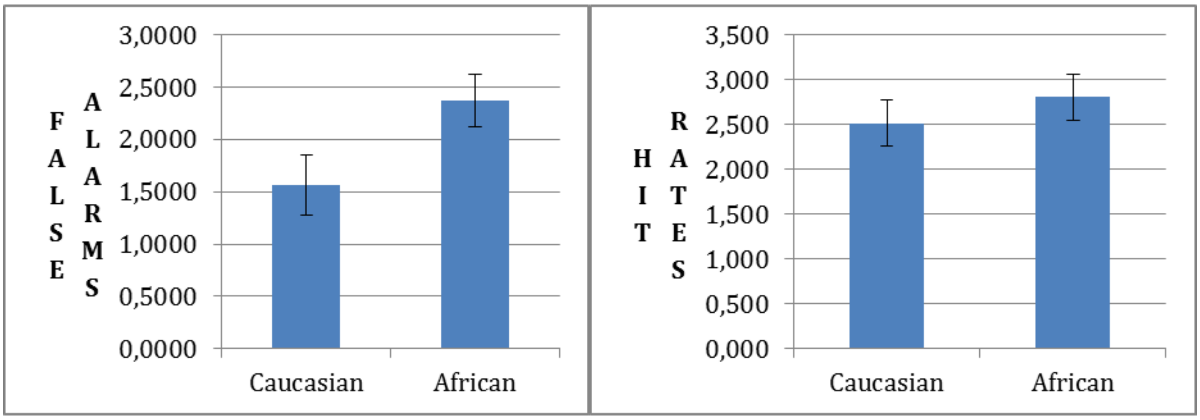

Figure 6. False alarms and Hit rates for Caucasian and African groups.

I also found an interaction between the position of the face and the participant gender, $F(1, 30)=4.522$, $p= .042$, $\eta^2_p =.131$, (*Figure 7*), so that female participants recognized faces on the right side (M= 2.861) better than faces on the left (M=2.250, Bonferroni adjusted alpha, p=.0125). Finally, also the interaction between the position of the face and its ethnicity was significant, $F(1, 30)=6.474$, $p= .016$, $\eta^2_p =.178$. In this case, Bonferroni corrected contrasts revealed that, on the left side, African faces (M=2.921) were recognized better than Caucasian faces (M=2.187), but, on the right side, Caucasian faces (M= 2.849) were recognized better than African faces (M = 2.690, *Figure 7*). The contact with African people was also assessed, but it did not interact with either the ethnicity of the face or its position.

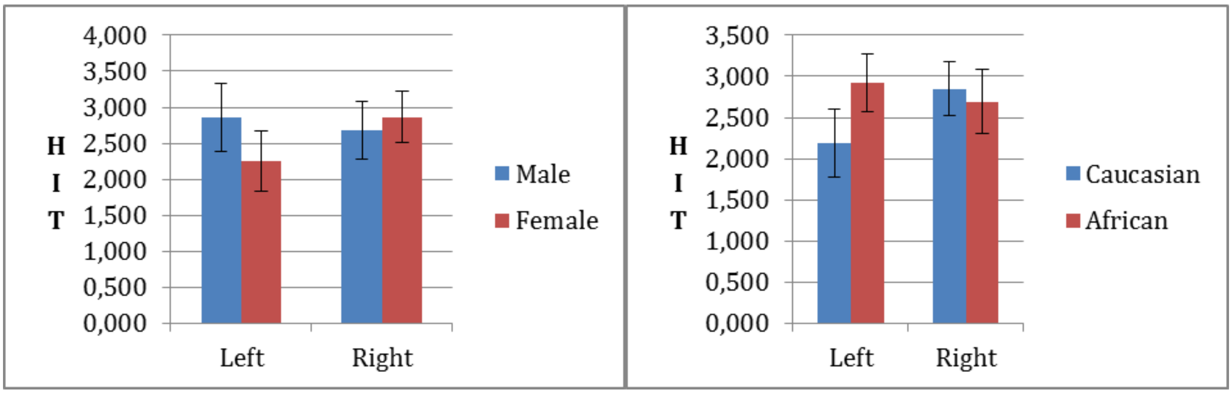

Figure 7. On the left, interactions between position and participant gender and, on the right, between the position and the ethnicity of the face.

Gaze behavior results. For the encoding phase, the gaze behavior on the face AOI was analyzed. The indexes used were the time to first fixation, the total length of fixation and the duration of the first fixation. No significant effects were found for the total length of the fixations and for the duration of the first fixation; therefore only the results for the time to first fixation are reported.

Because there were no differences between the cross or blank inter stimulus trial condition, all data were analyzed together. A repeated-measures ANOVA with Ethnicity (Caucasian-African) and Position (left-right) as factors was run. For time to first fixation, both the main effects for ethnicity, $F(1,30)= 5.606$, $p= .025$, $\eta^2_p= .157$, and position emerged, $F(1.30)= 44.628$, $p< .001$, $\eta^2_p = .598$. Participants looked faster to the left (M= 0.341s) compared to the right (M= 0.764s) and at African (M= 0.508s) compared to Caucasian faces (M= 0.597s, *Figure 8*). There was no interaction between these two variables.

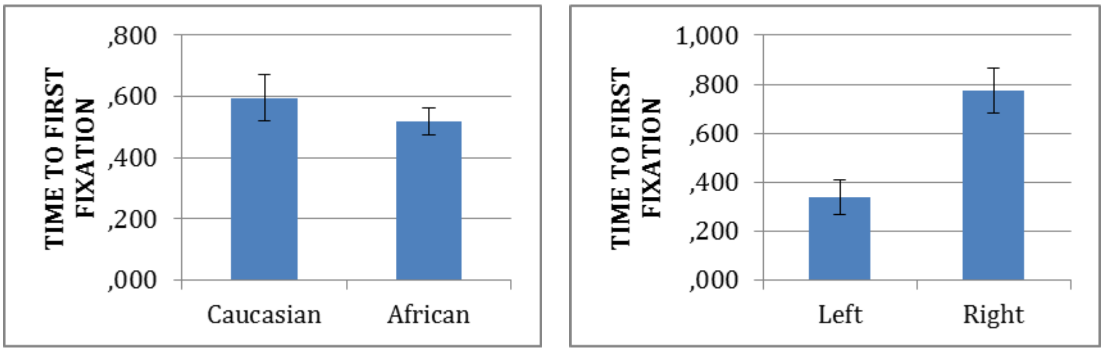

Figure 8. Main effect of Ethnicity, Position and Gender of the face on the Time to first fixation.

In the test phase of the recognition, the time to first fixation, the length of the first fixation and the total fixation indexes were analyzed. For all three indexes a repeated-measure ANOVAs with the 3 Parts of the face (eyes, nose, mouth) and Ethnicity (Caucasian-African) as within participant variables was run. On the total time of fixation, a main effect for Ethnicity, $F(1,31)=4.446$, $p= .043$, $\eta^2_p =.125$, and a main effect of the Face Part emerged, $F(2,62)= 13.042$, $p< .001$, $\eta^2_p = .296$. Caucasian faces were looked at longer (M=0.572s) than African faces (M= 0.509s); also the mouth-region (M=0.222s) was observed less than the other parts (nose M= 0.561s, eyes M= 0.838s). Also an interaction between the Part of the face and the Ethnicity was found, $F(2,62)=4.742$, $p= .018$, $\eta^2=.133$. Participants looked longer at own-race eyes (M= 0.916s) compared to other-race eyes (M=0.759s, Bonferroni corrected alpha, p= .0083) whereas no difference were found for other parts of the face (Figure 9).

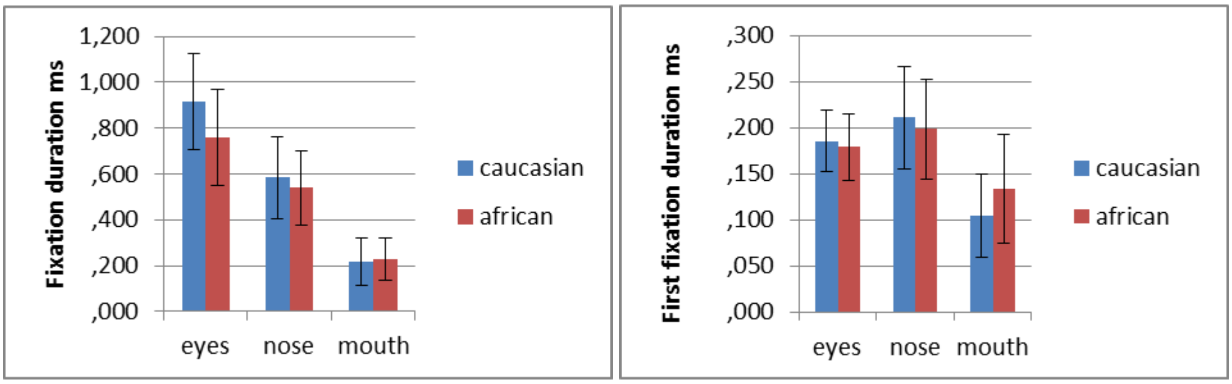

Figure 9. On the left. Longer fixation for Caucasian faces on the eye region. On the right. Longer first fixation on the African mouth.

For the duration of the first fixation, a main effect of face part was found, $F(2,62)= 4.448$, $p= .018$, $\eta^2_p = .125$. First fixation to the mouth-region was significantly shorter (M=0.119s) than that to the nose region (M= 0.204s) whereas the eyes had an intermediate index (M = 0.182). The interaction between Face Part and Ethnicity was also significant, $F(2,62)= 3.960$, $p= .026$, $\eta^2_p = .113$. Participants made a longer first fixation on the African mouth (M= 0.134s) compared to the Caucasian one (M=0.105s, Bonferroni adjusted alpha p =. 0083, see *Figure* 9). No correlation was found between the recognition data and the gaze behavior data both in the encoding and in the test phase.

Holistic and analytical thinking. Only the 'Locus of attention' subscale was analyzed, because it was the one mostly related to the elaboration style. The scale reliability was good, α= .812, so a mean '*global thinking'* index was calculated. Only one positive correlation was found with the time to first fixation to African faces $r(32)= -.375$, $p= .034$. Participants with a more global thinking style looked faster at African faces.

3.2.2.3 Discussion

In this study I have investigated the relationship between the gaze behavior and the ORE in a context of simultaneous face presentation. At the behavioral level, the global recognition performance was the same for own- and other-race faces, as hypothesized. Moreover, as in Study 2, both False Alarms and Hit rates were higher for other-race faces. The number of Hits interacted also with the gender of participants and the ethnicity of the face. Female participants recognized better face on the right side of the screen. This result could be reconcilable with some findings of the SAB literature, which shows that the stereotypic position of female targets is more on the right of the screen compared to male targets (McManus & Humphrey, 1973). It may be hypothesized that this better recognition could be related to the match between the position of the target and the stereotypical position of the participants' gender. Moreover, the effect of race led to a lower recognition of own-race targets in the left position. Usually, the left position is reserved for the most agentic targets (Maass, Suitner, Favaretto & Cignacchi, 2009). In this case, if we use a similar type of explanation used for the gender effects, we should suppose that the better recognition is linked to the stereotypic position of the face in space. On this line of thought, we should suppose that other-race faces are stereotypically imagined on the left, and, therefore, perceived as more agentic. This result is in contrast with previous findings that showed that the in-group is positioned in the more agentic position (Maass et al., 2009). Another type of explanation, could be that, because the left position would not be associated with the other-race faces, this situation elicits a violation of the expectation. This may produce surprise and lead to a better encoding in memory of those face. Nevertheless, to disentangle these hypotheses, more research on this causal attribution should be carried out.

Analyzing the gaze behavior during the face encoding part, only the time to first fixation index showed significant differences. The first fixation was faster to the left of the screen and for African faces, as hypothesized. This last result confirms the idea that other-race faces produce a faster orienting of attention. Moreover, this result positively correlates with the holistic tendency of participants. In this sense, it seems that this faster orienting towards other-race faces is linked to a difference in the elaboration strategy.

However, other-race faces were not observed any longer than same-race faces. The greater number of hits, then, cannot be attributed to a greater time spent on those faces. Therefore, one may suspect that a primacy effect is at work during the encoding phase: because these faces are fixated first, they are remembered better. However, in the present study, no correlation was found between the recognition and the gaze behavior data, both in the time to reach the target or the length of fixations. This result has already been presented by another eye-tracking study (Fu et al., 2012). Also in that study the authors have not found the recognition ORE, and this could have been a common cause for the lack this finding.

Anyway, if no link is present between current face processing and recognition indexes future research should disentangle if this link may be found with different indicators of gaze performance or if it is simply not present.

Finally, in the test phase, I have found a deeper scanning in the eye-region for own-race faces and a deeper scanning in the mouth region for other-race faces. These results are in line with the hypotheses and with previous literature (Fu et al., 2012; Goldinger et al., 2009; Wu et al., 2012) and provide further support to the presence of differential scanning strategies for own- and other-races.

In summary, this study has brought new evidence for the role of eye gaze strategies in the ORE. In the first encoding phase, other-race faces oriented attention faster than own-race faces, but did not elicit longer fixation. During the test phase, however, attention was directed less to the eye area and more to the mouth area of other-race faces. According to these findings, the scanning of own- and other-race faces is performed differently, both during multiple and single presentation, even though the link between the perception and recognition has not been proven.

3.3 Study 4 and 5

Neural bases of different encoding strategies for own- and other-race faces

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After having analyzed, at the behavioral level, the perceptual strategies used by adults for faces of different races, I turned my investigation towards the neural underpinnings of race perception. Moreover, in order to shed light on the development of those neural responses, comparative experiments with adult and infant samples were run. To measure the brain activation during these studies, I used the non-invasive functional near-infrared spectroscopy (fNIRS) technique.

3.3.1 Functional near-infrared spectroscopy

FNIRS is a neuroimaging technique that uses near-infrared light properties to assess brain activation. In human tissues, in the optical window between 700 and 900 nm (NIR region), light is mostly absorbed by the hemoglobin in the blood, while it can pass almost unaffected through skin, adipose tissue and bones. Moreover, oxygenated- (HbO) and deoxygenated-hemoglobin (HbR) have different absorption spectra, which also vary with wavelength, and their concentrations can therefore be separately detected (Figure. 90). In order to measure the hemoglobin concentration changes occurring in the human brain, a source, usually a laser diode or light emitting diode, is posed on the subject's head. Light emitted from the source travels through the scalp, skull, cerebro-spinal fluid and reaches the cortex. Interacting with the tissues, light undergoes processes of absorption and scattering, which cause the final shape of the path followed by the light to assume a banana shape. At a certain distance from the source, usually ~3 cm, a detector collects the light that survived the absorption and scattering processes (see Figure 10). From the difference in intensity between light emitted from the source and the one measured at the detector, under the hypothesis that absorption coefficients of HbO and HbR are known at each wavelength, it is possible to quantify the chromophore (HbO and HbR) concentration changes occurring under the measuring source-detector pair. Through the modified Beer Lambert Law, indeed, the relative concentration changes of oxy- and deoxy-hemoglobin can be calculated as a function of total photon path length, i.e. the total path followed by a photon emitted by the source and measured at the detector position. Each source-detector pair makes what is called a channel (see Boas, Franceschini, Dunn & Strangman, 2002; Calderon-Arnulphi, Alaraj & Slavin, 2009).

The calculation of the hemoglobin concentration changes in the blood is linked to the neural activation through the neurovascular coupling principle. In Figure 10 is graphically described the model of the expected blood flow changes in a brain area, related to the neural activity after a stimulation. Neurons require energy to work. In an active brain area oxygen demand increases, which, in turn, leads the recall of arterial blood. Oxygenated-hemoglobin, then, rises because of the great blood afflux. Also deoxy-hemoglobin at first rises because of the oxygen consumption accomplished by the neurons and, indeed, the model predicts a slight HbR increase in the very first part of the activation response. Nevertheless, the blood-recall effect is much bigger than the oxygen-consumption one. In general, an increase in HbO and a decrease in HbR are expected after stimulation: these are called hemodynamic response function (HRF, Buxton, 2009).

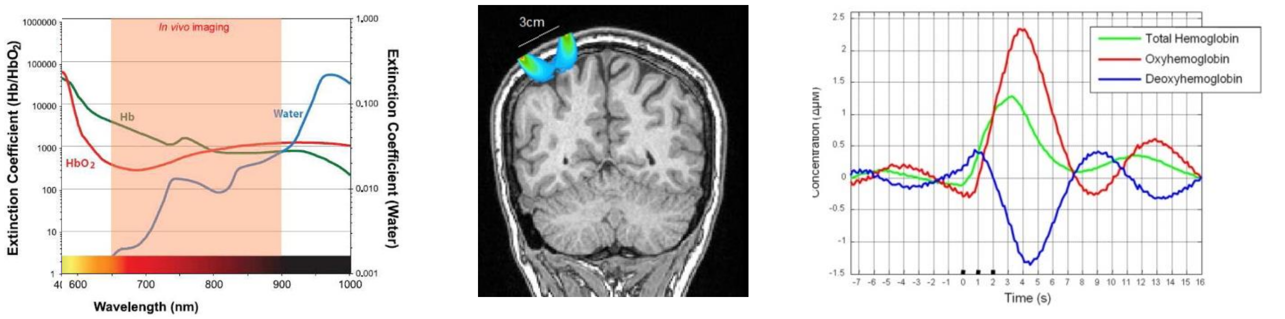

Figure. 90 Left. Spectrum of absorption of oxy- and deoxy-hemoglobin at different wavelengths in the near-infrared window. Adapted from "New strategies for fluorescent probe design in medical diagnostic imaging" by H., Kobayashi, M., Ogawa, R., Alford, P. L., Choyke, & Y., Urano, 2009, Chemical reviews, 110(5), 2620-2640. Copyright 2010 American Chemical Society. Middle. Example of banana-shape path followed by light emitted from a source and collected by a near-by detector, making a channel. Right. Examples of HRF: in red the expected increase of HbO, in blue the expected decrease in HbR and in green the total hemoglobin (HbT) given by the sum of HbO and HbR. Adapted from "Linear superposition of sensory-evoked and ongoing cortical hemodynamics" by M., Saka, J.,Berwick, & M. Jones, 2010, Frontiers in neuroenergetics, 2. Frontiers copyright statement 2007-2014.

FNIRS is an emerging technique and presents several advantages for psychological research. First of all, it is less sensitive to movements compared to other neuroimaging techniques and, most importantly, is not invasive. Therefore, it can be used with a large variety of populations (infants, epileptic patients, psychiatric patients..). It also has a good time and spatial resolution, it is not too expensive compared to other neuroimaging systems and it can be portable. Nevertheless, it has also some disadvantages. The biggest one is about the brain areas that can be investigate. FNIRS can only investigate the brain cortex as deep as 4 centimeters. This limit impedes researchers to investigate, with the adult population at least, phenomena at the subcortical level or at deeper cortical areas. Despite of this boundary, however, the fNIRS technique has been used in many applications (e.g. neonatal brain activity monitoring) and its employment is growing in various areas of psychological research, as cognitive and developmental psychology (for a review see Ferrari & Quaresima, 2012; Lloyd-Fox et al., 2010).

3.3.2 Neuroimaging studies with adults.

The neuropsychological research on race perception is still at the beginning, but some studies have found differences in the neural activation for own- and other-race faces (Feng et al., 2011; Golby et al., 2001; Lieberman et al., 2005; Liu et al., 2014; Wei, et al., 2014; for more details, see Chapter 1). The majority of those findings involve the Fusiform Face Area (FFA), a part of the Fusiform Gyrus with specific activation for faces (Feng et al., 2011; Golby et al., 2001; Lieberman et al., 2005; Wei, et al., 2014). Nevertheless, a growing body of studies is focusing on the broader face-selective brain network, that involves areas of the inferior/middle occipital gyrus, as the Occipital Faces Area (OFA), and, areas of the temporal cortex, as the Superior Temporal Sulcus (STS; Feng et al., 2011; Liu et al., 2014; Natu et al., 2011; Ng et al., 2006). For adult participants, a greater activation for own-race faces has been found in the FFA on perception tasks (see Golby et al., 2001) and in the FFA and OFA on categorization tasks (Feng et al., 2011). For other-race faces, instead, on both FFA and OFA a greater activation was found in recognition tasks than in categorization tasks (Liu et al., 2014).

In this research, I have focused the attention on the very first step of the other-race discrepancy, namely perception. My research question was about the differences in own- and other-race neural responses related to the styles of elaboration. In effect, behaviorally, previous research has demonstrated that own-race faces are perceived more holistically than other-race faces (for a review see Rossion & Michel, 2011). At the neural level, the activation for different face processing strategies has also been investigated. Starting from the common finding of a right hemispheric predominance on face over object perception (Sergent, Ohta & MacDonald, 1992; Puce, Allison, Gore & McCarthy, 1995; Kanwisher et al., 1997), Rossion and collaborators (2000) investigated the role of the two hemispheres in the holistic and analytical face perception. Analyzing FFA activation, they found a left hemisphere predominance for the analytical style whereas a right hemisphere predominance for the configural style. Other studies seemed to suggest that separate brain regions could play different roles in the face perception processing. For example, Schiltz and Rossion (2006) found an holistic advantage in the middle fusiform gyrus (MFG) and the inferior occipital gyrus (IOG), while Liu, Harris and Kanwisher (2010) found that the FFA and the STS are sensitive to both face parts and configuration, while the OFA is sensitive just to face parts.

The main objective of this research was to test the own- and other-race neural activation, related to the differences in the elaboration styles. The first hypothesis was to find a greater activation for own-race faces during a face perception tasks, as showed in previous studies (Golby et al., 2001). The activation differences should be observed in areas of the posterior occipital cortex such as the middle (MOG) and inferior occipital gyrus (IOG) or in temporal areas, as the Superior Temporal Sulcus (STS), because these areas have already been implicated in studies that involved differences in own- and other-race face processing (Feng et al., 2011; Natu et al., 2011; Ng et al., 2006). The second hypothesis was about the hemispheric asymmetry related to the face holistic perception. I expected to find a right hemisphere asymmetry for own-race faces as previous studies had shown (Kanwisher et al., 1997), but not for other-race faces. In effect, right hemisphere lateralization should be connected to the holistic elaboration style (Rossion et al., 2000), which I expected to be mainly used for own-race faces (Rossion & Michel, 2011).

Another factor of novelty of these studies was the technique used for measuring the neural response. Almost all the localization studies that have investigated brain activation for other-race face perception have used the fMRI technique (Feng et al., 2011; Golby et al., 2001; Lieberman et al., 2005; Wei, et al., 2014). Although a fNIRS study on own- and other-race recognition with children (7-12 years) has recently been published (Ding et al., 2014), these are the first studies using functional near-infrared spectroscopy (fNIRS) technique to investigate own- and other-race perception on the adult and infant population.

On the adult population two studies were run, both aimed to investigate the same phenomenon. The first study (Study 4) had brought to no conclusion because of problems in the protocol used and in the data acquisition. Therefore, a new improved protocol was designed and a second study was run (Study 5). The procedure of the Study 4 will be described for purpose of complete information and comparison with Study 5 methodology.

3.3.3 Study 4

This study was composed as an old/new recognition task, with a phase of presentation, a distractor and a recognition task. During the face presentation phase, participants were not told to remember, but just to look at the faces. The first task, hence, was a pure perception task. Faces were presented individually for a short time and were subsequently masked to impede their further elaboration. Indeed, the purpose of this investigation was to catch just the very first perceptual strategy used on the face. As distractor stimuli, the Navon composite letters were used (see Figure11). Also in this case participants were instructed to just look at the letters; hence, they could choose their preferred level of elaboration (holistic/analytical, see also Study 1). The aim of this task was to correlate the right and left hemisphere activation for the letters with the right and left hemisphere activation for the faces. Finally, a recognition task was performed in order to test if a better recognition could be related to the more configural processing of the stimuli. The final aim of this task was to correlate the behavioral with the neural results for own- and other-race faces.

3.3.3.1 Method

Participants. Twenty-two Caucasian participants with normal or corrected to normal vision were assessed (12 females, mean age = 24.14 years). Only 4 out of 22 reported not to have had contact with a person of black African descent.

Material. Forty frontal looking faces of Caucasian and African people were taken from the Minear and Park (2004) database as in the previous experiments. For the twenty faces of the presentation phase, twenty corresponding masks were created. The masks were made using Adobe Photoshop. The face was mashed and distorted so that its configuration and features were unidentifiable, but the color and spatial frequencies remained almost the same *Figure 11*).

Also 6 global/local letters (see Navon, 1977) and 6 global/local figures similar to Derryberry and Reed (1998) were created. The letters and the figures were always incongruent so that the local letter was always different from the global letter. For the letters, different mixes between “E”, “M” and “H” were created. The global letter subtended a visual angle of 4.50° X 5.72 ° while the local letter subtended an angle of 0.25° X 0.41° at a distance of 70 cm. For the figures, different mixes between a triangle, a square and a rhombus were created. The global figures subtended a visual angle of 6.13° X 6.13°, while the local figures subtended a visual angle of 0.57° X 0.57°.

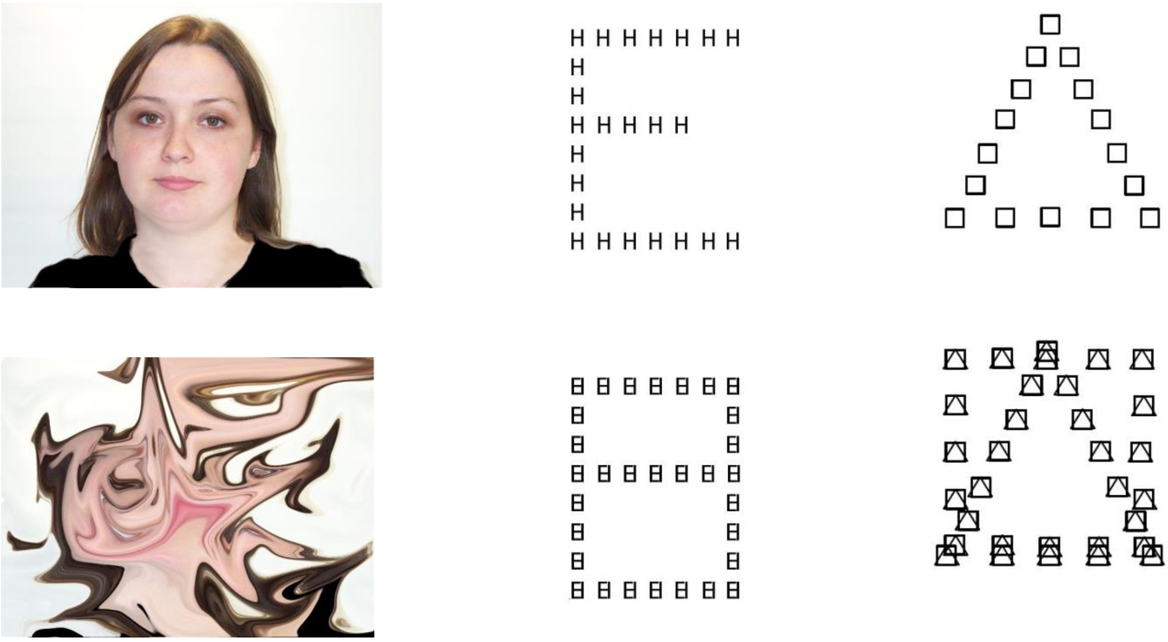

Figure 11 Face, letters, figures and mask stimuli used for the presentation.

Also for the letters and figures the corresponding masks were created: these masks were the juxtaposition of all the global and local elements of the two letters or figures forming the previous image. For example, if the image was a global triangle composed by local squares, the masking image was the global square made by local squares and triangles plus the global triangle made by local squares and triangles (See *Figure 1*).

Finally, participants' familiarity with other-race faces was assessed with a scale adapted from Brown, Vivian and Hewstone (1999). First, participants were asked if they have ever had contact with people of "Black African descent". If they responded positively they were asked, on a scale from 1 to 7, how many people of that descent they knew and how often they interacted (from 1 never to 7 every day) with the person of this descent they knew best (amount of contact). They were then asked about the intimacy of the contact with three items. On an eight-point scale they had to judge how much the relationship with the closest person was from 1 (a casual acquaintance, unfriendly and formal) to 8 (a close friendship, friendly and informal). On the same scale participants had to judge whether the relationship was competitive or cooperative (interdependence of contact). Finally, they were assessed on the salience of the membership: always on an eight-point scale from 1 (never) to 8 (always) they had to say how often they made references to one another's ethnicity in their encounters with this person and how much this person could be considered `typical' of his/her ethnic group.

Procedure. After filling in the informed consent participants were seated in front of an LCD monitor. The experiment was led into a sound attenuated and dimly lit room. Participants were given the instructions orally, before each task. For the presentation phase participants were told just to look at the pictures. Each trial began with the face presented on the screen for 2 seconds, after which the mask appeared and stayed on the screen for 8 seconds. This was done to let the hemodynamic activation for face return to the baseline. The second task was the same as the presentation one, except that, in this case, letters and figures appeared instead of the faces. This task was used as distractor. The presentation of figures and letters was randomized. Each figure or letter appeared for 2s and, then, the mask stayed on the screen for 8s. The test phase consisted in the old/new recognition task. The faces remained on the screen until participants gave their answer. They had to say, pressing a key, whether they had seen the faces during the previous presentation phase or the faces were new. After filling in the other-race contact questionnaire participants were debriefed.

fNIRS apparatus and probe placement. FNIRS data was acquired with a multi-channel, frequency-domain NIR spectrometer (ISS Imagent™, Champaign, Illinois) equipped with 32 laser diodes (16 emitting light at 690 nm and 16 at 830 nm) and 4 photo-multiplier tubes. The sources were modulated at 110 MHz while the detectors were modulated at 110 MHz plus 5 kHz for heterodyne detection. To separate the source light as a function of location, the lasers of each source were time-multiplexed during measures. The sampling frequency was 7.8125 Hz.

The positioning of source and detector fibers on the participants' head was done using a single-distance probe arrangement (see Figure 7), as the one described by Cutini and collaborators (2008). Sources and detectors were held in place on the scalp using a custom-made head-mount system provided with Velcro straps. Each source location consisted of two source optical fibers, one for each wavelength. Source-detector distance was set to 30 mm in order to reach an optical penetration depth of approximately 25 mm, hence probing the cortical tissue (Franceschini, Toronov, Filiaci, Gratton & Fantini, 2000). The two symmetric probes were positioned bilaterally in the temporal areas and points T3 and T4 from the 10-20 system were used as reference. These were located approximately in the middle of the patch, between the two detectors (see Figure 12).

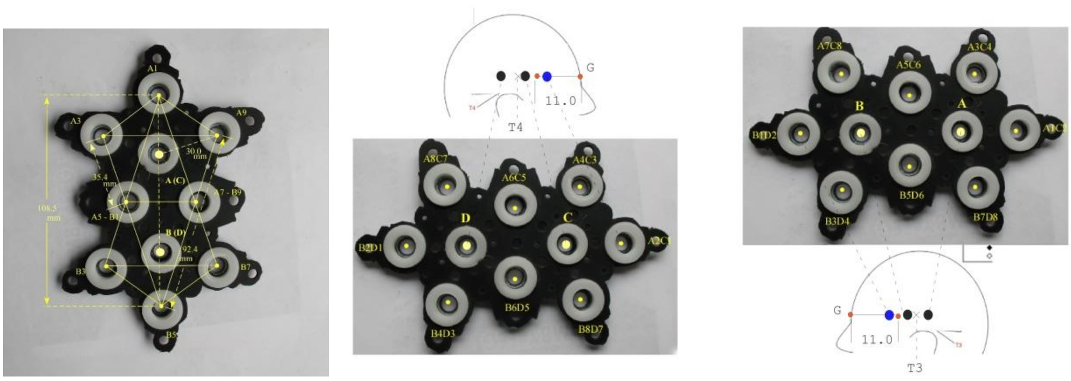

Figure 12 Channel probes and positions on the temporal areas of the scalp

3.3.3.2 Results and conclusion.

Unfortunately, technical problems with the acquisition equipment and methodology did not allow the finding of reliable hemodynamic responses. Moreover, the analyses were conducted by another laboratory that unfortunately did not conserve the data processing and the results, due to a transfer of the research staff in charge for the analysis. Nevertheless, the measured data showed some tendencies that highlighted the presence of further issues other than the acquisition problems and helped me in improving not only the acquisition part of the measurement but the paradigm as well.

Indeed, also the paradigm used did not allow measuring the predetermined phenomenon. Face presentation was too long (2s), compared to other perception studies, which investigated elaboration styles (see Rossion et al., 2000). Moreover, the masking technique was a too interesting stimulus and seemed to elicit more neural activation than the face stimulus. Each mask was related to the previous face but remained on the screen for longer time. Participants could easily figure out the relationship between the two stimuli and recollect some face cues on the mask. For these reasons I decide to start over this experiment and create a new experimental apparatus and procedure.

3.3.4 Study 5

This study, as the previous one, had the general purpose to investigate own- and other-race face activation according to different elaboration styles. Compared to the previous study, the methodology and the data acquisition have been revised. First, the paradigm was prolonged and it contained three distinct parts: the first was a passive viewing task, the second was a behavioral task, inducing an holistic or analytical elaboration style, and the third was an old/new recognition task.

In the first task (Task1), face presentation was performed in blocks. Each single face was presented for a time briefer than the one of the previous experiment (250ms instead of 2 s) but, instead of being masked, it was followed immediately by another stimulus of the same category, for a 5 seconds total presentation period. This method allowed the reiteration of the very first style of elaboration for a prolonged amount of time and reinforced the neural response to the stimulus. The hypotheses for this task were the same as those of the Study 4.

The second task (Task2) was aimed to induce a particular style of elaboration on both faces and letters. It was composed by different subtasks, divided by the type of the stimulus (Caucasian face, African face and letter) and the type of elaboration (holistic and analytical) for a total of six subtasks. Usually, tasks that assess the style of elaboration use some type of recognition or comparison processes (e.g. whole-parts task, composite face task, see Chapter 1). In this study, instead, I wanted to elicit a quick analytical or holistic processing. For this purpose, this new task has been created. On each trial, a block of faces appeared very fast (500ms each) and, for every face, participants had to respond, by pressing a key, depending on some facial characteristics. In the analytical condition, participants had to respond just to one facial particular (pupils), while, in the holistic condition, participants had to respond to the global configuration of the elements within the face. The purpose of this task was to compare the neural responses of the analytical or holistic elaboration style. Based on the right lateralization hypothesis of the holistic style, I expected to find more activation on the right hemisphere in the holistic than in the analytical condition.

Finally, the third task (Task3) was an old new recognition task and was composed by three sub-tasks: the face encoding, the distractor and the recognition task. In the encoding phase, faces were presented individually for a longer period of time, as in the Study 4 (2s), in order to allow participants to remember them. This task was used to compare the neural responses for own- and other- race faces with the ones of the Task 1. Those two conditions had two main differences: the time of presentation and the type of process involved. Task 3 was related to the encoding process and had a longer exposition time for each face, whereas the first task was about pure perception and had a very brief presentation of singular faces. It could be alternatively hypothesized that differences between own- and other-race faces, linked to the style of elaboration, are stronger in the very first step of perception (Task 1) or during the encoding process (Task 3). After that, as distractor task, a presentation of vehicle images was performed. These stimuli were used to compare the activation between faces and non-social stimuli. A greater activation for faces than for vehicles was expected, depending on channel locations. Finally, the recognition task was performed. A better recognition performance was expected for own- than for other-race faces. As in the previous study, participants' experience with other-race people was controlled.

Not only the paradigm, but also the data acquisition were modified and improved. A different arrangement was used to hold the optodes on the scalp and a different array configuration was created. The array location was moved backwards towards the occipital areas (see *Figure5*), in order to reach important cortical areas connected to face perception as the IOG and the OFA. The FFA is also in the temporal/occipital areas, but unfortunately, it is locate too ventrally, and therefore it is likely that it cannot be reached by fNIRS.

3.3.4.1 Method.

Participants. Twenty-seven Caucasian people took part in the experiment. Nine participants were excluded due to technical reasons (see 'fNIRS data processing' section), leaving the final sample with 18 participants (14 females; mean age= 23.9 years, 21 right-handed). Four people reported to have or have had a partner or a relative of Black African descent. Twenty-three people out of twenty-seven reported to have had contact with persons of Black African descent. The research was approved by the local ethical committee of the University of Padova. After the experiment, all participants were debriefed and were given a little reward (chocolate bars).

Materials. One hundred Caucasian and one hundred African faces were taken from the Minear and Park (2004) database and from license-free pictures of the Internet. Images were all upright, frontal looking faces and with a neutral emotion expression. Pictures had a resolution of 640 X 480 pixels. Only the face, hair and neck were selected and put on the same gray background. All accessories as jewels, piercing etc. were removed with the use of Adobe Photoshop. For the second part of the experiment, 80 of the previously presented faces (forty Caucasian and forty African) were modified. For the analytical task, the eyes of 40 faces were painted red, while for the holistic task, 40 faces were scrambled, so that face parts (e.g. eyes, nose and mouth) were displaced inside the face contour (see *Figure 13*).

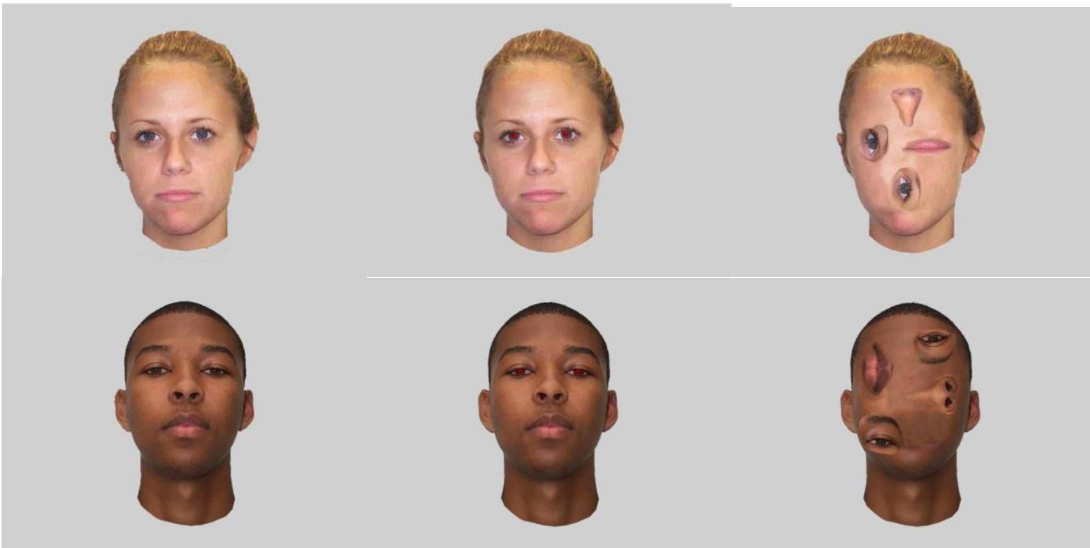

Figure 13. Caucasian and African faces used for the experiment. From left to right: normal faces, faces with modified pupils (analytical condition), faces with scrambled configuration (holistic condition)

In Task2, the analytical and holistic tasks were also performed with Navon letter stimuli and 10 letters for the analytical task and 10 for the holistic task were created. Because participants should only respond pressing the "M" or "E" keys on the keyboard, in the analytical task the global letters were "N", "H", "F","L" and "T" composed only by "E"'s or "M"'s local letters. For the holistic task, instead, the global letters were only "E"'s and "M"'s composed by other letters. Pictures had a resolution of 640 X 480 pixels: the global letters subtended a visual angle of 5.73° X 7.86° while local letters subtended an angle of 0.43° X 0.57° at a distance of 80 cm.

For the distractor task (in Task 3), images of means of transport were (e.g. cars, helicopters etc.) taken from the work of Lloyd-Fox and her collaborators (2009). These images were also used as a non-social control stimuli to compare their hemodynamic activation with the one of faces. The images had a resolution of 640 X 480 pixels.

To assess participants' contact with other-race people, the same adapted version of the scale of Brown and collaborators (1999) of the Study 4 was used.

Procedure. After completing the informed consent, participants were taken to a sound attenuated and dimly lit room. Participants were seated in front of an LCD computer monitor controlled by a computer running E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) at a distance of approximately 80 cm. In the first task (Task 1) participants had only to look at and pay attention to the faces. Each sequence began with a fixation cross for 250 ms. After that, the stimuli appeared in a block of 20 faces, each presented for 250 ms. The block stimulation was used in order to allow a very brief presentation of the single face, while achieving a total stimulus presentation of 5 seconds. A brief presentation of a single face was used in order to catch the very first style of elaboration (analytical/holistic) for that face. A single 250 ms face presentation, however, would have been an insufficient presentation time to assure a significant hemodynamic response. After each block a grey screen was presented for a random time between 12 and 13 seconds. This random time was chosen to impede any possible synchrony with physiological fluctuations caused by, for example, blood pressure (see *Figure4*). In the first task, 4 blocks of Caucasian and 4 blocks of African faces were presented.

The second task (Task 2) was intended to induce an analytical (Task 2A) or a holistic perception (Task 2H). Task 2 was, moreover, divided between face and letter presentation. In the analytical face task (Task 2A face) the pupils of some faces were modified, in order to focus participants' attention only to a single element of the face. The participants had to press the "z" key (this key was covered with the "e" letter for the subsequent letter task) if the faces had normal pupils and the "m" key if the faces had red pupils. The presentation sequence was the same as the one in the first task except that the single faces presentation lasted 500 instead of 250 ms, to allow the behavioral response. In order to maintain the same total stimulus presentation, the faces in each block were 10 instead of 20. Moreover, at the end of each block, a screen, repeating the instructions, was shown. That allowed participants to pause the experiment and start the new block when they were ready. For the holistic condition (Task 2H face), the task was basically the same. However, in this case, participants had to press the "z" button if the face was normal and the "m" button if the face was scrambled. This manipulation was aimed to focus participants' attention to the global configuration (Figure 13).

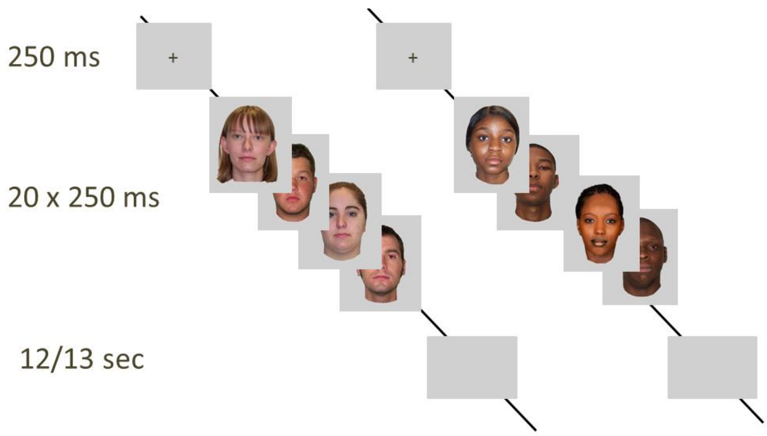

Figure 14. Example of the block stimulation used in the first task.

At the end of each face task, also a parallel letter task was proposed. In the analytical task (Task 2A letter) participants had to press the "z" button (labeled "e") when the local letter was an "e" and the "m" button when the local letter was an "m". In the holistic task (Task 2H letter), they had to do the same thing with the global letter. The order of the analytical and holistic tasks was counterbalanced to avoid fatigue effects.

The last phase consisted in a recognition task (Task 3). In the encoding phase (Task 3E), participants were told to memorize the faces that appeared on the screen. Faces were presented for 2 seconds each and were selected by a new set of faces compared to the set used in previous tasks. After every face, a grey screen appeared for a time between 12 and 13 seconds.

Subsequently, some vehicles images were presented as distractor task (Task 3D). Also in this case, participants were told just to look at the images. Three types of vehicles presentation were used, each one corresponding to a previous face presentation. In this task, 2 blocks of 20 images were presented for 250ms each (Task 3D 1), 2 blocks of 10 images were presented for 500 ms each (Task 3D 2) and 4 images were individually presented for 2s each (Task 3D 3). Different presentation types were created, in order to be able to compare vehicle and faces in all kind of tasks.

The last task was a new/old recognition task (Task 3R), as the one used in the previous experiments. Participants had to press "z" if they had already seen the faces in the presentation or "m" if the face was new. At the end they completed the contact questionnaire, which was the same of Study 4, and were debriefed about the experiment.

fNIRS apparatus and probe placement. The fNIRS data was acquired with a multi-channel, frequency-domain NIR spectrometer (ISS Imagent™, Champaign, Illinois) equipped with 32 laser diodes (16 emitting light at 690 nm and 16 at 830 nm) and 4 photo-multiplier tubes. The sampling frequency was set to 7.8125 Hz.

The positioning of source and detector fibers on the participants' head was done using an EasyCap (www.easycap.de), which is a cap commonly used in electroencephalographic/ evoked potentials experiments for electrode positioning. The cap was reinforced on the internal part with a silicon layer, in order to hold the optodes more tightly on the head surface (see *Figure 15*). Source-detector distance was set to 30 mm in order to reach an optical penetration depth of approximately 25 mm and probe the cortical tissue (Franceschini et al., 2000). Each source location consisted of two source optical fibers, one for each wavelength.

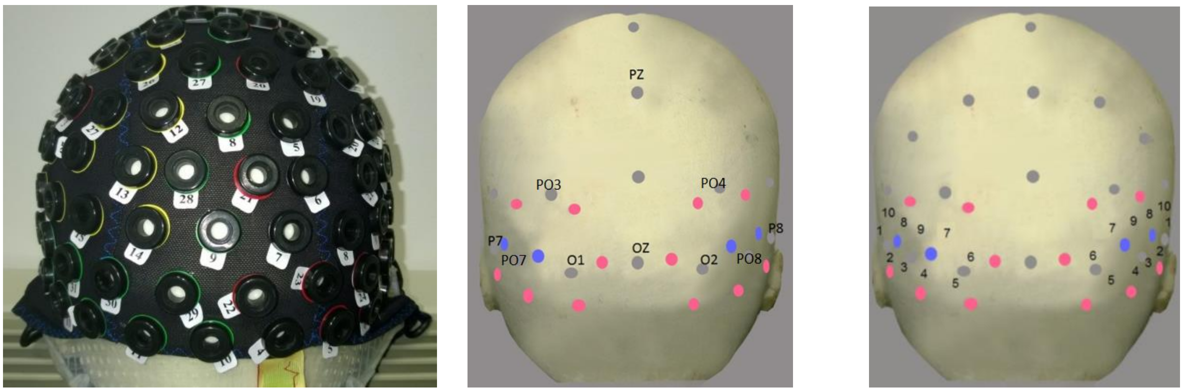

Figure 15. Left: Head cap with channel separation. Middle: Probe configuration on the ICBM152 physical model (Cutini et. al 2011). Blue points indicate the position of detectors, pink points indicate the sources and the grey points are the reference points of the 10-10 system. Right: channels' position on the head surface.

The positioning of the source and detector fibers on the participants' head was performed according to a probe-placement method based on a physical model of the ICBM152 head surface developed by Cutini and collaborators (Cutini, Scatturin & Zorzi., 2011). The occipital areas were sampled using as reference some points of the 10-10 system: O1 and O2 were almost in the middle between channels 5 and 6 (bilaterally). PO7 and PO8 laid almost in the middle between the two detectors located in the same hemisphere while P7 and P8 laid between the sources of channels 1 and 2 (bilaterally). On the upper part PO3 and PO4 laid between the sources of channel 7 and 9 (bilaterally). Finally, P5 and P6 almost overlapped with the sources of channels 10 (bilaterally, see *Figure5*). Before each session, the head circumference and the nasion to inion distance were measured and the cap was put on so that Cz measured on the participant's head matched Cz labeled on the cap. After the fibers were mounted, an elastic hairband was place around the cap in order to improve optodes contact with the scalp and constrain the movements of the optical fibers.

3.3.4.2 fNIRS data processing.

Data pre-processing was performed using some of the Homer2 NIRS processing package functions (Huppert, Diamond, Franceschini & Boas, 2009) based in MATLAB (Mathworks, MA USA). For every subject, channels with a very low optical intensity or with a signal-to-noise ratio lower than 2, were discarded from the subsequent data analysis using the function enPruneChannels. If more than half the number of channels located in each hemisphere was discarded, because of a weak signal, then the subject was excluded from further analyses. The raw optical intensity data were converted into optical density (OD) changes. For each channel, a motion detection algorithm hmrMotionArtifactByChannel was applied to the OD time-series to detect motion artifacts. This function finds data-points surpassing a threshold in the change of amplitude (AMPthresh) and/or a threshold in the change of standard deviation (SDThresh) within a given time period (tMotion). Then it marks those points from the beginning of the time window to tMask seconds later as motion artifacts. All the thresholds, the window length and tMask, can be set by the user. In this study, AMPThresh = 0.4, SDThresh = 15, tMotion = 0.5 and tMask = 1, which allowed me to find a compromise between the number of motion artifacts identified in noisier data series and the number identified in less noisy data series. This function works on a channel-by-channel basis; hence it detects motion artifacts independently in every single channel. This allows to apply the motion correction technique only where motion artifacts are actually present and to preserve, instead, unfiltered the data in motion-free channels located at the same time-points where a motion artifact was identified in other channels.

After motion artifact identification, the hmrMotionCorrectSpline function was applied, to try to correct the identified motion artifacts. This function performs a cubic spline interpolation on the artifacts detected in the previous step and subtracts it from the signal (Scholkmann, Spichtig, Muehlemann & Wolf, 2010). After motion artifact correction, Principal Component Analysis (enPCAFilter) was run in order to remove artifacts due to physiological noise oscillations (e.g. blood pressure, respiration). In this study the PCA filter was set to remove a number of components explaining 85% of the estimated variance, similarly to the value used in the work by Brigadoi and collaborators (Brigadoi, 2014).

After this, a band-pass filter with 0.01–0.5 Hz as cut-off frequencies was performed on the data in order to reduce very slow drifts and high frequency noise. A second motion detection algorithm (hmrMotionArtifact) was applied to the data with the same thresholds specified previously (except for SDThresh = 50). This function works as hmrMotionArtifactByChannel but on all channels simultaneously. Therefore, when it finds a motion artifact in one of the channels, it marks it as corrupted in all the channels time-series. Then, the enStimRejection function was applied on the data. This function excludes the stimuli that fall within a user-set window around the time points marked as motion artifacts. In this experiment tRange was set to -2-5 seconds.

The OD data were then converted into concentration changes using the modified Beer–Lambert law (Cope and Delpy, 1988; Delpy et al., 1988). Finally, a block average was performed on all remaining trials related to the same stimulus type. This produced fifteen mean HRFs, one per stimulus type, for each channel and each participant. On each HRF, some metrics can be extracted in order to compare conditions and channels with statistical analysis. Here, the area under the curve (AUC), calculated as the integral of the values of the curve in a time-range between 5 and 15 seconds after stimulus presentation, was chosen as metric. The area under the curve can be positive or negative depending on the sign of the HRF values.

3.3.4.3 Results.

Recognition performance. The d-prime indexes (d') were calculated separately for the Caucasian and for the African group, as in the previous experiments. The recognition advantage for the Caucasian group was not statistically significant, $t(17) = .697$, $p =$ n.s.

Fnirs results. The results of the Task 1, where participants had just to look spontaneously at faces, were first analyzed. A 2 Hemisphere (left-right) X 9 Channels X 2 Ethnicity of the face (Caucasian-African) repeated-measure ANOVA was run on the AUC values obtained from the mean HRFs of Task 1. Channel 6 was excluded from the analyses because it was eliminated in almost half of the participants.

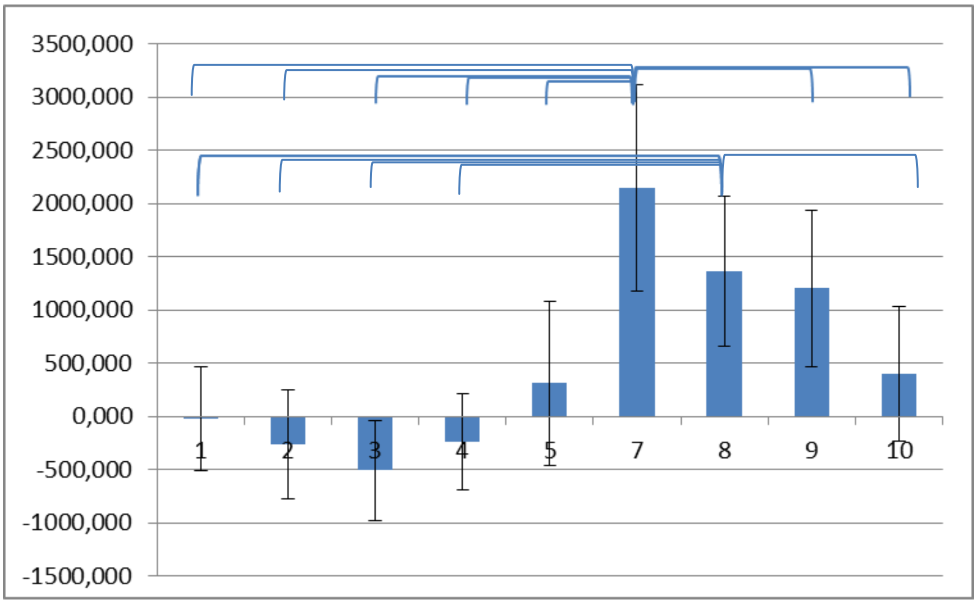

Figure 16. Distribution of channel activation (AUC) for faces in general. Error bars represent the 95% confidence interval. Horizontal lines depict significant contrasts.

This analysis revealed a main effect of the Channel, $F(8,136) = 16.949$, $p < .001$, $\eta^2_p = .499$. Bonferroni corrected contrasts, using an adjusted alpha levels of .0063 (.05/8), revealed that the channels exhibiting higher activation were channel 7 and 8 bilaterally (see *Figure 16*).

Channel 7 was significantly more active (M = 2144,33 nM) than all the other channels except for Channel 8 (M = 1357,64 nM). Channel 8 was more active than all other channels except channel 5, 7 and 9 (see Table 1).

Table 1. Activation for each channel for faces, mean, standard deviation and 95% confidence interval.

Channel	Mean nM	Standard Deviation Error	Confidence interval 95%	
			Lower boundary	Upper boundary
1	-25,639	231,597	-514,267	462,989
2	-260,658	244,271	-776,025	254,708
3	-506,899	220,772	-972,687	-41,112
4	-241,130	215,311	-695,396	213,136
5	310,629	363,013	-455,261	1076,519
7	2144,326	459,099	1175,711	3112,940
8	1357,639	333,870	653,236	2062,043
9	1202,074	347,140	469,671	1934,476
10	400,913	299,743	-231,490	1033,316

I found also a significant interaction between the Hemisphere and the Channel, $F(8,136) = 2.969$, $p = .025$, $\eta^2_p = .149$. For this effect, none of the contrasts was significant.

Finally, there was a significant interaction between the Channel and the Ethnicity, $F(8,136) = 2.449$, $p = .042$, $\eta^2_p = .126$. After adjusting the alpha to 0.0055 (0.5/9) with Bonferroni, channel 7, bilaterally, was significantly more active for Caucasian (M = 3304,62 nM) than African faces (M = 984,03 nM, *Figure 17*).

In Task 2, there was no effect of the stimulus type (Caucasian face, African face, letter). Therefore just the differences between the analytical and holistic condition were analyzed. The mean HRFs for the analytical and the holistic condition was computed averaging together the mean HRFs related to the analytical and holistic stimuli (Caucasian face, African face and letter), respectively. A 2 Hemisphere (left-right) X 9 Channels X 2 Elaboration Style (analytical-holistic) repeated-measure ANOVA was run. Only the main effect of the Channel was significant, $F(8,136) = 3.516$, $p = .016$, $\eta^2_p = .171$. Also a partially significant interaction between the Channel, the Hemisphere and the Elaboration Style was found, $F(8,136) = 2.488$, $p = .052$, $\eta^2_p = .128$ (Greenhouse-Geisser corrected). After adjusting the alpha to .0028 (0.5/18, Bonferroni) only Channel 1L was more active for the holistic (M = 526,27 nM) than the analytical condition (M = -340,26 nM).

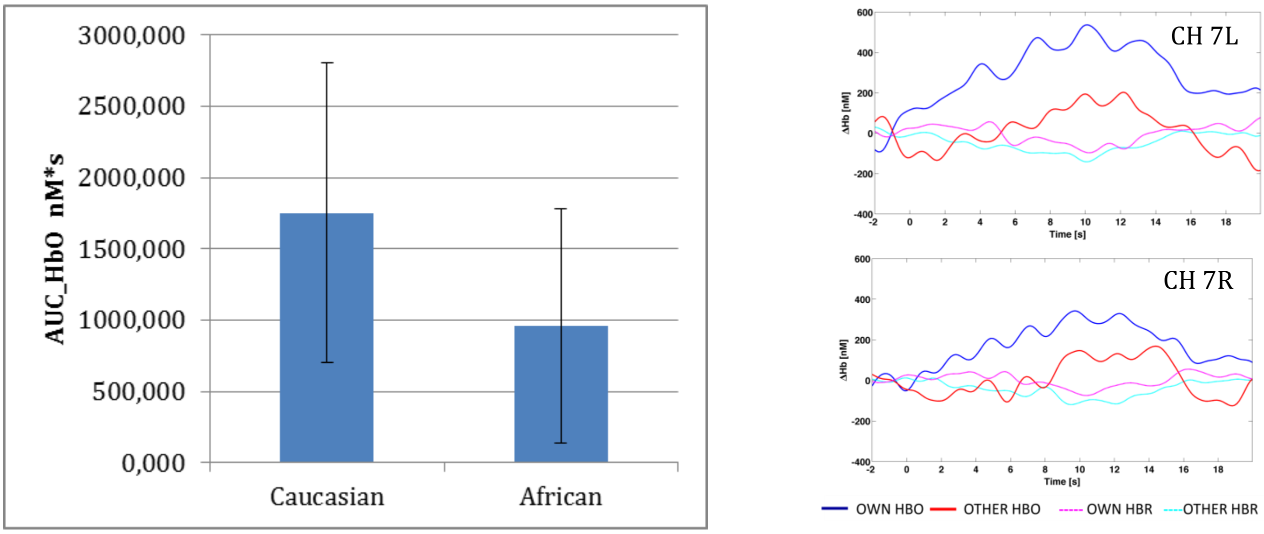

Figure 17. Left. Mean activation across participants on channel 7 for Caucasian and African faces. Error bars represent the 95% confidence interval. Right. Mean HRFs in channel 7Left and 7Right for own- (Caucasian) and other-race (African) faces. In blue and red the HbO hemodynamic responses are reported, while in magenta and cyan the HbR ones are displayed, for own and other-race faces respectively.

For each participant, an index of holistic tendency was computed, operationalized as the general activation in all channels for the holistic condition minus the general activation in all channels for the analytical condition. In the encoding part of the recognition task (Task 3E), the corresponding ANOVA with 2 Hemisphere (left-right) X 9 Channels X 2 Ethnicity of the face (Caucasian-African) as repeated-measure and the Holistic Tendency index as covariate was run. The interaction between the Ethnicity of the face and the Holistic index was significant , $F(1,16) = 7.682$, $p= .014$, $\eta^2_p = .324$ (*Figure 18*). People that showed a higher holistic tendency had a higher activation for African people.

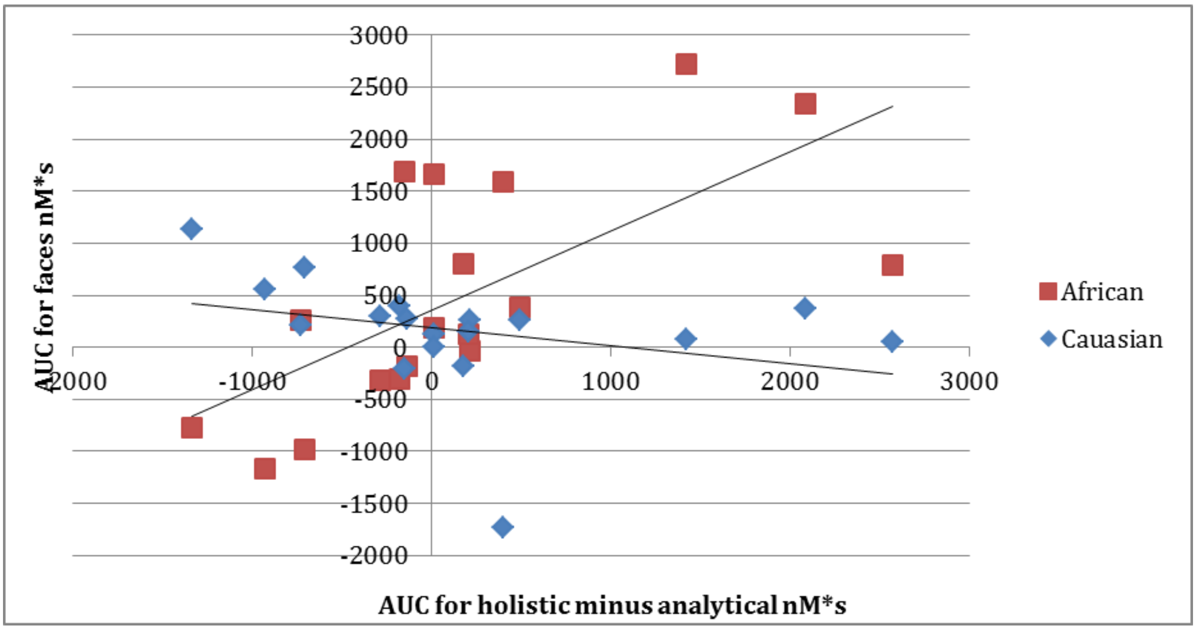

Figure 18. Interaction between holistic neural tendency and the activation for own- and other-race faces on the presentation part of the recognition task.

The difference between the AUC values obtained from the mean HRFs of faces in Task 1 and their respective vehicles presentation (Task 3D 1) was analyzed with an ANOVA with 2 Hemisphere (left-right) X 9 Channel X 2 Type of Stimulus (Face, Vehicles) as repeated-measures. A significant interaction was found between Channel and Stimulus Type, $F(8,136)= 2.771$, $p= .034$, $\eta^2_p = .140$. No contrast, between the stimulus types was significant.

Correlations with recognition performance. Another repeated-measure ANOVA was performed on the AUC values obtained from the mean HRFs of Task 3E (encoding task) with 2

Hemisphere (left-right) X 9 Channel X 2 Ethnicity of the face (Caucasian-African) with the D-prime index for Caucasian faces as covariate. A main effect of the Ethnicity was found, $F(1,16) = 4.982$, p= .040, $\eta^2_p = .237$. In this case African faces activated more than Caucasian ones (485.988 nM versus 32.310 nM, respectively, *Figure 19*).

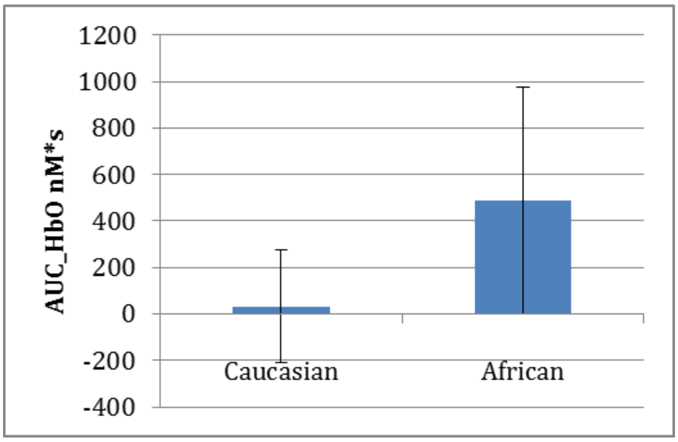

Figure 19. Presentation phase of the recognition task: activation for Caucasian and African faces without the effect of the Caucasian d-prime. Error bars represent 95% confidence intervals.

Moreover, also the interaction between the Ethnicity of the face and the D-prime for Caucasian faces was significant, $F(1,16) = 7.674$, $p = .014$, $\eta^2_p = .324$. People who recognized Caucasian faces better showed a greater activation for African faces (*Figure 200)*.

Finally, the relationship between the other-race contact scale and the ORE (calculated as the difference between the Caucasian and African d-primes, as in previous experiments) was analyzed. A significant negative correlation between the references to one another's ethnicity and the ORE was found, $r(15) = -.520$, $p = .047$. The more people made references to one's another ethnicity in their relationship with African people the better they recognized them.

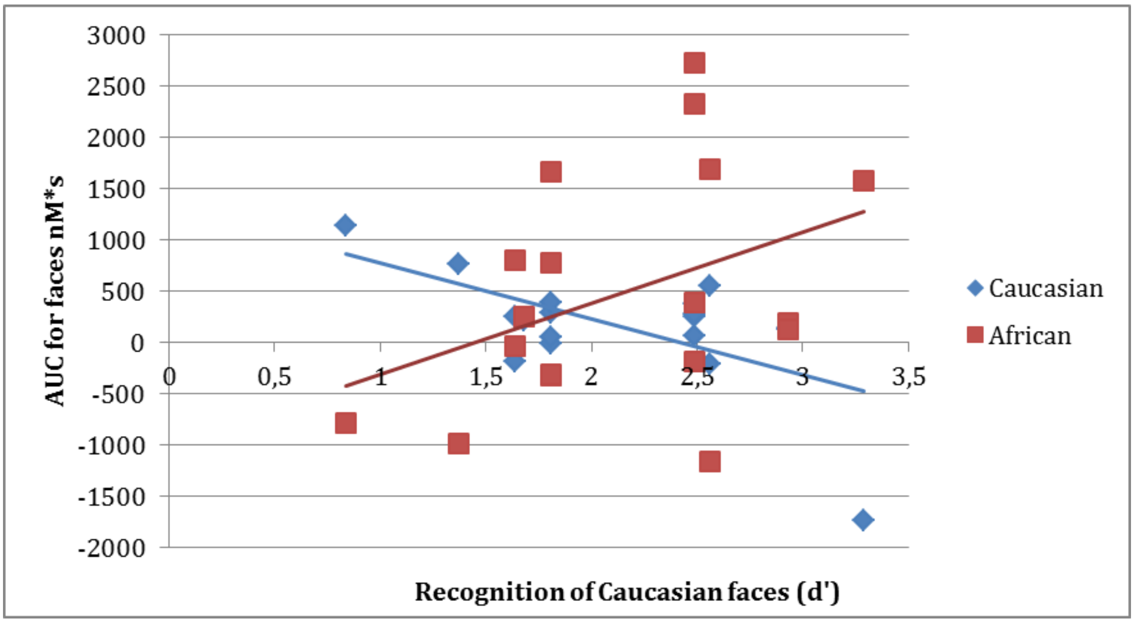

Figure 20. Presentation phase of the recognition task. Interaction between activation for own- and other-race faces and own-race recognition performance.

3.3.4.4 Discussion.

This study has investigated the neural activation for the very first type of elaboration of own- and other-race faces. Results of the first task showed that Channel 7 was bilaterally more active for the faces stimuli compared to the other channels, and specifically, was more active for own- than for other-race faces. Channel 7 laid between PO3 and O1 on the left hemisphere and PO4 and O2 on the right hemisphere. According to the cortical projection model of the 10-10 system (Koessler et al., 2009), this area lays in the middle between Broadmann Area 18 and 19, corresponding to the middle-superior occipital gyrus. In this area I have found confirmation of my hypothesis of a greater activation for own-race than for other-race faces in the first perception. This result is in line with previous studies that found a stronger activation for own-race faces in areas of the middle-inferior occipital gyrus (Feng et al., 2011; Natu et al., 2011; Ng et al., 2006). Moreover, this result is in line with a recent fNIRS study on own- and other-race face recognition, that was run with children (Ding et al., 2014). Researchers found a greater activation for other- than for own-race faces on a channel situated in BA18 in younger children. However, as children's age increased, the activation for own-race faces overtook the one for the other-race faces, a result similar to what I have found in adults.

In the encoding phase of the recognition task, anyway, was found an effect of the ethnicity with the opposite pattern, so that African faces activated more than Caucasian ones. This task differed from the other in two aspects: the first one was the timing and style of the stimulus presentation, while the second one was the psychological process involved. On one side, in the first task the faces were presented for 250ms each, in a block of 20 faces, whereas in the third task they were presented individually for 2 seconds each. This timing difference could have allowed different perceptual strategies in the two tasks. On the other side, the first task was a passive viewing task, so that participants had just to look at faces, while in the third task participants were instructed to memorize the observed faces. Therefore, in the latter case, they could have tried to encode faces more intentionally for the subsequent recognition task. In this sense, it could be hypothesized an effect of cognitive effort on the encoding task. People had to work harder to properly encode other-race faces, and this could explain their higher hemodynamic responses. This hypothesis is also in line with the significant interaction that was found between the ethnicity of the face and the recognition of own-race faces. People, who, subsequently, recognized better own-race faces, showed a lower activation for those and a higher activation for other-race faces. Moreover, the same pattern was shown by people who had a stronger holistic activation. If we think that the holistic elaboration style helps the encoding of own-race faces, it is plausible that those people have to make more effort to encode other-race faces.

The difference between hemispheric activation was not significant, either for pure face perception or for the induced elaboration style, so the hemispheric predominance hypothesis of the holistic elaboration style is not supported. This lack of hemispheric lateralization could be due, on one side, to the fact that own- and other-race faces are not linked to different styles of elaboration or, on the other side, that those styles do not subtend a lateralized activation. Since also in the holistic/analytical task no lateralization was found, the second hypothesis seems the more plausible. In effect, in the literature, some studies have not found a lateralized activation for the holistic or analytical style of elaboration (Schiltz & Rossion, 2006; Liu et al., 2010). Furthermore, this task was created ad hoc for this experiment because I wanted a task involving just perception and not recognition processes. The lack of differences between any condition could indicate that this task did not work properly and it could have induced a general and independent activation in all participants. In future research, more consolidated tasks should be used to test this lateralization hypothesis.

Finally, the greater activation for faces than for vehicles was not significantly different. This great activation for the vehicles could have been caused by their richness of particulars and by a novelty effect. First, the vehicles were presented almost at the end of the experiment, which was composed only by faces and some letters; vehicles stimuli were very colorful and full of particulars, so they can have elicited great interest. Another discrepancy was due to the number of repetitions of the vehicles trials, which were almost the half of the face ones. Fewer trials resulted in a less smoothed and noisier mean hemodynamic response, which is therefore more inclined to be affected by spurious noisy effects. In general, the comparison between the activation of faces and non-social stimuli should be better addressed in the future.

On the behavioral side, I did not find a significant ORE, but the recognition bias was negatively correlated with the number of references that people made to the ethnicity of other-race acquaintances. The reference to the ethnicity could be a sign of race acknowledgement and of awareness of the racial differences. This attitude could, therefore, lead people to pay more attention to the disparities between owns and other's physical characteristics and to encode other-race faces better. Anyway, more investigation on this effect should be carried out.

To summarize, this study has used the fNIRS technique to prove a difference in the neural processing of own- and other-race faces. At the very beginning of the face elaboration, own-race faces produce a greater activation in the bilateral middle-superior occipital gyrus. During a prolonged encoding face processing, instead, a mechanism of cognitive effort seems to better explain the general greater activation for other-race faces.

Nevertheless, the study has also shown some limitations and opened new research questions. First of all, although there was an effect of interaction between the type of stimulus and channel, no contrast revealed a higher activation for faces compared to vehicles. This result was probably due to some methodological problems (see discussion above), but it could also suggest that the effect found was not face-specific. Also Ding and collaborators (Ding et al., 2014) in their fNIRS study, compared only own- and other-race faces between each-other, but they did not compare these with activation due to non-social stimuli. Therefore, we do not know if this area should be more active specifically for faces but not for objects. In future research, this issue has to be further investigated.

The second issue is tightly connected to the first one and is about the effect of the face encoding strategies. I expected to find a difference in the neural activation for own- and other-race faces which was connected to the type of face elaboration. However, the study has not pointed out different activations for the holistic and analytical tasks, or a lateralization for the activation due to face processing. A question that has still to be answered, then, is about the meaning of the different activation for own- and other-race faces. This issue will have to be deeply investigated, disentangling between the type of face processing (e.g. perception, encoding, categorization) and the type of elaboration (holistic/configural and analytical).

In conclusion, this study has shed new light on the very first processing of racial cues on the face, with the use of the fNIRS neuroimaging technique. Thanks to its non-invasiveness and portability, this technique can be applied also to infants and this allowed me to perform a comparison between infants' activation to own- and other-race faces and the adults' results, to look deeper into the development of the brain reaction to the racial stimuli.

3.4 Study 6 and 7

Development of different encoding strategies for own and other race faces: neuropsychological study with 5 and 9 month old infants

The last two studies were conducted with infants within the first year of age, in order to investigate how the brain learns to differently respond to faces of other ethnicities. The literature on the ORE has shown that, behaviorally, this bias appears very early in the developmental time-line. At birth, infants treat all types of faces similarly. However, already at 3 months of age, some studies found a preference for and a better recognition of own-race faces (Hayden et al., 2007; Kelly et al., 2005; 2007a; Sangrigoli & De Schonen, 2004), although the bias is considered to become stable between 6 and 9 months of age (Fassbender et al., 2012; Kelly et al., 2007b). Anyway, this type of discrimination appears very soon and it means that the ethnicity is an important facial characteristic for human beings. Moreover, also the difference in the perceptual strategies used for those faces seems to appear in the same period. In the study of Ferguson and collaborators (Ferguson et al., 2009), the authors found a holistic perception of both own- and other-race faces at 4 months of age. At 8 months, however, only own-race faces were processed holistically.

In the neuroimaging literature, the only ERP study conducted on other-race faces has demonstrated that, at 9 months of age, only own-race faces elicited a N290 neural response

(Balas et al., 2011). The N290 is the corresponding ERP of the adult N170, which is usually the electrophysiological response connected to face perception and has been also linked to the FFA (Herrmann et al., 2005).

Furthermore, studies on the neural bases of face perception, have found a right-lateralized activation for upright faces whereas a left-lateralized activation for inverted faces in infants. The authors linked this difference to the holistic and analytical elaboration styles used, respectively, for upright or inverted faces (de Haan et al., 2003; Otsuka et al., 2007). If different elaboration styles are used also depending on racial cues, it is then plausible to expect similar neural finding also for the own- and other-race faces activation.

Therefore, in these two studies I have tested a group of 5 and a group of 9 months-old infants. At 5 months of age, infants should not have a stable other-race effect and should be more inclined to perceive all faces in a holistic way. Therefore, I expected to find no differences between own- and other-race faces, also at the neural level. Moreover, if the holistic type of perception is lateralized in the right hemisphere, I also expected a right-lateralized activation for both groups of faces. At 9 months, instead, because the behavioral ORE is already acquired, I expected to find a neural discrimination for the two groups of faces. The procedure of the two studies was identical and was as similar as possible to the Task 1 (pure perception) of study 5, in order to obtain comparable results with the adult population.

3.4.1 Method

Participants. A group of eighteen 5 months-old infants and seven 9 months-old infants with no history of neurological disorders took part in the experiment. Participants with a very low intensity fNIRS signal due to bad coupling between optodes and skin, with signals too much contaminated by motion artifacts and/or that did not look for at least 4 trials per type of stimulus face (Caucasian and African) were excluded from the analyses. The final 5 months-old sample was composed of 11 infants (7 Females; mean age = 153, 5 days) while the final 9 months-old group of 4 participants (1 Female; mean age = 271 days). All infants were Caucasian, living in the province of Padova, Italy. The research was approved by the local University ethical committee. After the experiment, all families were debriefed and were given a little price (a baby bib).

Materials and procedure. Infants were sat on a high chair in a sound attenuated and dimly lit room. Parents were always present in the room and, during the experiment, were asked to stay silent behind the infant. Infants were approximately 60 cm away from an LCD screen and, while the experimenters put the fNIRS cap on, they were presented with a cartoon. The procedure of the infants' experiment was almost the same as Task 1 of the adults' experiment. The pictures of faces and vehicles used were identical to those of the adults' experiment. The only differences were the timing of the stimulation and the insertion of some attention getters. Before the stimulus block appeared, instead of the cross, a 2 seconds flashing circle was inserted. This was done to catch the attention of the infants, so that, when the target stimulus appeared, they were already looking at the screen and did not corrupt the fNIRS registration with a motion artifact at the beginning of the trial. After the flashing circle, a grey screen was presented for 500ms, after which the face block appeared, with 10 faces presented for 500ms each. The single face presentation time was raised compared to adults, to give infants more time to look at the faces and to avoid a discomfort flashing sensation, due to the fastest presentation. At the end of each block, a grey screen was presented for a random time between 10 and 11 seconds. During this period, nothing was presented on the screen; therefore, to hold infants' attention, the experimenter sent out, randomly, and when needed, some sounds, by pressing one of four keys. For this task, 8 blocks of Caucasian faces and 8 blocks of African faces were presented. At the end of the first task, the same procedure was used to present vehicles images as a control stimuli. After the experiment, infants' parents were asked to fill in the same contact questionnaire used for the adult study (see Material section of Study 4). Parents were advised to report only other-race people that also infants could have come into contact with.

fNIRS apparatus and probe placement. The fNIRS data was acquired with the multi-channel, frequency-domain NIR spectrometer (ISS Imagent™, Champaign, Illinois) that is described in the previous experiment.

The adult probe configuration was rescaled to fit the infant's cap and to measure from the same occipital areas of the adults' experiment (see "fNIRS apparatus and probe placement" section of Experiment 5). The distance between detectors and sources was set to 20 mm, similar to previous experiments in infants (see Lloyd-Fox et al., 2010). Before each session, the head circumference and nasion to inion distance were measured and the cap was put on in order to match the Cz reference point of the cap with the one measured on the infant's head. After the fibers were mounted, an elastic hairband was placed around the cap in order to improve the contact between optodes and scalp.

3.4.2 fNIRS data processing.

Data pre-processing was performed using some of the Homer2 NIRS processing package functions (Huppert et al., 2009) based in MATLAB (Mathworks, MA USA). The processing stream for the infant subjects was similar to the one used for the adult subjects. However, there were some differences, mainly due to the different signal acquired in these two populations. Indeed, infants' data is usually more corrupted by motion artifacts, which are also usually higher in amplitude compared to the motion artifacts seen in adults' acquisitions, since adults are usually more prone to sit quietly during the experiment. Furthermore, infants' data presents usually higher variability between participants compared to adults' data. For every subject, channels with a very low optical intensity were discarded with the function enPruneChannels. The optical intensity data were, then, converted into optical density (OD) changes. For each channel, a motion detection algorithm hmrMotionArtifactByChannel was applied to the OD time-series to detect motion artifacts. In this study, because of the higher variability among subjects, the amplitude and standard deviation thresholds, the searching window length and masking window length, were set for each subject individually, in order to find the best compromise between noise identification and signal preservation for each participant. Specifically, in this case, parameters were set with the aim to identify only high amplitude and high frequency spike-like artifacts as well as step-like artifacts, due to an on-line change in detectors' gain during the acquisition. After having identified motion artifacts, two motion correction algorithms were applied, one following the other: hmrMotionCorrectSpline and hmrMotionCorrectWavelet. The spline motion correction algorithm was applied to correct for the spike-like motion artifacts identified by the previous motion detection algorithm and to correct for the baseline changes due to step-like artifacts. This step was performed in order to optimize data fed to the following wavelet motion correction algorithm. This latter performs a series of wavelet transformations of the data and sets all wavelet coefficients that exceed α times the interquartile range to zero, before applying the inverse wavelet transformation, which gives in output the original data, free from motion artifacts (for more details see Brigadoi et al., 2014; Molavi & Dumont, 2012). These outlier coefficients set to zero, indeed, are thought to represent the motion artifacts present in the data. In this study α was set to 0.8. After this, PCA was applied to the data to reduce physiological noise contamination and finally a band-pass filter with 0.01–0.5 Hz as cut-off frequencies was performed in order to remove slow drifts and high frequency noise. OD data were then converted into concentration changes using the modified Beer–Lambert law (Cope and Delpy, 1988; Delpy et al., 1988). Finally, a block average was performed on all remaining trials related to the same stimulus type. This produced three mean HRFs, one per stimulus type, for each channel and each participant. On each HRF, the area under the curve, defined as in the adult study, in the time range between 5 and 15 seconds after stimulus presentation was extracted as metric for statistical analysis. Only HbO data has been analyzed and reported.

3.4.3 Results.

Five months infants. A 2 Hemisphere (left-right) X 9 Channels X 2 Ethnicity of the face (Caucasian-African) repeated-measure ANOVA was run on the AUC index of the mean HbO HRFs of the first task. Because of technical problems during data acquisition, channel 1L was never acquired for any participant, and it was therefore excluded from the analyses along with its right symmetric counterpart. A significant main effect of the Hemisphere was found, $F(1,10) = 8.985$, $p = .013$, $\eta^2_p = .473$. The right hemisphere was generally more active (M=3227.732 nM) for faces than the left one (M= 497.264 nM, *Figure 21*).

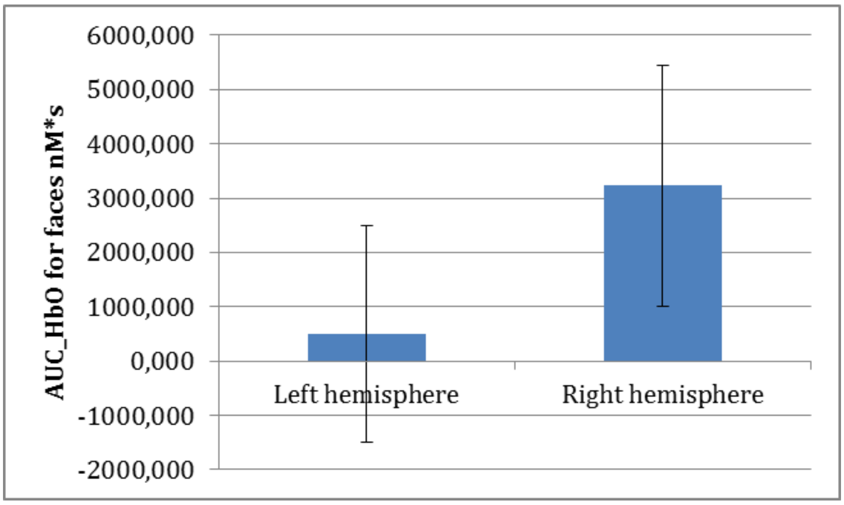

Figure 21. Above. Hemisphere lateralization for faces. Error bars represent 95% confidence intervals.

A main effect of the Channel was found, $F(8,80) = 5.403$, $p = .004$, $\eta^2_p = .351$ (see *Figure 23*). The distribution of the activation in the channels is similar to the adult's one. In this case, however, Bonferroni corrected contrasts, using an adjusted alpha levels of .0063 (.05/8), revealed that only the activation between channel 5 (M= -2773.64 nM) and channel 7 (M=

8370.23 nM) and between channel 5 and channel 9 (M= 5732.90 nM) were statistically significant (see Table 2).

In line with the hypotheses, I did not find an effect of ethnicity or an interaction between ethnicity and channel. The results for the vehicle condition could not have been analyzed because half of the infants did not complete this task.

Table 2. Channel activations for faces.

Channel	Mean	Standard Deviation Error	95% confidence interval	
			Upper boundary	Lower boundary
2	669.746	1299.651	-2226.056	3565.548
3	-724.358	1258.895	-3529.351	2080.634
4	233.212	1368.920	-2816.931	3283.355
5	-2773.643	1764.757	-6705.768	1158.481
6	5504.208	2324.664	324.534	10683.883
7	8370.233	2157.192	3563.710	13176.757
8	-108.349	1838.377	-4204.509	3987.811
9	5732.899	1965.716	1353.011	10112.788
10	-141.468	1071.890	-2529.788	2246.852

Nine months infants. The group of the 9 month-old is too small to allow any statistical conclusion. In this case, I will report just some preliminary result. The 2 Hemisphere (left-right) X 9 Channels X 2 Ethnicity of the face (Caucasian-African) repeated-measure ANOVA revealed a main effect of the Channel, $F(8,24)= 6.970$, $p= .036$, $\eta^2_p = .699$ (see *Figure 23*). After correcting for Bonferroni, no contrast was significant.

There was a tendency towards an interaction effect between the Channel and the Ethnicity, $F(8,24)= 3.541$, $p= .091$, $\eta^2_p = .541$. Bonferroni corrected contrast (alpha =.0055) revealed a greater activation for other- than for own-race faces in channel 4 (Caucasian M= -5491,73; African M = 9564,37) and, as a tendency, in channel 7 (Caucasian M= -7254,76; African M = 1087,69, see *Figure 23*).

Finally, the activation of the right hemisphere positively correlated with the other-race activation, $r(4)= .980$, $p= .020$ (*Figure 22*).

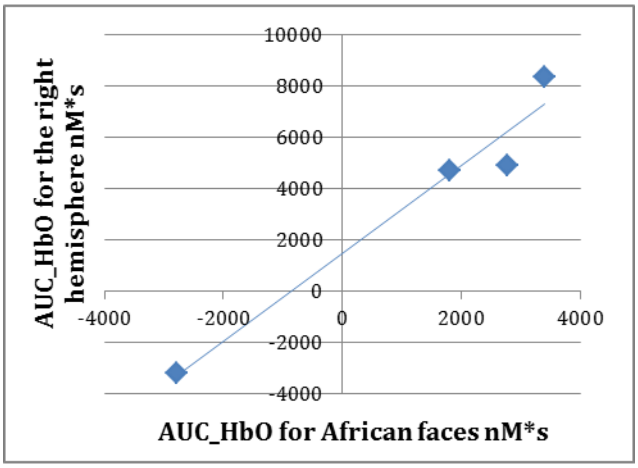

Figure 22. Interaction between right hemisphere activation and other-race activation.

Comparison between 5 and 9 months-old infants. The results of 5 and 9 months-old infants were also analyzed together. A significant interaction between the Channel activation and the Age of the participants was found, $F(8,104)= 6.285$, $p= .001$, $\eta^2_p = .326$ and also between the Channel and the Group (5 or 9 months), $F(8,104)= 8.029$, $p< .001$, $\eta^2_p = .382$. Contrasts adjusted with Bonferroni (alpha = .0063) revealed that channels 6, 7 were more active for the 5 months-old group, while channels 3, 8 and 10 were more active for the 9 months-old group. It is to note that channels 6 and 7 are located in the posterior areas of the probe, while channels 3, 8 and 10 are in the anterior part (see *Figure 23*).

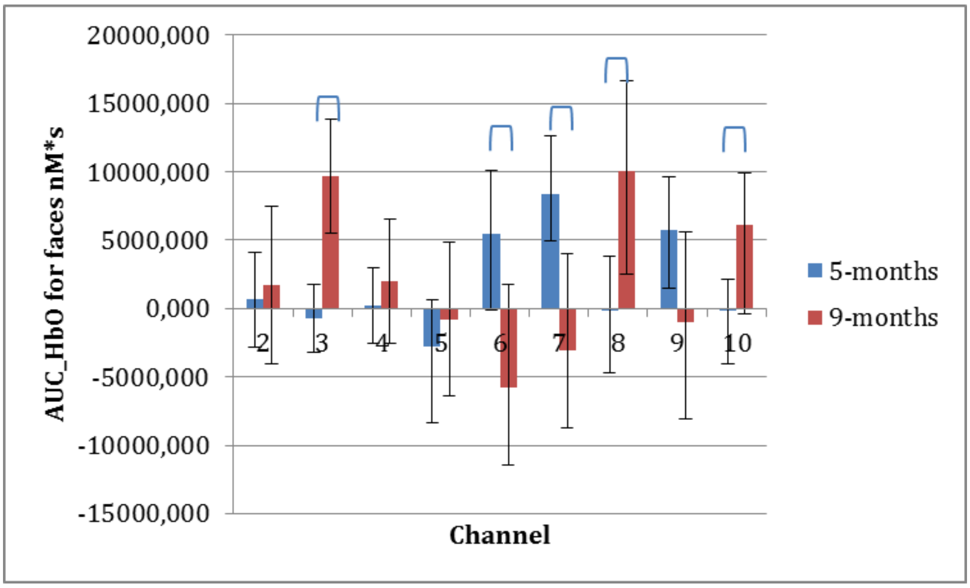

Figure 23. Channel distributed activation for faces for 5 and 9 months-old groups. Error bars represent 95% confidence intervals. Horizontal brackets indicate significant contrasts.

3.4.4 Discussion on infants' studies.

The results showed that the distribution of channels activation for faces in infants was very similar to the adults' one. Nevertheless, comparisons between the two groups of infants revealed a tendency towards a shift in face activation from posterior towards anterior brain areas. This developmental neural shift in face perception is in line with previous research findings (see de Haan et al., 2003).

At 5-months of age, the most important result is the hemispheric lateralization effect. Infants showed a predominant activity in the right hemisphere for faces. This result is in line with the hypothesis connected with the holistic account. At this age, indeed, infants should use the same holistic strategy in both groups of faces whereas the greater activation in the right hemisphere could be connected with the holistic processing. Moreover, this result is in line with other studies in the literature that demonstrated a right lateralization for face perception in infants (de Haan et al., 2003; de Haan & Nelson, 1997; de Schonen & Mathivet, 1989, 1990; Otsuka et al., 2007).

As what concerns the effects of the ethnicity, I did not find an effect in the 5 months-old group. This result was in line with the hypotheses. This finding seems to indicate that the absence of the ORE at the behavioral level reflects the lack of discrimination of racial characteristics at brain level.

In the 9 months-old group a tendency towards an interaction between the channel and the ethnicity of the face was found. This tendency seems to reflect a greater activation for other-race faces on some channels. Moreover, activation for other-race faces seems linked to the right hemisphere. It has to be considered that the number of infants tested was very restricted and it is too hazardous to infer reliable conclusions. However, this result could be used as indication of a possible effect of ethnicity in this cohort.

In the near future, the number of participants should be enlarged to allow more solid conclusions, and, at this time we can surely conclude that infants' represent a prosperous field of investigation for race perception studies.

3.4.5 General discussion of fNIRS studies.

I conducted comparable fNIRS studies with adults' and infants' samples to investigate the development of the neural responses to the very first elaboration of own- and other-race faces. In Study 5, with adults, I found a greater activation for own-race faces in the middle-superior-occipital gyrus for the very first spontaneous elaboration, but I did not find differences linked to the elaboration style. The 5 months-old group showed no face discrimination based on race, but this effect started to appear in the 9 months group. In this group it seems that the activation for other-race faces is greater than for own-race faces. This result is also in line with the findings of the study of Ding and collaborators (Ding et al., 2014). Although more research should be performed on this topic, these studies mark a trace of the developmental path of the neural processing of racial cues.

Moreover, the 5 months group showed a general right hemisphere predominance. This result is in line with the hypothesis linked to the right-lateralization of the holistic perception, but it is supported neither by the adults, nor by the 9 months-old findings. This inconsistency should be further investigated to clarify the influence of the style of elaboration on the brain responses to faces. One problem could be the investigated area. In the adult literature, Rossion and collaborators (Rossion et al., 2000) found an interaction between the elaboration style and the hemisphere in the FFA with the positron emission tomography (PET) technique, and other studies have investigated the temporal areas in infants (de Haan et al., 2003; Otsuka et al., 2007). Nevertheless, it is unlikely that fNIRS is able to probe the FFA, which is located quite deep in the cortex. It is possible that only for the 5 months-old infants, whose brain is much smaller, this deeper area has been reached by fNIRS and this could explain the lateralization effect.

Another issue with the adult study was the holistic/analytical task. Because it was a newly created task, its effectiveness cannot be assured. In the future, then, in order to better test the holistic disruption condition, the activation to the normal upright faces should be compared to the activation of their inverted version. This task, moreover, could also be used with infant participants (see Otsuka et al., 2007).

A future direction for this investigation would be also the employment of other neuroimaging techniques. Because I am interested in the encoding level of face perception, and the adults' study has shown differences based on the task and timing, an interesting improvement would be the use of the EEG technique. The analysis of ERPs could shed more light on the temporal evolution of the face processing phenomenon.

Moreover, future steps in research should better investigate the transition from pure perceptual distinction of faces in infancy towards a more cognitive discrimination of own- and other-race groups in childhood and adulthood. Researches showed that, at school age, children already hold stereotypes for different ethnic groups (Castelli, De Amicis, & Sherman, 2007). This socio-cognitive phenomenon seems to pass through the categorization process, so that infants learn to categorize other-race faces versus individualize own-race faces (see Anzure et al., 2013). The study of Scott and Monesson (2009) found that the other-species bias, a phenomenon similar to the ORE, could be eliminated in infants of 9 months of age, by training them to individualize monkey faces. In general, then, it would be interesting to investigate the growing complexity of other-race relationships.

Ultimately, to reach a global comprehension of the other-race perception, all aspects should be integrated in a general developmental model, and this research could be considered a first step towards a better comprehension of the phenomenon in a developmental perspective.

Conclusion

In my doctoral dissertation I have investigated the perceptual bases of the recognition disadvantage for other-race faces. In the existing literature, previous studies have demonstrated a disparity in the encoding of own- and other-race faces in the first place (Marcon et al., 2010; Walker & Tanaka, 2003; Walker & Hewstone, 2006), inducing agreement on the perceptual bases of the ORE. Although some authors have brought into question this contrast (Bukach et al., 2012; Crookes et al., 2013; Harrison et al., 2014; Hayward et al., 2013; Hayward et al., 2008; Rhodes et al., 2006; Zhao et al., 2014b), the best-studied distinction between the perception of own- and other-race faces relies on the holistic and analytical styles of elaboration. In fact, it has been shown, with different tasks, that own-race faces are perceived more holistically than other-race faces (Hancock & Rhodes, 2008; Michel, et al., 2006a; Michel et al., 2006b; Mondloch et al., 2010; Rhodes et al., 1989; Tanaka et al., 2004).

In the first part of my dissertation (Studies 1 to 3), I have investigated more in depth the relationship between the perceptual and the mnemonic bias, taking into account also contextual factors linked to the type of face presentation (Study 2 and 3). In Study 1 I have found confirmation to the own-race recognition advantage. Also the effect of the processing style on the recognition performance was confirmed. Specifically, I found a greater recognition bias in the holistic than in the analytical condition. This study has brought new evidence for the link between, on one side, own-race faces and the holistic processing and, on the other side, other-race faces and the analytical processing.

In Studies 2 and 3, I have investigate how the multiple presentation of own- and other-race faces, a condition closer to a real-life situation, could influence the encoding and recognition of those faces. In Study 2 no recognition advantage was found for own-race faces. Moreover, the Hit rate, the recognition index affected by the type of presentation, was better for other-race faces. This result suggests some effect of the multiracial presentation on the recognition performance. I have hypothesized that other-race faces may induce a faster attention orienting, due to some pop-out effects (Levine, 1996), and may be preferentially scanned during the encoding phase, leading to a better recognition.

To test this hypothesis, in Study 3, gaze behavior on own- and other-race faces was assessed during a multiple presentation paradigm. Results on the recognition data showed no ORE, with more False Alarms and Hit rates for other-race faces, as in Study 2, bringing new confirmation to the effect of the type of presentation on the mnemonic performance. Also the data from gaze behavior showed different patterns, based on the face ethnicity. Other-race faces were looked faster than own-race faces during the encoding phase, but no difference in the total looking time was found. Moreover, during the test phase of the recognition, own-race faces were scanned more in the eyes and other-race faces more in the mouth. These results were also consistent with previous literature on scanning differences between own- and other-race faces (Fu et al., 2012; Goldinger et al., 2009; Wu et al., 2012). However no evidence was found of a direct correlation between the scanning habits and the recognition performance. The absence of correlation between the eye-tracking and the recognition data is also in line with previous findings (Fu et al., 2012), but more research is needed to shed light on the influence of the perceptual strategies on face recognition.

In the second part of my dissertation, I moved the investigation to the neural underpinnings of other-race face perception (Studies 4 to 7). For this purpose I have used the fNIRS technique which has never been used to assess race perception in the adult and infant population. Also in these experiments, I hypothesized to find differences for own- and other-race faces depending on the processing style (holistic/analytical) used for them. For this purpose, the neural activations for faces was compared with the neural activation for the induced holistic or analytical processing (Study 5). Moreover, passive viewing was compared to the face encoding for recognition, to analyze the differences in the two perceptual processes. In the adult population (Study 5), results have shown a different activation for faces depending on the ethnicity. Specifically, I have found a greater activation for own-race faces in the middle-superior temporal gyrus. This finding is line with the literature results (Feng et al., 2011; Golby et al., 2001; Natu et al., 2011; Ng et al., 2006). Moreover, the pattern of activation in the passive viewing condition was different to the one in the encoding condition, with greater activation for other-race faces in the latter case. This result leads to hypothesize that these two types of perception are subtended by different cognitive processes. In future research, studies must investigate more deeply the differences between the various types of face perception and be careful to sum up results from different tasks. Finally, the link between face perception and the elaboration style was not found. However, some problems connected to the methodology and the areas investigated suggest the need of further research before discarding the holistic/analytical hypothesis.

In the final two studies (Study 6 and 7) the evolution of the neural responses to other-race faces was investigated. For this purpose, a group of 5 and a group of 9 months-old infants was assessed. These two age groups were chosen because the ORE at the behavioral level becomes stable between 6 and 9 months of age (Fassbender et al., 2012; Kelly et al., 2007b). For the first group, it has been, then, hypothesized that the brain would treat own- and other-race faces in the same way. At 9 months of age, instead, it has been hypothesized to find, also at the neural level, a different treatment for the two groups of stimuli. To investigate these hypotheses, the same experimental protocol and neuroimaging technique of the adults were employed. This procedure allowed the direct comparison of the two samples. The hypothesized pattern was partially confirmed. In effect, at 5 months of age, no difference based on the ethnicity was found in the neural activation for faces. However, a right hemisphere predominance was evidenced by the analyses. This effect was similar to the one found by Otsuka and collaborators (2007) and is hypothesized to be linked to the holistic face processing. In this group of participants, then, the link between face perception and holistic processing seems to be present. Finally, in the group of 9 months-old infants some effect of the ethnicity started to appear, although the activation seems to be higher for the other-race group. This effect is also in line with a recent study of Ding and collaborators (2014), who showed that in 7-8 years-old children the activation for other-race faces was higher in the left cuneus. However, the activation for own-race faces raised as the age increased, till it overtook the activation for other-race faces.

Although the last sample was somehow small to bring conclusive findings, a general pattern on other-race face perception seems to take shape. At 5 months of age, the brain does not yet distinguish the face based on its ethnicity. At 9 months and during the first childhood it may be possible that other-race faces elicit more neural activation, due to novelty preference effects (see also Ding et al., 2014). In later childhood and in the adulthood, instead, own-race faces seems the ones that elicit the greater brain activation (see also Feng et al., 2011; Golby et al., 2001). It is possible that this higher activation is linked to familiarity preference or to expertise-dependent brain specialization for own-race faces.

Besides enlarging the 9 months-old sample, an important question remains to be disentangled relatively to the link between face perception and processing styles. In effect, previous studies have often ascribed the differences found in own- vs other-race face activations to the type of face processing used for those faces (Feng et al., 2011; Golby et al., 2001; Ng et al., 2006). However, to date, no other study has directly tested this association. In Study 5, instead, the activation of own- and other-race faces was directly compared to the one of analytical/holistic processing. Results showed no direct link between the two processes. This link was not directly tested in the infant group. However, at 5 months of age, infants showed a typical right-hemisphere predominance, usually associated to holistic perception (Otsuka et al., 2007). A future direction would be surely to compare analytical and holistic perception in the infant sample. This could be done with the well-established face inversion effect, which is known to prevent configural face elaboration (see Otsuka et al., 2007). With the use of this task, any potential lack of correspondence between own-race face and holistic perception cannot be ascribed to a failure in the manipulation. In this sense, the effect of task would be ruled out. Moreover, because the hemispheric asymmetry has already been shown in the 5 months-old sample, we cannot refer to problems with the brain areas localization as causes of this lack of finding. Future research should address this issue with deeper investigation.

In summary, I have studied different aspects of the multifaceted scenario of the other-race face perception. Behaviorally, I have investigated the link between face processing and recognition (Study 1) and the effects of the type of presentation on both recognition (Study 2) and scanning behavior (Study 3). In the last studies, instead, I looked into brain activation differences in other-race face perception at a developmental perspective comparing neural responses of adults (Study 5) and of 5 and 9 months-old infants (Study 6 and 7).

The common theme, that characterized this research, was the comparison of different face processing strategies, namely holistic and analytical face processing. For the adult population, I have generally found significant differences between own- and other-race faces, in the recognition performance (Studies 1 to 3), in the scanning habits (Study 3) and neural responses (Study 4). However, the direct relationship between these results and the processing style was mostly absent. In effect, only Study 1 showed some link between the processing style and face recognition. In study 3, faces of own- and other-races were scanned differently, but this perceptual processing did not correlate with the recognition performance. Finally, in Study 4 the neural responses for own- and other-race faces did not show a correlated pattern with the neural responses to holistic and analytical processing. Both the lack of correlation between gaze behavior and recognition (Fu et al., 2012) and the inadequacy of the holistic/analytical antithesis, to explain differences between own-and other-race faces, has been pointed out in the literature (Bukach et al., 2012; Harrison et al., 2014; Hayward et al., 2008; Hayward et al., 2013; Rhodes et al., 2006; Zhao et al., 2014b). However, as also Hayward and collaborators (2013) highlighted, this mixed findings are probably attributable, at least in part, to the inconsistencies in the operationalization of the holistic/configural and analytical constructs. In effect, as previously discussed, also in my research a more systematic use of tasks, to assess face processing, would help to disentangle incongruent findings. In this sense, future research should conduct a more detailed distinction of processing styles and bring more order in this issue.

Another important contribution of this research was the developmental perspective in the study of the neural responses connected to the ethnicity. This topic, in effect, is almost unexplored with only two studies investigating the perception of own-and other-race faces in a developmental population (Balas et al., 2011; Ding et al., 2014). The results found are encouraging, showing a progression, parallel to behavioral findings, in the brain responses to other-race faces (Study 6 and 7). In this area more research is needed to confirm the first findings and to expand the investigation to the style of face processing and to face recognition. In effect, the fNIRS has proven to be a good neuroimaging technique to be used in infants' and children's research (see also Lloyd-Fox et al., 2010), and probably many more issues on other-race face perception could be investigated with it. For example, parallel to adult research, the link with the processing style should be better investigated (see discussion above, p 109). A further investigation should also be directed towards a better comprehension of race categorization processing. In effect, Anzures and colleagues (2010) have demonstrated that face categorization based on the race appears at about 9 months of age. It would be interesting, then, to test for a parallel brain categorization response.

Going beyond pure perception, a prosperous area of research involves also the emergence of phenomena connected to social categorization and group relationships, as in-group favoritism or out-group stereotypes and dehumanization (Hewstone, Rubin & Willis, 2002). In effect, as the social cognitive theories of the ORE have pointed out (see Hugenberg et al., 2010), factors connected to motivation, do play a significant role in the processing and recognition of other-race faces. Studies have shown the emergence of these social preference at about 3-to-4 years of age (see Anzures at el., 2013; Shutts, Roben, & Spelke, 2013). This preference and motivational factor may also play a role in face perception: in effect, when social factors come into play, the face becomes connected to a value (preference) or meaning (stereotypes) and this could change its elaboration. An interesting research question would be when and how the race cues evolve from a simple physical characteristic to a meaningful social marker. Future research should address this issue.

This dissertation has taken into account various aspects of the very first perception of other-race faces. In this sense, face perception is believed to be the very first interpersonal and interethnic type of relationship. Knowing that impression formation can occur only 100 ms after face exposure (Willis & Todorov, 2006), it clearly appears how important it is to investigate biases interfering with this phase of the interpersonal encounter. Moreover, in a developmental perspective, perception is the very first type of connection between the baby and the world. Newborns orient primarily to faces (Simion, Valenza, Umiltà & Barba, 1998) and mutual gaze is the first type of interaction between the baby and the caregiver (Farroni, Csibra, Simion & Johnson, 2002).

Knowing the influence of the very first face perception on subsequent reciprocal behavior, its investigation becomes even more important in the context of interethnic relationships. Nowadays, in effect, contact between different ethnic groups has become both frequent and complicated, usually made more difficult by stereotypes, prejudices and different ideologies. Identifying the mechanisms and the biases that compromise, at first, other-race face elaboration, may give us the chance to improve this perceptual process, with beneficial consequences on the subsequent interethnic relationship as well as at an earlier as possible stage of development.

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