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How early and later-acquired experience affects the age bias in face recognition: an exploration of age-of-acquisition effects.

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To my parents, Silvia and Roberto,

For their unconditional love and

Their unwavering support.

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ABSTRACT

In this doctoral dissertation I present some of the studies conducted during my PhD aimed to investigate how face processing abilities develop across the lifespan and how the face representation system adapts to reflect each individual's social experience. As adults we are expert at processing faces; nevertheless our ability is greater for some categories of faces than for others, giving rise to recognition biases based on social dimensions such as species, race and age. These biases have been interpreted as a result of the interaction between individual motivation and perceptual experience provided by social environment, which work together in affecting the way we encode, process and mentally represent faces. The studies presented in this dissertation focused on the age bias that is the variability in face recognition abilities determined by the relation between the age of the observer and the age of the perceived face. Specifically I will discuss recent evidence suggesting the presence of a processing advantage for adult versus non-adult faces in the lifespan (from infancy to old age) and I will provide novel evidence on how the time of acquisition modulates the effects of individual experience with non – adult faces on this perceptual advantage for adult faces across the life-span.

In Chapter 1 I will investigate the short- and long-term effects of early-acquired experience with a child or an infant face provided by the presence of a younger or older sibling in our participants' family household. Study 1 and Study 2 investigated the behavioral and the neural correlates of the perceptual tuning towards adult faces and its modulation as a consequence of sibling experience, within the first year of life. These two studies show that early-acquired experience has a critical role in the emergence of neurocognitive specialization for adult faces. Study 3 provides evidence on the long-lasting effects of this early acquired experience in interaction with later-acquired experience during adulthood: recognition ability for adult and infant faces was tested in first-time mothers who were or were not exposed to sibling experience in their first years of life. Results show that experience acquired early in life has a greater impact than the one acquired later in life, as a shorter re-exposure to that experience

in necessary in mothers with a younger sibling to bootstrap perceptual learning of infant faces from exposure to their own child. These findings suggest that early-acquired experience has continuous effects into adulthood, as it preserves the system from the loss of plasticity that would otherwise take place.

In Chapter 2 I will investigate the extent to which face representation system remains plastic during adulthood and old age. Results show that social experience with peers in old age and working experience with older adult individuals in adulthood reduce the magnitude of the recognition advantage for adult faces. This evidence suggests that experience with multiple individuals is capable to modulate face processing abilities even in adulthood and old age. Lastly Study 6 investigated how face age affects the deployment of selective visual attention and whether this effect is modulated by professional experience with non-adult faces acquired later in development. Findings provided by this last work extend the few existing evidence on the impact of face dimensions, such as age and race, on visual attention and yielded novel insights into the differential mechanisms underlying the age and the race bias.

Overall these studies confirmed the plasticity of the face representational system which constantly adapts to reflect the individual's current social and perceptual experience across the whole lifespan from infancy up to old age.

INTRODUCTION

Face recognition is one of the most critical abilities for human beings, as we need to process facial signals to infer social information about other individuals (e.g., identity, age, gender, ethnicity, emotional state). As adults, we are experts at processing faces and this expertise results from years of experience in individuating faces, an ability which is mediated by a distributed neural system involving the activation of multiple, bilateral regions (Haxby, Hoffman, & Gobbini, 2002; Kanwisher, McDermott, & Chun, 1997) and by a strong reliance on configural/holistic perceptual processing strategies (see review by Maurer, Grand, & Mondloch, 2002).

The ability to process faces is refined by experience, such that adults are better able to process faces belonging to categories with which they have abundant experience. For example, we are usually more accurate in the recognition of human faces compared to monkey faces (*own-species bias, OSB,* Scott & Nelson, 2006), as well as in the recognition of own-race faces compared to other-race faces (*own-race bias, ORB,* Meissner & Brigham, 2001). Recently a great deal of attention has been paid to the effect of a third facial dimension on face processing ability, namely face age (Macchi Cassia, 2011; Rhodes & Anastasi, 2012; Wiese, Komes, & Schweinberger, 2013). Age is one of the several sources of information that is rapidly extracted from faces by adults and affects how faces are encoded (e.g., (Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008; Macchi Cassia, Kuefner, Picozzi, & Vescovo, 2009) and remembered (e.g., Anastasi & Rhodes, 2005; Wright & Stroud, 2002). Many studies have shown that the impact of age information on our ability to recognize individual faces depends on the age of both the observer and the observed face; studies using eyewitness paradigms (Wright & Stroud, 2002) and intentional or incidental old/new recognition memory tasks (Firestone, Turk-Browne, & Ryan, 2007, see Macchi Cassia, 2011 for a review) demonstrated that faces of the observer's own-age group are more accurately recognized than other-age faces (*own-age bias, OAB*, see Macchi Cassia, 2011; Rhodes &

Anastasi, 2012 for a review). Nevertheless, much variation has been found in the expression of this bias across development: while young adults typically manifest a quite stable OAB, direct evidence on the existence of a systematic advantage in the processing of peer faces in populations other than young adults is sparse. Although some studies found an OAB in elderly participants (e.g., Anastasi & Rhodes, 2005; Perfect & Harris, 2003), others failed to find any age effect on seniors' ability to process faces (Bäckman, 1991; Fulton & Bartlett, 1991; Wiese, Schweinberger, & Hansen, 2008; Wright & Stroud, 2002). Similarly research with children has yielded a very mixed set of results (e.g., for evidence of an OAB in children see Anastasi & Rhodes, 2005; Hills & Lewis, 2011; Hills, 2012; for studies showing no OAB in children see Macchi Cassia, Pisacane, & Gava, 2012). This lack of consistency has been interpreted as directly related to specific characteristics of age as a "categorical" dimension. For example, unlike race, which remains stable across the individual's lifespan, age is a more changeable dimension inherent to faces, which implies that our exposure to various age groups is also changeable across the lifespan. While in the case of race we can generally affirm that, at least in ethnically homogenous societies, the majority of social and visual experience is with individuals belonging to our own-race group, the same can't be said with certainty in the case of age. When we are adults we generally have more contact with other members of our own-age group (i.e. adult individuals), but this does not consistently apply to other periods of life (i.e. infancy, childhood and even the elderly season). These intrinsic characteristics of age, as a categorical dimension, would explain the inconsistencies in the results of studies conducted with different age groups. Overall, these results show that, if present, the OAB is a much less reliable phenomenon in non-adult or older adult observers than in young adult observers.

To date, interpretations of the OAB have relied on the same theoretical frameworks proposed to explain other in-group biases in face memory, such as the own-race bias, and can be grouped in two broad categories: the perceptual learning/expertise model and the social cognitive account. The perceptual learning model links the enhanced proficiency in the processing of own-race faces to the continuous and consistent experience with individuals belonging to our own-race group. As a consequence of this substantial experience, we develop face-specific processing strategies, which allow for more efficient encoding of familiar compared to unfamiliar face categories. These strategies consist of the extraction of configural (i.e., spatial distances between facial features) and/or holistic information (i.e., integration of featural and configural information to form a global representation of the face) and the extraction of this information appears to be engaged most effectively with own-race faces compared to other-race faces (Rhodes, Brake, Taylor, & Tan, 1989; Tanaka, Kiefer, & Bukach, 2004). Conversely, we rely more on piecemeal, featural information (individual facial features in isolation from one another), which is considered a less effective encoding strategy, for the processing of other-race faces (Diamond & Carey, 1986; Rhodes, Tan, Brake, & Taylor, 1989). Evidence supporting a perceptual learning model comes from studies on the own-race bias showing that both exposure to racial out-groups (Hancock & Rhodes, 2008; Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005) and discrimination training with other-race faces (Goldstein & Chance, 1985; Malpass, Lavigueur, & Weldon, 1973; Tanaka & Pierce, 2009) can improve other-race face recognition, thus reducing the advantage in the processing of own-race faces.

In line with the perceptual learning model, a representational model has been proposed by Valentine (1991), which argues that the own-race bias does not emerge as a consequence of differential processing (configural vs featural), but rather it is due to the fact the own-race faces are better represented in memory compared to other-race faces. This model proposes that individual faces reside in a multi-dimensional space, with each dimension (vector) of the space representing a facial characteristic (e.g., eye size; distance between eyes and mouth) that varies across faces. In the center of the face space is a facial prototype, an average of the faces a given individual has encountered throughout his/her lifetime. Each perceived face is encoded based on its distance from the prototype, a process otherwise known as "norm-based coding". Given that the face space is finely tuned according to each individual's experience, visual processing abilities are posited to be optimized for the dimensions of the face categories most frequently encountered (Rhodes, Jeffery, Taylor, Hayward, & Ewing, 2014; Valentine & Endo, 1992). Therefore, faces of less experienced categories (e.g., monkey faces, other-race faces, other-age faces) are more distant from the prototype and tightly clustered (i.e., less distinguishable from one another) compared to faces of more experienced categories; this dense clustering accounts for the increased difficulty in discriminating between faces within these categories. In a highly related characterization of face representation, faces are represented in an exemplar-based system; again, faces are located in a multi-dimensional space with the density of faces varying, but they are represented independently of one another with no role for a face prototype (see Bruce & Young, 2012, for a discussion of these two models; Valentine, 1991).

Unlike perceptual learning accounts, social cognitive accounts stress the role of social categorization processes in the encoding of own- and other-race faces. For example, in his *feature-selection model* Levin (1996, 2000) proposed that when we encounter a face we immediately categorize it based on its ''in-group'' or ''out-group'' status, and this has important consequences on how we subsequently process it and on how well we recognize it. Out-group faces would be treated categorically and their homogeneity would be emphasized by focusing on category-specifying features (i.e., features common to all members of that group) at the expenses of individuating information (Levin, 2000) or through reduced motivation to attend to relevant individuating features (Rodin, 1987). The tendency to encode and process category-specifying features would lead to poor performance when we are asked to recognize identities from less familiar, out-group, categories. Conversely when individuals have to process faces of categories with which they collected great experience, individuating information is encoded first, followed by categorical information, leading to the well-known advantage in recognition for these familiar face categories at the expenses of categorical processing.

A recent study conducted by Ge and colleagues (2009) provides support to this hypothesis by showing a recognition advantage for own-race faces and a categorization advantage for other-race faces in the same group of participants. Even more interestingly, in this study the other-race categorization advantage predicted weaker recognition of other-race faces, confirming the hypothesis that the habit to categorize faces belonging to a social out-group is at the expenses of the ability to identify these faces.

More recently, Hugenberg, Young, Bernstein and Sacco, (2010) proposed an integrative framework, known as the *categorization-individuation* model (CIM), where social cognitive variables and perceptual expertise may interact, as they both contribute to an individual's motivation to focus on individuating facial characteristics. In fact, this model stresses the importance of three components: categorization, motivation, and experience. The first step in the encoding process is a categorical judgment based on low-level perceptual characteristics that signify social categories (e.g., sex, age and race); subsequently situational cues and individual motivation predict the effort the individual is willing to extend to individuate the face. The final component is perceptual experience with the category to which the encoded face belongs. While, according to the perceptual learning account, a large amount of experience with other-race faces is enough to reduce the own-race bias, by increasing recognition performance for other–race faces, the CIM predicts that experience with other-race faces translates into stronger face recognition most effectively when perceivers are motivated to individuate these faces. This hypothesis was confirmed by a recent study that showed that, only in interaction with motivation in individuating other-race faces, previous experience facilitates other-race recognition (Young & Hugenberg, 2011). Also, laboratory-training studies indicate that the own-race bias can be reduced only when participants are trained to individuate other-race faces, as the training does not exert the same effect when participants are simply exposed to other-race faces, but not asked to process other-race faces at the individual level. These findings suggest that, at least in the case of race, mere exposure to faces from unfamiliar face categories in not sufficient to modulate the own-group bias (McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011; Tanaka & Pierce, 2009).

Although both theories of in-group biases in face memory have received substantial support (e.g., Bernstein, Young, & Hugenberg, 2007; McKone, Kanwisher, & Duchaine, 2007), to the point that the own-race bias is currently viewed as the product of both perceptual expertise and social categorization processes (e.g., Short & Mondloch, 2010), the contribution of these factors to the age bias is still an open question. In fact, the direct role of experience with individuals from one's own-age group and other- age groups in shaping the age bias has just started to be directly investigated (see below), and even less is known about the influence of attitudes and in-group/out-group categorization on memory for own-age and other-age faces (e.g., He, Ebner, & Johnson, 2011). To date, only two studies have investigated the hypothesis of more efficient encoding of categorical information from other age faces as compared to own-age faces, reporting faster age categorization for child compared to young adult faces in adult participants (Johnston, Kanazawa, Kato, & Oda, 1997), and faster age categorization for older adult compared to young adult faces in young adult participants (Wiese et al., 2008).

In contrast, quite a few studies have investigated the contribution of perceptual experience to the OAB in adults and children by examining participants' proficiency in the processing of faces belonging to different age groups as a function of the amount of contact with own- and other-age individuals. Results from these studies provide support to the hypothesis that our face processing system adapts to reflect changes in our social and facial environment. For example, the amount of self-reported social exposure to own- and other-age individuals is related to the size of the OAB in both younger and older adults (Ebner & Johnson, 2009; He et al., 2011). In addition, adults who accumulated extensive contact with newborns (i.e., maternity ward nurses) or children (i.e., school teachers) through their working experience as maternity ward nurses (Macchi Cassia, Picozzi, Kuefner, & Casati, 2009; but see Yovel et al., 2012) or preschool teachers (de Heering & Rossion, 2008; Harrison & Hole, 2009; Kuefner et al., 2008; Kuefner, Macchi Cassia, Vescovo, & Picozzi, 2010) showed enhanced discrimination/recognition and processing skills for infant or child faces compared to non-experienced age-matched controls (see Macchi Cassia, 2011 for a review).

Critical evidence for the role of experience in shaping age biases in face processing comes from developmental studies conducted with children and preverbal infants. A series of studies on this topic have shown that 3-year-old (Macchi Cassia, Kuefner, et al., 2009, Exp. 1; Macchi Cassia, Pisacane, & Gava, 2012) and 6-year-old children (Macchi Cassia, Proietti, & Pisacane, 2013), just like adults, manifest a processing advantage for adult faces compared to other-age faces, including those of peers (Macchi Cassia et al., 2012). Recently, a discrimination advantage for adult over infant faces has been found to emerge in infants between 3 and 9 months of age (Macchi Cassia, Bulf, Quadrelli, & Proietti, 2014) that is the same time window during which face discrimination abilities narrow toward human (vs non-human) faces (e.g., Pascalis, de Haan, & Nelson, 2002) and own-race (vs other-race) faces (e.g., Kelly et al., 2007). Like for species and race, the discrimination advantage for adult faces in infancy was interpreted as resulting from a process of perceptual narrowing (for review see (Scott, Pascalis, & Nelson, 2007), by which face discrimination abilities narrow towards the faces that are more frequently represented in the infant's environment. Evidence based on parents' reports (Rennels & Davis, 2008) and observational studies (Sugden, Mohamed-Ali, & Moulson, 2014) suggests that this narrowing process is linked to the infants' social and facial experience, since the majority of the infants' interactions in the first year of life are with faces of the same race, gender, and age as the primary caregiver.

Overall, developmental findings add to evidence from adult studies in giving support to the recent argument that the precocious, continuous, and extensive nature of experience accumulated with adult faces throughout development has dramatic effects on the tuning of the perceptual processes used for face recognition later in development, resulting in early specialization of the face representational system for adult faces and in enhanced face processing ability for this category compared to non-adult faces (Macchi Cassia, 2011). Nevertheless, much has still to be learned regarding how and when experience exerts its effects. The studies presented in this dissertation aim to contribute to the understanding of this issue by exploring the effects of facial experience provided by the social environment on the ability to process faces of different ages, and by exploring how the effects of this experience vary depending on the time of acquisition. These studies extend existing research because they investigate the effects of experience acquired in highly motivating contexts, such as social interactions within the household (i.e. sibling experience in childhood and adulthood, experience with one's own offspring; experience with peers in elderly adults) or within working environment (i.e, professional experience with other-age groups in adulthood). Therefore, the research presented here lies at the border between two theoretical frameworks: perceptual learning theories and social cognitive accounts of face processing biases.

The studies presented in the following chapters investigated the expression of the age bias across a wide temporal range: starting with the emergence of the bias in infancy up to the investigation of whether and how the bias changes during old age. I'll discuss how experience with adult faces interacts with individual experience with non-adult individuals (e.g. sibling experience or experience with one's own offspring) in shaping the tuning of the perceptual system and in modulating face processing abilities across development. Specifically, the research presented in this dissertation focused on the effects of early-acquired (i.e., during the first 6 years of life) experience with a significant other, namely an older or younger sibling (Study 1-3) and the effects of later-acquired (i.e., in adulthood and old age) experience with one individual (Study 3) or multiple individuals (Studies 4-6) within every-day social context and working environment.

Chapter 1 will focus on the role of experience with at least one significant non-adult individual - a younger or an older sibling –, acquired during both infancy and childhood, on the development of the ability to recognize adult and non-adult faces. The investigation of the effects of sibling experience in infancy has the strength of focusing on facial experience acquired through social interactions in natural contexts, thus extending the generalizability and ecological validity of the evidence provided by training studies on the other-species effect (Scott & Monesson, 2009, 2010) and the other-race effect (Anzures et al., 2012; Heron-Delaney et al., 2011). It is known that the presence of a sibling in the family household has important effects on infants' language and cognitive development (Brody, 2004); however no studies investigated the effect of sibling experience on the development of infants' perceptual abilities, and specifically face recognition abilities.

The studies here presented used a behavioral habituation paradigm (Study 1) and an electrophysiological event-related potentials (ERPs) paradigm (Study 2) to explore the effects of sibling experience on infants' processing and perceptual discrimination of adult and child faces. As already mentioned, a recent study by Macchi Cassia and colleagues (2014) showed that perceptual tuning toward adult faces occurs between 3 and 9 months of age: this is the same time window during which perceptual narrowing for species and race is known to occur. Perceptual narrowing leads to the tuning of the perceptual system toward highly prevalent stimuli in the environment, but it is also accompanied by a decline in infants’ responsiveness to non-relevant, non-native or infrequent stimuli. Our goal in Study 1 was to verify whether the narrowing towards adult faces that occurs between 3 and 9 months of age could be modulated by experience with an older sibling, preventing from the loss of discrimination ability for child faces that would normally occur during this time-lapse. Specifically in Study 1 we investigated the ability to discriminate adult and child faces in two groups of 3-month-old infants and two groups of 9-month-old infants selected for having or not having an older sibling whose age ranged between 3 and 6 years at the time of the infant's birth.

Study 2 extends Study 1 by providing the first investigation of the neural correlates of perceptual narrowing for adult faces in infancy, measuring ERPs while 9-month-old infants with and without an older sibling viewed upright and inverted adult and child faces. By measuring the effects of stimulus orientation on infants' face sensitive components (P1, N290 and P400), we tested for the presence of a selective response to adult faces in the no-sibling group, which was not expected in the group of infants with an older sibling. Together, results of Study 1 and Study 2 provide the first evidence that experience acquired in the first year of life with at least one older sibling has immediate effects on infants' ability to discriminate child faces and on the neural responses elicited by these faces.

Study 3 was aimed to explore the long-term effects of sibling experience. In this study we extended existing demonstrations of the impact of early experience with a younger sibling on face processing ability of adults who had been re-exposed to a similar experience. Specifically, we compared perceptual recognition of adult and infant faces in first-time mothers of 4-, 9- and 12-month-old infants. Participants were tested in a two alternative forced-choice (2-AFC) match-to-sample task measuring perceptual recognition of upright and inverted adult and infant faces. By testing participants with upright and inverted faces, we were able to measure the size of the face inversion effect (Yin, 1969; see review by Rossion & Gauthier, 2002) for own- and other-age faces, using this measure to unravel perceptual processing differences between adult and infant faces. Crucially, half of the sample for each group of mothers was composed of mothers without a younger sibling, whereas the other half was composed of mothers who had been exposed to a younger sibling's face within their first 6 years of life. Results of Study 3 show that, although early experience has a critical facilitating effect on adults' ability to learn from newly encountered face types, the face processing system retains flexibility even into adulthood, as 12 months of experience acquired with the infant face allows first-time mothers to bootstrap perceptual learning of infant faces from the exposure to their own infant's face, even in the absence of early exposure to the sibling's face.

Chapter 2 will focus on the effects of facial experience acquired later in life, on face processing abilities during adulthood and old age. Previous studies indicated that adults who accumulated extensive experience with children (e.g. preschool teachers) or infants (e.g. maternity-ward nurses), unlike novice participants, show signs of perceptual expertise (i.e., heavy reliance on configural-holistic cues) when processing both adult and child or infant faces (see Chapter 2 for a more detailed discussion of these findings). In order to provide further evidence for the influence of social and perceptual experience on face processing skills, in Study 4 and 5 we compared perceptual processing strategies and discrimination abilities for faces of young adult individuals and another category of adult individuals, namely elderly adults, using the same 2AFC task employed in Study 3. Specifically, Study 4 investigated the interactive effects of recent experience with older adult peers and past and continuous experience with younger adults in shaping face recognition abilities in elderly adults. This study provides the first demonstration that elderly adults do not manifest an OAB in perceptual recognition of faces. Study 5 showed that experience with older adult faces acquired by nurses working in retirement homes is capable to eliminate the recognition disadvantage for this class of faces in adulthood, although the effects of natural experience with elderly people are magnified when acquired within the first 3 years of life.

Study 6 extended the investigation of the effects of perceptual experience acquired in adulthood in working context (preschool teachers) to the attentional domain by using a visual search task. Results from this study showed that the impact of face age on attention deployment parallels the effects that this face attribute has on face recognition in adults with limited experience with infants or children and in adults who have had extensive recent experience with children (preschool teachers).

In the last section presented in this dissertation I will combine the evidence provided by the Studies 1-6 to draw an overall picture of the effects of perceptual experience provided by the social environment on face processing abilities across the life-span, underlying how, due to its changeable nature, face age represents one of the best tool to investigate the hypothesis that the face processing system adapts to reflect each individual's changing life situations.

CHAPTER 1

The effects of sibling experience on face processing abilities across the lifespan

Introduction

It is known that having an older sibling facilitates the development of various perceptual and cognitive abilities early in development. For example, both observational and laboratory studies show that older siblings can teach new cognitive/social concepts and language skills to their younger siblings (Brody, 2004). This effect is bidirectional: older siblings learn how to simplify tasks and adjust their behaviors to the younger sibling's ability, and by doing so, they develop the ability to take other people's perspectives. In the linguistic domain, the presence of an older sibling changes the linguistic environment of the last-born child in different ways (more direct speech from the caregivers, more activities and social interaction talking in triadic speech; Oshima-Takane, Goodz, & Derevensky, 1996). Also the presence of the older sibling as a source of linguistic input exerts an influence on the linguistic development of the last-born (Hoff, 2006). Recent studies have shown that the effects of sibling experience extend to perceptual discrimination abilities, and specifically to the face recognition domain (Macchi Cassia, Kuefner, et al., 2009; Macchi Cassia et al., 2012a, 2013) . In these studies 3-year-old children's ability to discriminate adult, infant and child faces was measured in a two alternative matching-to-sample task. The hypothesis that perceptual processing strategies differed for adult and non-adult faces was tested by comparing the disrupting effect produced on participants' performance by stimulus inversion, which is typically used as a gross indicator of the ability to extract the relevant configural and/or featural information needed for face recognition (Yin, 1969; see review by Rossion & Gauthier, 2002). Results indicate that, in the absence of consistent experience with infant or child faces - i.e., in the absence of a younger or older sibling, children showed higher recognition accuracy for adult faces over non-adult faces and a selective inversion effect for adult compared to non-adult faces

(Macchi Cassia et al., 2009 Exp. 1, 2012). This perceptual discrimination advantage for adult faces was not present in children with a younger or an older sibling.

A similar modulatory effect of sibling experience was found later in childhood, as 6-year-old children without a younger sibling manifested a processing advantage for adult over child faces. This advantage was absent in same-aged children who had a younger sibling born either before of after the children turned 3 years (Macchi Cassia et al., 2013). These results demonstrate that the face processing is flexible and it adapts to a newly encountered face type (infant faces), at least within the first 6 years of life.

Critically, the effect of early-acquired sibling experience is no longer evident in adulthood, as young adults who had a younger sibling early in life, but were never re-exposed to an infant face since then, do not maintain the ability to discriminate infant faces, showing a perceptual processing advantage for adult over infant faces not dissimilar from that shown by adults without a younger sibling (Macchi Cassia et al., 2009a Exp. 3). Further, the same research has shown that the plasticity of the face processing system in reflecting the individual's present and past experience decreases with age. This was shown by the fact that later acquired experience with a single infant was not able to reduce the perceptual bias for adult faces: first-time mothers who had, at time of testing, 9 months of exposure to their own child's face, but who never had experience with infants before their own child's birth, showed no modulation of the processing advantage for adult faces (Macchi Cassia et al., 2009a). The only condition under which mothers were able to bootstrap perceptual learning of infant faces from exposure to their child faces was when they had been exposed to a similar experience earlier in their life, through the presence of a younger sibling in their household. These findings suggest that early life experiences are of critical importance in building face representation and shaping face processing biases across the lifespan and they may produce sleeper effects that boost perceptual learning later in development when reactivated by re-exposure to the original experience.

The three studies presented in this first chapter add evidence on the importance of sibling experience by investigating two aspects: the immediate effects exerted by sibling experience on infants' discrimination ability and its neural correlates (Study 1, 2); the time-course of the reactivation effects engendered by experience acquired by mothers who had earlier exposure to a younger sibling (Study 3). Specifically, in Study 1 discrimination ability for adult and child faces was tested in infants with and without an older sibling between 3 and 9 months of age, when the perceptual tuning toward adult faces normally occurs (Macchi Cassia et al., 2014). Study 2 extended this evidence by measuring 9 month-olds' electrophysiological activation in response to the processing of adult and child faces always as a function of the presence of an older sibling. The investigation will then move on the effect of sibling experience later in life: study 3 was aimed at quantifying how much exposure to an infant's face is needed to allow mothers to bootstrap perceptual learning of infant faces as function of the presence/absence of early experience with a younger sibling.

Study 1

Sibling experience modulates perceptual narrowing towards adult faces in the first year of life[1]

The aim of study 1 is to investigate the emergence of the perceptual narrowing towards one of the most familiar face categories, namely adult faces. Furthermore, in this study we explored how this perceptual tuning changes to reflect the infant visual experience with non-adult faces. For this reason we used a habituation paradigm to test discrimination ability for adult and child face in 3- and 9-month-old infants who had or not had experience with child faces through the presence of an older sibling in their household.

As mentioned in the introduction, infants and children collect continuous and consistent experience with adult faces leading to a discrimination and recognition advantage for faces belonging to this age group compared to faces belonging to other age groups. Furthermore, recent studies suggest that this advantage can be modulated during childhood by extensive experience with sibling (younger or older) as shown by studies where adult faces were compared to infant (Macchi Cassia et al., 2013) or child faces (Macchi Cassia et al., 2012). Up-to-date only one study demonstrated that this advantage has its roots in the early tuning of the perceptual system towards adult faces as effect of the experience with adult caregivers (Macchi Cassia et al., 2014). Conversely when sibling experience starts exerting its effect is still an open question.

As demonstrated in the study mentioned above (Macchi Cassia et al., 2014) and in other studies on the species and race bias, during the first year of life the infants' perceptual system specialized in the processing of the most familiar face categories available in the infants' environment (own-species faces, Pascalis, de Haan, & Nelson, 2002; own-race faces, Kelly et al., 2007; adult faces, (Macchi Cassia et al., 2014). This phenomenon is known as perceptual narrowing and it occurs across several domains of

[1] This study was carried out in collaboration with Prof. Macchi Cassia, at the University of Milano-Bicocca (UNIMIB). Data collection and data analysis were conducted in collaboration with Marta Rigoldi and Emanuela Croci, research assistant and Lab coordinator at the Infant Lab, Department of Psychology, UNIMIB.

perceptual processing such as speech (Werker & Tees, 1984), music perception (Hannon & Trehub, 2005) and, more interestingly for the goals of this work, face perception (see Scott et al., 2007 for a review). Infants' perceptual sensitivity narrows, resulting in two opposite outcomes: it drives perceptual tuning toward the most experienced and relevant stimuli in the environment, and leads to a decline in sensitivity to infrequent and non-relevant stimuli (see Maurer & Werker, 2014 for a recent review). Within the face processing domain, perceptual narrowing was found to occur for faces of different species (Pascalis et al., 2002) and faces of different races (Anzures, Quinn, Pascalis, Slater, & Lee, 2010; Kelly et al., 2007, 2009; Spangler et al., 2013). Around the age of 3 months infants were found to be able to discriminate among faces from both familiar and unfamiliar categories, while by around 9 months they lose the ability to discriminate unfamiliar face categories (non-human, other-race faces) while maintaining the ability to discriminate familiar face categories (human, own-race faces). Perceptual tuning is also accompanied by increased holistic processing of own-race faces in comparison to other-race faces (Ferguson, Kulkofsky, Cashon, & Casasola, 2009). In fact, eye-tracking studies indicate that monoracial infants use different scanning patterns when exploring own-race as compared to other-race faces (Liu et al., 2011), and that proficiency at discriminating own-race faces is related to extensive exploration of the internal features, which is a hallmark of adult-like face processing (Gaither, Pauker, & Johnson, 2012). Moreover at the neural level, perceptual tuning toward human faces within the infant's own race translates between 6 and 9 months into an increased specificity and right-lateralization of infants' electrophysiological responses to those faces (e.g., Balas, Westerlund, Hung, & Nelson, 2011; de Haan, Pascalis, & Johnson, 2002; Scott & Monesson, 2010).

This process of tuning has been interpreted as deriving from the natural asymmetries in the amount of early experience with different face types: recent evidence suggests that infants spent the majority of waking time exposed to individuals that share the same demographic characteristic of the caregivers. Two studies have tried to quantify this exposure through interviews administered to parents

(Rennels & Davis, 2008) or directly measuring infants' visual experience with the use of a camera located on the baby's head (Sugden, Mohamed-Ali, & Moulson, 2014). Both these studies reported that infants collect the majority of their facial experience with individuals of the same race, gender, and age as their primary caregiver; this predominant experience constrains the infant visual system leading to the emergence of the above mentioned biases.

In the case of the age bias, the greater experience with adult caregivers leads to the tuning of the infants' face system towards this face category, as shown by the study conducted by Macchi Cassia and colleagues (2014). In this study 3 and 9 month-old infants were tested for their ability to discriminate adult and infant faces using a visual habituation paradigm: after an infant-controlled habituation phase during which infants were familiarized to an adult or an infant face, infants were administered two test trials in which the familiar face was presented simultaneously with a novel face from the same age group. Looking times to the familiar and the novel faces were transformed into a novelty preference score, which was used as a marker of the presence of discrimination ability when significantly different from chance (50%). Results showed that 3-month-old infants were able to discriminate between both infant and adult faces, whereas 9-month-olds discriminated adult faces but failed in the discrimination of infant faces. Moreover, discrimination of adult faces in 3-month-olds' was accompanied by a post-habituation preference for the familiar face, whereas it was accompanied by a preference for the novel faces in 9-month-olds infants. Familiarity preferences are typically observed when test stimuli include dramatic modifications from the habituating stimuli (e.g., Turati, Di Giorgio, Bardi, & Simion, 2010) or when the task involves cross-modal transfer of information (e.g., Streri & Féron, 2005), all conditions that did not apply to the Macchi Cassia et al. (2014)'s study. In this case, the authors interpreted the preference for the familiar faces in 3 month-olds as reflecting infants' difficulty to disengage attention from the familiar adult face as a consequence of the saliency of this stimulus category. In line with the argument that the developmental task of building an attachment relationship with caregivers constrains infants' face perception abilities (Scherf & Scott, 2012), the Authors argued that in post-habituation trials with faces of adult strangers infants may have followed a familiarity rule, as much as infants do when they prefer to look at their mothers' face over a stranger's face in visual preference tasks (Bushnell, 2001; but see Barrera & Maurer, 1981 for novelty preference for stranger after habituation to the mother's face).This change in perceptual strategies used by infants at 3 and 9 months of age (i.e. from familiarity to novelty preference) can also be interpreted as an effect of perceptual tuning toward adult faces occurring as a counterpart of the decline in infants' sensitivity to differences among non-adult faces. In Study 1 (Experiment 1) of the current dissertation we replicated this evidence by specifically comparing infants' discrimination abilities for adult faces at 3 and 9 months of age. We used the same paradigm employed by Macchi Cassia et al. (2014, Exp. 2) with the aim of verifying whether the change in discrimination strategies observed by those authors is a stable phenomenon (Experiment 1).

Study 1 (Experiment 2) also tested 3- and 9-month-old infants' ability to discriminate child faces as a function of experience accumulated with at least one child face through exposure to an older sibling's face. Two groups of infants were included in the study: one group of first-born infants and one group of infants with at least one older sibling whose age at the participant's birth was not older than 6 years. The aim of the experiment was to provide direct evidence for the role of experience in driving perceptual narrowing toward adult faces. Few studies have shown that the loss of discrimination ability for monkey faces and other-race faces that typically occurs by 9 months can be prevented or reversed by exposing infants to perceptual training with these face categories (other-species and other-race faces) between 6 and 9 months (Scott & Monesson, 2009; Heron-Delaney et al., 2011) or immediately after 9 months (Anzures et al., 2012). These studies experimentally manipulated infants' experience by administering infants perceptual training through illustrated story books depicting monkey or other-race faces (Heron-Delaney et al., 2011; Scott & Monesson, 2009) or video recordings with other-race faces presented in laboratory settings (Anzures et al., 2012). In Experiment 2 we investigated the effects of a different kind of experience, acquired in natural contexts through social interactions with a sibling. Experiment 2 tested whether sibling experience is able to prevent from the loss of discrimination abilities for child faces that occurs by 9 months of age in the absence on this experience. As already discussed, recent evidence suggests that sibling experience affects 3- and 6-year-old children's ability to process and discriminate infant and child faces (Macchi Cassia et al., 2009a Exp. 1, 2012, 2013). However, the question of how sibling experience comes to exert this effect into childhood remains open.

So far, the impact of perceptual experience provided by the social environment on infants' face processing has been investigated in two studies with monoracial and biracial 3-month-old infants, who showed different performance in the way they scanned faces of individuals from different race groups (Gaither et al., 2012) as well as in their visual preference for faces of different races (Bar-Haim, Ziv, Lamy, & Hodes, 2006). Nevertheless, no study has been conducted so far to investigate how facial experience provided by social interactions affects face processing abilities at the end of the first year of life, when perceptual narrowing has occurred. To address this unanswered question, in Experiment 2 we measured the effect of facial experience provided by the presence of an older sibling on 3 and 9 month-olds' ability to discriminate child faces. As predicted by the perceptual learning hypothesis, we expected 3 month-old infants to be able to discriminate between child faces regardless of sibling experience. At 9 months of age we expected to see a decline in discrimination ability for child faces in those infants who did not have experience with an older sibling as a consequence of perceptual tuning towards adult faces. Conversely, due to the frequency and motivational relevance of sibling interactions, we expected 9-month-old infants with an older sibling to be able to discriminate child faces both at 3 and at 9 months of age.

Experiment 1

Method

Participants Fifteen 3-month-old infants (7 females, M age = 116 days; range = 101 – 135 days) and fifteen 9 month-olds (5 females, M age = 306 days; range = 274 – 328 days) without an older sibling were included in the final sample. All participants were Caucasian, healthy and full-term. Eleven infants were tested but not included in the analysis because of fussiness (N= 9) or because they showed a side bias during the test trials (i.e., they looked more than 85% of the time to one side of the screen across the test trials; N = 2). Participants were recruited via a written invitation that was sent to parents based on birth record provided by neighboring cities. Detailed information regarding the study was provided to parents before obtaining informed written consent. Further, at the end of the testing session, parents were asked to fill a questionnaire with general demographic inquiries, but also specifically aimed at assessing infants' experience with female and male individuals. This inquiry confirmed that in our samples, both 3 and 9 month-old infants spent the majority of their visual experience exposed to female faces (average waking time spent with female individuals= 80%, average waking time spent with male individuals= 20%).

Stimuli*.* Stimuli consisted of colored photographs of 4 female adult faces of Caucasian origin, all displaying a full-front neutral expression with open eyes. Based on previous studies showing that infants have a preference for faces of the same gender of the main caregiver (Ramsey-Rennels & Langlois, 2006) and because infants in the current study had more exposure to female faces than male faces (they spent 80% of their waking time in interaction with a female adult), stimulus gender was kept constant, with all adult faces being female. Faces were paired into two invariable pairs chosen based on perceptual similarity. Using the software Adobe Photoshop, face images were cropped maintaining some external features like ears and hair, and pasted on a black background (Figure 1). When viewed from approximately 60 cm, faces were subtended 13,37° of visual angle vertically and 13,52° of visual angle horizontally.

Figure 1 Examples of adult faces used as stimuli in Experiment 1.

Apparatus. All infants were tested in a dedicated cabin, while seated in an infant-seat or on their parent's lap and positioned at a distance of approximately 60 cm from a 24-inches computer screen. The parent was instructed to remain silent and keep the infant aligned to the monitor's midline. The whole experiment was recorded through a video-camera, hidden over the screen, which fed into a TV monitor and a digital video recorder, both located outside the testing cabin. The recorded session was coded online by one of the experimenters and was reanalyzed frame by frame offline by a second experiment.

Procedure. Testing session began with a colored cartoon animated image associated to a sound displayed on a black background to direct infants' attention toward the center of the screen. As soon as the infant fixated the animated image the experimenter turned off the cartoon and started the habituation phase. During habituation trials, infants were familiarized with a single face using an infant-controlled habituation procedure. Infants' looking time were recorded by the experimenter who hold the mouse button whenever the infant fixated on the stimulus. Each habituation trial lasted until the infant looked away from the stimulus for more than 2 s, at which point the image was automatically turned off and the cartoon animation reappeared on the screen to re-attract the infant's attention on the center of the screen before the stimulus presentation was repeated. The infant was judged to have been habituated when, from the fourth fixation on, the sum of any three consecutive trials was 50% or less than the total of the first three trials. When this habituation criterion was reached, the test session began. Infants were presented with two test trials with the familiar face paired with a novel face of the same age group. Each trial ended following the same criterion used in the habituation phase (2 s look – away). Left-right position of the stimuli on the screen were counterbalanced across infants on the first test trial and reversed on the second test trial for each infant. The direction and duration of looking times were recorded throughout the whole testing session. Both the experimenter that codified the testing session online and the one that codified it offline were blind to the left/right position of the familiar and novel faces on the screen.

Results and Discussion

Habituation phase. Mean habituation looking times were entered into a two-way, mixed-model analysis of variance (ANOVA) with subject's age (3, 9 months) as the between-participants factor and habituation trials (first three, last three) as the within-participants factor. The ANOVA confirmed the presence of an overall significant decline in mean looking time from the first three (M = 24.3 s) to the last three habituation trials (M = 6.9 s), $F(1,28)= 29.57$,$p<.001$, $\eta^2 = .51$. There was also a main effect of participant's age, $F(1,28)= 9.85$,$p= .004$, $\eta^2 = .26$, which was qualified by a significant Habituation Trials x Participant's Age interaction, $F(1,28)= 6.43$,$p= .017$, $\eta^2=.19$. Three-month-old infants looked significantly longer than 9-month-old infants during the first three trials as well as during the last three trials (*ps* < .01), and, although for both age groups looking times decreased significantly between the first three and the last trials (*ps* < .002), the decrement was larger for younger than for older infants, $t(28)= 2.536$, $p = .017$ (Figure 2a).

Test phase. To facilitate the comparison of looking times during test trials across the two age groups, a novelty preference score was computed for each participant by dividing looking time toward the novel face by total looking duration toward both the novel and familiar face across both trials of the test phase and multiplying this ratio by 100. A group mean novelty score that is significantly different from the chance level of 50% reflects discrimination, whereas a score that is not different from 50% indicates a lack of discrimination. Novelty preference scores manifested by younger and older infants were compared through an independent t test, which revealed that the 9-month-olds' score was significantly higher (M= 55,7 %) than the score manifested by the 3-month-olds (M= 43,9 %), t(28)= 3,76, p= .001. One-sample *t*-tests showed that the percentage of time spent looking at the novel stimulus was significantly above the chance level of 50% for the 9-month-olds, t(14) = 2.61, p = .021, whereas it was significantly below the chance level for the 3-month-olds, t(14) = 2.71, p = .017(Figure 2b). We finally examined data for individual infants through binomial tests; for both age groups the number of infants who looked longer to the novel stimulus (3 month-olds: N= 6 ; 9 month-olds: N= 10) did not differ from the number of infants who looked longer to the familiar one (3 month-olds: N= 9 ; 9 month-olds: N= 5), *ps* > .302 .

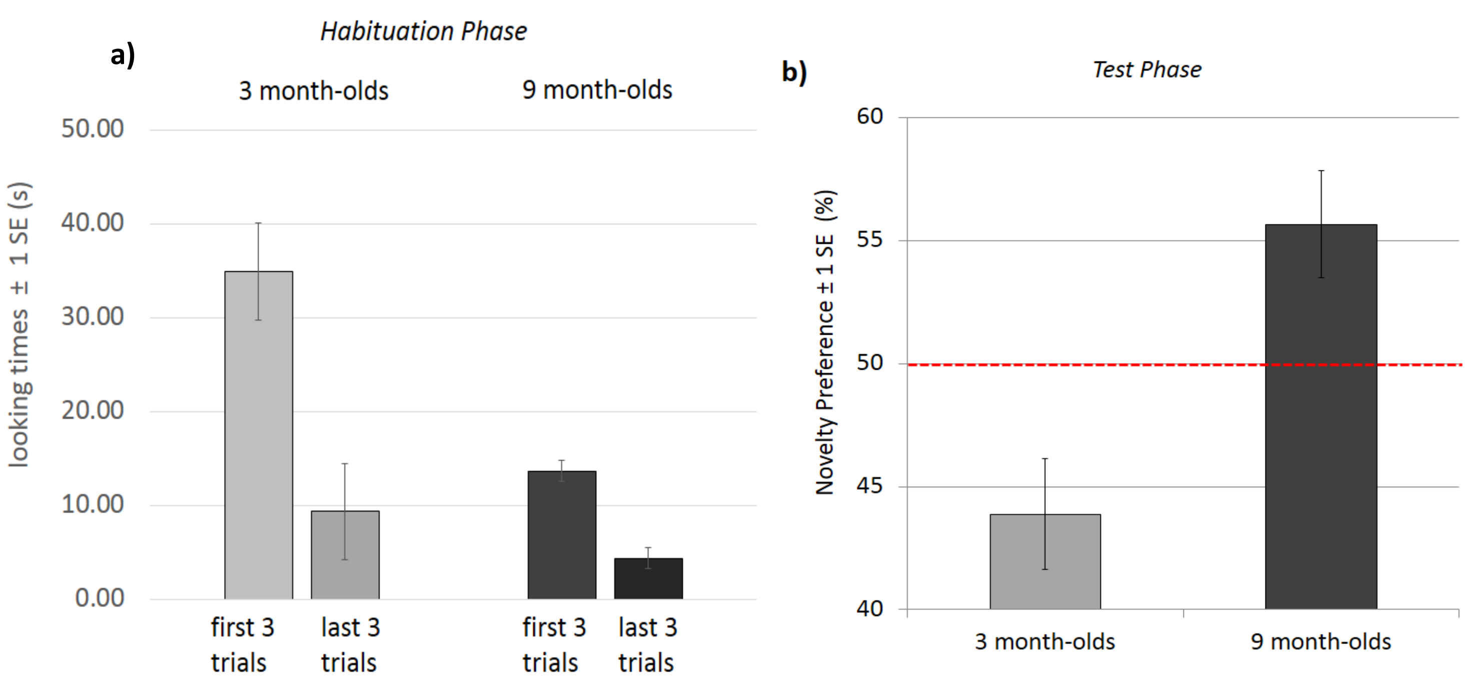

Figure 2 Looking time during the first 3 and the last 3 trials of the habitation phase (**a**) and percent of time spent on the novel face across the two test trials (**b**) for 3 and 9 month-old infants. The red line (b) in panel represents the chance level (50%).

Results replicated earlier findings by Macchi Cassia and colleagues (2014), showing that both 3-month-old and 9-month-old infants are able to discriminate faces within the adult age group. Moreover, like in Macchi Cassia et al. (2014), adult face discrimination in 3-month-olds and in 9-month-olds was accompanied by post-habituation preferences in opposite directions, since 3-month-olds preferred the familiar face, whereas 9-month-olds preferred the novel face. Our current replication of the earlier finding lands further support to the proposed interpretation that the developmental task of forming attachment relationships with the adult caregivers would constrain infants' face processing abilities, by inducing them to follow a familiarity rule, as much as they do when they prefer mother over stranger in visual preference tasks (Bushnell, 2001; but see Barrera & Maurer, 1981 for novelty preference for stranger after habituation to the mother's faces). The developmental task that infants face during the first year of life would make the familiarity preference a functional strategy in the processing of face stimuli.

Having shown that between 3 and 9 months of age infants maintain the ability to discriminate adult faces but lose the ability to discriminate child faces, the goal of Experiment 2 was to test whether such an ability would be maintained if natural experience with a child faces would be acquired from birth through interaction with an older sibling.

Experiment 2

Experiment 2 tested infants' discrimination of child faces as a function of participant's age (3 vs 9 months) and sibling experience (sibling vs no-sibling). As expected based on earlier findings (Macchi Cassia et al., 2014), we expected that first-born infants would lose their discrimination ability between 3 and 9 months, whereas infants with an older sibling would manifest such an ability at 3 months and would maintain it at 9 months.

Method

Participants. Thirty 3-months-old infants (14 females, M age = 111 days; range = 91-132 days) and thirty 9 to 11-month-olds (11 females, M age = 307 days; range = 275-333 days) were included in the final sample. All participants were Caucasian, healthy and full-term. Fifteen infants for each age group had one older sibling and were included in the sibling group, and 15 had no siblings and were thus included in the no-sibling group. Thirty additional infants were tested by excluded from the analyses because of fussiness (N= 27) or because they showed a side bias during test trials (N= 3). Participants were recruited as in Experiment 1, and parents gave their written informed consent. At the end of the testing session, parents were asked to fill a questionnaire with general demographic enquiries aimed at quantifying the amount of contact each infant has had in the past 9 months with children aged between 2 and 6 years. Infants in the no-sibling group were included in the final sample only if they had less than 10 hours of experience per week with children between 2 and 6 years old (M= 1 h/week, range= 0-10 h/week). Infants in the sibling group had an older sibling, whose age at the time of test ranged between 2 and 6 years of age (M = 4.5 years).

Stimuli. Stimuli were color photographs of 8 Caucasian child faces (4 male and 4 female), all displaying a full-front neutral expression with open eyes. Faces were paired into invariable pairs chosen based on perceptual similarity. Using the software Adobe Photoshop, face images were cropped maintaining some external features like ears and hair, and pasted on a black background. When viewed from approximately 60 cm, child faces measure 13,24° in height and 13,61° in width. The gender of the child faces presented to infants in the sibling group were chosen to match the gender of the actual sibling, while for infants in the no-sibling group face gender was chosen randomly.

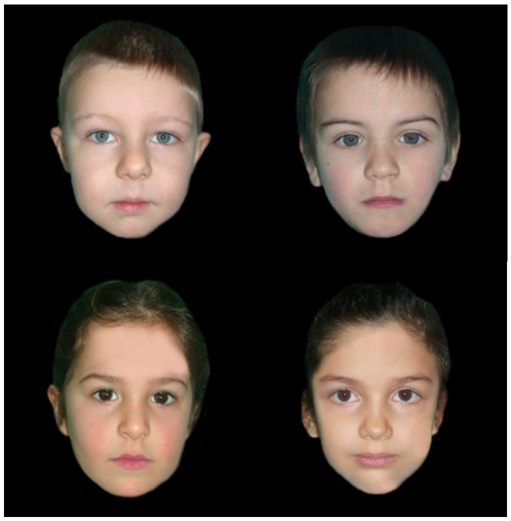

Figure 3 Examples of child faces used as stimuli in Experiment 2.

Apparatus and procedure. The apparatus and procedure were the same as in Experiment 1.

Results and Discussion

Habituation phase*.* Mean habituation looking times were entered into a 2 x 2 x 2 ANOVA with participant's age (3, 9 months) and sibling group (sibling, no-sibling) as between-participants factors and habituation trials (first three, last three) as the within-participants factor. The ANOVA showed the presence of an overall significant decline in mean looking time from the first three (M = 30,4 s) to the last three habituation trials (M = 10,3 s), $F(1,56) = 80.238$,$p < .001$, $\eta^2 = .59$, as well as a significant main effect of participant's age, $F(1,56) = 7.837$,$p = .007$, $\eta^2 = .12$, and a significant Participant's Age x Habituation Trial interaction, $F(1,28) = 6.43$,$p = .017$, $\eta^2 = .19$. Three-month-old infants looked significantly longer than 9-month-old infants during the first three trials as well as during the last three trials (*ps* < .05) and, although for both age groups looking times decreased significantly between the first three and the last three trials (*ps* < .001), the decrement was larger for the younger than for the older infants, t(58)= 2.943, *p* = .005). Neither the main effect of the factor "sibling group" nor any interaction involving this factor resulted significant (*p*s>. 11) (Figure 3a).

Test phase. Novelty preference scores were analyzed in a 2 x 2 ANOVA with subject's age (3, 9 months) and sibling group (sibling, no-sibling) as between-participants factors. The analysis yielded a significant interaction between the two factors, F(1,56) = 11,57, *p*= .001, η^2= .17. To investigate novelty preferences within each age group, we conducted independent t-tests to compare the percentage of time spent looking at the novel stimuli in the sibling and no-sibling conditions. The comparison was significant for both the 3-month-old infants, t(28) = 2.17, *p* = .039, and the 9-month-olds, t(28) = 2.83, *p* = .009, showing that novelty preferences differed between the sibling and no-sibling groups for both the younger and the older infants. These findings were further explored through a series of one-sample t-tests, which showed that the percentage of time spent looking at the novel stimulus was significantly above the chance level of 50% for the 3-month-olds in the no-sibling group (M= 57.3 %), t (14) = 2.3, *p* = .037, but not for the 3-month-olds in the sibling group (M= 48.9 %), t(14) = .47, *p* = .64, whereas it was above the above the chance level for the 9-month-olds in the sibling group (M= 56.1 %), t(14) = 4.13, *p* = .001, but not for the 9-month-olds in the no-sibling group (M= 48,4 %), t(14)= .69, *p* = .5 (Figure 3b). Binomial tests confirmed the results of the analysis on mean novelty preferences, revealing that 12 out of the 15 3-month-old infants without an older sibling looked longer to the novel face compared to the familiar one (12 vs. 3, p < .05), whereas only 7 out of the 15 three-month-olds in the sibling condition showed the same preference for the novel face (7 vs. 8, n.s.). As for the 9-month-olds, 13 out of the 15 infants in the sibling condition looked longer to the novel face compared to the familiar one (13 vs. 2, p < .05), whereas only 7 out of the 15 infants without an older sibling (7 vs. 8, n.s.) showed longer looking times to the novel face compared to the familiar one across the two test trials.

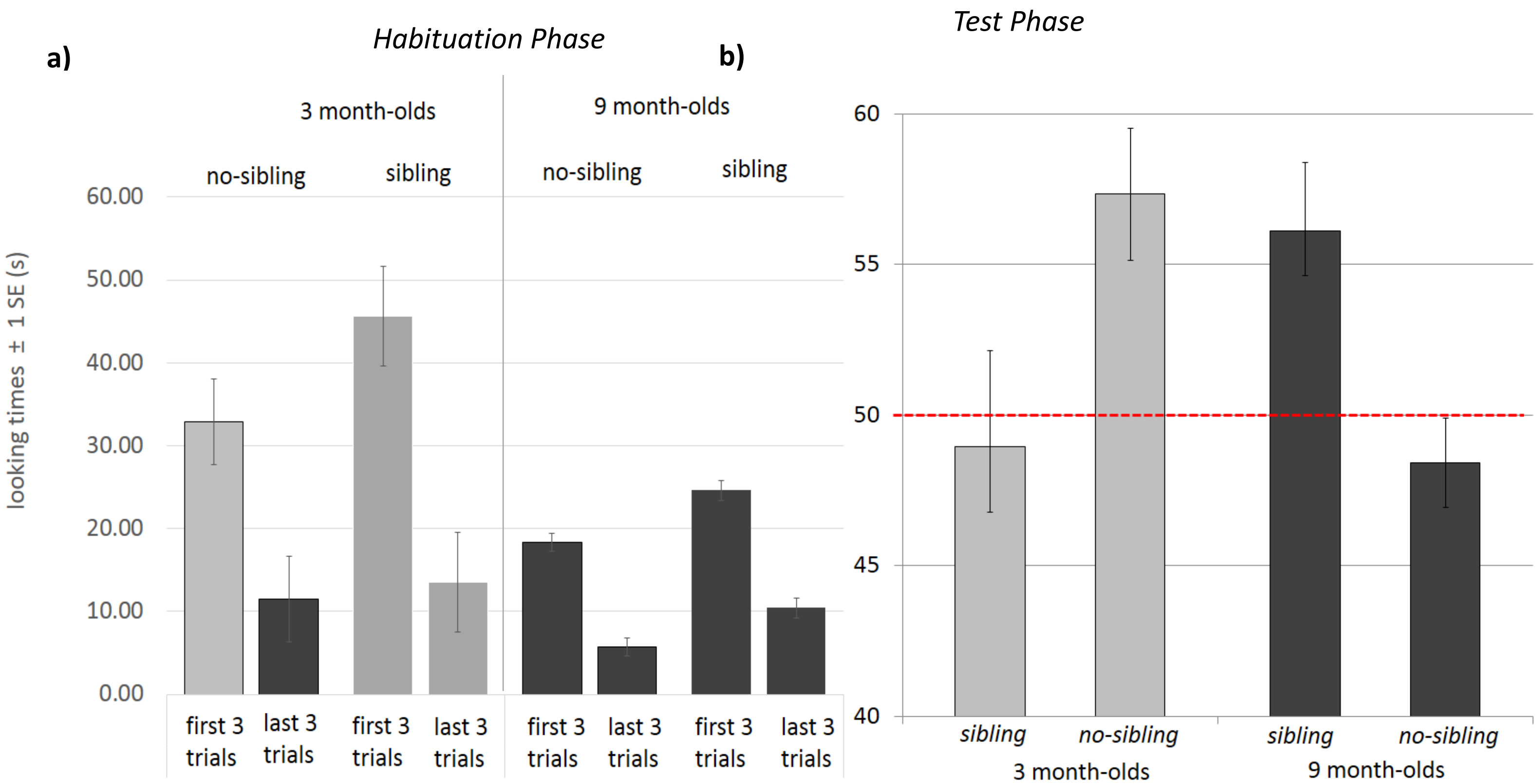

Figure 3 Looking time during the first 3 and the last 3 trials of the habitation phase (**a**) and percent of time spent on the novel face across the two test trials (**b**) for 3 and 9 month-old infants with and without an older sibling. The red line represents the chance level (50%).

Experiment 2 tested infants' discrimination of child faces as a function of participant's age (3 vs 9 months) and sibling experience (sibling vs no-sibling). Infants without an older sibling showed the expected pattern of results, as 3 month-olds discriminated the novel from the familiar face during test trials, whereas 9-month-olds failed to do so showing no preference at test. In contrast, infants with an older sibling showed an opposite pattern of results at both 3 and at 9 months of age, as 3-month-olds were unable to discriminate the familiar from the novel child face, while 9-month-olds discriminated between the two faces showing a preference for the novel face. The finding that only 9-month-olds with an older sibling were able to discriminate between child faces suggests that sibling experience had a critical effect in facilitating discrimination abilities for child faces, which would otherwise get lost across the 3-to-9-months time window.

These findings resonate well with those obtained by Scott and colleagues (2009) showing that 9 month-old infants are capable to discriminate monkey faces after 3 months of training with these faces, an ability that is normally not evident at 9 months in the absence of perceptual training. These results together suggest that perceptual narrowing reflects each infant's individual experience with faces during the first months of life.

An unexpected result emerged from 3 month-old infants with an older sibling, who, unlike those without an older sibling, failed to manifest any significant preference at test, neither for the novel face nor for the familiar one. This finding was unexpected because, if sibling experience were to have an impact on infants' discrimination abilities, it should have been that of facilitating child face discrimination, rather than hindering it. Irrespective of the possible factors mediating this null result, the differential performance of 3-month-olds with an older sibling with respect to those without a sibling shows that sibling experience have an impact on infants' face representation already at 3 months of age (see General Discussion for further discussion on this point).

Discussion of Study 1

This study provides novel evidence on the impact of face age in interaction with sibling experience on infants' face processing and discrimination abilities. Specifically, the study here presented extended previous evidence on the existence of a perceptual tuning toward adult faces that emerges in infants' face representational space during the same time window when other biases in infants' face processing have been shown to emerge (Cashon & DeNicola, 2011; Nelson, 2001; Scott et al., 2007). As found by Macchi Cassia and colleagues (2014), in the absence of sibling experience 3-month-old infants exhibited generalized discrimination abilities for adult and child faces, whereas 9-month-olds showed reliable discrimination of adult faces, but chance-level discrimination of child faces. These results confirmed that when infants spent the majority of their waking time with their adult caregivers, by the end of the first year of life, their perceptual system tunes toward adult faces.

Results from Experiment 1 replicated those from the study by Macchi Cassia and colleagues (2014) as they show that sensitivity to differences among individual adult faces was not only maintained across ages, but was accompanied by the transition from a post-habituation familiarity preference at 3 months of age to a post-habituation novelty preference at 9 months of age. In line with this finding, existing evidence provided by studies using adult faces as stimuli shows that the nature of face processing changes in many ways between 3 and 9 months, with infants becoming more sensitive to configural second-order information (Bhatt et al., 2005) and more capable of integrating internal and external features of the face (Cashon & DeNicola, 2011; Schwarzer, Zauner, & Jovanovic, 2007). These changes in perceptual processing abilities likely contributed to the shift in the direction of post-habituation preferences observed in the current study and in the study by Macchi Cassia and colleagues (2014) for 3- and 9 month-old infants. Also, as mentioned in the discussion of Experiment 1, developmental task, such as the formation of attachment relationship, can constrains infants' face perception abilities: in post-habituation trials with faces of adult strangers infants may have followed a familiarity rule, similarly to what they do when they prefer to look at their mothers' face over a strangers' face in visual preference tasks (Bushnell, 2001; but see Barrera & Maurer, 1981 for novelty preference for stranger after habituation to the mother's faces).

A different pattern of results emerged for the discrimination of child faces. For infants without an older sibling and with limited experience with children, sensitivity to differences among individual child faces declined between 3 and 9 months, as indicated by the transition from a post-habituation novelty preference at 3 months of age to a null post-habituation preference at 9 months. Conversely, for those infants that were consistently exposed to at least one child faces through the presence of an older sibling, a decline in discrimination abilities for child faces did not occur. Rather, and quite unexpectedly, results followed an opposite developmental pattern, as indicated by the transition from a null post-habituation preference at 3 months to a post-habituation novelty preference at 9 months. To our knowledge, this is the first evidence showing that sibling experience is able to exert an effect on face processing in early infancy: in fact, 9 months of experience with an older sibling were enough to prevent from the selective tuning toward adult faces. Moreover, while 3-month-old infants who did not have experience with child faces showed discrimination ability for child faces, 3 month-olds who had an older sibling did not. This lack of capacity can be due to the fact that sibling experience starts to have an impact on the infants' perceptual system already at 3 months of age: this impact may lead to a partial change in the processing strategies used to discriminate child faces (familiarity vs novelty preference) for 3 month-olds as found for adult faces in Experiment 1. It is likely that for infants with at least one older sibling, child faces acquire an importance partially comparable to that of adult faces, as these infants are involved in meaningful and motivationally relevant interactions with their siblings. For this reason a lack of discrimination ability could be the outcome of the competition between a novelty preference (like the one shown by 3 month-olds without an older sibling in the processing of child faces) and a familiarity preference (like the one shown by 3 month-olds without an older sibling in the processing of adult faces). The fact that these infants did not show a significant familiarity preference might be due to the fact that, although important, children do not have the same unique role as the adult caregiver, for which a reliable familiarity preference is found at 3 months.

In conclusion, findings from Study 1 add to existing evidence from young children in challenging the notion of a stable "own-age" bias in face processing across the lifespan. Current results suggest that the processing advantage for adult faces found at 3 years of age has its roots in the perceptual tuning towards adult faces that occurs during the first year of life, in absence of extensive experience with individuals belonging to non-adult groups. These results also suggest that the infants' perceptual system, as children's perceptual system, adapts to reflect the predominant age morphologies of the individual faces that are more common and socially relevant in the infant's environment, which could be selectively adult faces or both adult and child faces in the case of sibling experience.

Study 2

The impact of sibling experience on the neural correlates of perceptual narrowing for adult faces in the first year of life [2]

The aim of Study 2 was that of extending available evidence on the neural mechanisms underlying infants' face processing abilities using event-related potentials (ERPs), a non-invasive technique which provides a critical contribution in the investigation of the temporal ordering and strength of these neural mechanisms.

As for behavioral studies, a great deal of attention has been given to the investigation of the differential neural activation in response to familiar and unfamiliar face categories during adulthood , much less is known on the developmental trend of the same phenomenon. Infant studies on the species bias confirmed that neurophysiological mechanisms also appear to be modulated by experience, possibly explaining the perceptual narrowing evident in behavioural responses. Specifically, by the end of the first year of life, the neural circuits responsible for face processing change from being activated equivalently by a broad range of face categories to producing a greater response to the categories of faces most experienced, giving rise to a more localized and specialized neural response (Johnson, 2000). The neurophysiological evidence of this phenomenon comes from event-related potential (ERP) studies that compared processing of human faces to that of non-human primate faces in infants over the first year of life. These studies show increasing selectivity, between 6 and 12 months, to upright human (versus monkey) faces (de Haan et al., 2002; Halit, de Haan, & Johnson, 2003), at two distinct ERP components the N290 and the P400 (de Haan, Johnson, & Halit, 2003; de Haan et al., 2002), "precursors of adult N170" which is considered to be an electrophysiological marker of specialized mechanisms for

[2] This study was carried out in collaboration with Prof. Macchi Cassia and Prof. Chiara Turati, at the University of Milano-Bicocca (UNIMIB). Data collection and data analysis were conducted in collaboration with Ermanno Quadrelli and Stefania Conte, PhD candidates at UNIMIB, and Marta Rigoldi, research assistant at the Infant Lab, Department of Psychology, UNIMIB.

face processing (Bentin, Allison, Puce, Perez, & McCarthy, 1996). Both the adult N170 and the infant N290 and P400 are posterior-occipital components and they showed sensitivity to familiar vs unfamiliar face categories (e.g. human vs monkey faces, own- vs other-race faces, adult vs non adult faces).

Similar pattern of results was found in another study which investigated the differential response to own and other-race faces at 9 month of age. This study found higher amplitude for the N290 component over the occipital temporal regions for own- compared to other-race faces (Balas 2011).

To the best of our knowledge, no studies have investigated whether infants show differential electrophysiological activation for faces belonging to different age groups. Only two studies explored this issue during childhood and provided conflicting results. A first study, conducted by Melinder, Gredebäck, Westerlund, & Nelson (2010), found that 5-year-old children' s face-sensitive component (N170) was enhanced for child compared to young and older adult faces and P2 was smaller for child than older adult faces. Conversely, Peykarjou, Westerlund, Macchi Cassia, Kuefner, & Nelson, (2013) found that 3-year-olds' neural responses were enhanced, in the P1 and the N170 components, for adult compared to infant faces. The authors of this study suggested that this enhanced activation may reflect stronger engagement in the processing of adult faces which are perceived as more salient compared to infant faces. Findings from these two studies (Melinder et al., 2010; Peykarjou et al., 2013) may seem at odds, nevertheless similar conflicting evidence comes from behavioral studies indicating that face representation of children around 3 years of age is tuned toward adult faces, whereas peer faces are over-represented in older children's memory. This discrepancy has been explained as reflecting a developmental change that would occur in children's ability to process faces between 3 and 5 years of age. According to this change, younger children would be strongly motivated to attend to faces of individuals whose perceptual characteristics resemble those of the caregiver as evident in the recognition advantage for adult faces compared to non–adult faces (Macchi Cassia et al., 2014, 2012a;

Macchi Cassia, Kuefner, et al., 2009) and enhanced activation in face-sensitive component for adult faces compared to infant faces (Peykarjou et al., 2013). Conversely, in older children peer faces may have been perceived as potentially more interesting social partners than adults, leading to an increase in attentional engagement to child faces expressed both at the neural (Melinder et al., 2010) and at the behavioral level (Anastasi & Rhodes, 2005; Hills & Lewis, 2011). Following this view, and based on evidence suggesting that 9 month-old infants show a perceptual tuning toward adult faces (Study 1, Macchi Cassia et al., 2014), we would expect infants by the end of the first year of life to show an increased activation and specialization toward adult faces compared to non-adult faces.

The first goal of Study 2 was to test this prediction by investigating the 9 month-olds' electrophysiological responses to adult and non-adult faces as shown in the face-sensitive components analyzed in previous study (i.e., P1, N290 and P400).

The second goal of this study is to explore the neural correlates of the effects of sibling experience observed at the behavioral level in Study 1 by looking at the effect of sibling experience on the neural responses for adult and child faces. To date only one study on the species bias measured the malleability of the infant perceptual tuning toward the most familiar face categories by looking at the effect of a perceptual training with monkey faces on the neural activation during the processing of these faces (Scott & Monesson, 2010). The training was administered between 6 and 9 month of age and electrophysiological activation during the processing of monkey faces was measured before (6 months of age) and after (9 months of age) the training. Infants were trained using a picture book containing 6 images of monkeys following 3 different training procedures: an *individual training* where monkey faces were given individual names (e.g. ''Carlos", "Iona"), a *categorical training* where each monkey face was labeled as "monkey", and a *no-label training* where monkey faces weren't labeled at all. Electrophysiological activation was recorded while infants were passively presented with upright and inverted monkey faces. The inversion effect is commonly used to measure the degree of expertise with a certain face category: in behavioral studies inversion is associated with an increase in reaction times and decrement in accuracy performance in recognition tasks (Yin, 1969), as it provokes significant impairment in the typical processing of faces for which we normally use face-specific processing strategies (e.g. configural strategies). In event-related potential (ERP) studies, inversion leads to an increase in amplitude (Itier & Taylor, 2002) and/or latency (de Haan et al., 2002; Itier & Taylor, 2002) of the face-sensitive components (e.g. N170 in adults, P1 and N170 in children) on lateral posterior channels. In the study by Scott & Monesson (2010) the development of the infant ERP face-inversion effect was measured and considered as the result of the training experience with monkey faces. Only infants who followed the individual training, in fact, showed an occipital–temporal ERP inversion effect for monkey faces, not present prior to training. This inversion effect was similar to the cortical activation usually found during the processing of human faces and it was the result of an increased response to inverted monkey faces after individual-level training (greater peak-to-peak -N290/P400- amplitude to inverted relative to upright monkey faces post-training). Notably, the individual training was the only one exerting an effect, as neither the category-level nor exposure training resulted in inversion effects for monkey faces in the post-training session. This result suggests that perceptual exposure is not enough to modulate the neural mechanisms responsible for face processing which are instead affected by early experience individuating faces.

No study has yet investigated the impact of experience with faces of different ages on the neural activation for these faces during infancy. One study, though, did look that at this aspect in children at 3 years of age (Peykarjou et al., 2013): electrophysiological response to upright and inverted adult and newborn faces was recorded in 3 year-old children with and without a younger sibling. Results suggest that daily experience with a younger sibling affected the processing of adult and newborn faces via the moderating influence of age of sibling at test: age at sibling at test was negatively correlated with P1 amplitude for both adult and infant faces. Assuming that reduced activation reflects the ease of perceptual processing (B Rossion, 1999), the authors speculated that longer experience with the sibling's face would progressively broaden children's face representation, which would then become more flexible as a consequence of experience with both adult and infant faces.

When considered together, findings from Peykajouru and collegues's (2013) study and those obtained by Scott & Monesson (2010) seem to reflect partially different processes: sibling experience does not seem to exert the same effects in 3-year-old children as the perceptual training with monkey faces in 9-month-old infants. For example, while in the study on the species bias perceptual training led to the emergence of an inversion effect for monkey faces in a time window between the two components of interest (i.e. the N290 and the P400), the study on the age bias only found an effect of sibling experience on the P1 regardless of orientation for adult faces and on newborn inverted faces. Nevertheless, these differential results can be due to intrinsic differences between the categories considered (adult vs infant faces compared to human vs monkey faces), as well as the different time in development when the investigation was carried out.

In the current study we elucidated the impact of sibling experience on electrophysiological activation in response to adult and child faces in 9 month-old infants. We tested 9 month-old infants with and without an older sibling while passively viewing adult and child faces. These faces were presented with upright and inverted orientation in order to measure sensitivity of the face-sensitive ERP components to stimulus inversion. One of the strength of this study is that we employed a within-subjects design so that for each subject we had a direct measure of electrophysiological activation in the 4 condition (adult upright, adult inverted, child upright, child inverted).

We examined the two components of the ERP response, the N290 and the P400, thought to be putative markers of infant face processing and thereby precursor of the adult N170 (de Haan et al., 2003). Recently also the P1, a positive occipital ERP component peaking around 100 ms sensitive to low-level stimulus characteristics (Dering, Martin, Moro, Pegna, & Thierry, 2011; Bruno Rossion & Caharel,

2011) and to the presence of faces in some studies (Eimer, 2000), was found to be modulated by different face dimensions (e.g., species and age) in childhood (Peykarjou et al., 2013) and in infancy (Peykarjou, Pauen, & Hoehl, 2014). Based on this evidence and on visual inspection of the waveforms obtained in our study we examined also the specific responses of the P1 to faces of different ages and their modulation as effect of sibling experience.

Our hypothesis were based on evidence coming from Study 1 in which infants selected to have had an older sibling did show a modulation of the perceptual tuning towards adult faces as effect of sibling experience. Specifically, we expected to see neural marker of the advantage for adult faces (e.g. a stronger inversion effect for adult faces) in the group of infants without an older sibling, conversely in the sibling group we expected to see similar activation for adult and child faces.

Method

Participants. Twenty-three 9 month-old infants (8 males, mean age= 295,6 days, age range= 261-327 days) were included in the final sample, 16 in the sibling group and 7 in the no-sibling group (data collection for the sibling group is still in progress). An additional 38 infants were tested but could not be included in analyses for the following reasons: excessive eye and/or body movements that resulted in recording artifact (n = 15, too few trials were recorded for inclusion (n = 18), equipment failure or experimenter error (n = 1), or refusal to wear the sensor net (n = 4). All participants were Caucasian, healthy and full-term. Infants in the no-sibling group had less than 10 hours of experience per week with children between 2 and 6 years old, (M= 2.45 h/week, range= 0-10 h/ week). Children in the no-sibling group were first-born children; children in the sibling group had one older sibling, whose age at the time of test ranged between 2 and 6 years of age (M = 3.5 year). Participants were recruited via a written invitation that was sent to parents based on birth record provided by neighboring cities. The study was explained to the parents and their written consent was obtained.

Stimuli. The stimuli were 20 coloured images of women faces (20-30 years) and 20 coloured images of children faces (3-5 years). The faces were oval-cropped such that the external features of the face (i.e. hair and ears) were not visible; to reflect the natural differences in the size of real adult and child faces, adult faces were slightly bigger compared to child faces. When viewed from approximately 60 cm, adult faces subtended 15,28° of visual angle vertically and 10,5° of visual angle horizontally, and child faces subtended 13,37° of visual angle vertically and 10,5° of visual angle horizontally (Figure 4). Adult and child faces were equalized for luminance and contrast using Photoshop and presented on a gray background. Inverted stimuli were created by rotating each face 180˚.

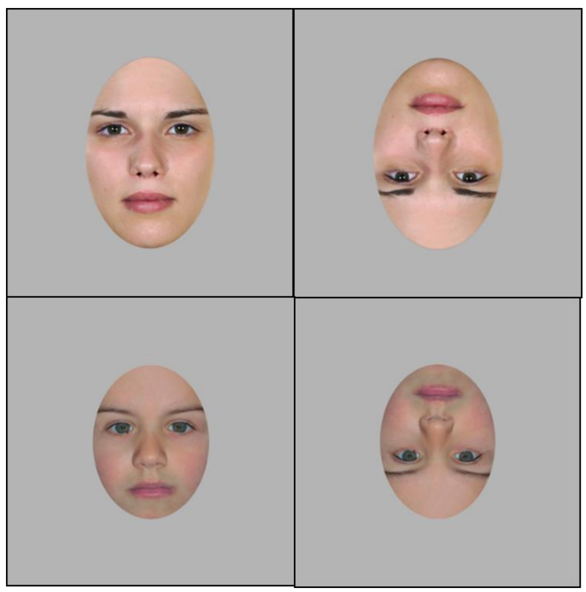

Figure 4 Examples of the adult (top line) and child (bottom line) faces used as stimuli in Study 2. Inverted faces were created by rotating stimuli 180 ˚.

Procedure. Testing took place in a darkened, quiet room after application of the sensor net. Infants were tested while sitting on their parent's lap. Stimuli were presented using E-Prime software and appeared on the center of the screen on a gray background. The computer monitor was 55 cm wide and 35 cm high. A digital video camera mounted above the monitor and centered on the infant's face allowed for observation of the infant at all times during the testing session. The video-recording was then used for off-line coding. Face age (adult and child faces) was blocked and alternated across trials and the face age presented in the first block was counterbalanced across participants (half the sample started with an adult block always followed by a child block, vice versa the other half of the sample started with child faces followed by adult faces).In each block 20 faces were presented (10 upright, 10 inverted) with orientation semi-randomized across trials (no more than three faces with the same orientation were presented consecutively). A trial consisted of 1000 ms stimulus presentation followed by a silent inter-stimulus with a red fixation cross over a gray background which varied randomly in duration between 900 and 1100 ms. The procedure continued until a maximum of 240 trials (12 blocks) were presented (60 trials for each category: adult upright, adult inverted, child upright, child inverted) or until the infant became bored. Parents were instructed to stay silent and to avoid visual contact and any attempt for social interaction with the participant. Stimulus presentation lasted approximately 12 minutes. The procedure followed the ethical standards (the Declaration of Helsinki, BMJ 1991; 302:1194) and was approved by the University ethical committee**.**

Electroencephalogram recording. The electroencephalogram (EEG) was recorded continuously using a 128-electrode HydroCel Geodesic Sensor Net (Electrical Geodesic Inc., Eugene, OR) and amplified using an EGI NetAmps 300 amplifier. The signal was referenced online to the vertex electrode (Cz), a bandpass filter of .1 to 100Hz was applied, and the data were sampled at 500 Hz. Impedances were checked prior to the beginning of recording and considered acceptable if lower than 50KΩ. EEG data were further processed offline using NetStation v4.6.4 (Eugene, OR). The signal was band-pass filtered (0.3-30 Hz), and the ERP trials were segmented with a 100 ms baseline and 1000 ms following stimulus onset. Data were corrected to the average voltage during baseline and re-referenced to the algebraic mean of all channels. To eliminate artifacts, segmented data were automatically rejected whenever the signal exceeded ± 200 μV at any electrode. The recorded session was coded offline by an experimenter who indicated which trials could be considered valid based on the infant’s movements and looking behavior. Trials considered valid after the offline coding, were further checked through visual inspection for eye-movements, eye-blinks and other body movement artifacts not detected by the automated algorithm. Trials were excluded if more than eighteen bad channels were detected. Of the remaining trials, individual bad channels were replaced using spherical spline interpolation. Individual subject averages were computed separately for each channel across all trials within each condition and then re-referenced to the average reference. Across participants, the mean number of trials contributing to the average ERP was 16 (Adult Upright: M = 17.04, SD = 5.88; Adult Inverted: M = 16.91, SD = 7.43; Child Upright: M = 16.9, SD = 5,02; Child Inverted: M = 16.35, SD = 6,49). A similar number of trials contributed to the final 1 analysis for each condition, $F (3, 66) = .165$ $p > .919$. Inspection of the grand-averaged waveforms revealed a well-defined, P1 component subsequently analyzed within a time window of 110-170 ms, a N290 component was subsequently analyzed within a time window of 190-300 ms and lastly a P400 component was analyzed within a time window of 320-500 ms. The effects of orientation on the amplitude and latency of each component were tested by computing two measures: (1) mean amplitude (V) within the target time window, and (2) peak latency (ms) by calculating the time at which the peak (i.e., most negative or most positive depending on the polarity) occurred. Electrode groupings and time windows were chosen based on previous literature as well as visual inspection of the grand- averaged and individually averaged waveforms. We grouped the selected sensors into left and right regions, comprising sensors 69, 70, and 74 on the left hemisphere and sensors 82, 83, and 89 on the right hemisphere (Figure 5). Within these groups of sensors the ERP signal was averaged across the individual sensors to yield a single average waveform per subject for the left and right groups.

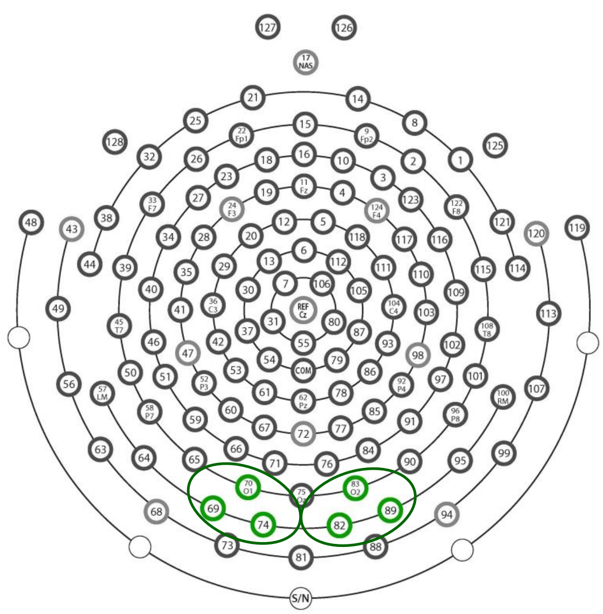

Figure 5 Electrodes selected for the analysis. P1, N290 and P400 were measured over the left and right groups of electrodes outlined in green (the top of the array is the front of the head, the bottom is the back).

Results

Due to the different number in the groups of infants, data analysis was carried out separately the no-sibling group (Figure 6) and for the sibling group (Figure 7). For both amplitude and latency we conducted a 2 x 2 x 2 repeated-measure ANOVA with three within-subjects factors: Face Age (adult, child), Orientation (upright, inverted).

No-sibling group

P1

Amplitude. The ANOVA on mean amplitude revealed a main effect of the factor Orientation $F(1, 15) = 7.664$, $p = .014$, $\eta^2 = 338$, with larger amplitude for inverted (M = 15.52 µV) than upright faces (M = 10.79 µV). All other main effects and interactions did not reach the significance level, *p*s >. 065.

Latency. The ANOVA on peak latency revealed only a main effect of the factor Face Age $F(1, 15) = 17.748$, $p = .002$, $\eta^2 = .496$, in that the response to adult faces (M = 140 ms) was faster compared to the response to child faces (M = 148.65 ms). All other effects did not reach the significance level, *p*s >. 44.

N290

Amplitude. The ANOVA on peak amplitude revealed a main effect of the factor Orientation $F(1, 15) = 6.169$, $p = .025$, $\eta^2 = .291$ in that upright faces (M = -1.116 µV) elicited significantly larger N290 amplitude than inverted faces (M = 4.983 µV). The interaction between Face Age and Orientation also resulted significant $F(1, 15) = 6.684$, $p = .021$, $\eta^2 = .308$ with selective inversion effect for adult faces, as indicated by the significant difference between adult upright (M = -2.466 µV) and inverted faces (M = 7.762 µV), $t(15) = 3.327$, $p = .005$ (the same comparison for child faces did not reach the significance level, $p > .45$). Furthermore, a significant difference emerged between the adult and child faces (M = 2.205) only in the inverted condition $t(15) = 2.739$, $p = .015$ (the same comparison in the upright condition did not reach the significance level, $p > .25$).

Latency. The ANOVA on peak latency revealed only a main effect of the factor Orientation F (1, 15) = 4.801, *p* =.045, η^2=.242, in that the response to inverted faces (M = 233.51 ms) was faster compared to the response to upright faces (M = 237.82 ms). A significant interaction emerged also between the factors Face Age and Hemisphere, F (1, 15) = 4.846, *p* =.044, for which all post-hoc comparisons failed to attain significance (ps > .07). All other effects did not reach the significance level, *p*s >. 41.

P400

Amplitude. The ANOVA on peak amplitude revealed a main effect of the Orientation F (1, 15) = 4.993, *p* =.041, η^2= 250, in that inverted faces (M = 27.33 µV) elicited significantly larger N290 amplitude than upright faces (M = 21.96 µV). No other effects did reached the significance level, *p*s >. 065.

Latency. There were no effects on P1 amplitude, *p*s >. 198.

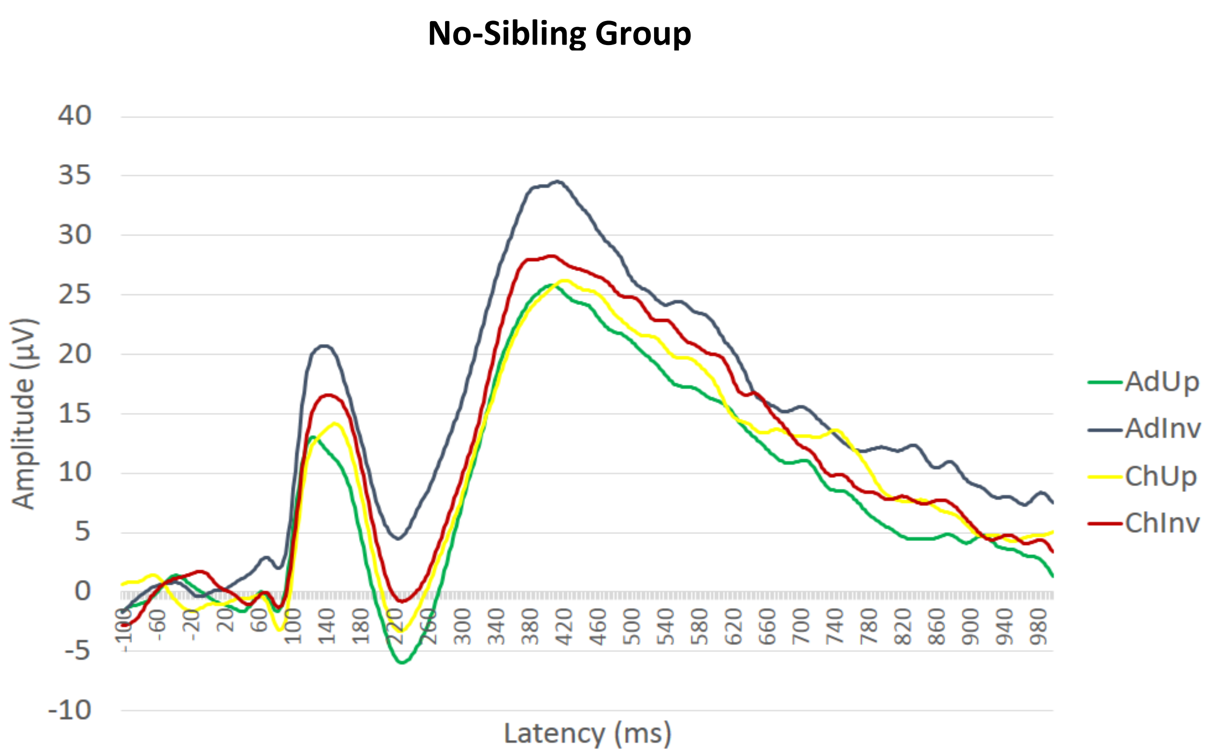

Figure 6 ERP waveforms for the no-sibling group. ERP responses were averaged across hemispheres in response to upright and inverted adult and child faces.

Sibling group

P1

Amplitude. There were no effects on P1 amplitude, *p*s >. 13.

Latency. The ANOVA on peak latency revealed a significant interaction between Face Age and Orientation F (1, 6) = .6485, *p* =.044, η^2= .519, with a selective inversion effect for child faces: response to child faces was significantly faster in the upright condition (M = 144.52 ms) compared to the inverted condition (M = 152.62 ms), t (6) = 4.901, *p* =.003. No inversion effect was found for adult faces, p=.279 and no differences emerged between child and adult faces, p>. 12. Furthermore the interaction between Face Age and Hemisphere resulted significant F (1, 7) = 6.622, *p* =.042, η^2=.525. Follow-up tests failed to reach significance.

N290

There were no effects on N290 amplitude and latency, *p*s >. 10.

P400

Amplitude. There were no effects on P400 amplitude, *p*s >. 10.

Latency. The ANOVA on peak latency revealed a significant interaction between Face Age and Orientation F (1, 6) = 7.996, *p* =.030, η^2= .571, with a selective inversion effect for child faces: response to child faces was significantly faster in the upright condition (M = 417.81 ms) compared to the inverted condition (M = 447.71 ms), t (6) = 2.427, *p* =.051. No inversion effect was found for adult faces, p=.225 and no differences emerged between child and adult faces, p>. 11.

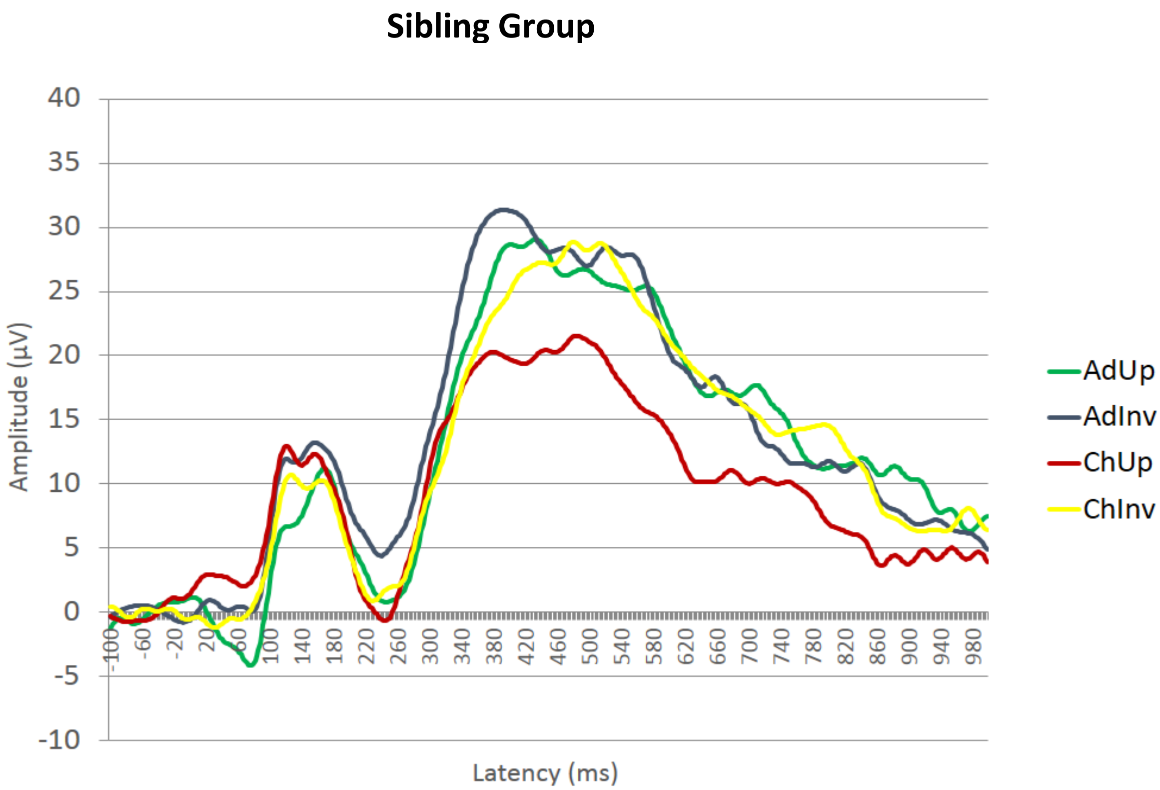

Figure 7 ERP waveforms for the sibling group. ERP responses averaged across hemispheres in response to upright and inverted adult and child faces.

Discussion of Study 2

Study 2 measured 9-month-olds' electrophysiological brain activity in response to adult and child faces and its modulation as a function of infants' social and visual experience with the face of an older sibling. Nine-month-old infants with and without an older sibling were tested while presented with upright and inverted adult and child faces. For each group three face-sensitive ERP components, the P1, the N290, and the P400, were observed and analyzed.

As mentioned in the introduction only recently developmental studies started looking at the modulation of the P1 component for different face categories. Data on the P1 activation are quite conflicting: one available study showed a modulation of the P1 based on face species (higher activation for ape compare to human faces; Peykarjou et al., 2014) at 9 months of age; conversely a study on the age bias found higher activation in this component for adult faces compared to newborn faces in 3 year-old children. In line with these last mentioned study on 3 year-old children, results obtained in our work from the no-sibling group showed that adult faces elicited an earlier P1 than child faces. Interestingly in the sibling group again the latency of P1 was modulated by face age as indicated by the selective inversion effect for child faces with child faces eliciting an earlier P1 compared in the upright compared to the inverted condition. These results on P1 suggest that, in our sample, the latency of this early component is peculiarly sensitive to age information and also to the effect of experience with faces. The fact that adult faces elicited earlier activation of the P1 than child faces in the group of infants without sibling experience could be explained taking into account structural differences between the two stimulus categories (e.g. adult face are slightly bigger than child faces); nevertheless the fact that this effect was not found in the sibling group makes this explanation unlikely. Conversely that adult faces in the no-sibling group and child faces in the sibling group elicited faster P1 activation seems to suggest that the "face diet" to which infants are exposed during the first 9 months of life makes infants particularly sensitive in distinguishing between perceptual information carried by adult and child faces.

Concerning the N290 component, previous studies investigating the specificity of infants' neural responses showed that infants normally manifest enhanced activation of this component (i.e. N90 is generally larger in amplitude and often shorter in latency) for familiar face categories such as own-race (Balas et al., 2011), own-species (de Haan et al., 2002; Halit et al., 2003) and female face (Righi, Westerlund, Congdon, Troller-Renfree, & Nelson, 2014). Our finding from the group of infants in the no-sibling group extend this evidence by showing that in the case of face age the advantage for adult faces is not expressed in a general increased activation for this face category compared to child faces, but it takes the more adult-like shape of a selective inversion effect for adult faces compared to child faces. Only for adult faces the upright and inverted condition significantly differed; this significant difference was not found between upright and inverted faces in the child condition. This last result is in line with what found in a study on the species bias which showed that slightly older infants (12 month-olds) showed an inversion effect on the N290 component selective for human compared to monkey faces as normally showed in adult ERP studies, while monkey faces did not elicit any inversion effect (Halit et al., 2003). Nevertheless while in 12 month-old infants and in adults, the N290/N170 are normally larger for inverted human faces compared to upright human faces, in our study face orientation elicited a weaker activation in the N290 for inverted faces compared to upright faces. Another unexpected result emerges from the N290 latency: infants in the no-sibling group showed a generalized inversion effect with delayed N290 for upright faces compared to inverted faces. Our study is the first one reporting an inversion effect at 9 months of age when normally the N290 is not sensitive to face orientation yet (de Haan et al., 2003): as reported in the review by De Haan and colleagues (2003) "the N290 appears to become more sensitive to upright, human faces with age" with the first evidence of an inversion effect on the N290 around 12 months of age (Halit et al., 2003). Nevertheless our result would need to be replicated to see whether it is related to our stimulus set or other methodological aspects, or if this reversed inversion effect on the N290 (delayed and enhanced N290 for upright faces compared to inverted faces) is a transient phenomenon that anticipates the emergence of the inversion effect in the adult-like shape (larger and delayed N290/N170 for inverted faces).

Surprisingly no significant differences emerged from the sibling group where the N290 was not modulated by neither face age nor orientation. The absence of differences between adult and child faces could be due to the experience with sibling based on which child faces become as meaningful and as perceptually salient as adult faces. More subjects are needed to understand if this lack of differences is a stable phenomenon or if it is due to the limited sample size.

Finally results from the P400 are, similarly to what found for the P1, interesting for the comparison between the two samples. The no-sibling group showed an inversion effect on the P400 amplitude with greater activation for upright compared to inverted faces, but no effect of face age;

conversely in the sibling group the P400 showed the same pattern of results showed for the P1, which is an inversion effect selective for child faces on the P400 latency.

Together these findings suggest that face age, as other facial dimensions, exerts an effect on neural activation and that this effect is modulated by face experience already during the first year of life, as shown by the different results obtained for the two groups. Infants who had predominant experience with adult individuals showed evidence of the expertise with adult faces as indicated by the earlier activation on the P1 and the selective inversion effect on the N290 component. Differently, infants with an older sibling didn't show enhanced activation for adult faces and manifested markers of expertise for child faces (selective inversion effect on the P1 and P400 latency). It is important to underline again that the sibling sample is only composed of 7 subjects, for this reason conclusions drawn from its results are only speculative. A more stable picture will be provided by the full sample of infants that will also allow for direct comparison with results from the group of infants without an older sibling.

In conclusion, Study 2 confirmed that perceptual narrowing towards adult faces, evident in discrimination ability (Macchi Cassia et al., 2014; Study 1), is likely linked to an experience-dependent specialization of the neural circuits in occipital-temporal regions towards adult faces. This specialization does not occur when infants face experience during the first year of life is extended to multiple meaningful face categories (e.g. caregiver: adult faces; older siblings: child faces). As suggested in the only previous study investigating the effects of sibling experience on the neural correlates of face processing in 3 year-old children, contact with faces of various ages may change the way faces are perceptually encoded and represented within the infants' face space (Valentine, 1991).

Study 3

The effects of early-and later-acquired experience on adults' ability to process infant faces[3]

The goal of Study 3 was to extend existing evidence on the role of early-acquired experience with non-adult faces in boosting adults' ability to learn from newly encountered face types (Macchi Cassia, Kuefner, et al., 2009). In particular, the aim of the study was to trace the time-course of perceptual learning effects engendered by experience acquired by mothers with the face of their first-born child as function of the presence/absence of early experience with a younger sibling.

As discussed in the Introduction, developmental studies showed that within the first 6 years of life children exhibit adult-like biases in the processing of adult faces compared to other-age faces, at least when perceptual discrimination tasks are employed (Macchi Cassia et al., 2012, 2014, Kuefner, 2008, but see Anastasi and Rhodes, 2005). This advantage is characterized by superior within-category discrimination and greater use of face-specific processing strategies (e.g. configural, holistic processing strategies), as shown by the selectivity of the inversion effect for adult faces. Nevertheless, there is also evidence (see Study 1 and Study 2 of the current dissertation) that subtle variations in the amount of differential experience with faces of non-adult individuals during the first 6 years of life have dramatic effects on the direction/magnitude of the age bias. Specifically, experience with an older sibling occurring between 1 and 3 years of age eliminates the bias in 3-year-old children (Macchi Cassia et al., 2012); similarly experience with a younger sibling occurring anytime between 1 and 6 years of age eliminates the bias in both 3 and 6-year-old children (Macchi Cassia et al., 2009 Exp. 1; 2013). Conversely, the effect of sibling experience are not evident later in life, as suggested by the study of Macchi Cassia and colleagues (2009 Exp. 3) where adults, who had a younger sibling born before they reached the age of 6, showed an advantage for adult faces not dissimilar from the advantage shown by

[3] This study was carried out in collaboration with Prof. Viola Macchi Cassia, at the University of Milano-Bicocca Unimib). Data collection and data analysis were conducted in collaboration with Dr. Gudrun Schwarzer and Dr. Claudia Kubicek, respectively Professor and Post-Doctoral Researcher at the University of Giessen, Germany.

adults without a younger sibling. This evidence suggests that early-acquired experience exerts an effect on face processing abilities early in life, but this modulation effect does not remain constant later in the lifespan, becoming dormant in the absence of continued experience.

Nevertheless evidence has been provided suggesting that visual experience acquired in adulthood can mitigate/eliminate age (and race) biases. This modulation effect was demonstrated in studies using laboratory training with other-race faces which found a reduction in the magnitude of the own-race bias (Lebrecht, Pierce, Tarr, & Tanaka, 2009; McKone et al., 2007). Also experience with out-group faces acquired in natural context is able to cancel the advantage normally found for in-group faces. In the case of the race bias, evidence from a group of Asian adults who were adopted early in life by Caucasian families suggested that not only these individuals did not show an own-race bias, but they show an advantage for Caucasian faces (other-race faces). Similarly for the age bias, working experience with infants or children reduces or eliminates the advantage for adult faces normally found in adult individuals (de Heering & Rossion,2008; Kuefner et al.,2008; Macchi Cassia et al.,2009b, Harrison & Hole, 2009). The same modulation effect is not exerted by experience acquired later in life with one single individual: in the study that we want to replicate in this work, first-time mothers were tested when their first-born child was 9 month-olds in the recognition of adult and infant faces and showed the typical advantage for adult faces found in adults who did not collect experience with an infant face during adulthood. Conversely the perceptual advantage for adult faces was not evident in first-time mothers who had been exposed to an infant face early in life indicating that exposure to an infant face is capable of engendering perceptual learning of infant faces only if preceded by a similar type of experience earlier in development, such as the presence of a younger sibling in the first 6 years of life, (Macchi Cassia et al., 2009 Exp. 2).

Two main conclusion have been drawn from these findings: first, the plasticity of the face processing in adapting to each individuals’ experience acquired in everyday natural contexts likely decreases with age; second, the early visual experience acquired by mothers with younger siblings early in life left long-lasting effects that did not remain evident between childhood and adulthood, but rather became dormant in the absence of continued experience or were reactivated in first-time mothers by re-exposure to an infant face.

In light if this evidence, the aim of Study 3 was to investigate the time-course of the perceptual learning effects induced by mothers' experience with the child's face in interaction with early-acquired experience with a younger sibling. To this aim, we compared discrimination abilities and the size of the inversion effect for infant (vs adult) faces in mothers with or without younger siblings, who gave birth to their child 4 or 12 months before testing, and compared the results with those previously obtained by Macchi Cassia et al. (2009a) with mothers of 9-month-old infants. We used the same stimuli and the same perceptual discrimination task (two-alternative-forced choice, 2AFC) employed in previous studies on the topic (Macchi Cassia et al., 2009a, 2009b; Kuefner et al., 2008). Participants had to identify a briefly presented target face when presented beside another face identity of the same age. This task places emphasis on the encoding stage of visual processing and limits memory demands for participants. Moreover, to investigate the effects of experience on the perceptual processing strategies (e.g. configural, holistic strategies) adopted by participants in discriminating adult and infant faces, we measured the size of the inversion effect for the two types of faces. Detection of configural information drops abruptly when faces are inverted, giving rise to the face inversion effect (Yin, 1969), which is commonly used as a measure of perceptual expertise. Accordingly, the stronger or selective inversion effect observed for own-race versus other-race faces (e.g., Rhodes, Tan, Brake, & Taylor, 1989) and for own-age versus other-age faces (e.g., (Kuefner et al., 2008) in adults has been interpreted as arising from asymmetrical race and age experience. Furthermore, the inversion effect has been reported to be face- specific in children as young as 3 years (Picozzi, Cassia, Turati, & Vescovo, 2009) and even at this age, like in adulthood, the effect is modulated by asymmetrical race and age experience, since it is larger for own-race than other-race faces (Sangrigoli & de Schonen, 2004) and for adult faces than newborn or child faces, unless experience with a younger or older sibling occurred (Macchi Cassia et al., 2009 Exp. 1, 2012). Based on this earlier evidence, in the current study, we used the size of the inversion effect as a measure of perceptual learning engendered by mothers' experience with their child face.

Method

Participants. The sample included 30 first-time mothers of 4-month-old infants, 23 first-time mothers of 9-month-old infants and 30 first-time mothers of 12-month-old infants. Participants were divided in two groups based on the presence/absence of a younger sibling who was born during the first 6 years of age of the participant. Two participants were excluded because their performance was 2 standard deviations below the group mean in at least 1 condition. We selected participants using the same criterion employed in Macchi Cassia and colleagues (2009a Exp. 2,3), which is participants were included in the final sample only if in the past year, they had not acquired more than 24 hours of experience with infants in any month. Specifically participants included in the final sample reported to have on average 7,5 hours of experience with infants per month (range = 0-20 hours/month).

Stimuli. Stimuli were 48 gray-scale photographs of adult (20- to 30-year- old) female faces and 48 gray-scale photographs of newborn-infant faces. Each photograph displayed a full-front neutral expression (Figure 8). Faces within each age category were cropped to be the same size. To reflect the natural differences in the size of real adult and infant faces, we cropped the photographs so that the adult stimuli were slightly larger than the infant stimuli. When viewed from approximately 40 cm, adult faces subtended visual angles of 4.43° (horizontal) and 6.04° (vertical), and the infant faces subtended visual angles of 4.00° (horizontal) and 5.05° (vertical), and appeared on a grey background. An attempt was made to pair faces based on subjective criteria of luminance and overall similarity, so as to generate 24 pairs for each face age. Inverted stimuli were created by rotating each face 180°.

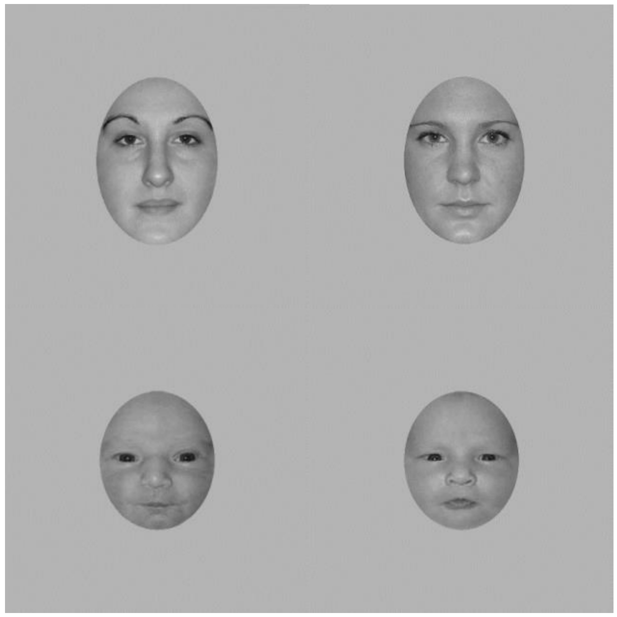

Figure 8 Examples of the adult (top line) and infant (bottom line) faces used as stimuli in Study 3.

Procedure. Before starting the testing session we obtained informed consent from each adult participant and explained the instruction for the task. Each participant completed a two-alternative, forced-choice recognition task, presented on a computer. The task began with 4 practice trials with non-face stimuli in order to make the participant aware of and comfortable with the task structure. Each practice and test trial began with the display of a target stimulus in the center of the screen for 1 second. This display was followed by a blank inter-stimulus interval (1 s) and after that by the presentation of two probe stimuli, the target stimulus and a novel one. The probe stimuli appeared side by side until the participant responded. Participants had to identify the target stimulus among the two probes by pressing a key on the keyboard. The left-right position of the novel probe was randomized across trials. Participants completed two sessions identical except for the stimulus orientation: the first session was always with upright stimuli, while in the second session stimuli were presented in inverted orientation. Adults completed two blocks of 24 trials for each condition (total of 196 trials). Each participant saw both adult and infant faces, with face age alternated between blocks and the age of the faces in the first block counterbalanced across subjects. We thoroughly screened adult participants prior to testing to ensure that, in recent years, they had not acquired significant experience with infants or young children up to the age of 3 years, apart from the exposure to their own children. Response accuracy and response time to correct responses on test trials were recorded as dependent variables.

Results

To compare participants' performance for young and infant faces we analyzed mean accuracy rates and median response times for correct responses in two mixed Analyses of Variance (ANOVAs) with face age (adult, infant) and orientation (upright, inverted) as within-participants factors, and sibling group (sibling, no-sibling) and child's age (4, 9, 12 months) as between-participants factors.

Response Accuracy. The ANOVA on response accuracy revealed main effects of face age, $F(1, 77)= 35.336$ $p <.001$, $\eta^2= .315$, and orientation, $F(1, 77)= 83.592$, $p <.001$, $\eta^2= .521$, as participants were overall more accurate at recognizing adult faces as compared to infant faces, and faces presented in the canonical upright orientation as compared to inverted faces. These main effects were qualified by several two-way and three-way interactions (*p*s < .003), and more crucially by a significant four-way interaction, $F(2, 77)= 5.189$, $p = .008$, $\eta^2= .119$, indicating that accuracy for adult and infant faces in the two orientation conditions differed as a function of sibling experience and child's age.

To follow-up this interaction, we ran separate ANOVAs for the sibling groups and the no-sibling groups. For the no-sibling group, the ANOVA revealed main effects of face age, $F(1, 39)= 12.322$, $p =.001$, $\eta^2= .240$, and orientation, $F(1, 39)= 22.892$, $p <.001$, $\eta^2= .370$, as well as significant two-way interactions between face age and child age, $F(2, 39)= 4.539$, $p = .017$, $\eta^2= .189$, and between face age and orientation, $F(1, 39)= 5.759$, $p = .021$, $\eta^2= .129$. Crucially, there was also a significant three-way interaction between face age, orientation and child's age, $F(2, 39)= 6.285$, $p = .004$, $\eta^2= .244$. Planned paired-sample t-tests revealed that mothers of 4-month-olds and 9 month-olds were more accurate at recognizing upright adult faces than upright infant faces, $t(14) = 3.607$, $p = .003$ and $t(11) = 2.479$, $p = .031$, and showed a significant decrease in recognition accuracy between upright and inverted adult faces, t (14) = 4.045, p = .001 and t (11) = 4.045 p = .002, but no between upright and inverted infant faces, t (14) = .646, p = .529 and t (11) = -.489, p = .634. Mothers of 12-month-olds were more accurate at recognizing upright adult faces compared to upright infant faces, t (14) = 2.551, p = .023; however, unlike mothers of 4- and 9-month-olds, they showed a significant inversion effect for both adult, t (14) = 2.407, p = .030, and infant faces, t(14) = 3.270, p = .006 (Figure 9).

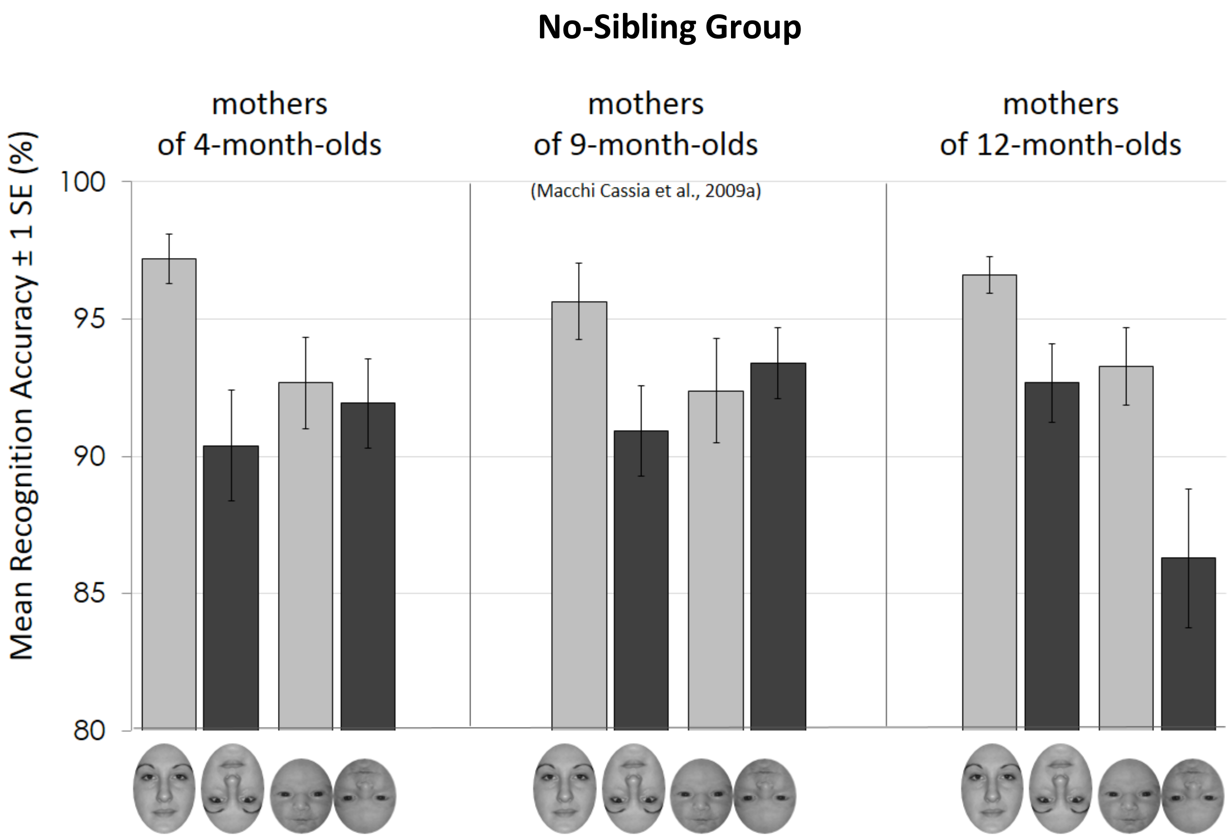

Figure 9 Mean percent of correct responses for adult and infant faces exhibited by first-time mothers of 4 month-old infants (left), 9 month-old infants (center) and 12 month-old infants (right)in the no-sibling group. Data from the group of mothers of 9 month-olds are the same presented in Macchi Cassia et al., (2009a).

The ANOVA performed on the sibling groups revealed main effects of face age, $F(1, 38)= 22.959$, $p <.001$, $\eta^2=.377$ and orientation, $F(1, 38)= 65.155$, $p < .001$, $\eta^2=.632$, due to participants being overall more accurate at recognizing adult faces compared to infant faces, and showing a generalized inversion effect for both adult and infant faces. No other main effects or interactions were significant (*p*s > .15). (Figure 10)

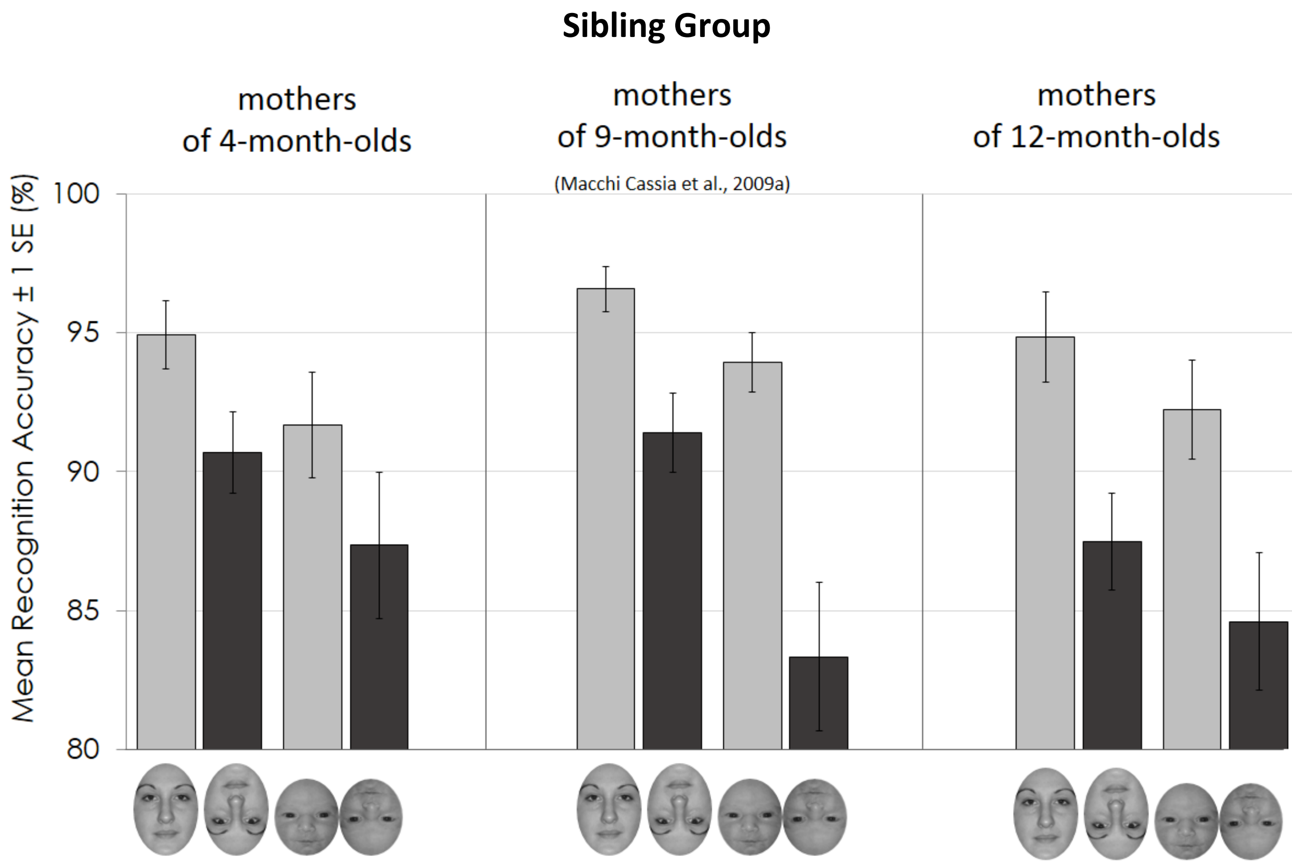

Figure 10 Mean percent of correct responses for adult and infant faces exhibited by first-time mothers of 4 month-old infants (left), 9 month-old infants (center) and 12 month-old infants (right)in the sibling group. Data from the group of mothers of 9 month-olds are the same presented in Macchi Cassia et al., (2009a).

Response Times. The ANOVA on response times for correct trials revealed a main effect of child age, $F(2,77) = 7.790$, $p = .001$, $\eta^2=.168$ due to mothers of 9-month-olds being slower in providing their response than mothers of 4-month-olds and 12 month-olds. The analysis also revealed main effects of face age, $F(1, 77) = 51.668$, $p < .001$, $\eta^2=.402$, and orientation, $F(1, 77)= 30.276$, $p < .001$, $\eta^2=.282$ which were qualified by a significant Face Age x Orientation interaction, $F(1, 77) = 13.361$, $p < .001$, $\eta^2=.148$. Irrespective of sibling experience and length of exposure to their child's face, first-time mothers were overall faster in recognizing upright adult faces (M = 907.39 ms) than upright infants faces (M = 984.65 ms), $t(82) = -7.852$, $p < .00$. Moreover, although an inversion effect was evident for both adult faces (inverted adult: M = 1007.84 ms), $t(82) = -7.724$, $p < .001$, and infant faces (inverted infant: M = 1037.06

ms), $t(82) = -2.948$, $p = .004$, the magnitude of the inversion effect was significantly larger for young adult (M = 100.44 ms) compared to infant faces (M = 54.41 ms), $t(82) = 3.370$, $p = .001$. The ANOVA revealed also an Orientation x Sibling Group interaction, $F(1,77) = 4.011$, $p = .049$. Nevertheless no difference were found in the two groups as participants in both the sibling and the no-sibling group were faster at recognizing upright faces than inverted faces (*p*s < .01) and performance for the two groups did not differ in the upright nor in the inverted condition (*p*s >. 21).

Discussion of Study 3

Study 3 was aimed at exploring the time-course of the reactivation effects engendered by facial experience acquired by mothers who had earlier exposure to a younger sibling. Overall, results showed that the extent to which mothers were able to develop perceptual expertise at processing infant faces was critically modulated by the experience they accumulated with the sibling's face earlier in development.

The other important issue faced in this study was on the effects of experience with one's own child and it concerned the hypothesis that the effect of longer exposure to the child's face (more than 9 months, as tested in the study of Macchi Cassia and collegues, 2009a) allowed mothers without earlier experience to bootstrap perceptual learning of infant faces. Our results confirmed this hypothesis as showed by the fact that, while mothers without a younger sibling did not show any modulation of the age bias after 4 months of experience with their own child as previously found after 9 months of experience (Macchi Cassia, et al., 2009a), mothers who had 12 months of experience with their own child did show a modulation of the advantage for adult faces, with a generalized inversion effect for both adult and infant faces. These findings suggest that the impact of *experience acquired in adulthood* with at least one facial identity varies as a function of exposure length, as 12 months of exposure to the child's face, but not less, allowed mothers to improve their processing skills for infant faces even in the absence of early experience. Furthermore, this result adds important evidence on previous findings on the role of experience with non-adult faces by suggesting that although later in life the perceptual system is less flexible than during early development, it still retains a certain degree of flexibility as shown by the fact that not only professional and extended experience with multiple non-adult individuals (e.g. maternity-ward nurses or preschool teacher), but also 12 months of contact with one's own child are able to modulate face processing ability.

The finding that performance of mothers with a younger sibling did not differ as a function of child's age confirmed the critical role of early sibling experience in boosting adults' ability to learn from exposure to their own child's face. Importantly our results suggest that only 4 months of exposure to the child's face are sufficient to reactivate the sleeper effects of experience acquired early in life, inducing the emergence of an inversion effect for infant faces that is absent in mothers without a younger sibling.

Of note, although mothers in the sibling groups used the same processing strategies to recognize adult and infant faces, they were still overall more accurate at recognizing adult as compared to infant faces. This finding is in line with earlier demonstrations that extensive experience acquired in adulthood with multiple infant faces is not capable to eliminate the recognition advantage for adult faces over infant faces in maternity-ward nurses (Macchi Cassia et al., 2009b)

Another interesting aspect of the comparison between this study and the one testing maternity-wars nurses with adult and newborn faces concerns the results obtained on response times: in both cases the analysis revealed a modulation of response latency based on face age and face orientation. Regardless of sibling experience and experience with their own-child, first-time mothers in our study as well as novices and maternity ward-nurses in the study by Macchi Cassia and collegues (2009b) showed both behavioral markers of the advantage for adult faces as they were faster with adult faces in the upright condition compared to newborn faces and they showed selective inversion effect for adult faces. These results suggest that response times seem to be less sensitive to the effect of experience compared to response accuracy which is modulated by both working experience (Macchi Cassia et al., 2009b) and experience with an older sibling and/or experience with one own' s child. These results are at odds with findings from the study on preschool teachers (Kuefner et al., 2008) in which, using the same paradigm here employed for adult and child faces, response times did show a modulation as effect of working experience as evident in the fact that preschool teachers showed generalized inversion effect for both adult and child faces and no advantage for adult faces. This difference might be related to the intrinsic differences between the face categories considered: newborns are very infrequently present in our typical everyday environment, being less familiar than child faces. Consequently they might be perceptually more difficult to process and the processing strategies employed in their encoding less malleable as a consequence of experience compared to child faces.

Conclusively, findings from this study, together with previous evidence on the role of experience with non-adult faces on the age bias, suggest that time of acquisition of the experience with a certain face category matters, in terms of the magnitude of the effects of this experience on perceptual abilities. Nevertheless evidence suggesting that experience acquired later in life is able to modulate face processing, although not at the same extent to which experience acquired earlier in life does, provides insightful contribution to the debate on the existence of a sensitive period versus a critical period in for face perception, during which, socially meaningful visual stimuli attract the infant's attention and play an important role for the development of face processing abilities. Our findings support the idea of *sensitive period* early in development, as although early experience is important in tuning some aspects of the neurocognitive mechanisms involved in face perception, there is still room for plasticity in adulthood. Nevertheless more experience is necessary to modulate such mechanisms in adulthood compared to earlier in development (first 6 years).

General Discussion

Results of the studies presented in this first chapter extend available evidence on the role of sibling experience on the development of face processing ability across the life span.

Insightful and novel findings come from Study 1 and 2, where evidence on the existence of a perceptual narrowing process and on its malleability already during the first year of life was provided both at the behavioral and at the neural level. Infants, who for the first 9 months of life had predominantly been in contact with adult individuals through extensive experience with adult caregivers, show the typical developmental trend of perceptual tuning towards adult faces and loss of discrimination ability for non-adult faces (infant faces, Macchi Cassia et al., 2014; child faces, Study 1) that occurs between 3 and 9 months of age. This process is accompanied by emerging specialization of the neural circuits that become increasingly dedicated to the processing of faces and show, already at 9 months of age, markers of expertise (greater activation and selective inversion effect) for adult faces compared to other face categories (e.g. child faces, Study 2). A different developmental trend is followed by infants who had extensive experience with both adult and child faces through contact with adult caregivers and with an older sibling. The effect of this contact with individuals belonging to a variety of age groups lead to changes in infants' perceptual ability as measured as early as at 3 months of age and changes in both perceptual processing and neural activation in response to child faces at 9 months of age. From these findings we can draw important conclusions regarding the effect of early-life experience on infants' perceptual processing abilities. Specifically, infants' face representational system appears to adapt continuously to reflect ongoing experience with faces, such that selective exposure to adult caregivers leads to the narrowing of the face system towards adult faces, whereas a broader array of exposure (to faces of different age categories) reduces this narrowing. One remaining question, however, is whether or not the exposure to child faces in addition to adult faces leads to selective expertise with these two face categories or if any variation from experience with adult faces leads to a broader face space and more generalized use of face-specific processing strategies. In other words, if faces can be categorized into three main groups other than young adults (infants, children, older adults), does exposure to any one of the three groups (in addition to exposure to young adults) lead to increased processing performance across all of the groups? Or, alternatively, does the additional experience lead to selective enhanced processing ability for the two face categories of expertise, in this case, adult and child faces? In order to address this question, in the case of sibling experience considered in chapter 1, the investigation of infants' perceptual abilities should simultaneously consider the two category of expertise, in this case adult and child faces, and an additional third category for which infants do not have experience (e.g. infants with an older sibling should be tested with adult, child and infant faces, for example). Such an investigation would tease apart the possibility of selective tuning towards the two categories of expertise, versus an overall, broad improvement in the processing of other age-categories and it represents an interesting direction for future studies.

In conclusion, Study 3 provides important evidence on the plasticity of face system during adulthood (Macchi Cassia, et al., 2009a). Although there is an undeniable decline in the plasticity of perceptual system later in life, the adult face system retains significant flexibility as shown by two findings: (1) only 4 months of re-exposure to at least one infant face is enough to re-activate the effect of experience with a younger sibling acquired early in life; (2) 12 months of first-time exposure to at least one infant face are enough to modulate processing strategies for this face category. These results challenge the view that early development represents a critical time window during which experience shapes perceptual processing abilities and after which the modulation of perceptual processing ability are less likely to occur. They instead support the idea that the first 12 months of life represent a sensitive period, as, although early experience is important in tuning some aspects of the neurocognitive mechanisms involved in face perception, there is still room for plasticity later in development.

CHAPTER 2

The effects of later acquired experience on face processing abilities in adulthood and old age

Introduction

In this second chapter I will discuss existing evidence on the effects of facial experience acquired in social and working contexts on face processing abilities during adulthood and old age.

As mentioned in the introduction the advantage in the processing of adult faces has been found to be stable and robust during adulthood, likely because of the contribution of both experiential and motivational factors: as adults we generally have more experience with other adult individuals and we are highly motivated to individuate faces of adult individuals as they represent our in-group (own-age group). The first study investigating how age of the perceiver and age of the perceived face interact and affect face processing ability was conducted by Bäckman (1991): in this study, both young (18-26 years) and young-older adults (62–69 years) recognized own-age faces more accurately than other-age faces. This original finding of an OAB in young adult individuals has been replicated in numerous studies investigating either identity recognition or identity matching when performance for young adult faces (i.e., own-age faces) was compared to that for older adult faces (e.g.,Anastasi & Rhodes, 2006; He, et al., 2011; Wiese, et al., 2008), child faces (Anastasi & Rhodes, 2005; Harrison & Hole, 2009; Hills & Lewis, 2011; Kuefner et al., 2008 Exp. 2) or newborn faces (Kuefner et al., 2008; Macchi Cassia, et al., 2009a; Macchi Cassia, et al., 2009b). Electrophysiological studies also confirmed the existence of differential processing of young and older adult faces among young adult participants, by showing enhanced ERP responses to own-age faces compared to older adult faces (Ebner, He, Fichtenholtz, McCarthy, & Johnson, 2011; Wiese, Komes, & Schweinberger, 2012; Wiese et al., 2008).

Although the own-age bias in young adults is a robust and stable phenomenon, there is some evidence that, in both younger and older adults, the amount of self-reported social exposure to own- and other-age individuals is related to the size of the OAB (Ebner & Johnson, 2009; He et al., 2011). In addition, adults who accumulated extensive experience with newborns (i.e., maternity- ward nurses) or children (i.e., school teachers) showed enhanced discrimination/recognition and processing skills for infant (Macchi Cassia, Picozzi, et al., 2009b) and child faces (de Heering & Rossion, 2008; Harrison & Hole, 2009; Kuefner et al., 2008, 2010) compared to non-experienced age-matched compared to non-experienced age- matched controls (see Macchi Cassia, 2011 for a review).

Studies 4 to 6 included in the present dissertation were aimed at exploring the extent to which experience acquired in young and older adulthood with specific face age groups is capable to modulate the disadvantage that adults typically manifest in the processing and discrimination of other-age compared to own-age faces. By using the same two-alternative forced choice matching to sample (2AFC) task utilized in Study 3, Study 4 investigated the effects of perceptual experience provided by social interactions with peers and non-peer individuals on young and older adults' ability to process and recognize young and older adult faces. The aim of the study was to test whether the face processing system in elderly people is still capable to adapt to reflect the “face diet” experienced by each individual. Although older adults often report more recent experience with older adults (i.e., their own face, their spouse, peer-friends) than young adults, they have collected early and continuous experience with young adult faces across the lifespan. Study 4 tested the hypothesis that the own-age bias, that is typically manifested by young adults, is not present in older adults, since in this age group recent experience with older faces is not enough to overcome the effects of continuous exposure to young adult faces, and encoding the identities of young adult faces is likely to be motivationally relevant to older people.

Previous research investigated the plasticity of the adult's face processing system by looking at the impact of facial age diversity on face processing skills in adults who had extensive contact with non-adult faces through their working experience (maternity-ward nurses, preschool teachers). Results have shown that these individuals do not manifest a typical own-age bias in the recognition of adult vs. non-adult faces (e.g., (de Heering & Rossion, 2008; Harrison & Hole, 2009; Kuefner et al., 2008, 2010; Macchi Cassia, et al., 2009b). The two last studies included in the current dissertation were aimed at extending available evidence on the impact of facial experience acquired in working contexts on two face processing abilities: perceptual recognition (Study 5) and recruitment of selective attention (Study 6). Study 5 used the same 2AFC task employed in Study 3 and 4 to investigate the processing of young and older adult faces in two groups of adults (Experiment 1) and two groups of 3-year-old children (Experiment 2) who accumulated different amounts of experience with elderly people. Results showed that, in both adults and children, visual experience with older adult faces can tune perceptual processing strategies to the point of abolishing the discrimination disadvantage that participants typically manifest for those faces in comparison to younger adult faces.

Study 6 investigated whether face age can modulate attention deployment, as measured in a visual search task, in individuals with limited experience with infants and children and in adults working as preschool-teachers. Previous studies have shown that attention deployment in visual search tasks is modulated by face race (Levin, 1996; 2000; Levin & Angelone, 2001) and emotional expression (Hansen & Hansen, 1988; LoBue, 2009; Mather & Knight, 2006; Öhman, Lundqvist, & Esteves, 2001b), with a search asymmetry in favour of those faces that are less efficiently discriminated and recognized at the individual level (i.e., other-race faces and angry faces). By comparing adults' search efficiency for own- and other-age faces in a visual search task in which face age was the target feature, Study 6 explored whether a similar mirror pattern of detection and recognition effects generalize to age biases, and whether search efficiency for adult and non-adult faces is modulated by experience accumulated with non-adult faces. Results showed that the influence of age on attention deployment parallels the effects that this face attribute has on face recognition, and that both effects are experience-based.

Study 4[4]

The processing of own- and other-age faces in young and elderly adults

As mentioned in the Introduction, studies investigating the presence of OAB in older adult individuals provided mixed and sometimes conflicting results. Whereas some studies demonstrated a recognition advantage for own-age faces in older participants (Anastasi & Rhodes, 2005; Perfect & Harris, 2003), others reported a less reliable or non-existent bias in older adults relative to young adults (Bäckman, 1991; Bartlett & Leslie, 1986; Fulton & Bartlett, 1991; Wiese et al., 2008; Wright & Stroud, 2002). A recent review by Rhodes and Anastasi (2012) showed that, although the OAB has been found in older adults across many studies, the effect is weaker compared to that observed in young adults. Indeed, it is not surprising that elderly adults show a less robust OAB than young adults given perceptual experience being accumulated with different age groups over the lifespan (Anastasi & Rhodes, 2006; Wiese et al., 2008). Although older adults often report more current experience with older adults (i.e., their own face, their spouse, friends) than young adults, experience early in life is primarily with young adult faces (Rennels & Davis, 2008). Given the special influence of early experience in shaping perceptual expertise for adult faces (Macchi Cassia et al., 2014) and the continuous nature of experience with young adult faces across the lifespan, it is perhaps not surprising that recent experience with older faces does not translate into a robust OAB later in life. Discrepant results also can be attributed to variability among older adults in recent daily-life contact with own-age people (which varies depending on living conditions). For example, although Wiese and colleagues (2008) did not find an OAB among older adults, in a later study by the same group (Wiese et al., 2012), older adults who reported having more recent contact with older adults compared to young adults showed a significant OAB, as well as a

[4] This study was carried out in collaboration with Prof. Viola Macchi Cassia, at the University of Milano-Bicocca (UNIMIB). Data collection and data analysis were conducted in collaboration with Dr. Cathy Mondloch, Professor at Brock University, Canada, where I spend a year as research fellow during my PhD. The data presented here are part of a wider data set described in a paper that has been recently accepted for publication: Proietti, V., Macchi Cassia, V., & Mondloch, C.J. (2014). The own-age face recognition bias is task dependent. *British Journal of Psychology*.

more negative N250 (an event–related potential thought to reflect identity perception; Schweinberger, Pfütze, & Sommer, 1995; Zheng, Mondloch, & Segalowitz, 2012) for correct rejections than hits for own-age faces; these patterns were absent in older adults who reported more recent experience with young than older adults.

Based on the face space model presented in the Introduction, one conceptualization of the cross-race and cross-age effects is that the perceivers' face space is optimized for the dimensions of the face categories most frequently observed (Rhodes et al., 2014; Valentine & Endo, 1992). According to the most well-known conceptualization of how faces are represented in memory -i.e. norm-based coding (Valentine, 1991)- faces reside in a multi-dimensional face space in which each dimension (vector) represents a characteristic (e.g., eye size; distance between eyes and mouth) on which faces vary. A prototype or norm resides in the center of the face space, it is the average of the faces viewed previously and is continuously updated by experience. Faces from unfamiliar categories are difficult to discriminate and recognize because they all deviate from the norm in the same way and so are clustered together in the periphery of the face space. According to this model, the OAB among young adults may be attributable to perceivers being less sensitive to dimensions that distinguish among infant, child, or older faces compared to young adult faces. Support for this hypothesis comes from a recent study providing direct evidence that both young and older adults are less sensitive to deviations from the norm in older compared to young adult faces (Short & Mondloch, 2013). Participants were shown two versions of a facial identity; one version was undistorted and the other had facial features that were compressed or expanded. For each face pair participants were asked to express two judgments: a normality judgment (which face looks more normal?) and a discrimination judgment (which face looks more expanded). Face age did not influence accuracy when participants were asked to indicate which member of each pair was expanded, a discrimination task that does not require referencing a prototype. In contrast, both age groups were more accurate with young faces than older faces when asked which member of each pair was more typical, a task that requires referencing a norm. Critically, the older adults in Short and Mondloch's study reported significant more recent contact with older adults than young adults, comparable to the high-contact older adults tested by Wiese et al. (2012) who showed an OAB in an old/new recognition task.

Building on this evidence, in the current study we examined whether older adults and young adults who report preferential contact with own-age people would show an OAB in a 2AFC task measuring perceptual recognition with upright and inverted young and older adult faces. By testing participants with upright an inverted faces we were able to measure the size of the face inversion effect for own- and other-age faces, using this measure to reveal perceptual processing differences between young and older adult faces in young and older adult participants. To increase ecological validity, we created a set of stimuli in which hair was visible but held constant across identities within each age group (i.e., did not contribute to face recognition; see Figure 11). The 2AFC paradigm has proved to be a sensitive measure of the OAB and of the modulatory effects of experience in numerous previous studies (e.g. Kuefner et al., 2008; Macchi Cassia, et al., 2009b) . This task places emphasis on the encoding stage of visual processing and limits memory demands for participants, thus being specifically suitable for testing elderly people.

For the purpose of the current study, ‘‘older adults’’ were defined as being older than 60 years of age. Faces of elderly adults were chosen because, although the amount of each participant's active experience with individuals from this specific age group can still be quantified, sporadic and non-intentional contact with elderly people is common in our everyday environment. For these reasons, it is likely that passive exposure to older adult faces occurs for virtually any child or adult individual. Moreover, although older adult faces differ from younger adult faces on a number of features (e.g., Burt & Perrett, 1995), they also share more relevant perceptual characteristics with younger faces than infant and child faces do (Enlow & Hans, 1996). Therefore, the finding of better discrimination of younger compared to older adult faces in adults with limited exposure to elderly people would provide further evidence for the robustness of the OAB in adults.

The main goal of the study was to test whether the older adults' face processing system retains enough flexibility to adapt to recently acquired experience with older faces to the point of eliminating or even reversing the processing and discrimination advantage for young adult faces compared to older adult faces. If this were the case, we expected two possible outcomes: older adults could either show equal performance in the processing and discrimination of young and older adult faces, or be better at discriminating own-age than other-age faces with a larger or selective inversion effect for the former than for the latter. If, in contrast, the face processing system does not retain plasticity in older adulthood, older adults' performance would not differ from that of young adults, all being better at discriminating identity for young adult faces compared to older adult faces and all showing a larger or selective inversion effect for the former than for the latter.

Method

Participants. Twenty Caucasian undergraduate students (mean age = 21.25 years; range = 18 – 27; 10 males) and 20 Caucasian older adults living in independent housing (mean age = 67.8 years; range = 60 – 83 years; 13 males) participated in the study. Half of the participants in each group were tested in Canada and half in Italy. Experience with older adults can shape perceptual mechanisms involved in face recognition (Study 5), so young adult participants were selected for having acquired less than 500 hours of experience with older faces in the last year (modelled after Kuefner al., 2008). Both young and older adult participants reported spending more time with own-age peers (58.4 and 50.32 hours per week, respectively) than with other-age (3.4 and 11.8 hours per week, respectively) individuals. Young adult participants reported normal or corrected-to-normal vision. Older adults had at least 20/30 vision with 31 participants having 20/20 vision.

Questionnaire. Each participant completed a questionnaire to determine the amount of experience he/she had accumulated with young versus older adult faces. The questionnaire assessed the composition of the participant's household, the amount of contact with relatives, friends and acquaintances belonging to different age groups, and contact with people belonging to different age groups through full- or part-time employment.

Stimuli. Stimuli consisted of gray-scale photographs of young adult (20- to 30-year-old) and older adult (60- to 90-year-old) faces (n = 24 per age). All faces were Caucasian, female, displayed full-front neutral expressions, and were unfamiliar to the participants. Older adult faces were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) whereas younger adult faces were the same as those used in Zheng et al. (2012). To increase ecological validity, hair was kept visible for all faces; to eliminate hair cues to identity we applied the same hair-style to all faces within each age group (Figure 11). All faces subtended 15.3° x 12.1° visual degrees when viewed from 60 cm and appeared on a white background. We created 12 face pairs for each face age; pairs were selected based on subjective criteria of similar luminance and overall similarity, so as to maximize task difficulty despite our task having minimal memory demands and presenting identical pictures at study and test. An additional four male face images (two for each face age) were used as stimuli in the practice trials. Inverted stimuli were created by a 180° rotation of each face.

Figure 11 Examples of the face stimuli used as stimuli in the study 4.

Procedure. All procedures received clearance from the Research Ethics Boards of the University of Milano-Bicocca and Brock University. Participants were tested individually on a portable computer using the same delayed two-alternative forced-choice matching-to-sample task (2AFC) employed in Study 3 and 5. They were told that one face, the target, would appear on the screen and that they would be asked to recognize that target between two faces, the probes, appearing after the initial presentation. The target face was presented centrally for 1 (young participants) or 2 (older adults) s, followed by a 500-ms blank inter-stimulus interval (ISI) and then two probe stimuli, the target face and a novel face that appeared side by side. Participants were asked to indicate which face was the target by pressing one of two keys on the keyboard as quickly and as accurately as possible. Our goal in using different presentation times for younger and older adults in this study was not to match performance; rather, we wanted to encourage participants in both groups to be engaged in the task. We presented stimuli to young adults for 1 s to match the presentation time used in previous studies in which a similar paradigm was used (Kuefner et al., 2008; Macchi Cassia, Kuefner, et al., 2009b; Macchi Cassia, Picozzi, et al., 2009a), with the specific goal of investigate the recognition bias for young over older adult faces in young adults. We chose a longer presentation time for older adults based on pilot testing and on previous studies reporting a longer presentation time for this age group (Chaby, Narme, & George, 2011; Short & Mondloch, 2013). The two probe stimuli remained on the screen until a response was made; after that an inter-trial interval of 500 ms elapsed before the start of a new trial. The left or right position of the target and novel faces was counterbalanced across trials. The target face and the two choices appeared in same orientation. The experiment consisted of eight blocks of trials, two for each face age (younger adult, older adult) and orientation (upright, inverted) condition. There were 12 trials per block, for a total of 24 trials per condition and an overall total of 96 trials. Upright and inverted trials were administered in two sessions separated by a 15-min break. All participants were tested with upright trials first, whereas face age was alternated between blocks, with the age of the faces in the first block counterbalanced across subjects. Each session began with four practice trials with male faces (two young adult, two older adult) followed by 48 test trials. Each face pair was presented twice (once in each block) but which member of the pair was the target varied between the blocks. Response accuracy and response time to correct responses on test trials were recorded as dependent variables.

Results

To compare participants' performance for young and older adult faces we analyzed mean accuracy rates and median response times for correct responses in two mixed Analyses of Variance (ANOVAs). Each ANOVA had two within-subjects factors – face age (young and older) and orientation (upright, inverted), and one between-subjects factor – participants' age (young adult and older adult). Median response times were used to control for outliers.

Accuracy rates. The ANOVA on response accuracy revealed main effects of face age, $F(1,38) = 4.197, p = .047, \eta^2 = .099$, and orientation, $F(1,38) = 49.426, p < .001, \eta^2 = .565$, as participants recognized young faces (M = 91.2%) more accurately than older faces (M = 89.3%) and upright faces (M = 93.5%) more accurately than inverted faces (M = 87%). These main effects were qualified by a significant Face Age x Orientation interaction, $F(1,36) = 5.017, p = .031, \eta^2 = .117$. Participants in both age groups were significantly more accurate at recognizing upright young adult faces (M = 95.3%) than upright older adult faces (M = 91.7%), $t(39) = 4.323$, $p < .001$. Moreover, although an inversion effect was evident for both young adult faces (inverted young adult: M = 87%), $t(39) = 7.621$, $p < .001$, and older adult faces (inverted older adult: M = 86.9 %), $t(39) = 3.611$, $p = .001$, the magnitude of the inversion effect (computed by subtracting the mean accuracy for the inverted condition from the mean accuracy for the upright condition) was marginally larger for young adult (M = 8.3%) compared to older adult faces (M = 4.8%), $t(39) = 2.006$, $p = .052$. No other main effect or interactions attained significance, *p*s > .07.

Because the primary question in this study concerned the presence of an OAB in older adult participants, we analyzed accuracy data separately for the young and older participants' group using two 2 (face age) x 2 (orientation) ANOVAs. While for young adults the analysis confirmed the presence of a significant Face Age x Orientation interaction, $F(1,19) = 10.609$, $p = .004$, $\eta^2 = .358$, for older adults there was only a main effect of orientation, $F(1,19) = 24.212$, $p < .001$, $\eta^2 = .560$. Planned comparisons revealed that young adults were better at discriminating young adult (M = 97.4%) as compared to older adult faces (M = 91.7%) in the upright orientation, $t(19) = 4.965$, $p < .001$, and showed an inversion effect of larger magnitude for the former (M = 8.0%) than the latter (M = 3.15%), $t(19) = 3.257$, $p = .004$, whereas older adults showed a generalized inversion effect whose magnitude did not differ between young (M = 8.6%) and older (M = 6.45%) adult faces, $t(19) = .783$, $p > .44$, (Figure 12).

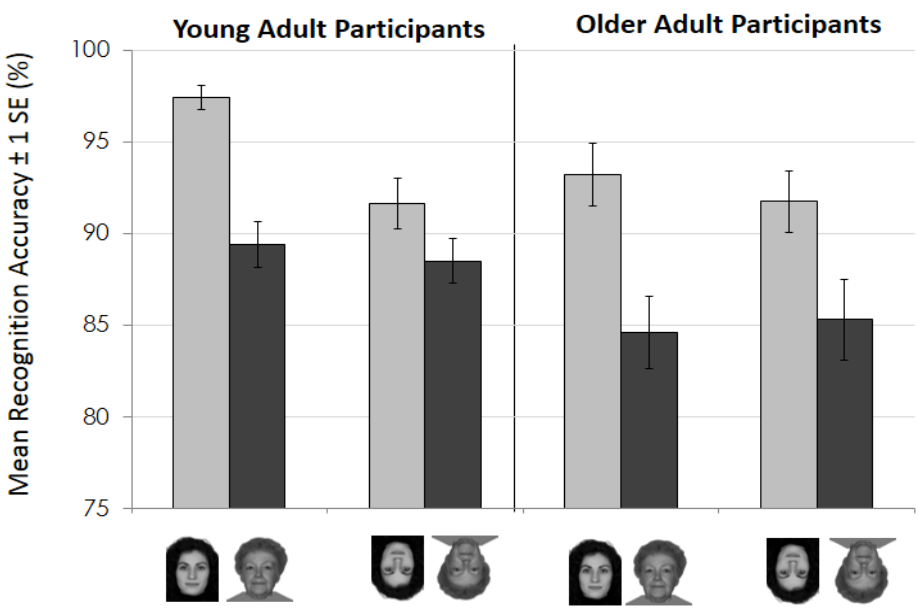

Figure 12 Mean percent of correct responses for young and older adult faces exhibited by young adults and older adults.

Response times. The analysis on median response times for correct responses revealed significant main effects of age group, $F(1,38) = 44.932$, $p < .001$, $\eta^2 = .542$, with young adults responding faster (M = 801.7 ms) than older adults (M = 1252.7 ms), and orientation, $F(1,38) = 32.014$, $p < .001$, $\eta^2 =$

.457, with faster responses on upright trials (M = 876.8 ms) than on inverted trials (M = 1028.8 ms). There were no main effect of face age, p > .47, or interactions, *p*s > .17.

Separate 2x2 ANOVAs were performed on response times for each group of participants. A main effect of orientation was found for both young adults, $F(1,19) = 29.068$, $p < .001$, $\eta^2 = .605$, and older adults, $F(1,19) = 10.594$, $p = .004$, $\eta^2 = .358$, with no other main effect or interaction attaining significance.

Discussion of Study 4

Young adults were more accurate at discriminating young adult compared to older adult faces and manifested a larger inversion effect for the former than for the latter face types, thus showing both behavioral markers of the OAB (for reviews see Macchi Cassia, 2011; Rhodes & Anastasi, 2012; Wiese et al., 2013). Of note, the inversion effect was not selective to own-age faces, but only larger for this face age group compared to older adult faces. This result fits well with earlier demonstration by Kuefner and colleagues (2008) of a generalized, but larger inversion effect for adult faces compared to child faces. Together, these findings suggest that passive exposure to child and older adult faces, which are often seen in movies, on television, or in print advertisements, may have been enough to roughly tune processing strategies, normally used selectively for young adult faces, also to the processing of child and older adult faces. It is also important to note that the stimuli used in Study 4 were different from those used in previous studied investigating this same topic with the same paradigm (Kuefner et al., 2008; Macchi Cassia, et al., 2009a; Macchi Cassia, et al., 2009b), in that in the study here presented faces had hair, neck and the top of the shoulders, and hair were kept constant among facial identities, whereas in previous mentioned studies faces were cropped in an oval occluder. This more realistic stimulus set may have favored the use of configural strategies to process older adult faces, giving rise to an inversion effect for this face category. Nevertheless, despite being present for older as well as young adult faces, the inversion effect was significantly smaller in size for older compared to younger adult faces.

Overall, these results replicated the well-established OAB in young adults using a set of stimuli in which hair was visible, but did not contribute to face recognition. Better recognition for young adult faces cannot be attributed to them being inherently easier to recognize because older adults did not show this advantage. The recognition advantage for young adult faces cannot be attributed to a speed-accuracy trade-off, since response times did not vary as a function of face age. Rather, this advantage may be explained by experiential and/or motivational factors leading to enhanced sensitivity to perceptual differences among own-age faces in young adults.

In contrast, neither older adults' accuracy nor their response times varied as a function of face age, a finding that is consistent with some (e.g., Bartlett & Leslie, 1986; Wiese et al., 2008), but not all (e.g., Anastasi & Rhodes, 2006) previous studies. Our ability to detect an OAB in older adult participants in the current study was not constrained by floor effects, because accuracy was above 80%. Furthermore, although older adults' response times were consistently slower compared to those of young adults, they were not influenced by face age. Based on the fact that the older adults we tested reported more recent contact with older adults than young adults, the lack of an age effect may reflect the mutual influence of early and continuous experience with young adult faces and recent experience with older adult faces. This result provides further support to the perceptual learning hypothesis, which stresses the importance of experience in shaping processing abilities across development.

Nevertheless, social cognitive accounts may, as well, partially explain the lack of an OAB among older adults. Although older adults may perceive older individuals as part of their social in-group, both young and older adults often provide more positive evaluations of young people (He et al., 2011a). Just as minority ethnic groups often fail to show an own-race recognition advantage (see Meissner & Brigham, 2001), older adults may fail to show a consistent OAB because encoding the identities of young adult faces is likely to be motivationally relevant to them. In line with this view, when shown with young and older faces simultaneously in naturalistic scenes, both young and older adults attend preferentially to young adult faces (Short, Semplonius, Proietti, & Mondloch, in press).

To conclude, these findings suggest that the face processing system retains a certain degree of plasticity in older adulthood, as it adapts to reflect older adults' current face diet, which includes older adult people as well as young adult individuals.

Study 5[5]

Natural experience modulates the processing of older adult faces in adulthood and childhood

As outlined in Chapter 1 and in the Introduction to Chapter 2, in both childhood and adulthood the processing bias towards young adult faces is related to the extensive experience accumulated with adult individuals and the high motivation to individuate faces form this age group. In the case of young children, both perceptual experience and motivational factors are more likely biased toward caregivers and other adult individuals than towards peers, although under particular conditions it may extend as well to individuals of other ages (Macchi Cassia, et al., 2009; Macchi Cassia et al., 2012, 2013; see also Study 1 and 2). During adulthood, social experience is heavily biased towards same-aged individuals, unless living conditions (e.g. Study 3 and 4) and/or working experience (Harrison & Hole, 2009; Kuefner et al., 2008 Exp.3; Macchi Cassia, et al., 2009b) facilitate frequent contact with other age groups.

Study 5 extends previous demonstrations of the impact of facial experience acquired later in life as consequence of one's profession on face processing skills to an untested face category, namely older adult faces. To this end, we compared perceptual processing strategies and discrimination abilities for young and older adult faces in two groups of young adults (Experiment 1) and two groups of 3-year-old children (Experiment 2) differing in the amount of experience accumulated with elderly adults. Experiment 1 included a group of low-experienced adults who reported low contact with older adults and a group of high-experienced adults who had accumulated extensive experience with older adults as they worked as nursing home assistants in a retirement home. Experiment 2 included a group of low-experienced preschool-age children who had limited contact with grandparents and other elderly

[5] This study was carried out in collaboration with Prof. Macchi Cassia, at UNIMIB. Data collection was conducted in collaboration with Antonella Pisacane, research assistant at the Infant Lab, Department of Psychology, UNIMIB. The data are published in Proietti, V., Pisacane, A., Macchi Cassia, V. (2013). Natural experience modulates the processing of older adult faces in young adults and 3-year-old children. *PlosOne,* 8, e57499.

people over the last three years and a group of high-experience children who had acquired extensive experience with elderly people over the same time frame.

Like Study 3 and in Study 4, to place emphasis on the encoding stage of visual processing and limit memory demands for the participants, we tested young adults and children in a delayed 2AFC task, in which they were asked to match a briefly presented target face to two simultaneously presented test faces appearing after a short delay. Moreover, to investigate the effects of experience on the perceptual processing strategies adopted by participants in discriminating younger and older adult faces, we measured the size of the inversion effect (Yin, 1969) for the two types of faces. As in Study 4, ‘‘elderly adults’’ were defined as being older than 60 years of age.

The investigation of whether the OAB is abolished or at least mitigated in adults who recently accumulated extensive experience with elderly adults would add to existing demonstrations that face representation retains enough flexibility into adulthood so as to adapt to newly encountered face-age groups. The finding of a perceptual processing advantage for young adult faces in 3-year-old children when these faces are compared to another sub-class of adult faces would add to extant demonstrations that younger adult faces are over-represented in young children’s face space (Short, Mondloch, & Hackland, 2015), possibly resulting from early and repeated experience acquired with adult caregivers. Nevertheless, it is also possible that young children perceive younger and older adults as part of the same broad social group, thus generalizing their motivation to actively seek for experience with faces of adult caregivers to elderly people. If this were the case, we would expect that, even in the absence of extensive exposure to elderly people, 3-year-old children were equally good at discriminating younger and older adult faces. In any case, like for adults, the comparison between children with different amounts of contact with elderly individuals would provide further demonstration that the developmental trajectory of age biases in face processing are directly related to the amount of differential environmental exposure that children have or have had with faces of different ages.

Experiment 1

Method

Participants. The sample included 36 adult females, 18 in the low-experienced control group (mean age = 34 years; range = 23–53 years) and 18 in the high-experienced group (mean age = 44.8 years; range = 30–57 years). All participants were screened prior to testing via a questionnaire, which included specific enquiries aimed at assessing if, in the past year, they have been living with parents and/or grandparents older than 60 years, if they have had contact with parents or grandparents of friends or acquaintances, and if they have had a job (full-time or otherwise), which put them in contact with elderly people. Participants were included in the low-experienced group if, in the last year, they had not acquired more than 500 hours of experience (see Kuefner et al., 2008) for a similar selection criterion applied to adult novices of newborns and children) (see Table 1). Participants in the high-experienced group were nursing home assistants working full time or part time (working hours per week: M = 34; range = 21–55) in a retirement home. All had a working experience of at least 5 years (M = 14 years range = 5–25), and had acquired more than 1000 hours of experience with elderly people within the past year (see Table 1).

Stimuli. Stimuli consisted of gray-scale photographs of young adult (20- to 30-year-old) and older adult (60- to 90-year-old) faces (n = 48 per age) that displayed full-front neutral expressions and were unfamiliar to the participants (Figure 13). To control for possible interfering effects of gender, all faces were female, so that stimulus gender was matched to participants' gender. Older faces were taken from Minear and Park (2004), whereas younger adult faces were taken from our own database (Kuefner et al., 2008). Face images were cropped in a standard oval, eliminating cues from external features such hair, ears and neck. All faces subtended a horizontal visual angle of 4.43° and a vertical angle of 6.04° when viewed from approximately 40 cm and appeared on a gray background. An attempt was made to pair faces based on subjective criteria of luminance and overall similarity, so as to generate 24 pairs for each face age. An additional 16 face images (8 for each face age) were used as stimuli in the practice trials. Inverted stimuli were created by a 180° rotation of each face.

Low-Experienced Group		High-Experienced Group		
Subject no.	Tot. hr contact in last year	Subject no.	Tot. hr contact in last year	Tot. hr working experience
1	96	1	2640	20
2	24	2	1248	13
3	96	3	2736	12
4	12	4	1968	11
5	0	5	3408	19
6	192	6	2400	12
7	72	7	1824	14
8	288	8	1872	9
9	108	9	2400	24
10	20	10	2328	12
11	96	11	1680	10
12	288	12	1200	13
13	0	13	3456	25
14	336	14	1920	5
15	60	15	2544	12
16	288	16	3888	14
17	48	17	1296	24
18	288	18	1584	11

Table 1. Questionnaire-based information concerning the amount of contact that participants in the low-experienced and in the high-experienced group had with elderly adults aged 60 to 90 years.

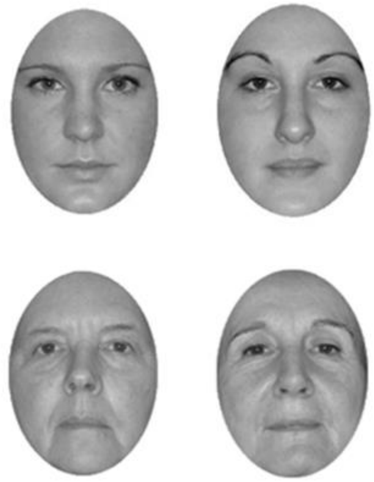

Figure 13. Examples of the younger adult and older adult faces used as stimuli in both Experiment 1 and Experiment 2.

Procedure. Participants were tested individually on a portable computer using the same delayed two-alternative forced-choice matching-to-sample task (2AFC) employed in Study 3 and 4. They were told that one face, the target, would appear on the screen and that they would be asked to recognize that target between two faces, the probes, appearing after the initial presentation. The target face was presented centrally for 1 s, followed by a 500-ms blank ISI and then the two probe stimuli, the target face and a novel face that appeared side by side. The participants' task was to respond as quickly and accurately as possible by pressing a key on the keyboard corresponding to the side of the screen on which the target face appeared. The two probe stimuli remained on the screen until a response was made; after that an inter-trial interval of 500 ms elapsed before the beginning of a new trial. The left or right position of the target and novel faces was counterbalanced across trials. The target face and the two choices appeared in same orientation. The experiment consisted of eight blocks of trials, two for each face age (younger adult, older adult) and orientation (upright, inverted) condition. There were 24 trials per block, for a total of 48 trials per condition and an overall total of 192 trials. Upright and inverted trials were administered in two sessions separated by a 15-min break. All participants were tested with upright trials first, whereas face age was alternated between blocks, with the age of the faces in the first block counterbalanced across subjects. At the beginning of each session, we gave participants 8 practice trials (4 for each face age condition) to ensure that they understood the task.

Response accuracy and response times to correct responses on test trials were recorded as dependent variables.

Results and Discussion

To compare recognition performance of participants in the two groups we analyzed mean accuracy rates and mean response times to correct responses in two 2 x 2 x 2 repeated-measures Analyses of Variance (ANOVAs) with face age (younger adult, older adult) and orientation (upright, inverted) as within-participants factors, and experience group (low-experienced, high-experienced) as the between-participants factor.

Accuracy rates. The analysis of mean accuracy rates revealed a significant main effect of orientation, $F(1,34) = 52.13$, $p < .001$, $\eta^2 = .605$. This main effect was qualified by a significant Face Age x Orientation interaction, $F(1,34) = 21.47$, $p < .001$, $\eta^2 = .387$, as well as by a significant three-way interaction between face age, orientation and experience group, $F(1,34) = 4.18$, $p < .05$, $\eta^2 = .109$, indicating that accuracy for younger adult and older adult faces in the two orientation conditions differed for the low-experienced and the high-experienced group. To further explore this interaction, separate 2 x 2 ANOVAs were performed on accuracy data for each group of participants. While a main effect of orientation was found for both the low-experienced group, $F(1,17) = 23.95$, $p < .001$, $\eta^2 = .585$, and the high-experienced group, $F(1,17) = 28.82$, $p < .001$, $\eta^2 = .629$, the critical Face Age x Orientation interaction was present only for the low-experienced group, $F(1,17) = 19.77$ $p < .001$, $\eta^2 = .538$. Planned comparisons revealed that these participants were better at discriminating upright young adult faces ($M = 96.7\%$) compared to upright older adult faces ($M = 92.6\%$), $t(17) = 5.66$, $p < .001$, and showed an opposite discrimination advantage for older adult faces over young adult faces in the inverted orientation ($M = 92\%$ vs 87.9.%), $t(17) = 2.25$, $p < .05$. Accordingly, they showed a significant inversion effect for young adult faces ($M = 96.7\%$ vs 87.9%), $t(17) = 5.14$, $p < .001$, but not for older adult faces (M

= 92.6% vs 92.0%) (p > .4) (Figure 14). In contrast, nursing home assistants in the high-experienced group showed a significant decrement in performance on inverted compared to upright trials for both young adult faces (upright: M = 94.9% vs. inverted: M = 86.2%), $t(17) = 5.33$, $p < .001$, and older adult faces (upright: M = 93.1% vs. inverted: M = 87.6%), $t(17) = 3.76$, $p < .005$, resulting in an inversion cost (computed by subtracting the mean accuracy for the inverted condition from the mean accuracy for the upright condition) of similar magnitude for the two face sets (younger adult faces: M = 8.7%, older adult faces: M = 5.5%). Nurses' discrimination performance did not differ for younger adult and older adult faces in either the upright (M = 94.9% vs 93.1%) (p > .09) or the inverted condition (M = 86.2% vs 87.6%) (p > .42) (Figure 14).

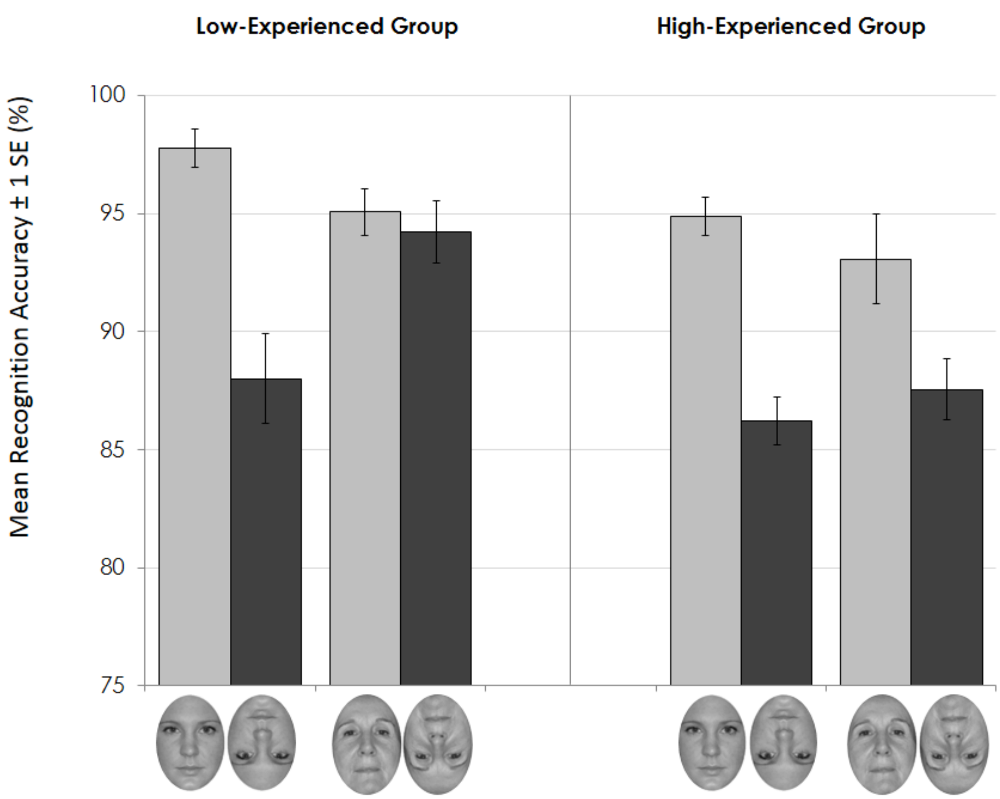

Figure 14 Mean accuracy rates of adult participants in the low-experienced group (left) and in the high-experienced group (right) when younger and older adult faces were presented upright and inverted.

To complete the exploration of the differences between the two groups, we directly compared accuracy rates for each condition and found the comparison to be significant only for the inverted older adult face condition, $t(34) = 2.32$, $p < .005$ (all other ps > 16.). Finally, between-group comparisons of the size of the inversion cost for each face age revealed that, for older adult faces, the inversion cost was significantly larger in the high-experienced group than in the low-experience group (M = 5.5% vs 0.6%), $t(34) = 2.95$, $p < .01$, whereas for younger adult faces the effect was not significantly different in the two groups ($p > .96$).

Response Times. The 3-way ANOVA on correct response times revealed a significant main effect of orientation, $F(1,34) = 14.67$, $p < .001$, $\eta^2 = .301$, which was qualified by a significant two-way interaction between orientation and experience group, $F(1,34) = 9.64$, $p < .005$, $\eta^2 = .221$. This interaction was further explored through separate 2 X 2 ANOVAs on RT data from each group. The ANOVA performed on the low-experienced group revealed a significant main effect of orientation, $F(1,17)=15.39$, $p <. 001$, $\eta^2 = .475$, due to overall faster responses to upright (M = 887.2 ms) compared with inverted (M = 968.3 ms) faces, whereas the interaction between face age and orientation was not significant, $p > . 87$. The ANOVA performed on the high-experienced group did not reveal any significant main effect or interaction (all ps > .25).

Results showed that a quantifiable amount of contact with elderly individuals in adulthood modulates the ability to discriminate individual faces from this age group as well as the perceptual processes used to perform such discrimination.

Accuracy data showed that adults who had limited contact with elderly individuals were better at discriminating younger adult faces compared to older adult faces in the canonical upright condition, and exhibited an inversion effect which was specific for younger adult faces. Interestingly, this result differed from what found in Study 4, where young adults showed an inversion effect for older faces as well as for young adult faces.

Importantly, because participants in Study 4 and in the current study were selected based on the same criteria for having had limited contact with elderly individuals, the presence of an inversion effect for older adult faces in Study 4, but not in the current experiment, cannot be explained in terms of differential amount of experience with older adult faces. One possibility is that the observed difference in the way younger participants in Study 4 and in the current experiment processed older adult faces arose from differences in the stimulus material used in the two studies. Stimuli in Study 4 were created so as to preserve natural appearance of faces by keeping hair, neck and top of the shoulder visible, whereas the stimuli used in the present experiment were all cropped to the same oval in order to eliminate external feature that may act as cue to identity. It is possible that the hair themselves, or the overall naturalistic appearance of the faces in Study 4 have boosted participants' sensitivity to the featural/configural cues embedded in older adult faces, leading to an inversion effect for this face age group as well as for younger adult faces.

Unlike low-experienced participants, nursing home assistants in the current study were equally proficient at discriminating upright younger and older adult faces, and manifested an inversion effect of equal magnitude for both face ages. Although analyses of response times proved that this pattern of results could not be explained by a speed-accuracy trade-off, in line with what obtained in Study 4, response time data were less sensitive in discriminating the effects of face age and experience across the two groups. In fact, correct responses provided by low-experienced participants were as fast to upright younger adult faces as they were to upright older adult faces and were slower on inverted compared to upright trials for both face types. Moreover, the time it took to the nurses to provide their correct responses did not differ across conditions.

Overall, the finding that, in the low-experienced participants, stimulus inversion consistently affected both discrimination accuracy and response times to younger adult faces whereas it only affected response times to older adult faces indicates that the inversion effect in these participants was more robust for the former than for the latter type of faces. This suggests that low-experienced participants were better able to extract the relevant featural/configural cues necessary for efficient face recognition from younger adult faces, whereas they possibly relied more heavily on featural cues, such as wrinkles and eye shape, to efficiently discriminate older adult faces. Most crucially, the finding of a generalized inversion effect for younger and older adult faces in the high-experienced participants indicates that perceptual experience improved nursing home assistants' sensitivity to the featural/configural cues embedded in older adult faces, mirroring the sensitivity that they have for these same cues in younger adult faces. The demonstration that, unlike low-experienced participants, the nursing home assistants did not show an own-age discrimination bias, being equally good at discriminating upright younger and older adult faces, lends further support to this conclusion.

Of note, between-groups comparisons showed that, although nursing home assistants were significantly less accurate than low-experienced adults at discriminating inverted older adult faces, they did not show a corresponding improvement in the discrimination of upright older adult faces. Although not predicted, this finding was not completely unexpected, since it is not new in the literature. The finding that experience acquired in adulthood with a specific stimulus category can induce the emergence of an inversion effect without producing a significant increase in discrimination or recognition performance on upright trials has been reported previously in the seminal study conducted by Diamond and Carey (Diamond & Carey, 1986, Exp. 2 and 3) where dog experts were significantly worse at recognizing inverted dog images with respect to the novices, while showing with no corresponding increase in recognition accuracy for upright dog trials with dog experts. Macchi Cassia and colleagues al. (2009b) found similar results in their recent study on the effects of experience on adults' ability to process newborn faces, where maternity ward-nurses, unlike adult novices, manifested an inversion effect of the same magnitude for adult and newborn faces, without being able to perform equally well at discriminating the two face categories in the upright orientation. Our results add to this evidence in suggesting that experience acquired in adulthood can tune visual processes involved in face recognition for use with newly experienced classes of faces, but that is not sufficient to produce a corresponding improvement in discrimination/recognition abilities for those faces.

Overall, results of Experiment 1 allowed us to confirm that, in the absence of extensive experience, young adults exhibit a perceptual processing advantage for own-age faces over faces of older adults, and that extensive exposure to elderly adults can eliminate this advantage. In Experiment 2, we aimed to extend these findings to 3-year-old children, to investigate whether younger adult faces are processed more efficiently than older adult faces even when they do not match the age of the beholder, and whether experience with elderly people can modulate the age bias in children in the same way as in adults. To this end, we tested two groups of 3-year-old children with different amounts of experience with elderly people for their recognition of upright and inverted younger adult and older adult faces.

Experiment 2

Method

Participants. The final sample consisted of 36 3-year-old children (20 females; mean age=3 years 7 months, range = 3 years 1month - 3 years 11 months), 18 in the low-experienced group, and 18 in the high-experienced group. Three additional children were tested, but excluded from the sample due to failure to reach criteria established for data analyses (see Results). Children's assignment to each group was based on parents' responses to a questionnaire that included specific enquiries aimed at assessing the amount of contact that children have or have had with grandparents and other people older than 60 years from the time of their birth. On the basis of parents' responses, we calculated the total amount of hours each child had contact with elderly people within each year over the past three years. Children were included in the low-experienced group if they had not acquired an average of more than 500 hours of experience per year over the past three years. Children assigned to the high-experienced group had acquired an average of more than 1000 hours of experience with elderly people within the same time frame (see Table 2).

Low-Experienced Group		High-Experienced Group	
Subject no.	Average hr contact	Subject no.	Average hr contact
1	528	1	1164
2	144	2	2256
3	12	3	1725
4	432	4	2125
5	368	5	2480
6	156	6	1600
7	344	7	1640
8	480	8	1955
9	306	9	2225
10	300	10	1015
11	410	11	1584
12	369	12	1356
13	70	13	1587
14	280	14	1867
15	453	15	1144
16	144	16	2712
17	459	17	1782
18	528	18	1423

Table 2. Questionnaire-based information concerning the amount of contact that 3-year-old children in the low-experienced and in the high-experienced group had with elderly adults aged 60 to 90 years. For each participant, the table reports the average number of hours of contact per year.

Stimuli and Procedure. Stimuli were the same as in Experiment 1 (Figure 13), with the exception that only 48 (12 pairs for each face age) of the original 96 face images were used. Unlike Experiment 1, no efforts were made to keep the relation between stimulus gender and participants' gender constant, as all faces were female and both boys and girls were included in the sample. This was done in light of studies on gender development indicating that complete gender constancy is achieved not earlier than 6 years of age (Ruble, Martin, & Berenbaum, 1998). This makes it unlikely that, in 3-year-old children, gender acts as a grouping factor driving social categorization processes that have been found to affect face encoding (e.g., Short & Mondloch, 2010). The procedure was also the same as in Experiment 1 except as follows. Exposure time of the target face was extended to 5 s, the number of blocks and trials per condition were reduced to 4 and 12, respectively, for an overall total of 48 trials, the length of the break between the two testing sessions ranged from 1 to 24 hours, and children were invited to provide their response either by pointing to the target or pressing a computer key. The experimenter determined the start of the next trial by pressing the mouse, and response accuracy was recorded as the dependent variable.

Results and Discussion

Data were included in the analyses only if the child was correct on more than 50% of upright young adult trials; 3 children were excluded because they did not meet this criterion. For the remaining children in each group, one-sample t-tests confirmed that accuracy was significantly above chance (i.e., 50%) for both face ages in the upright orientation condition (all $ps < .005$).

To compare discrimination performance of children in the two groups we performed a preliminary ANOVA with face age (younger adult, older adult) and orientation (upright, inverted) as within-participants factors, experience group (low-experienced, high-experienced) as the between-participants factor and gender (male, female) as an additional factor.

The ANOVA revealed no main effect or interactions involving gender, and data were consequently collapsed across this factor in the subsequent three-way ANOVA. The analysis revealed significant main effects of face age, $F(1,34) = 6.36$, $p < .05$, $\eta^2 = .158$, and orientation, $F(1,34) = 46.71$, $p < .001$, $\eta^2 = .579$, which were both qualified by a marginally significant Face Age x Orientation interaction, $F(1,34) = 4.07$, $p = .051$, $\eta^2 = .107$. The interaction between face age and experience group was also significant, $F(1,34) = 6.20$, $p < .05$, $\eta^2 = .154$, indicating that discrimination accuracy for younger and older adult faces differed for the two groups of children. To further explore this interaction, we performed separate 2 x 2 ANOVAs on the accuracy data for each group. Both main effects of face age, $F(1,17) = 10.05$, $p < .01$, $\eta^2 = .397$, and orientation, $F(1,17) = 11.21$, $p < .005$, $\eta^2 = .372$, were significant for the low-experienced group, whereby children were generally more accurate at discriminating younger adult (M = 68.8%) than older adult faces (M = 59.6%), irrespective of orientation, and provided more correct responses on upright trials (M = 70.5%) than on inverted trials (M = 57.9%), irrespective of face age. Because our primary question concerned experience effects on upright face discrimination, we compared accuracy for younger and older adult faces on upright trials. The comparison was significant, $t(17) = 2.73$, $p < .05$, whereby low-experienced participants were better at discriminating upright younger adult faces (M = 74.8%) compared to upright older adult faces (M = 66.2%). The ANOVA on the high-experienced group revealed a main effect of orientation, $F(1,17) = 53.64$, $p < .001$, $\eta^2 = .759$, as well as a Face Age x Orientation interaction, $F(1,17) = 5.96$, $p < .05$, $\eta^2 = .260$. Unlike low-experienced participants, high-experienced children were more accurate at discriminating upright older adult faces (M = 81.6%) compared to upright younger adult faces (M = 73.2%), $t(17) = 2.71$, $p < .05$. They also showed a significant inversion effect for both younger adult faces (upright: M = 73.2% vs inverted: M = 60.8%), $t(17) = 2.377$, $p< .05$, and older adult faces (upright: M = 81.6% vs inverted: M = 52.3%), $t(17) = 8.307$, $p < .001$, but the size of the inversion cost was larger for older adult faces (M = 29.2%) than for younger adult faces (M = 12.4%), $t(17) = 2.44$, $p < .05$ (Figure 15).

To complete the exploration of the differences between the low-experienced and the high-experienced group, we directly compared accuracy data of the two groups for each condition. Between-group comparisons were significant only for the upright older adult faces condition (low-experienced group: M = 66.2% vs high-experienced group: M = 81.6%), $t(34) = 3.21$, $p < .005$, whereas all other comparisons were non-significant (all $ps > .66$). Finally, between-group comparisons of the size of the inversion cost for each face age revealed that, for older adult faces, the inversion cost was larger in the high-experienced group than in the low-experienced group (M = 29.3% vs 13.9%), t(34) = 2.57, p < .05, whereas for younger adult faces, the effect was not significantly different in the two groups (p > .96).

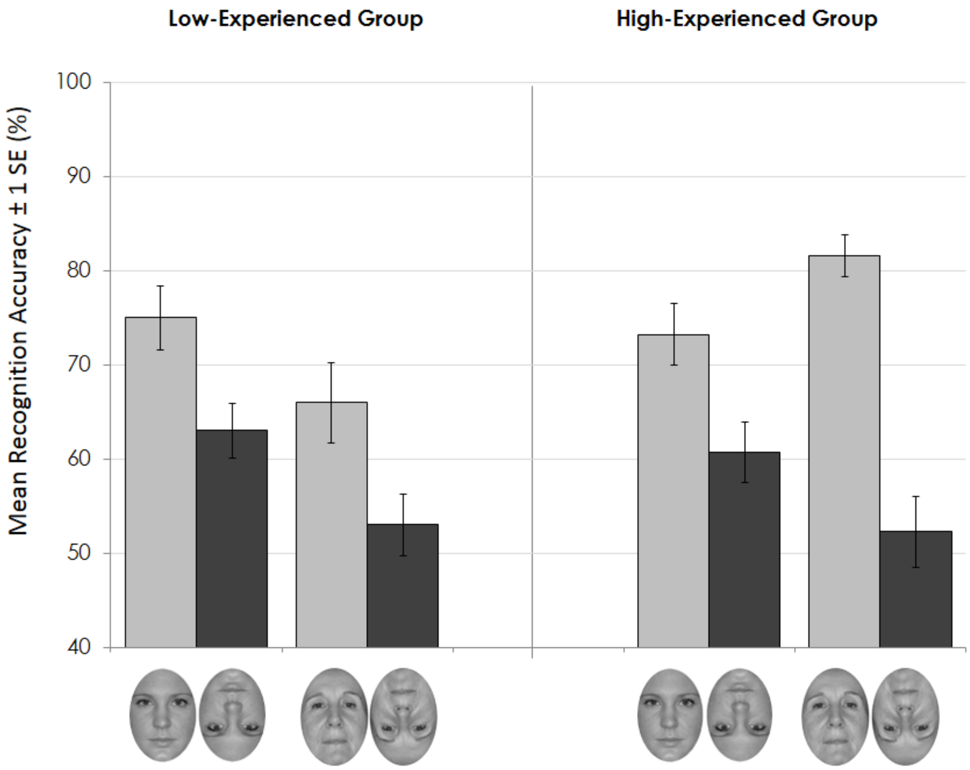

Figure 15 Mean accuracy rates of 3 year-old participants in the low-experienced group (left) and in the high-experienced group (right) when younger and older adult faces were presented upright and inverted.

Results showed that 3-year-old children with limited experience with elderly people were better at differentiating among upright young adult faces than among upright older adult faces. Crucially, this discrimination advantage was not only absent, but was even reversed in children who, from the time of their birth, had extensive contact with elderly adults. These children were more accurate in discrimination of upright older adult faces than upright younger adult faces and, accordingly, they were more experts at processing older adult faces than younger adult faces, as inferred by the size of the inversion effect. These findings add to previous demonstrations that sibling's experience affects the processing and discrimination of infant and child faces (Macchi Cassia, et al., 2009a Exp.1; Macchi Cassia et al., 2012), providing further evidence that experience with faces from a specific age group in the first three years of life can modulate perceptual discrimination abilities for those faces.

An important aspect of the current findings is that children in both the low-experienced and the high-experienced groups showed a significant inversion effect for older adult faces. This implies that even a limited amount of contact with elderly people was sufficient to render children in the low-experienced group as sensitive to the relevant featural/configural cues embedded in older adult faces as they are to the same relevant cues in younger adult. Accordingly, we found that the average number of hours of contact with elderly people within each year across both groups of children was significantly correlated with the accuracy of upright older adult face discrimination ($r = .47$, $p < .005$) (Figure 16a) and the magnitude of the inversion score for older adult faces ($r = .33$, $p < .05$) (Figure 16b).

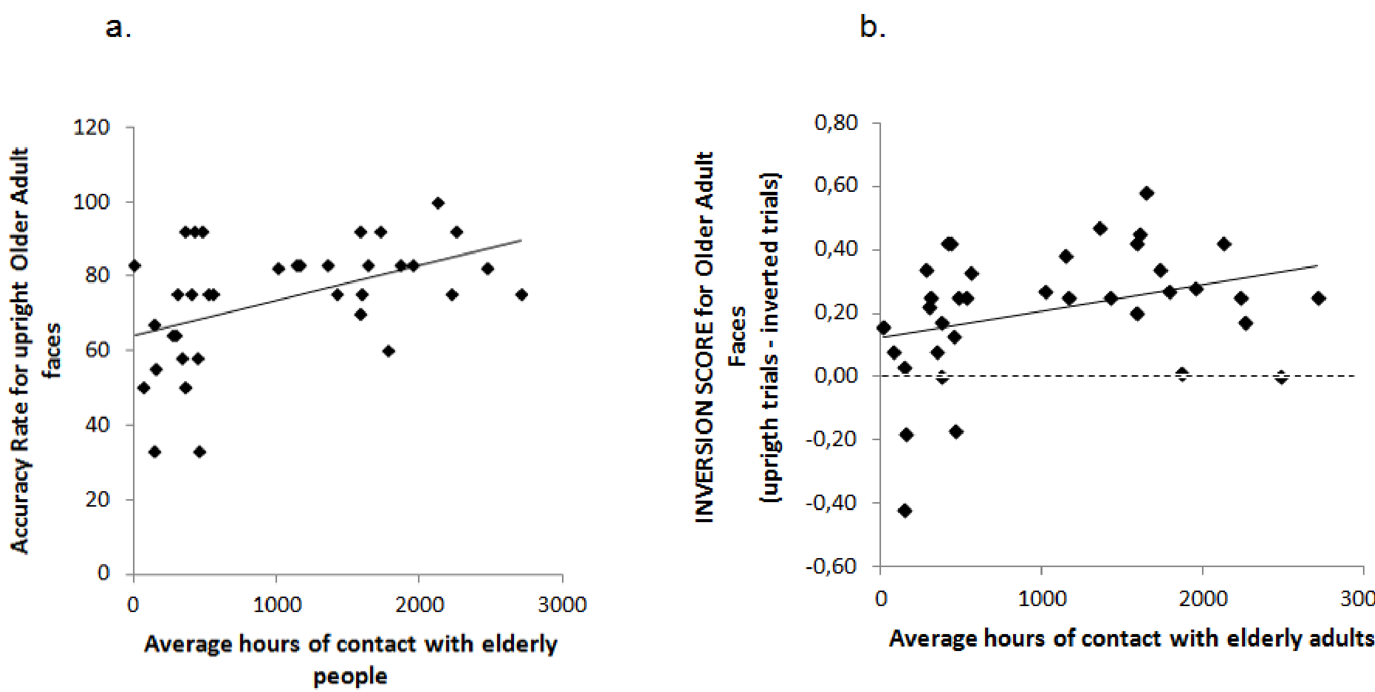

Figure 16 Children's accuracy rate for upright older adult faces (a) and inversion score for older adult faces (b) collapsed across experience plotted as a function of the average number of hours of contact per year with elderly adults.

Discussion of Study 5

The purpose of Study 5 was to provide further evidence for the role of social and perceptual experience in modulating age-related face processing biases in adults and young children.

Results showed that adults (Experiment 1) and 3-year-old children (Experiment 2) who had limited contact with elderly adults were better able to distinguish among younger adult faces than among older adult faces. In contrast, discrimination performance of participants who accumulated extensive experience with elderly adults did not differ for the two types of faces. Together, these findings provide further evidence for the existence of a processing advantage for young adult faces over faces of other-age groups in adults and young children, and extend current evidence for a perceptual learning account of such advantage.

Specifically, results extend previous demonstrations of better within-category discrimination for young adult faces over infant and child faces in adults (Kuefner et al., 2010; Macchi Cassia, et al., 2009a; Macchi Cassia, et al., 2009b) and 3-year-old children (Macchi Cassia, et al., 2009a; Macchi Cassia et al., 2012) by showing that, in the absence of extensive experience, a discrimination advantage for young adult faces is apparent even when these faces are compared with another class of adult faces. Moreover, the comparison between discrimination abilities of adult and child participants in the low-experienced and the high-experienced groups showed that, for both adults and children, visual experience with older adult faces can tune perceptual processing strategies towards this type of faces to the point of eliminating the discrimination advantage for younger adult faces. As for the adults, accuracy measures revealed that, unlike low-experienced participants, high-experienced participants exhibited an inversion effect, which was generalized across both younger and older adult faces, and showed no differences in the discrimination of the two types of face. As for the children, high-experienced participants, unlike the low-experienced, were equally good at discriminating younger and older adult faces. They also manifested an inversion effect for older adult faces, which was larger than that for younger adult faces and larger than the inversion effect for older adult faces in low-experienced participants.

An important difference between the results obtained with adults and children concerns the processing of older adult faces in low-experienced participants. Unlike adults, children in the low-experienced group showed a significant inversion effect for older adult faces, whose size across the whole sample was related to the amount of contact with elderly adults. This suggests that, in children, even a small amount of experience may be sufficient to engender perceptual learning of a specific face age group, and that increasing experience has progressive and cumulative effects on the tuning of the perceptual processes involved in face discrimination and recognition.

Importantly, because both adults and children in the low-experienced groups were selected based on the same criteria for having had limited contact with elderly individuals, the presence of an inversion effect for older adult faces in children but not in adults cannot be explained in terms of differential amount of experience with older adult faces. One possibility is that children's learning from the limited experience they had with elderly individuals was boosted by motivational mechanisms arising from their tendency to perceive younger and older adults as members of the same broad social group, which may have enhanced children's interest in older adult faces. Another possibility is that the observed difference in the way low-experienced children and adults processed older adult faces is indicative of a decrease in plasticity of the perceptual processes involved in face recognition between childhood and adulthood, whereby children may have learned more easily than adults from the limited amount of perceptual experience they had with older adult faces. Indeed, earlier studies have reported a loss of plasticity of face processing abilities between childhood and adulthood in response to experience with one face from a specific age group, as in the case of the face of an infant sibling in 3-year-old children or the face of an infant in first-time mothers (see Study 3; Macchi Cassia, et al., 2009a). The current study extends this earlier evidence by showing that, although the face processing system remains plastic in response to experience with multiple facial identities from one single age group well into adulthood, such plasticity is limited in comparison to that manifested by young children.

Despite these differences in adults' and children's responsiveness to the effects of limited experience, there is an interesting similarity between adults' and children's data in the relations between perceptual expertise and discrimination abilities. In children, the presence of an inversion effect for older adult faces did not allow low-experienced participants to overcome their deficit in discriminating among these faces in comparison to younger adult faces. This finding resonates well with the results emerging from Experiment 1, showing that although high-experienced adults were worse than low-experienced adults at discriminating inverted older adult faces, they were not any better at discriminating these faces in the canonical upright orientation. Together, these findings add to some already existing evidence (Diamond & Carey, 1986; Harrison & Hole, 2009; Macchi Cassia, et al., 2009b) suggesting that visual experience acquired in adulthood can shape perceptual processes used to discriminate faces without necessarily improving face discrimination abilities, and extend this evidence to children.

Study 6[6]

Searching for faces of different ages: evidence for an experienced-based own-age detection advantage in adults

Although many studies have been published on how face age modulates face perception and recognition memory, little is known about whether and how age affects attentional responses to faces. Study 6 was aimed at investigating the impact of facial age on attentional responses to faces and whether perceptual experience acquired in adulthood with a specific face age group affects how easily is selective visual attention deployed to those faces.

Multiple lines of research suggest that, in humans, faces are a class of stimuli that receives high priority from attention (see review by Palermo & Rhodes, 2007). This attentional advantage of faces over non-face stimuli is typically interpreted as originating from the special status that faces have, being the most biologically and socially significant visual stimuli in the human environment. However, faces are also objects for which humans naturally develop the greatest perceptual expertise. Since various behavioral and neural effects observed for faces were found also for other homogeneous categories of expertise (see review by Bukach, Gauthier, & Tarr, 2006; but see McKone, Kanwisher, & Duchaine, 2007), some researchers have argued that also the face attentional advantage may stem from human facial expertise. This hypothesis is indirectly supported by evidence showing that bird and car experts had a search advantage for faces and targets of expertise over novice targets in a visual search task in which they searched for face, car or bird photographs in heterogeneous displays comprised of photographs of real objects (Hershler & Hochstein, 2009). This effect of expertise on visual category

[6] This study was carried out in collaboration with Prof. Macchi Cassia and Prof. Bricolo, at UNIMIB. Data collection was conducted in collaboration with Dr. Gava, postdoctoral fellow at the Infant Lab, Department of Psychology, UNIMIB. The data presented here are described in a paper that is under review in the *Journal of Experimental Psychology: Human Perception and Performance* (revise and resubmit).

search was interpreted as an example of top-down influence on attentional control generated by stimulus familiarity. Irrespective of the specific contribution of biological saliency and/or perceptual expertise on the preferential processing of faces over other objects present in a visual scene, it is known that deployment of attention can be modulated by specific face traits. For example, a wide range of studies across various experimental paradigms suggests that, compared to neutral or happy faces, angry faces more readily capture or hold attention and distract from other stimuli. In visual search tasks, both adults and children show a search asymmetry in favour of angry faces, whereby searching for angry faces among neutral or happy faces is faster and more accurate than the reverse (e.g., (Hansen & Hansen, 1988; LoBue, 2009; Mather & Knight, 2006; Öhman et al., 2001a). This search asymmetry is often explained from an evolutionary standpoint as being of adaptive value to preferentially detect and quickly respond to potentially harmfull stimuli, which may include threatening facial expressions as well as threatening animals (e.g., LeDoux, 1996; Öhman, 1993; see also LoBue, 2012). Another facial attribute that appears to modulate the extent to which faces engage mechanisms of selective attention is race. In a series of visual search studies, Levin (1996, 2000; Levin & Angelone, 2001) showed that Caucasian participants were faster to search for the face of a male African-American among multiple images of a male Caucasian face than viceversa, suggesting the presence of a search asymmetry in favour of other-race faces. Although the search asymmetry favouring other-race faces was not always found (Levin & Angelone, 2001; Lipp et al., 2009) and did not extend to non-Caucasian participants (Chiao, Heck, Nakayama, & Ambady, 2006; Levin, 1996), it suggested that race-specifying information may function as a visual feature. The feature-selection model proposed by Levin (1996, 2000), that I briefly described in the Introduction, posits that other-race faces have race-specifying information that is lacking in own-race faces for which we normally process information at the individual level. Because feature-present targets are detected more quickly than feature-absent targets in a search display (Treisman & Gormican, 1988), when the feature is the membership in a contrasting race, other-race face targets are detected more efficiently than own-race face targets.

For both emotional expression and the race of the face, the items that more readily capture attention –i.e, angry faces and other-race faces– when compared to their within-category counterparts –i.e., happy/neutral faces and own-race faces– are those that are less efficiently discriminated and recognized at the individual level. These attentional advantages are respectively defined as “angry-face detection advantage” and “other-race detection advantage” and they contrast with the widely reported facilitating effect of positive emotional expressions on face recognition memory and familiarity ratings (e.g., Baudouin, Gilibert, Sansone, & Tiberghien, 2000; Gallegos, & Tranel, 2005; Lander & Metcalfe, 2007) and the well-known own-race recognition advantage (e.g., Brigham & Malpass, 1985; Chiroro & Valentine, 1995; Valentine, 1991; see review by Meissner & Brigham, 2001).

In the case of race, this mirror pattern in participants’ performance for own-race/other-race face processing in visual search tasks and recognition memory tasks has been interpreted as resulting from the processing differences involved in detecting categorical facial information versus recognizing individual facial information in own-race and other-race faces (Ge et al., 2009; Levin, 2000; Susa, Meissner, & de Heer, 2010; Zhao & Bentin, 2008). To detect an own-race face among other-race faces, one must rely on race-specifying information, that is, information diagnostic of the race category. In contrast, to discriminate and recognize a face among other same-race faces, one must rely on identity-specifying information, that is, information diagnostic of the individuality of each face. It is known that, when participants are asked to explicitly categorize faces by their race, they respond faster to other-race faces than to own-race faces, showing the so-called other-race categorization advantage (e.g., Caldara, Rossion, Bovet, & Hauert, 2004; Ge et al., 2009; Zhao & Bentin, 2008). Based on the assumption that a race-based categorization task and a visual search task, in which face race is the target feature, tap comparable perceptual processes, some researchers claimed that the other-race categorization advantage can explain the search asymmetry in favour of other-race faces (e.g., Levin, 2000).

The aim of Study 6 was to extend the available evidence on the effects of face race and emotional expressions on the deployment of selective visual attention to a different facial attribute, namely age. As discussed in earlier sections of this dissertation, adults typically show a recognition advantage for adult compared to non-adult faces and this advantage can be mitigated through exposure to non-adult faces provided by the individual's social and working experience. There are studies investigating how face age affects the automatic orienting of attention toward non-face stimuli (Brosch, Sander, & Scherer, 2007; Ebner & Johnson, 2010; Hodsoll, Quinn, & Hodsoll, 2010; Proverbio, De Gabriele, Manfredi, & Adorni, 2011). In these studies, adult participants were tested in face-unrelated tasks, and the extent to which task-irrelevant adult and non-adult faces modulated participants' performance was measured. In most cases adult and baby faces were used as stimuli, and results showed greater attention capturing effects for baby faces. For example, adults had shorter response times to lateralized targets preceded by a baby face compared to those preceded by an adult face (e.g., Brosch et al., 2007; Hodsoll et al., 2010; Proverbio et al., 2011) or longer response times to a target visual feature within a search display composed of baby faces compared to one composed of adult faces (Thompson-Booth et al., 2013). This bias toward baby faces in the automatic allocation of attention was interpreted as a universal and inborn response driven by the high biological relevance of infants for adult members of a species ("baby schema" effect; Lorenz, 1971), in line with other evidence of attentional prioritization of biologically significant stimuli.

The only study that did not use infant faces as stimuli reported a larger attentional interference from own- as compared to other-age faces in young adult participants, as indicated by longer response times to report the identity of a target number when young as compared to older faces appeared in the background (Ebner & Johnson, 2010). These findings are in line with those obtained in Study 4 and Study

5 showing a recognition advantage for young versus older adult faces in young adults, as due to young adults' greater expertise at processing peer faces as compared to non-peer faces. Of note, however, not even in this study was the age of the face relevant to the task. Thus, the results remain uninformative as to whether an attentional bias exists in tasks involving group categorization along the face age dimension, and whether the bias parallels or mirrors the own-age bias observed in other aspects of face processing (i.e., perceptual discrimination and recognition). Moreover, in none of the above mentioned studies was the amount of participants' current/previous experience with other-age individuals measured or manipulated, this variable being sometimes confounded with parental status (Thompson-Booth et al., 2013). Thus, available evidence remains uninformative also regarding the impact of perceptual experience on attentional responses to face age.

In Study 6, we explored these questions by using a visual search task with own- and other-age faces, in which face age (i.e., adult, infant or child) was the target feature, and participants were explicitly required to process age-specifying information in order to provide their responses. With the purpose of comparing search efficiency for own- and other-age faces, in Experiment 1 adults searched for an adult face among infant faces or for an infant face among adult faces, whereas in Experiment 2 they searched for an adult face among child faces or the reverse. The influence of experience with other-age faces was controlled in Experiment 1 by selecting participants for having null or limited direct contact with infants (i.e., infant novices), whereas it was investigated in Experiment 2 by contrasting search efficiency for adult and child faces in a group of adults with null or limited contact with children (i.e., child novices) and a group of experienced adults working full time as preschool teachers (i.e., child experts). Previous research has shown that preschool teachers recognize child faces more accurately than child novices (Harrison & Hole, 2009), have no discrimination or recognition advantage for adult faces compared to child faces (Harrison & Hole, 2009; Kuefner et al., 2008) and rely to the same extent on configural/holistic strategies to process both face types (de Heering & Rossion, 2008; Kuefner et al., 2008, 2010).

On the basis of existing evidence, different predictions can be made. If the mirror pattern of recognition and categorization effects observed for happy vs angry faces and for own- vs other-race faces is a manifestation of a broader phenomenon which holds for different face attributes, including age, novice participants in Experiment 1 and 2 should manifest a visual search asymmetry in favour of infant and/or child faces, whereby the efficiency of the search would be greater for these faces than for adult faces. This prediction applies in particular to Experiment 1 if the so-called "baby schema" effect in the automatic allocation of attention (Brosch et al., 2007; Hodsoll et al., 2010) generalizes also to the deployment of selective attention to faces of different ages. Alternatively, if the influence of face age on attention deployment parallels the effects that this face attribute has on face recognition, we would expect to find a search asymmetry in favour of own-age adult faces in novice participants in Experiment 1 and 2, but not in the teachers in Experiment 2. The comparison between performance of novice and experienced participants in Experiment 2 will allow determining whether perceptual expertise has any impact on the extent to which face age engages mechanisms of selective attention.

Experiment 1

The aim of Experiment 1 was to investigate whether adults' efficiency in searching for an own-age adult face among infant faces differed from efficiency of the search for an infant face among adult faces. To this end, adults with limited experience with infants were tested in a visual search task with adult and infant faces.

Method

Participants. The final sample included 20 young adults (15 females; M age = 21.75 years, range = 19-29). One participant was excluded from the sample because he/she manifested extremely low (<

70%) search accuracy in one of the experimental conditions. Recruiting of participants was limited to individuals who had no offspring and had not acquired extensive experience with infants (i.e., 2 years or younger). To this end, all participants were screened prior to testing via a questionnaire that included specific enquiries aimed at assessing whether, in the past 5 years, they had had nieces or nephews, contact with infants of friends or acquaintances, and/or a job (full-time or otherwise) that put them in contact with infants. Inclusion criteria were modelled after Kuefner et al. (2008) (i.e., less than 520 hours of experience per year in the past 5 years).

Stimuli. Six gray-scale photographs of three adult (20-30-year-old) female faces and three newborn infant faces displaying a full-front neutral expression with open eyes served as stimulus materials. Faces were cropped in a standard oval subtending a visual angle of 4.8° horizontally and 5.7° vertically, and dropped in a gray background (Figure 17a). Adult and infant faces were equalized for luminance and contrast using Photoshop and were then matched based on subjective criteria of overall similarity to generate 3 adult-baby stimulus pairs, one used for practice trials and the other two for test trials, with stimulus pair counterbalanced across participants. Thus the mapping of stimuli to target and distractors was fixed within the task for each participant. Faces from each pair were presented within arrays composed of 2, 4, 6 or 8 elements located contiguously in one of 12 possible locations, equally spaced (6.7°) along a circle of 12.4° diameter centered on the fixation cross (Figure 17b). For each set size there were four possible arrays, two displaying only the adult or the infant face (i.e., target absent), and the other two displaying the infant face as background and the adult face as the target or the reverse (i.e., target present). The target was equally likely to appear in each location within the target present arrays.

Apparatus and Procedure. Participants were tested individually in a quiet, darkened room while seated 60 cm from a 15.4-inch Toshiba color LC monitor that was used to display the stimuli. The task was implemented using E-Prime 2.0 software. Participants were instructed to determine whether an adult or infant face was present as quickly as possible without sacrificing accuracy. Then they saw an instruction screen indicating which face was the target and which was the distractor for the upcoming block of trials. Each trial began with a black fixation cross (0.6° x 0.6°) that appeared in the center of the screen and remained visible throughout the trial. Participants were instructed to keep their eyes focused on the cross until the stimulus array appeared, 500 ms after the cross. The search display remained on the screen until the subject pressed one of two possible keys on the keyboard to indicate whether the target was present or absent. After giving each response, the subjects received feedback in the form of a 330-ms green screen for correct responses and a 330-ms red screen for incorrect responses. The inter-trial interval was 1000 ms. Participants completed two blocks of trials, one with the adult face as the target and one with the infant face as the target. The order of the blocks was counterbalanced between subjects. There were 96 trials in each block, for a total of 192 experimental trials. In addition, the subjects completed 24 practice trials before beginning each block. On each trial, either the stimulus pair, the presence or absence of the target and the set size of the display were chosen randomly, with a 50% probability of either stimulus pair 1 or 2 and a target absent or a target present trial and a 25% probability of a display with 2, 4, 6, or 8 items.

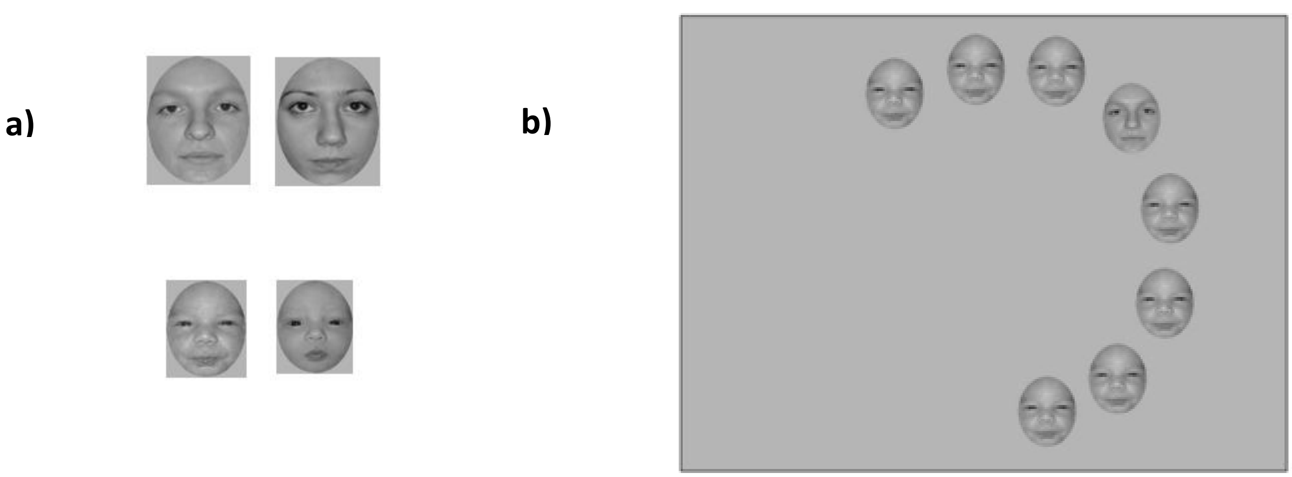

Figure 17 Examples of the adult faces (top) and the infant faces (bottom) (a). Panel (b) shows an example of a target present search display with 8 elements.

Results and Discussion

Mean accuracy and reaction times (RTs) for correct responses were calculated separately for target-absent and target-present trials of each face age condition as a function of set-size. Accuracy was above 92% in both the target-absent and target-present trials of the two face age conditions, and was not considered for statistical analyses. As a measure of search efficiency we computed and analyzed the slope of the RTs x set size function, which provides an estimate of the search in terms of items per unit time (i.e., the steeper the slope, the less efficient the search; Wolfe, 2008). We conducted a preliminary analysis of variance (ANOVA) on search slopes with target presence (present, absent) and target face age (adult, infant) as within-subjects factors and order (adult target first, infant target first) as an additional between-subjects factor. There were no significant effects involving the factor order except for a marginal three-way interaction, $F(1,18) = 4.36$, $p = .051$, η^2= ,195, for which all post-hoc comparisons failed to attain significance (ps > .07). Therefore, data were collapsed across order in a subsequent two-way ANOVA, which revealed significant main effects of both target presence, $F(1,19) = 34.76$, $p < 0.001$, $\eta^2= .647$, and target face age, $F(1,19) =31.618$, $p < 0.001$, $\eta^2= .625$. As shown in Figure 18, search slopes were steeper for target absent trials (M = 47.37 ms/item) than for target present (M = 22.47 ms/item) trials irrespectively of the age of the target face, and were steeper for infant targets (M = 42.81 ms/item) than for adult targets (M = 27.03 ms/item) across both target present and target absent trials. The interaction between the two factors was not significant ($p > .23$).

Results showed that search efficiency, as measured by the slope of reaction times per set size function, varied as a function of the age of the target face, suggesting the presence of a search asymmetry driven by face age. Although in both the adult target and baby target conditions searches depended on the number of distractors, the slopes were less steep for the search of an adult face among baby faces than vice versa, indicating that search asymmetry was in favour of adult faces. This was true on target present trials as well as on target absent trials, indicating that participants were not only faster at detecting an adult face among baby faces (on adult present trials) than vice versa, but also slower to disengage attention from adult face distractors while searching for a baby target (on baby absent trials) than from baby face distractors while searching for an adult target. Importantly, because our experimental procedure maximizes distractors and target homogeneity and holds distractors and target similarity constant by using a single exemplar of each age category across trials, the observed difference in search time for adult and baby target faces reflects a true search asymmetry (Duncan & Humphreys, 1989), which is indicative of preferential detection of own-age faces.

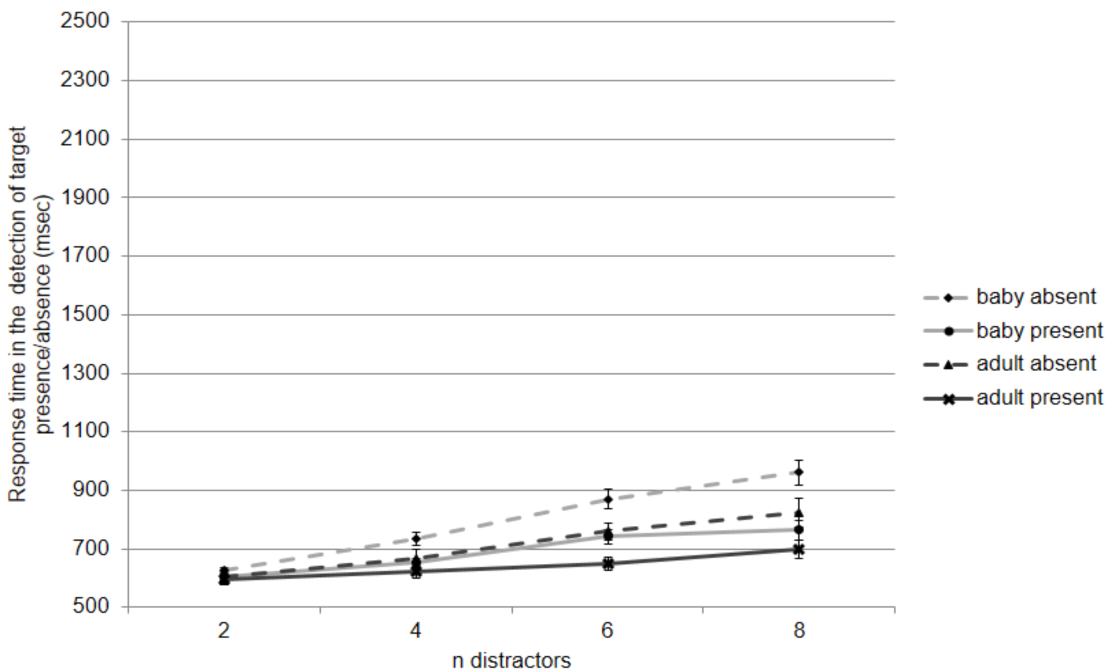

Figure 18 Slopes of reaction time x set size functions describing participants' search for an adult face among infant faces, or vice versa, in Experiment 1.

This finding is at odd with the other-race detection advantage found in studies investigating adults' search asymmetries for faces of different races (e.g., Levin, 1996, 2000; Levin & Angelone, 2001; Lipp et al., 2009). Unlike race, face age appears to influence attention deployment in the same way as it affects identity discrimination and recognition, own-age faces being more easily detected and more difficultly rejected than other-age faces during visual search.

The current demonstration of a search advantage for own-age faces in participants selected for having very limited experience with other-age faces converges with earlier demonstration of a search advantage for objects of expertise in bird and car experts (Hershler & Hochstein, 2009). When considered together, these findings suggest that participants' familiarity with the search target may influence the deployment of attention, in the form of an enhanced attentional response toward the more familiar target compared to the less familiar one. Crucially, in the study with bird and car experts the two participants' groups searched exactly the same displays but reacted differently according to their prior experience with exemplars of the target versus distractor category. Accordingly, more critical to the role of stimulus familiarity in the search advantage for own-age faces observed in Experiment 1 would be evidence from adult individuals differing in the amount of experience accumulated with non-adult faces.

To this end, in Experiment 2 we compared the efficiency of the search for an adult face among child faces with that for a child face among adult faces in a group of adults with limited experience with children (i.e., novice group) and a group of preschool teachers (i.e., experienced group) working fulltime with young children. If experience and stimulus familiarity contribute to the search advantage for own-age faces, we expected to find a search advantage for adult faces over child faces in novice participants, but no search advantage in preschool teachers. If, on the other hand, preschool teachers maintain a search advantage for adult faces, it could be claimed that such an advantage relies on low-level stimulus properties that differentiate adult from child faces.

Experiment 2

Method

Participants. Subjects included 40 adult women of Caucasian origins, 20 in the experienced group (M age = 46.8 years, range = 32-60) and 20 in the novice group (M age = 39.0 years, range = 24-50). Three additional participants were tested but excluded from the analyses because they manifested extremely low (< 70%) search accuracy in one of the experimental conditions. The experienced group consisted of teachers working full-time in a local preschool. Teachers were selected for having been in contact with children between the ages of 1 and 6 years in their current work environment for about 25 hours per week (M = 24.74 hours, range = 12-24 hours) for at least two years (M = 25.3 years, range = 2-40 years), according to the same criteria previously used by Kuefner et al. (2010). Fifteen teachers had at least one child of their own, who, in three cases, was 6-year-old or less. Women in the novice group were selected for having limited experience with children (i.e., 1 to 6 years) according to the same criteria used in Experiment 1 (Kuefner et al. 2008).

Stimuli. Stimulus material consisted of six gray-scale photographs of three adult (20-30-year-old) female faces, and three child (3-4-year-old) faces displaying a full-front neutral expression with open eyes (Figure 19). Photographs were manipulated and search arrays were constructed in the same way as in Experiment 1.

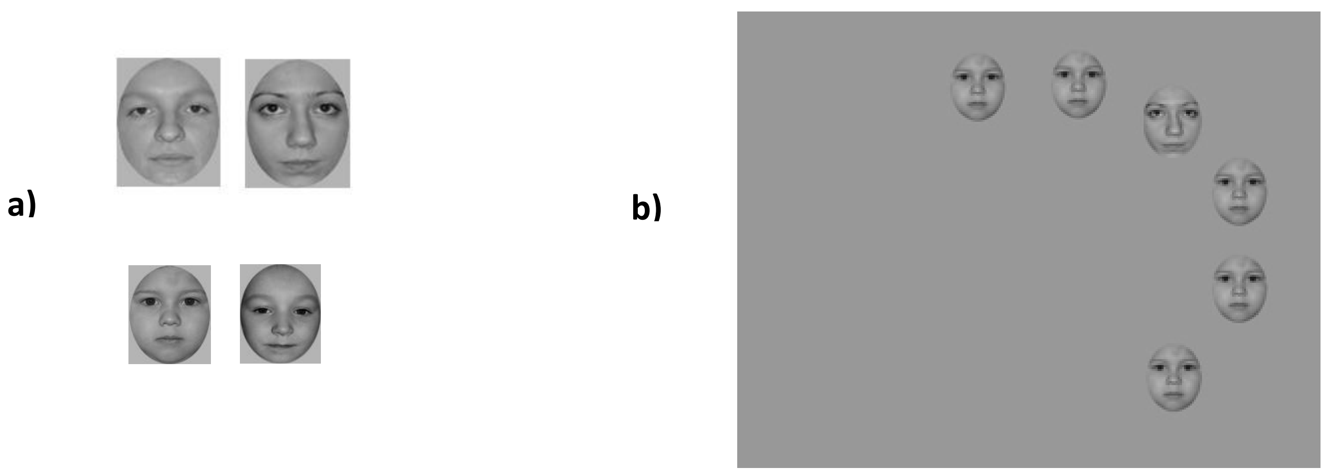

Figure 19 Examples of the adult faces (top) and the child faces (bottom) (a). Panel (b) shows an example of a target present search display with 6 elements.

Apparatus and Procedure. Participants were tested in the same manner as in Experiment 1.

Results and Discussion.

Mean accuracy and reaction times (RTs) for correct responses were computed in the same manner as in Experiment 1. Accuracy was above 93% in both the target-absent and target-present trials of the two face age conditions for both participants' groups, and was not considered for statistical analyses.

Similarly to Experiment 1, we computed and analyzed the slope of the RTs x set size function as a measure of search efficiency. Data were collapsed across order (adult target first, infant target first) as preliminary analyses indicated that there was no main effect or interactions involving this factor (all ps > .17). A 2 (participant group: novice, experienced) x 2 (target presence: present, absent) x 2 (target face age: adult, child) mixed ANOVA revealed significant main effects of both target presence, $F(1,38) = 115.793$, $p < .001$, $\eta^2 = .753$, and participant group, $F(1,38) = 5.998$, $p = .02$, $\eta^2 = .195$, suggesting that search slopes were steeper on target absent trials (M = 151.42 ms/item) than on target present trials (M = 73.21 ms/item), and were steeper for participants in the experienced group (M = 130,16 ms/item) than for subjects in the novice group (M = 94,48 ms/item). There was also a significant Target face age x Participant group interaction, $F(1,38) = 5.145$, $p = .03$, $\eta^2 = .119$, suggesting that face age affected search efficiency differently for the novice and the experienced participants. To follow-up on this interaction, we performed two separate two-way ANOVAs, one for each participant group. Like in Experiment 1, for the novice group there were significant main effects of target presence, $F(1,19) = 69.148$, $p < .001$, $\eta^2 = .78$, and target face age, $F(1,19) = 21.561$, $p < .001$, $\eta^2 = .53$, indicating that novices' search was more efficient on target present trials (M = 62.13 ms/item) than on target absent trials (M = 126.84 ms/item) and for adult face targets (M = 85.15 ms/item) compared to child face targets (M = 103.82 ms/item) (Figure 20a). For the experienced group, there was only a main effect of target presence, $F(1,19) = 55.796$, $p < .001$, $\eta^2 = .75$, confirming that also for these participants visual search was more efficient on target present trials (M = 84.30 ms/item) than on target absent trials (M = 176.01 ms/item) (Figure 20b).

For neither of the two groups the interaction between target face age and target presence was significant (ps >. 12).

The comparison between visual search performance of novices and teachers showed that the search advantage for adult (own-age) faces manifested by novice participants was modulated by the experience they had accumulated with non-adult (other-age) faces. Search efficiency was greater for adult faces than for child faces when experience with children was limited, whereas there was no sign of search asymmetry in the performance of preschool teachers who have had extensive recent experience with children. In fact, novices showed a search asymmetry in favour of adult faces, which more easily captured participants' attention on target present trials and more strongly hold attention on target absent trials. In contrast, teachers' performance was not at all affected by the target face age, as they were as fast when searching through child face distractors as when searching through adult face distractors, and child face distractors were as easy to reject as adult face distractors. These findings rule out the possibility that the search advantage for adult faces manifested by novice participants in both Experiment 1 and 2 relied on low-level stimulus properties that differentiate adult from non-adult faces. More importantly, by showing that a quantifiable amount of experience acquired with multiple child faces is capable of attenuating the detection advantage of own-age faces in adults, our findings point to the critical role of perceptual experience in modulating attentional responses to face age.

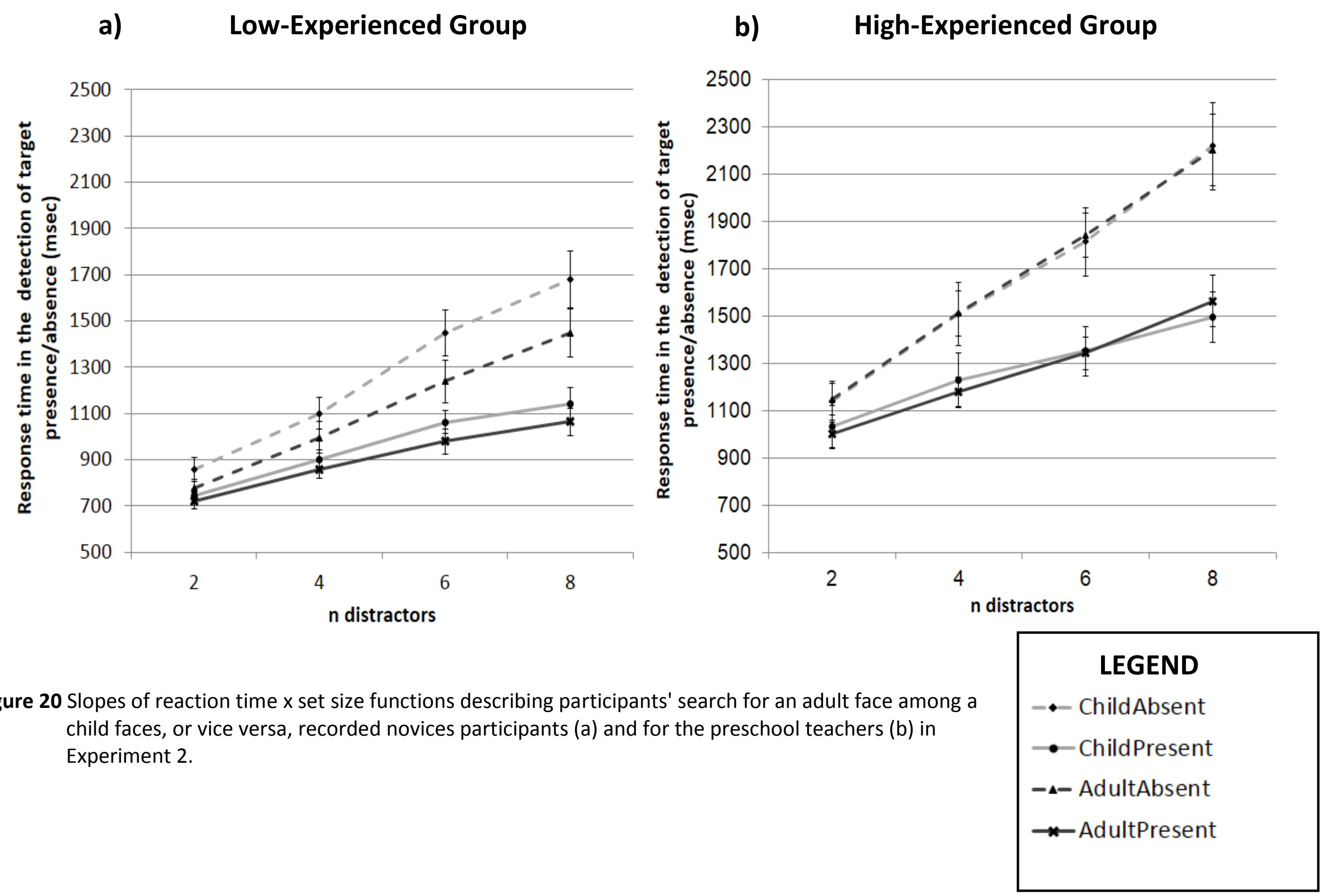

Figure 20 Slopes of reaction time x set size functions describing participants' search for an adult face among a child faces, or vice versa, recorded novices participants (a) and for the preschool teachers (b) in Experiment 2.

Discussion of Study *6*

Study 6 showed, for the first time, that face age can act as an attentional guiding attribute in a visual search task, and that perceptual experience with a specific face age group affects how easily selective visual attention is deployed to those faces.

By comparing search efficiency for adult and baby faces (Experiment 1) and for adult and child faces (Experiment 2) in a visual search task in which face age was the relevant target feature, we provided consistent evidence for a detection advantage in favour of own-age faces in adults. Results from Experiment 1 contrast with earlier demonstrations of greater capturing effects for baby faces compared to adult faces (Brosch et al., 2007; Hodsoll et al., 2010; Proverbio et al., 2011; Thompson-Booth et al., 2013) in the automatic allocation of attention in tasks in which face age was irrelevant to the task and had not to be explicitly processed in order for the task to be performed. Although the biological relevance of baby faces for adult members of the species (e.g., Brosch et al., 2007) may explain these latter findings, it is likely that the explicit request to process age-specifying information and the use of faces as the relevant, to-be-attended stimuli in our task has opened the gate to top-down influence on attentional control generated by stimulus familiarity and perceptual expertise, which overcame any "baby schema" effect.

The advantage of adult faces over infant and child faces in guiding the deployment of attention in participants selected for having limited experience with infant and children mimics the recognition advantage that participants selected according to analogous criteria exhibited for adult faces compared to infant (e.g., Kuefner et al., 2008; Macchi Cassia et al., 2009a) and child (Kuefner et al., 2008) faces. This similarity suggests that analogous mechanisms may underlie the recognition and the detection effects induced by face age. Although it has been speculated that social cognitive mechanisms, similar to those contributing to the own-race bias (see Young, et al., 2012), may also contribute to the own-age bias (e.g., Hugenberg, et al., 2010), extant evidence indicates that the age bias is mediated by perceptual learning mechanisms, as reduced contact with other-age faces prevents adults from developing sensitivity to the same configural/featural cues that mediate their efficient recognition of over-experienced peer faces (e.g., Harrison & Hole, 2009; Kuefner et al., 2008). The role of perceptual learning mechanisms and stimulus familiarity in the own-age detection bias observed in the current study is also confirmed by the finding that the preschool teachers tested in Experiment 2, who accumulated a great deal of recent experience with children, did not show the same search asymmetry in favour of adult faces shown by novice participants. Rather, they were equally good at searching for a child face among adult face distractors as they were at searching for an adult face among child face distractors. Because the two participants' groups viewed exactly the same stimuli and were tested under the same exact conditions, any bottom-up processing effects evoked by stimulus material were identical, expertise remaining the only possible factor explaining the difference in groups' performance.

Quite interestingly, our finding of preferential detection of own-age faces in adults contrasts with evidence of preferential detection of other-race faces in visual search tasks (Levin, 1996, 2000; Levin & Angelone, 2001). Recent research has shown that methodological variations related to stimulus presentation, such as the degree of perceptual similarity between own- and other-race faces (Levin & Angelone, 2001) or participants' ethnicity (Chiao et al., 2006), can modulate the search asymmetry, up to the point of eliminating the advantage for other-race faces. In particular, the search asymmetry flips in favour of own-race faces if more than one exemplar is used per category and the nature of target and distractor stimuli varies across trials (Lipp et al., 2009). The procedure used in the present study was modeled on Levin's (2000) original research reporting preferential detection of other-race faces among own-race faces, as it employed a fixed mapping of stimuli to target and distractors by testing each participant with a single exemplar face per age category. Thus, our finding of preferential detection of own-age faces emerged under the same task conditions in which preferential detection of other-race faces is evident.

Levin's findings were interpreted, together with the widely reported other-race advantage in face categorization (e.g., Caldara et al., 2004; Ge et al., 2009), as evidence that race-specifying information is spontaneously coded in other-race faces at the expense of individuating information (Levin, 1996, 2000), thus making race categorization of other-race faces faster than categorization of own-race faces. Our data suggest that a similar feature-selection model cannot be generalized to age biases, because the detection advantage in our visual search task was in favour of own-age faces, and not of other-age faces. We propose that there are important differences in the way race and age information are processed and represented in adults' memory, which may explain the difference between the current findings and those found in race studies.

One important difference relates to the characteristics of race and age experience across the lifespan. Because one's own age, unlike race, continuously changes, as does the age of faces to which one is primarily exposed, age experience is less stable than race experience across an individual's lifespan. Indeed, although by the end of the first year of life infants show better discrimination of own-race compared to other-race faces (e.g., Kelly et al., 2007) as well as better discrimination of adult faces compared to infant faces (Macchi Cassia, et., 2014), by the time they've grown into young adults they typically show a recognition bias favouring peer faces (see review by Rhodes & Anastasi, 2011). In contrast, the direction of the own-race bias typically remains unchanged from infancy to adulthood (see review by Meissner & Brigham, 2001). This and other evidence (e.g., Hills & Lewis, 2011; Macchi Cassia et al., 2009b) indicates that the individual's face representation constantly adapts to continuous changes in age experience that naturally occur across the lifespan, whereas, under typical conditions, this does not happen for race experience. As a consequence, it is possible that the proposed difference in perceptual processing strategies for own- and other-race faces (Hugenberg, Miller, & Claypool, 2007, but see Rhodes, Locke, Ewing, & Evangelista, 2009 for an alternative account) does not holds in the same way for own- and other-age faces, and this could explain why other-age faces do not elicit a search advantage as other-race faces do.

A second possible difference in how race and age information are processed relates to the impact of social cognitive and motivational factors on such processing (Hugenberg et al., 2010; Sporer, 2001). A variety of findings in the social cognition literature converge on the hypothesis that members of social groups distinctly apart from one's own are processed more at the category level than as individuals (e.g., Bernstein, Young, & Hugenberg, 2007). However, although research has shown that social categorization mechanisms play a role in driving the recognition advantage for own-race faces (e.g., Cassidy, Quinn, & Humphreys, 2011; Freeman et al., 2011; Lebrecht, Pierce, Tarr, & Tanaka, 2009), there is currently no evidence that these same mechanisms are at play in the case of the own-age bias. Indeed, it is likely that continuous variations in one's own age and in the age of the faces to which one is primarily exposed change the individual's manner of self-categorization across the life span. Thus, even assuming that age is a facial attribute that induces social categorization, it is likely that in-group/out-group boundaries as well as the differences between the members of the two groups are less refined when the critical feature is age as opposed to race. Again, within the framework of social-cognitive theories of face processing biases (see review by Young et al., 2012), this could explain why the search advantage for other-race faces does not generalize to other-age faces.

In conclusion, the present study is the first to show that own-age faces enjoy an advantage in driving adults' allocation of selective visual attention as measured by visual search tasks, and that perceptual experience has a critical role in driving this attentional advantage. By showing that the detection advantage is towards own-age faces, rather than other-age faces, our results suggest that the mirror pattern of recognition and categorization effects observed for own- versus other-race faces does not generalize to age biases. A goal for future studies will be to test whether this pattern of results holds when adults' proficiency at categorizing own- and other-age faces is tested more directly in a categorization task.

General Discussion

Studies 4, 5 and 6 confirmed the importance of perceptual experience acquired in social and working contexts in shaping face processing abilities during adulthood and old age.

Study 4 provides novel evidence regarding the presence of an OAB in elderly adults. Results showed that older adults' performance in the processing of young and older adult faces did not significantly differ for the two face categories, although they show a tendency for an advantage for young adult faces. This result has been interpreted as reflecting the mutual influence of early and continuing experience with young adult faces and recent experience with older adult faces. This finding suggests that, when perceptual processing abilities are considered, experience with peers acquired in older age is not capable to overcome the bias towards young adult faces which is typically manifested by younger adults (Short & Mondloch, 2013).

Additionally, Study 5 and 6 exploited the effects of extensive exposure to elderly adults or children occurring in adulthood as part of the individual’s working experience. Results of Study 5 confirmed that the face processing system remains plastic in response to experience with multiple facial identities from one single age group well into adulthood, as shown by the modulation of the advantage for adult faces. Nevertheless, such plasticity is limited in comparison to that manifested by young children as previously emerged in other studies (Macchi Cassia, et al., 2009a).

Study 6 showed, for the first time, that own-age faces enjoy an advantage in driving adults' allocation of selective visual attention and that perceptual experience has a critical role in driving this detection advantage. In fact, results showed that later-acquired experience with a specific face age groups is capable to modulate attentional responses to those faces. Importantly, by showing that the detection advantage is in favour of own-age faces, and thus mimics the recognition advantage that is typically observed for own-age faces, results suggest that analogous mechanisms may underlie the recognition and the detection effects induced by face age. The presence, in the case of the age bias, of similar mechanisms underlying recognition and attentional detection sheds light on important differences in the way race and age information are processed and represented in adults' memory, which may explain the difference between the current findings and those found in race studies. In the case of race, social cognitive accounts provide an effective explanation of the mirror effect between categorization and recognition, with a more categorical processing of other-race faces compared to own-race faces, which facilitates performance for other-race faces in visual search and categorization tasks. The same interpretation does not hold for age biases, for which perceptual learning mechanisms and stimulus familiarity appear to be the driving factors.

GENERAL DISCUSSION

The present research focuses on the role of perceptual experience provided by the social environment in shaping the age-related face processing bias across the lifespan. In the series of studies presented in this dissertation, we explored how the face processing system adapts to reflect each individual experience, and the extent of such adaptability across the lifespan, from infancy to old age.

The age bias phenomenon describes how our ability to encode, process and recognize faces depends on the interaction between the age of the poser and the age of the perceiver. As discussed in the Introduction and confirmed by the results of our studies (Study 3-6), in adulthood this phenomenon takes the form of an advantage in the processing of peer faces (i.e. own-age bias; OAB). In infancy (Study 1 and 2) and early childhood (Study 5) the age bias takes the form of a processing advantage for young adult faces, and in the old age the bias is much less stable and often non-present (Study 4). This variability in the manifestations of the bias reflects the fact that, unlike species and race, which are face traits that typically remain stable across an individual's lifespan, age is a more changeable dimension inherent to faces as well as to the perceiver's status, and our exposure to various age groups is also changeable across the lifespan. Due to the changeable nature of age as a categorical facial dimension across the lifespan, research on age biases in face processing represents an ideal tool to investigate the way the face processing system adapts to reflect individual variability in social experience, including exposure to specific face types and/or relevant face-to-face interactions.

Our series of studies show how experience with one significant non-adult individual (i.e. an older or younger sibling and/or one's own child; Studies 1-3) or with multiple individuals (i.e. elderly adults or children; Studies 4-6) affects face processing abilities so as to modulate the bias towards young adult faces.

Results from Study 1 and 2 showed that perceptual narrowing towards adult faces occurs between 3 and 9 months of age, and that this process is directly related to the proportional size of the encountered age groups within each infant's social environment. For first-born infants, such proportional size is greatly unequal, since at least 80% of their awakening time is spent in interactions with adult-age faces (Rennels & Davis, 2008; Sugden et al., 2014). As a consequence, Study 1 showed that the ability of these infants to recognize the difference among non-adult faces declines from 3 to 9 months, whereas their ability to discriminate among adult faces is maintained, although based on different perceptual processing strategies. Critically, discrimination abilities for child faces are maintained when infants had the opportunity to interact with an older sibling from the time of their birth onward. Study 2 showed that early infant experience with adults and siblings also shapes the neural structures underlying face processing, as we found neural specialization for adult faces in infants without an older sibling, but not in infants with an older sibling. This evidence extends earlier demonstrations that perceptual training with unfamiliar face categories (other-race and other-species faces) allows infants to maintain the ability to discriminate among those faces (Anzures et al., 2012; Heron-Delaney et al., 2011; Scott & Monesson, 2009, 2010). These findings show that infants' face representational system adapts continuously to reflect ongoing experience with faces, such that selective exposure to adult caregivers leads to the narrowing of the face system towards adult faces, whereas a broader array of exposure to faces from different age groups prevents narrowing from occuring.

Study 3 explored the long-term effects of early-acquired experience with a sibling face on adults' ability to acquire perceptual expertise through exposure to their child's face. Results showed that 4 months of exposure to an infant face are sufficient to modulate the own-age bias in first-time mothers only if this experience is preceded by a similar type of experience in early childhood. Importantly, results also showed that much longer exposure to the infant face is needed in order for the mothers to show a modulation of the own-age bias in the absence of early experience as compared to when early experience did occur (i.e., 12 months vs. 4 months). These findings suggest that the face processing system retains enough flexibility to adapt to a newly encountered face type under condition of extensive and prolonged exposure. Further, this flexibility is boosted by early experience. Early experience appears to produce long-lasting effects that can be reactivated in adulthood by re-exposure to the original experience. These results support the view that the first years of life represent a sensitive time window, during which the neural and perceptual systems are particularly sensitive to the effects of perceptual experience with relevant categories of stimuli in the environment. This does not preclude the possibility that there is room for plasticity, although reduced, even later in life.

Studies 4-6 extended available evidence on the plasticity of the face processing system in adulthood. Study 4 showed that experience acquired by older adults with peer individuals interacts with the effects of the lifetime and current experience acquired with younger adults, eliciting comparable performance in the recognition of older and younger adult faces. These findings add to those obtained from Study 3, showing that the face processing system adapts to reflect the current facial experience of each individual even in adulthood, but that the extent to which the system is open to the influence of age experience decreases with age, as exposure to peers did not reverse the bias towards young adult faces in older adults. Importantly, the absence of an advantage in the processing of peer faces also indicates that social categorization mechanisms (e.g., identification) play a limited role in elderly adults' processing of younger and older adult faces, thus disconfirming the predictions of the social cognitive interpretation of the own-age bias.

Results of Study 5 and 6 extended available evidence on the plasticity of the face processing system in adulthood by showing that extensive exposure to elderly adult individuals or children acquired through working experience allows young adults to become experts at processing older adult and child faces. Study 5 confirmed that the adult face processing system retains flexibility in response to experience with multiple facial identities from one single age group, even when this experience occurs with another subcategories of adult faces (i.e. older adults). Nevertheless, the study also showed that plasticity decreases from early childhood to adulthood, since experience with multiple individuals from the elderly adult age group have more dramatic effects in childhood compared to adulthood.

Study 6 extended the demonstration of the effects of experience with multiple individuals to selective visual attention. Results showed that adults with limited experience with non-adult faces show an advantage in the detection of own-age faces compared to other-age faces in visual search tasks were face age was the target feature, but this advantage is absent in adults who accumulated extensive experience with non-adult faces, as in the case of preschool teachers. These findings are the first to demonstrate that face age modulates attention deployment in the same way as it modulates perceptual recognition and recognition memory, and that both effects are mediated by perceptual expertise. These findings provide critical evidence against the predictions of the social cognitive account of the age bias, according to which adults should manifest a search advantage in favour of other-age faces, in the same way as they show a search advantage in favour of other-race faces. Within this view, the perceptual processing strategies used in a visual search task, where participants need to focus on category-specifying features to detect adult and non-adult faces, would lead to a more efficient detection of other-age faces than own-age faces, as found for the other-race advantage in face categorization. By showing that the influence of age on attention deployment parallels the effects that this face attribute has on face recognition, and that both effects are experience-based, Study 6 provided evidence that the mechanisms underlying the age bias do not completely overlap with those mediating the own-race bias in face recognition, and that perceptual learning mechanisms play a more critical role in driving the former than the latter.

The results of our series of studies have a number of implications for our understanding of not only the origins of age biases in face processing, but also the way experience affects face-processing abilities across development. Results do not lend support to the existence of an OAB, similar to that observed for race and species. Rather, they show that the face processing system adapts to reflect the facial experience provided to each individual by the ever-changing properties of the social environment. In particular, evidence derived from studies testing infants' and children's discrimination abilities are compatible with the hypothesis that, under typical conditions, early in development perceptual processes become tuned to adult faces, as these are the faces that children most frequently experience during the first few years of life. In contrast, when infants or children accumulate experience with non-adult individuals (e.g. younger or older siblings, elderly adults), facial processing abilities change as do the neurocognitive mechanisms thought to underlie them. Specifically, when children or infants have consistent and meaningful experience with non-adult individuals the face processing system no longer appears to be selectively tuned toward adult faces.

Similarly, in adulthood perceptual recognition, configural processing and selective visual attention are modulated by experience with faces from specific age groups, with an OAB being present only in the absence of extensive experience with non-adult individuals. This evidence supports the idea that visual processing system in adulthood are still malleable and can be shaped by experience.

One interesting direction for future research would be to investigate whether the differential processing abilities for faces belonging to different age groups are mediated by the way face are visually explored (e.g. scanning paths used to process faces). Studies investigating perceptual-processing differences between adult and non-adult faces measured face-specific effects like the face inversion effect and the composite face effect (e.g., Kuefner et al., 2008; 2010), using these effects as markers of configural/holistic processing. Nevertheless, a more direct measure of the processing strategies utilized for the encoding and/or recognition of own- and other-age faces would be available through the use of an eye-tracking paradigm. To best of my knowledge, only one study investigated visual scanning strategies as a function of face age, finding overall differences in looking times for own-age compared to other-age faces in adulthood (Ebner, He, & Johnson, 2011). However, in this study face age was manipulated in interaction with emotional expression. A specific goal for future research would be to follow-up previous research on perceptual processing differences between own-age and other-age faces by utilizing eye tracking measurements within recognition/discrimination paradigms in order to investigate whether visual scanning strategies change when we are asked to learn or to recognize the identity of faces belonging to different age groups, and whether changes in scanning strategies occurring as a function of experience with other-age individuals correspond to improvements in recognition performance for other-age faces.

In conclusion, results from Studies 1-6 provides direct support to the perceptual learning interpretation of the age biases, suggesting that from infancy to old age perceptual experience provided by the social environment directly affects and shapes face processing abilities. Nevertheless, available evidence does not rule out the possibility that, at least during adulthood, social categorization mechanisms and/or motivational factors may contribute as well to the generation of the own-age bias, and further research is needed to explore this contribution.

REFERENCES

Anastasi, J. S., & Rhodes, M. G. (2005). An own-age bias in face recognition for children and older adults. *Psychonomic Bulletin & Review*, *12*(6), 1043–7.

Anastasi, J. S., & Rhodes, M. G. (2006). Evidence for an Own-Age Bias in Face Recognition. *North American Journal of Psychology*, *8*(2), 237–252.

Anzures, G., Quinn, P. C., Pascalis, O., Slater, A. M., & Lee, K. (2010). Categorization, categorical perception, and asymmetry in infants' representation of face race. *Developmental Science*, *13*(4), 553–64.

Anzures, G., Wheeler, A., Quinn, P. C., Pascalis, O., Slater, A. M., Heron-Delaney, M., Tanaka, J. W., & Lee, K. (2012). Brief daily exposures to Asian females reverses perceptual narrowing for Asian faces in Caucasian infants. *Journal of Experimental Child Psychology*, *112*(4), 484–95.

Bäckman, L. (1991). Recognition memory across the adult life span: the role of prior knowledge. *Memory & Cognition*, *19*(1), 63–71.

Balas, B., Westerlund, A., Hung, K., & Nelson III, C. a. (2011). Shape, color and the other-race effect in the infant brain. *Developmental Science*, *14*(4), 892–900.

Bar-Haim, Y., Ziv, T., Lamy, D., & Hodes, R. M. (2006). Nature and nurture in own-race face processing. *Psychological Science*, *17*(2), 159–63.

Barrera, M. E., & Maurer, D. (1981). Recognition of Mother's Photographed Face Infant by the Three-Month-Old, *Child Development*, *52*(2), 714–716.

Bartlett, J. C., & Leslie, J. O. E. (1986). Aging and memory for faces versus single views of faces, *Memory & Cognition* *14*(5), 371–381.

Baudouin, J.Y., Gilibert, D., Sansone, S. & Tiberghien, G. (2000). When the smile is a cue to familiarity. *Memory, 8*, 285-292.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological Studies of Face Perception in Humans. *Journal of Cognitive Neuroscience,* 8(6), 551–565.

Bernstein, M. J., Young, S. G., & Hugenberg, K. (2007). The cross-category effect: mere social categorization is sufficient to elicit an own-group bias in face recognition. *Psychological Science*, *18*(8), 706–12.

Brigham, J.C., & Malpass, R.S. (1985). The role of experience and contact in the recognition of faces of own- and other-race persons. *Journal of Social Issues, 41*, 139-155.

Brosch, T., Sander, D., & Scherer, K.R. (2007). That baby caught my eye. Attention capture by infant faces. *Emotion, 7,* 685-689.

Brody, G. H. (2004a). Siblings' Direct and Indirect Contributions to Child Development. *Current Directions in Psychological Science*, *13*(3), 124–126.

Bruce, V., & Young, A. W. (2012). *Face perception*. Psychology Press.

Bukach, C. M., Gauthier, I., & Tarr, M. J. (2006). Beyond faces and modularity: the power of an expertise framework. *Trends in Cognitive Sciences*, *10*(4), 159–66.

Burt, D. M., & Perrett, D. I. (1995). Perception of age in adult Caucasian male faces: computer graphic manipulation of shape and colour information. *Proceedings of the Royal Society of London. Series B: Biological Sciences, 259*(1355), 137–143.

Bushnell, I. W. R. (2001). Mother's face recognition in newborn infants: learning and memory*. Infant and Child Development, 10*(1-2), 67–74.

Cashon, C. H., & DeNicola, C. A. (2011). Is perceptual narrowing too narrow? *Journal of Cognition and Development*, *12*(2), 159-162

Caldara, R., Rossion, B., Bovet, P., & Hauert, C.A. (2004). Event-related potentials and time course of the 'other-race' face classification advantage. *Neuroreport, 15*, 905-910.

Cassidy, K.D., Quinn, K.A., & Humphreys, W. (2011). The influence of ingroup/outgroup categorization on same- and other-race face processing: The moderating role of inter- versus intra-racial context. *Journal of Experimental Social Psychology, 47*, 811-817.

Chaby, L., Narme, P., & George, N. (2011). Older adults' configural processing of faces: role of second-order information. *Psychology and Aging, 26*(1), 71–79.

Chiao, J.Y., Heck, H.E., Nakayama, K., & Ambady, N. (2006). Priming race in biracial observers affects visual search for Black and White faces. *Psychological Science, 17*,387–392.

Chiroro, P. & Valentine, T. (1995). An investigation of the contact hypothesis of the own-race bias in face recognition. *Quarterly Journal of Experimental Psychology, 48*, 879-894.

De Haan, M., Johnson, M. H., & Halit, H. (2003). Development of face-sensitive event-related potentials during infancy: a review. *International Journal of Psychophysiology, 51*(1), 45–58.

De Haan, M., Pascalis, O., & Johnson, M. H. (2002). Specialization of neural mechanisms underlying face recognition in human infants. *Journal of Cognitive Neuroscience, 14*(2), 199–209.

De Heering, A., & Rossion, B. (2008). Prolonged visual experience in adulthood modulates holistic face perception. *PloS One, 3*(5), e2317.

Dering, B., Martin, C. D., Moro, S., Pegna, A. J., & Thierry, G. (2011). Face-sensitive processes one hundred milliseconds after picture onset. *Frontiers in Human Neuroscience, 5,* 93.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: an effect of expertise. *Journal of Experimental Psychology. General, 115*(2), 107–17.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review, 96*, 433–458.

Ebner, N. C., He, Y., Fichtenholtz, H. M., McCarthy, G., & Johnson, M. K. (2011). Electrophysiological correlates of processing faces of younger and older individuals. *Social Cognitive and Affective Neuroscience, 6*(4), 526–35.

Ebner, N. C., He, Y., & Johnson, M. K. (2011). Age and emotion affect how we look at a face: visual scan patterns differ for own-age versus other-age emotional faces*. Cognition & Emotion, 25*(6), 983–97.

Ebner, N. C., & Johnson, M. K. (2009). Young and older emotional faces: are there age group differences in expression identification and memory? *Emotion*, *9*(3), 329.

Eimer, M. (2000). Effects of face inversion on the structural encoding and recognition of faces. *Cognitive Brain Research, 10*(1-2), 145–158.

Enlow, D. H., & Hans, M. G. (1996). *Essentials of facial growth*. Saunders Philadelphia.

Ferguson, K., Kulkofsky, S., Cashon, C., & Casasola, M. (2009). The Development of Specialized Processing of Own-Race Faces in Infancy. *Infancy, 14*(3), 263–284.

Firestone, A., Turk-Browne, N. B., & Ryan, J. D. (2007). Age-related deficits in face recognition are related to underlying changes in scanning behavior. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 14*(6), 594–607.

Freeman, J.B., Penner, A.M., Saperstein, A., Scheutz, M., & Ambady, N. (2011). Looking the Part: Social Status Cues Shape Race Perception. *PLoS ONE, 6*, 325107,

Fulton, a, & Bartlett, J. C. (1991). Young and old faces in young and old heads: the factor of age in face recognition. *Psychology and Aging, 6*(4), 623–30.

Gaither, S. E., Pauker, K., & Johnson, S. P. (2012). Biracial and monoracial infant own-race face perception: an eye tracking study. *Developmental Science, 15*(6), 775–82.

Gallegos D.R., & Tranel D. (2005). Positive facial affect facilitates the identification of famous faces. *Brain & Language, 93*, 338-348.

Ge, L., Zhang, H., Wang, Z., Quinn, P. C., Pascalis, O., Kelly, D., Slater, A., Tian, J., & Lee, K. (2009). Two faces of the other-race effect : Recognition and categorisation of Caucasian and Chinese faces, 38, 1199–1211.

Goldstein, A. G., & Chance, J. E. (1985). Effects of training on Japanese face recognition: Reduction of the other-race effect. *Bulletin of the Psychonomic Society*, 23(3), 211–214.

Halit, H., de Haan, M., & Johnson, M. . (2003). Cortical specialisation for face processing: face-sensitive event-related potential components in 3- and 12-month-old infants. *NeuroImage, 19*(3), 1180–1193.

Hancock, K. J., & Rhodes, G. (2008). Contact, configural coding and the other-race effect in face recognition. *British Journal of Psychology*, *99*(1), 45–56.

Hannon, E. E., & Trehub, S. E. (2005). *Proceedings of the National Academy of Sciences of the United States of America*, *102* (35), 12639–12643.

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54*(6), 917–924.

Harrison, V., & Hole, G. J. (2009). Evidence for a contact-based explanation of the own-age bias in face recognition. *Psychonomic Bulletin & Review, 16*(2), 264–9.

Haxby, J. V, Hoffman, E. A., & Gobbini, M. I. (2002). Human Neural Systems for Face Recognition and Social Communication. *Biological psychiatry*, *51*(1), 59-67.

He, Y., Ebner, N. C., & Johnson, M. K. (2011). What Predicts the Own-Age Bias in Face Recognition Memory? *Social Cognition, 29*(1), 97–109.

Heron-Delaney, M., Anzures, G., Herbert, J. S., Quinn, P. C., Slater, A. M., Tanaka, J. W., … Pascalis, O. (2011). Perceptual training prevents the emergence of the other race effect during infancy. *PloSOne, 6*(5), e19858.

Hershler, O., & Hochstein, S. (2009). The importance of being expert : Top-down attentional control in visual search, *Attention, Perception, & Psychophysics*, *71*(7), 1478–1486.

Hills, P. J. (2012). A developmental study of the own-age face recognition bias in children. *Developmental Psychology, 48*(2), 499–508.

Hills, P. J., & Lewis, M. B. (2011). The own-age face recognition bias in children and adults. *Quarterly Journal of Experimental Psychology (2006), 64*(1), 17–23.

Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review, 26*(1), 55–88.

Hodsoll, J., Quinn, K. A., & Hodsoll, S. (2010). Attentional prioritization of infant faces is limited to own-race infants. *PlosOne, 5,* e12509.

Hugenberg, K., Miller, J., & Claypool, H. (2007). Categorization and individuation in the cross-race recognition deficit: Toward a solution to an insidious problem. *Journal of Experimental Social Psychology, 43*, 334-340.

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The categorization-individuation model: an integrative account of the other-race recognition deficit. *Psychological Review, 117*(4), 1168–87.

Itier, R. J., & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: a repetition study using ERPs. *NeuroImage, 15*(2), 353–72.

Johnson, M. H. (2000). Functional Brain Development in Infants: Elements of an Interactive Specialization Framework*. Child Development, 71*(1), 75–81.

Johnson, M. H., & Morton, J. (1991). B*iology and cognitive development. The case of face recognition*. Oxford, England: Basil Blackwell.

Johnston, R., Kanazawa, M., Kato, T., & Oda, M. (1997). Exploring the Structure of Multidimensional Face-space: The Effects of Age and Gender. *Visual Cognition,* 4(1), 39–57.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 17*(11), 4302–11.

Kelly, D. J., Liu, S., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., & Ge, L. (2009). Development of the other-race effect during infancy: evidence toward universality? *Journal of Experimental Child Psychology, 104*(1), 105–14.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007a). The other-race effect develops during infancy: evidence of perceptual narrowing. *Psychological Science, 18*(12), 1084–9.

Kuefner, D., Macchi Cassia, V., Picozzi, M., & Bricolo, E. (2008). Do all kids look alike? Evidence for an other-age effect in adults. *Journal of Experimental Psychology. Human Perception and Performance, 34*(4), 811–7.

Kuefner, D., Macchi Cassia, V., Vescovo, E., & Picozzi, M. (2010). Natural experience acquired in adulthood enhances holistic processing of other-age faces. *Visual Cognition, 18*(1), 11–25.

Lander, K., & Metcalfe, S. (2007). The influence of positive and negative facial expressions on face familiarity. *Memory, 15*, 63-69.

Lebrecht, S., Pierce, L. J., Tarr, M. J., & Tanaka, J. W. (2009). Perceptual other-race training reduces implicit racial bias. *PloS One, 4*(1), e4215.

Levin, D. T. (1996). Classifying faces by race: the structure of face categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(6), 1364–1382.

Levin, D. T. (2000). Race as a visual feature: using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition deficit. *Journal of Experimental Psychology. General, 129*(4), 559–74.

LeDoux, J. E. (1996). *The Emotional Brain.* New York: Simon and Schuster.

Levin, D. T., & Angelone, B. L. (2001). Visual search for a socially defined feature : What causes the search asymmetry favoring cross-race faces?. *Perception & psychophysics*, *63*(3), 423–435.

Lipp, O.V., & Deraksan, N. (2005). Attentional bias to pictures of fear-relevant animals in a dot probe task*. Emotion, 5,* 365.

Lipp, O.V., Terry, D.J., Smith, J.R., Tellegen, C.L., Kuebbeler, J., & Newey, M. (2009). Searching for differences in race – Is there evidence for preferential detection of other-race faces? *Emotion, 9,* 350-360.

Liu, S., Quinn, P. C., Wheeler, A., Xiao, N., Ge, L., & Lee, K. (2011). Similarity and difference in the processing of same-and other-race faces as revealed by eye tracking in 4-to 9-month-olds. *Journal of experimental child psychology*,*108*(1), 180-189.

LoBue, V. (2009). More than just another face in the crowd: superior detection of threatening facial expressions in children and adults. *Developmental Science, 12*(2), 305–13.

LoBue, V. (2012). What are we so afraid of? How early attention shapes our most common fears. *Child Development Perspectives, 7,* 38-42.

LoBue, V., & DeLoache, J.S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science, 19*, 284-289.

LoBue, V., & DeLoache, J.S. (2010). Superior detection of threat-relevant stimuli in infancy. *Developmental Science, 13,* 221-228.

LoBue, V., & Larson, C. L. (2010). What makes angry faces look so ... angry? Examining visual attention to the shape of threat inchildren and adults. *Visual Cognition, 18*, 1165-1178.

Lorenz, K. (1971). *Studies in animal and human behavior*. Cambridge, MA: Harvard University Press.

Macchi Cassia, V. (2011). Age biases in face processing: the effects of experience across development. *British Journal of Psychology, 102*(4), 816–29.

Macchi Cassia, V., Bulf, H., Quadrelli, E., & Proietti, V. (2014). Age-related face processing bias in infancy: evidence of perceptual narrowing for adult faces*. Developmental Psychobiology, 56*(2), 238–48.

Macchi Cassia, V., Kuefner, D., Picozzi, M., & Vescovo, E. (2009a). Early experience predicts later plasticity for face processing: evidence for the reactivation of dormant effects. *Psychological Science, 20*(7), 853–9.

Macchi Cassia, V., Picozzi, M., Kuefner, D., & Casati, M. (2009b). Why mix-ups don't happen in the nursery: evidence for an experience-based interpretation of the other-age effect. *Quarterly Journal of Experimental Psychology, 62*(6), 1099–107.

Macchi Cassia, V., Pisacane, A., & Gava, L. (2012a). No own-age bias in 3-year-old children: more evidence for the role of early experience in building face-processing biases. *Journal of Experimental Child Psychology,* 113(3), 372–82.

Macchi Cassia, V., Pisacane, A., & Gava, L. (2012b). No own-age bias in 3-year-old children: more evidence for the role of early experience in building face-processing biases. *Journal of Experimental Child Psychology, 113*(3), 372–82.

Macchi Cassia, V., Proietti, V., & Bricolo, E. (under review). Searching for faces of different ages: evidence for an experienced-based own-age detection advantage in adults.

Macchi Cassia, V., Proietti, V., & Pisacane, A. (2013). Early and later experience with one younger sibling affects face processing abilities of 6-year-old children. *International Journal of Behavioral Development, 37*(2), 160–165.

Macchi Cassia, V., Simion, F., & Umiltà, C. (2001). Face preference at birth: The role of an orienting mechanism. *Developmental Science, 4*, 101-108.

Malpass, R. S., Lavigueur, H., & Weldon, D. E. (1973). Verbal and visual training in face recognition. *Perception & Psychophysics, 14*(2), 285–292.

Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly : threat detection is not impaired among older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 61*(1), 54–57.

Maurer, D., Grand, R. Le, & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6*(6), 255–260.

Maurer, D., & Werker, J. F. (2014). Perceptual narrowing during infancy: a comparison of language and faces. *Developmental Psychobiology, 56*(2), 154–78.

McGugin, R. W., Tanaka, J. W., Lebrecht, S., Tarr, M. J., & Gauthier, I. (2011). Race-specific perceptual discrimination improvement following short individuation training with faces*. Cognitive Science, 35*(2), 330–47.

McKone, E., Kanwisher, N., & Duchaine, B. C. (2007). Can generic expertise explain special processing for faces? *Trends in Cognitive Sciences, 11*(1), 8–15.

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

Melinder, A., Gredebäck, G., Westerlund, A., & Nelson, C. a. (2010). Brain activation during upright and inverted encoding of own- and other-age faces: ERP evidence for an own-age bias. *Developmental Science,* 13(4), 588–98.

Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli, 36(4), 630–633.

Nelson, C. A. (2001). The development and neural bases of face recognition. *Infant and Child Development, 10*(1-2), 3–18.

Öhman, A. (1993). Fear and anxiety as emotional phenomena: Clinical phenomenology, evolutionary perspectives, and information processing mechanisms. In M. Lewis & J.M. Haviland (Eds.) *Handbook of emotions* (pp. 511-536). New York: Guilford Press

Öhman, A., Lundqvist, D., & Esteves, F. (2001a). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology*, *80(*3), 381–396.

Öhman, A., Lundqvist, D., & Esteves, F. (2001b). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*, 381-396.

Oshima-Takane, Y., Goodz, E., & Derevensky, J. L. (1996). Birth Order Effects on Early Language Development: Do Secondborn Children Learn from Overheard Speech? *Child Development, 67*(2), 621–634.

Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact*. Neuropsychologia, 45*(1), 75–92.

Pascalis, O., de Haan, M., & Nelson, C. A. (2002). Is face processing species-specific during the first year of life? *Science*, *296*(5571), 1321-1323.

Perfect, T. J., & Harris, L. J. (2003). Adult age differences in unconscious transference: source confusion or identity blending*? Memory & Cognition, 31*(4), 570–80.

Peykarjou, S., Pauen, S., & Hoehl, S. (2014). How do 9-month-old infants categorize human and ape faces? A rapid repetition ERP study. *Psychophysiology, 51*(9), 866–78.

Peykarjou, S., Westerlund, A., Macchi Cassia, V., Kuefner, D., & Nelson, C. a. (2013). The neural correlates of processing newborn and adult faces in 3-year-old children. *Developmental Science, 16*(6), 905–14.

Picozzi, M., Cassia, V. M., Turati, C., & Vescovo, E. (2009). The effect of inversion on 3- to 5-year-olds' recognition of face and nonface visual objects. *Journal of Experimental Child Psychology, 102*(4), 487–502.

Proietti, V., Macchi Cassia, V., & Mondloch, C. J. (2014). The own-age face recognition bias is task dependent. *British Journal of Psychology*.

Proietti, V., Pisacane, A., & Macchi Cassia, V. (2013). Natural experience modulates the processing of older adult faces in young adults and 3-year-old children. *PLoS ONE, 8*, e57499.

Proverbio, A.M., De Gabriele, V., Manfredi, M., & Adorni, R. (2011). No race effect (ORE) in the automatic orienting toward baby faces: when ethnic group does not matter. *Psychology, 2,* 931-935.

Rennels, J. L., & Davis, R. E. (2008). Facial experience during the first year. *Infant Behavior & Development, 31*(4), 665–78.

Rhodes, G., & Anastasi, J. S. (2012). The own-age bias in face recognition: a meta-analytic and theoretical review. *Psychological Bulletin, 138*(1), 146–74.

Rhodes, G., Brake, S., Taylor, K., & Tan, S. (1989). Expertise and configural coding in face recognition. *British Journal of Psychology*, *80*(3), 313-331.

Rhodes, G., Jeffery, L., Taylor, L., Hayward, W. G., & Ewing, L. (2014). Individual differences in adaptive coding of face identity are linked to individual differences in face recognition ability, *Journal of Experimental Psychology: Human Perception and Performance*, 40(3), 897–903.

Rhodes, M.G., Locke, V., Ewing, L., & Evangelista, E. (2009). Race coding and the other-race effect in face recognition. *Perception, 38*, 232-241

Rhodes, G., Tan, S., Brake, S., & Taylor, K. (1989). Expertise and configural coding in face recognition. *British Journal of Psychology*, *80*(3), 313–331.

Righi, G., Westerlund, A., Congdon, E. L., Troller-Renfree, S., & Nelson, C. a. (2014). Infants' experience-dependent processing of male and female faces: insights from eye tracking and event-related potentials. *Developmental Cognitive Neuroscience, 8*, 144–52.

Rodin, M. J. (1987). Who is memorable to whom: a study of cognitive disregard. *Social Cognition, 5*(2), 144–165.

Rossion, B. (1999). Spatio-temporal localization of the face inversion effect: an event-related potentials study. *Biological Psychology, 50*(3), 173–189

Rossion, B., & Caharel, S. (2011). ERP evidence for the speed of face categorization in the human brain: Disentangling the contribution of low-level visual cues from face perception. *Vision Research, 51*(12), 1297–311.

Rossion, B., & Gauthier, I. (2002). How does the brain process upright and inverted faces? *Behavioral and cognitive neuroscience reviews, 1*(1), 63–75.

Ruble, D. N., Martin, C. L., & Berenbaum, S. A. (1998). Gender development.*Handbook of child psychology*.

Sangrigoli, S., & de Schonen, S. (2004). Effect of visual experience on face processing: a developmental study of inversion and non-native effects. *Developmental Science,* 7(1), 74–87.

Sangrigoli, S., Pallier, C., Argenti, a-M., Ventureyra, V. a G., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood*. Psychological Science, 16*(6), 440–4.

Scherf, K. S., & Scott, L. S. (2012). Connecting developmental trajectories: biases in face processing from infancy to adulthood. *Developmental Psychobiology, 54*(6), 643–63.

Schwarzer, G., Zauner, N., & Jovanovic, B. (2007). Evidence of a shift from featural to configural face processing in infancy. *Developmental Science, 10*(4), 452–63.

Schweinberger, S. R., Pfütze, E.-M., & Sommer, W. (1995). Repetition priming and associative priming of face recognition: Evidence from event-related potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(3), 722–736.

Scott, L. S., & Monesson, A. (2009). The origin of biases in face perception. *Psychological Science*, *20*(6), 676-680.

Scott, L. S., & Monesson, A. (2010). Experience-dependent neural specialization during infancy. *Neuropsychologia, 48*(6), 1857–61.

Scott, L. S., & Nelson, C. a. (2006). Featural and configural face processing in adults and infants: A behavioral and electrophysiological investigation. *Perception, 35*(8), 1107–1128.

Scott, L. S., Pascalis, O., & Nelson, C. A. (2007). A Domain-General Theory of the Development of Perceptual Discrimination. *Current Directions in Psychological Science, 16*(4), 197–201.

Short, L. a, & Mondloch, C. J. (2010). The importance of social factors is a matter of perception. *Perception, 39*(11), 1562–1564.

Short, L. a, & Mondloch, C. J. (2013). Aging faces and aging perceivers: Young and older adults are less sensitive to deviations from normality in older than in young adult faces. *Perception, 42*(8), 795–812.

Short, L. a, Mondloch, C. J., & Hackland, A. T. (2015). Attractiveness judgments and discrimination of mommies and grandmas: Perceptual tuning for young adult faces. *Journal of Experimental Child Psychology, 129*, 1–11.

Short, L.A., Semplonius, T., Proietti, V. & Mondloch, C.J. (in press). Differential attentional allocation and subsequent recognition for young and older adult faces. *Visual Cognition.*

Spangler, S. M., Schwarzer, G., Freitag, C., Vierhaus, M., Teubert, M., Fassbender, I., Lohaus, A., Kolling, T., Graf, F., Goertz, C., Knopf, M., Lamm, B., & Keller, H. (2013). The other-race effect in a longitudinal sample of 3-, 6- and 9-month-old infants: evidence of a training effect. *Infancy*, *18*(4), 516–533.

Sporer, S.L. (2001). Recognizing faces of other ethnic groups: An integration of theories. *Psychology, Public Policy and Law, 7,* 36-97.

Streri, A., & Féron, J. (2005). The development of haptic abilities in very young infants: From perception to cognition. *Infant Behavior and Development, 28*(3), 290–304.

Sugden, N. a, Mohamed-Ali, M. I., & Moulson, M. C. (2014). I spy with my little eye: typical, daily exposure to faces documented from a first-person infant perspective. *Developmental Psychobiology, 56*(2), 249–61.

Susa, K. J., Meissner, C. A., & de Heer, H. (2010). Modeling the role of social-cognitive processes in the recognition of ownand other-race faces. *Social Cognition, 28,* 523-537.

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: evidence from a cross-cultural study. *Cognition, 93*(1), B1–9.

Tanaka, J. W., & Pierce, L. J. (2009). The neural plasticity of other-race face recognition, *Cognitive, Affective, & Behavioral Neuroscience*, *9* (1), 122–131.

Thompson-Booth, C., Viding, E., Mayes, L.C., Rutherford, H.J.V., Hodsoll, S., & McCrory, E.J. (2013). Here's looking at you, kid: attention to infant emotional faces in mothers and non-mothers. *Developmental Science, 17,* 35-46.

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review, 95,* 15-48.

Turati, C., Di Giorgio, E., Bardi, L., & Simion, F. (2010). Holistic face processing in newborns, 3-month-old infants, and adults: evidence from the composite face effect. *Child Development*, 81(6), 1894–905.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology, 43*(2), 161–204.

Valentine, T., & Endo, M. (1992). Towards an Exemplar Model of Face Processing: The Effects of Race and Distinctiveness *The Quarterly Journal of Experimental Psychology, 44*(4), 671–703.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of experimental psychology*, *81*(1), 141.

Young, S. G., & Hugenberg, K. (2011). Individuation Motivation and Face Experience Can Operate Jointly to Produce the Own-Race Bias. *Social Psychological and Personality Science, 3*(1), 80–87.

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The categorization-individuation model: an integrative account of the other-race recognition deficit*. Psychological review, 117*(4), 1168.

Young, S.G., Hugenberg, K., Bernstein, M.J., & Sacco, D.F. (2012). Perception and motivation in face recognition: a critical review of theories of the cross-race effect. *Personality and Social Psychology Review, 16,* 116-14

Yovel, G., Halsband, K., Pelleg, M., Farkash, N., Gal, B., & Goshen-Gottstein, Y. (2012). Can massive but passive exposure to faces contribute to face recognition abilities? *Journal of Experimental Psychology. Human Perception and Performance, 38*(2), 285–9.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*(1), 49–63.

Wiese, H., Komes, J., & Schweinberger, S. R. (2012). Daily-life contact affects the own-age bias and neural correlates of face memory in elderly participants. *Neuropsychologia, 50*(14), 3496–508.

Wiese, H., Komes, J., & Schweinberger, S. R. (2013). Ageing faces in ageing minds: A review on the own-age bias in face recognition. *Visual Cognition*, *21*(9-10), 1337-1363.

Wiese, H., Schweinberger, S. R., & Hansen, K. (2008). The age of the beholder: ERP evidence of an own-age bias in face memory. *Neuropsychologia,* 46(12), 2973–85.

Wright, D. B., & Stroud, J. N. (2002). Age differences in lineup identification accuracy: people are better with their own age. *Law and Human Behavior, 26*(6), 641–54.

Zheng, X., Mondloch, C. J., & Segalowitz, S. J. (2012). The timing of individual face recognition in the brain. *Neuropsychologia, 50*(7), 1451–61.

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