LEARNING FROM EXPERIENCE:

EXPOSURE TO, ATTENTION TO, DISCRIMINATION OF, AND BRAIN RESPONSE TO FACES AT 3, 6, AND 9 MONTHS

By

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Abstract

Infants learn and develop immensely in the first year of life. They show substantial learning in their ability to use the information provided by faces. Faces are important stimuli in infants' world and infants reliably prefer faces over other visual stimuli (Fantz, 1963). While experience likely plays a role in infants' early face processing, little is known about how infants' natural exposure to faces shapes attention and learning. We use head-mounted infant-perspective cameras to capture infants' natural experience with faces. We also measured infants' attentional preference for, ability to discriminate between, and electrical brain response to familiar (i.e., female, own-race) and unfamiliar (i.e., male, other-race) face types. Infants' face experience was highly homogenous: their primary caregiver's face represents the 57% of infants' experience and was present in all locations and nearly all contexts. Infants' other caregiver represented only 11% of their face experience, but was also highly consistent across location and context. Infants showed greater visual attention to female faces of familiar race at 3 months, but not later. They showed no race preference at any age. At 3 months, infants discriminated all face types except for male own-race faces. At 6 months, infants discriminated all face types. At 9 months infants discriminated all face types except for male other-race faces. Electrical brain response only differentiated male from female faces at 6 months, not at 3 or 9 months; there was no effect of race at any age. This may be due to the immaturity of the early face processing system or differential processing being indexed at later attentional components. Infants' overall face exposure, mom face exposure, and attentional preference for female faces predicted female own-race face discrimination at 3 months, accounting for 62% of the variance. Exposure to male faces correlated with attention to male faces and attention to male faces predicted discrimination of male faces at 3 months, accounting for 11% of the variance. At 6 months dad face exposure predicted discrimination of male faces, accounting for 17% of the variance. Infants' early experience, particularly to caregivers' faces, tunes infants' attention to faces, which in turn predicts discrimination.

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Dedication

To my Dad

Robert (Bob) Charles Sugden

November 30, 1941 - September 21, 2011

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Chapter 1 Introduction

What shapes early learning? Infants grow, develop, and learn immensely throughout the first year of life. There is no doubt that multiple factors determine how and what infants learn. It is likely that these factors interact at any given time as well as across developmental time. Infants' early experience is likely a catalyst of early learning, with input determining how and what infants learn. To consider this question, however, a model system is required with clear inputs, an established developmental trajectory, measurable behavioural outcomes, and known neural correlates. The face processing system is an ideal system to model early learning for 3 reasons: faces are visual stimuli that can be quantified in infants' early experience (e.g., Sugden, Mohamed-Ali, & Moulson, 2014), the developmental trajectory for face processing (i.e., attention and discrimination) has been well established in the literature (e.g., D. J. Kelly, Quinn, et al., 2007; Liu et al., 2015), and there are measurable brain responses specific to faces (e.g., de Haan & Nelson, 1999). Although natural, daily exposure to faces likely relates to later face processing abilities, no study has yet linked infants' typical experiences with later attentional preference, discrimination, and brain response to faces. Although these outcome processes of faces are typically considered separately, none of them develops independently of the other. Consequently, here we consider all three of these outcome measures to describe how they change over time within the same cohort of children. It could be that early exposure shapes infants' attention, directing their attention preferentially towards some over other stimuli. It may also be that early experience influences infants' ability to discriminate between different exemplars. Experience may also shape early brain development. We will start with an overview of infants' early experience, attention, learning, and brain development. Then we will propose how we anticipate these relate to each other to create smart, dynamic learning in infancy.

General overview of infant learning

From birth to their first birthday, infants metamorphose. At birth, they have limited ability to voluntarily move their eyes, head, and limbs. They have a limited ability to communicate their needs. Their vision is poor (Gelskov & Kouider, 2010) and they have difficulty parsing visual objects from the background (Takashima, Kanazawa, Yamaguchi, & Shiina, 2014). They are entirely dependent on their caregivers. They do, however, have some internal biases that shape their behaviour. For example, they have grasping and sucking motor reflexes, which likely help in keeping them near to their caregivers and well fed. They prefer areas of high contrast over low contrast and particular forms over others, likely as a consequence of their visual constraints (Fantz, 1961b, 1963, 1965). The high and low contrast areas must be sufficiently visible (i.e., fewer cycles per degree, de Heering et al., 2008). Despite their poor vision they prefer visual stimuli that have more items in the upper visual field and that include a symmetric contour (Fantz & Miranda, 1975; Simion, Macchi Cassia, Turati, & Valenza, 2001), a visual bias that may drive their early preference for faces. From birth onwards, they learn how to control their limbs, direct their eyes, and understand the people they experience in their world.

Why faces? Face processing develops early and progresses in a typical trajectory, with substantial, important development within the first year of life. Faces are a preferred stimulus in early life, although this preference for faces declines in later infancy (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991). Hours after birth, infants are able to discriminate between faces (e.g., mom’s face, Bushnell, 2001) and within mere months show improvement in ability to discriminate between faces within familiar categories (e.g., other-race faces, Kelly et al., 2007). This further refines as they accrue experience (e.g., children starting school, De Heering, Bracovic, & Maurer, 2014). Most typical adults have become face experts (Yin, 1969). The fact that nearly all of us develop this expertise speaks to its importance. Using their face processing skills adaptively, infants extract information from faces (e.g., emotions, Leppänen & Nelson, 2009) and use information gleaned from faces to direct their own behaviour (e.g., gaze, Brand, Shallcross, Sabatos, & Massie, 2007).

Babies learn from their environment. Infants learn from the experiences they receive. This is visible across many domains in infancy. For example, early language learning is dependent on the types of input that infants receive in the first year of life, e.g., phonetic processing (Kuhl et al., 2006) . The same is true of infants' preference for music (Trehub, 2001). Experimentally changing the oral input changes infants' capacities (e.g., language; Kuhl, Tsao, & Liu, 2003). Similarly in the motor domain, natural changes in motor experiences can drive infants' experience of (Kretch, Franchak, & Adolph, 2013), processing of visual stimuli in (Cashon, Ha, Allen, & Barna, 2013), and interaction with (Karasik, Tamis-LeMonda, & Adolph, 2011) their world. As with language and other capacities, providing experimental exposure to motor experiences before infants show this capacity also changes infants' attention to and interaction with their visual world (Libertus & Needham, 2011; Needham, Barrett, & Peterman, 2002). Within the domain of face perception, experience drives infants' ability with faces (e.g., mom's face, Bushnell, 2001) and experimental changes to this experience changes infants' face processing (e.g., other-race faces, Anzures et al., 2012).

Early visual development requires experience: lessons from atypical development

Unlike the auditory system, which begins its development in utero (Graven & Browne, 2008), infants' patterned visual experience begins at birth with the infant visual system showing increased acuity over development (Dobson & Teller, 1978). At birth infants also show a preference for face-like schematic stimuli (Fantz, 1963; Goren et al., 1975; Johnson et al., 1991). Although it is likely that experience is playing a role in this development, typical development makes it difficult to tease apart the role of experience from maturation. Perturbations of early experience are more informative.

Disruption in early visual input has been found to seriously impact the visual and face processing system throughout childhood and into adulthood, despite years of normal input. Highlighting the importance of experience, Maurer and colleagues have studied adults who did not receive typical patterned visual input to faces, due to bilateral congenital cataracts that fully blocked infants' retinas. One hour and one month after the cataracts are removed, infants show rapid improvement in their visual acuity (Maurer, Lewis, Brent, & Levin, 1999). This increase is unrelated to the length of the deprivation or age of the infant, suggesting that the visual system requires patterned visual input and, once it receives this input, rapidly takes advantage of it. It also suggests that development, without input, is not effectively changing the visual system. Infants' pattern of preference for faces also shows a delay. Infants between 5 and 25 weeks old show a pattern of preference for schematic over realistic faces in the first hour of having their cataracts removed (Mondloch, Lewis, Levin, & Maurer, 2013), a pattern that is typical of newborns.

Combined with the results for acuity, this suggests that their visual system is behaving as if it were the system of a newborn infant.

Despite this rapid increase in acuity, patients show permanent acuity deficits (Maurer & Lewis, 2001). In adulthood, they show a pattern of deficits in remembering and recognizing faces that is similar to that of adults with developmental prosopagnosia (de Heering & Maurer, 2014). Like infants (Mondloch, Geldart, Maurer, & Grand, 2003), patients have greater difficulty recognizing faces over changes in orientation (i.e., if they initially see a face in frontal view, they cannot still recognize that face if it later is presented in a profile view; Geldart, Mondloch, Maurer, De Schonen, & Brent, 2002). Patients also show deficits in face processing, using more immature face processing strategies overall (Le Grand, Mondloch, Maurer, & Brent, 2001, 2004; Robbins, Nishimura, Mondloch, Lewis, & Maurer, 2010). This pattern differs from adults with developmental prosopagnosia, who do not show deficits on maturity of face processing (i.e., holistic as compared to featural processing). Patients also show immature patterns in their discrimination of facial expressions of emotion, rating emotions more like 7-year-olds than like adults (Gao, Maurer, & Nishimura, 2013). Typically emotion discrimination continues to develop beyond the age of 10 (Gao & Maurer, 2010.)

Not all areas of face perception are deleteriously affected by early deprivation. Patients do not differ from control participants in their ability to detect faces (Mondloch, Segalowitz, et al., 2013), a capacity also spared in developmental prosopagnosia (Le Grand et al., 2006). Patients are equally able to recognize monkey faces (de Heering & Maurer, 2014; Robbins et al., 2010) and are superior in their recognition of inverted faces (de Heering & Maurer, 2014), as compared to typically developed adults. Furthermore, there is some plasticity left in the adult system; training with visually diverse video-games improves some of the deficits (e.g., acuity, contrast sensitivity, global motion, and face recognition, Jeon, Maurer, & Lewis, 2012).

This pattern is consistent with studies on infants and children who suffered early deprivation by being homed in orphanages; they show deficits in visual attention and memory for faces despite having received visual input from birth (Pollak et al., 2010). Despite showing normal face recognition, institutionalized children also show differences in electrical brain response to faces (Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009; Parker, Nelson, & The Bucharest Early Intervention Project Core Group, 2005a) and to facial expressions of emotion (Moulson, Fox, Zeanah, & Nelson, 2009; Parker, Nelson, & The Bucharest Early Intervention Project Core Group, 2005b). Children who moved from the institutions into foster care showed nearer-to but not-quite normal brain response. That these infants had visual experience from birth suggests that experience alone is insufficient to tune the developing system; the type of experience also matters. Since the visual world of the institutionalized children was restricted and had reduced adult-infant face-to-face interactions, it is likely that diversity of experience and face experience both play a role in early visual development.

Maurer argues that early deprivation has ‘sleeper effects’, with early experience setting the stage and establishing neural architecture for later capacities that do not come online until much later in development (Maurer, Mondloch, & Lewis, 2007). Although the system does show recovery and, at some stages, may show no difference as compared to children or adults who had not undergone a period of deprivation, this recovery has upper limits that are sometimes not evident until much later in life (T. L. Lewis & Maurer, 2009). Consistent with this, there are differences between typically developed adults and patients’ electrical brain response (components P100 and N170) to faces; patients’ responses were greater in amplitude, with the degree of the difference related to the length of their early visual deprivation (Mondloch, Segalowitz, et al., 2013). But what does early visual experience look like and how does it tune the early visual and face processing system in typical development?

Typical exposure

While experimental and correlation evidence suggests experience can influence the development of face processing, appreciating infants’ experience is key to understanding how infants naturally learn about faces. Parents’ assessments of the faces to which their infants were exposed during the first year of life suggests that infants are primarily exposed to female, adult, own-race faces, such as those of their primary caregiver (Rennels & Simmons, 2008). This first empirical assessment of infants’ natural exposure to faces supports the view that differential experience is likely at the root of differential processing. Adult-perspective questionnaires, however, are limited in how much they can capture. To truly appreciate what underlies how infants learn about faces requires documentation of how they experience these faces in their day-to-day lives.

The infant-perspective. To understand infants' natural experiences, an infant perspective is required. Using head-mounted child-perspective camera, Smith and colleagues have documented that an adult perspective cannot provide an understanding of the unique perspective of a child (Smith, Yu, & Pereira, 2011). While the child's point of view is influenced both by their parent (Yu & Smith, 2013) and themselves (K. H. James, Jones, Swain, Pereira, & Smith, 2014), only the child's perspective is predictive of what a child will learn (Yurovsky, Smith, & Yu, 2013). From the wealth of rich data recorded from a first-person perspective, it is episodes of clear sensory input, discernable only from the child's perspective, that have been found to facilitate learning (Pereira, Smith, & Yu, 2014). Similarly, documenting infants' daily lives with head-mounted cameras provides rich data on their natural experiences with faces (Sugden, Mohamed-Ali, & Moulson, 2014; Sugden, 2012). Based on Smith and colleagues' work, we suggest that it is likely that infants' experiences with faces, recorded from the infant's perspective, will be predictive of what infants will learn.

Although infants indubitably learn during experimental lab tasks, this is not the context in which they do the majority of their learning. The lion's share of infants' learning happens at home, with parents, during their natural, daily, experiences. It is in this experience that specific faces and particular face types become familiar. What does this early visual world look like? Early visual experience contains faces one-quarter of the time (Sugden et al., 2014). This is in stark contrast to the adult experience, where only 11% includes faces (Sugden, 2012). The faces that infants experience are primarily female, own-race, and own-age (Sugden et al., 2014). Much of this face experience is represented by three faces (Jayaraman, Fausey, & Smith, 2015), particularly mom and other caregivers (Rennels & Simmons, 2008). Faces are typically presented in a way that facilitates early processing: near, upright, alone in the field of view, and facing towards the infant (Sugden & Moulson, 2016). This likely ensures that infants attend to the face – they can do nothing else in the majority of cases since the face occupies all or the majority of their field of view. Three-month-olds presented with a face so near as to prevent them from being able to see anything except for the face are not capable of moving themselves and, consequently, cannot change this visual input. Synthesizing this, the early environment can be characterized as structured to facilitate early learning of faces: infants are primarily exposed to a few faces, repeatedly, and clearly. The faces capture infant attention through this exposure because infants *cannot help but attend*. This is the first step in early learning: learning the aspects of the world to which to attend.

Attention

Infants can and do deploy their visual attention in a coordinated fashion moments after birth. At birth, infants can move their head, albeit with difficulty, and their eyes (as described in Johnson et al., 1991). This limited ability to coordinate and control their attention provides a mechanism by which to measure how infants deploy their attention and to what type of stimuli within their visual environment, a mechanism exploited by the preferential looking paradigm developed by Fantz (Fantz, 1961a). In this paradigm, infants are presented with two visual stimuli. If they visually fixate one stimulus more than another, then it can be inferred that they can discriminate between the two and visually prefer the one to which they dedicated a greater amount of looking. From this basic motor capacity, infants' differential visual attention was first used to measure infants' early visual and perceptual capacities (e.g., Fantz, 1963, 1965; Fantz & Miranda, 1975; Fantz & Nevin, 1967). One of the first visual stimuli infants reliably recognize and prefer are faces (Johnson et al., 1991). Despite the challenges infants experience in coordinating their eye and head movements, they also show a greater visual attention to faces and will expend efforts, by moving their head and eyes, to maintain a face in their field of view (Goren et al., 1975; Johnson et al., 1991). That infants show early volitional attention to faces suggests these are important features in their visual experience.

Attention is flexible. Infants' visual attention is not rigid. Visual attention changes on both large and small time-scales. On smaller time-scales, infants' visual attention changes within a test of visual attention. Infants show an initial preference for the familiar followed by a novelty preference (Fantz, 1964). This was initially believed to be related to age, with younger infants generally showing a preference for familiar stimuli and older infants generally showing a preference for novel stimuli (Wetherford & Cohen, 1973). Although it is generally true that older infants show a novelty preference sooner than do younger infants, this is related to the amount of exposure that they have had to the familiar stimulus prior to the introduction to the novel (Hunter, Ames, & Koopman, 1983). The preference for the familiar persists only until infants have had an opportunity to fully process the stimulus, after which they show a preference for the novel (Hunter & Ames, 1988). When this shift happens depends not just on age, but also depends on the properties of the stimulus (e.g., complexity, Hunter et al., 1983).

Influences on attention. Faces are complex stimuli; evidence argues that attention to faces follows these same rules of novelty and familiarity. Within a few hours of birth, infants show a preference for their mother's face, however this preference depends on the amount of exposure they have received to their mother's face (Bushnell, 2001). Infants without sufficient exposure seem unable to recognize their mother. After 6 months of exposure to their mother’s face, they no longer show a preference for their mother's face over that of an unknown female (de Haan & Nelson, 1997). At 3 months, infants show a preference for female (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002), own-race (D. J. Kelly et al., 2005), and own-species faces (Heron-Delaney, Wirth, & Pascalis, 2011a). Although this is presumably because infants rarely see male, other-race, and other-species faces, early experience has not been measured and related to this preference. Furthermore, infants appear to be able to classify faces by gender and consequently show a preference for female over male faces if the infant has a female primary caregiver but show a preference for males if not (Quinn et al., 2002). This preference for female depends on the race of the face because although own-race female faces are preferentially attended, infants do not show greater visual attention to female faces over male faces if the faces are other-race (Quinn et al., 2008). This is also true with faces of different races. Three-month-old infants show a preference for own-race faces (Fassbender, Teubert, & Lohaus, 2016; Liu et al., 2015), suggesting that they are still learning about and processing this familiar face type. At 6 months, however, there is no evidence for preference for own- or other-race faces. By 9 months, infants' visual attentional preference has reversed from own-race to other-race, suggesting not just categorization but also adequate processing of the familiar face category.

Trajectories of attention. Understanding these trajectories of attention is important because of what they suggest about learning. Since infants show a familiarity preference until the face has been sufficiently processed, after which infants show a novelty preference, the point at which infants transition from a preference for familiar to a preference for novel suggests the point at which infants have adequately processed and learned the face or face type. This operates on small time-scales, such as within familiarization, habituation, and discrimination tasks whereby infants show a preference for familiar stimulus until they have processed it sufficiently, at which point they prefer the novel (e.g., Fantz, 1964; Fantz & Nevin, 1967).. This may also operate on larger time-scales as well, for example when infants have learned enough about particular face types (e.g., as female or male, own-race or other-race). For example, infants understand females and males as different, as demonstrated through their preference for female and categorization of faces by gender (Anzures, Quinn, Pascalis, Slater, & Lee, 2010), and that own- and other-race faces are different, as demonstrated through their categorization of faces by race (Quinn, Lee, Pascalis, & Tanaka, 2016). If face experience on the larger timescale operates similarly to that on the smaller timescale, then it is only after sufficient experience with faces of different types that infants will show reliable differences in attention.

Attention and exposure. It is likely that infants' visual attention to faces is shaped by exposure. This was measured in newborns, with a positive correlation between exposure to and attention to mom's face (Bushnell, 2001). No direct measure of exposure has been linked to attention later in infancy; only indirect evidence exists. The trajectory of preference argues for the link between exposure and attention. Infants' pattern of preference suggests that exposure is likely driving infants' visual attention. At 3 months, the preference reflects the most primary-caregiver-like faces: female and own-race. At 3 months, infants' face exposure is nearly exclusively own-race and nearly three-quarter female (Sugden et al., 2014). Whether and how exposure shapes infants' attention to faces is an empirical, testable question that has yet to be answered. This potentially-exposure-driven attention presages later patterns of visual discrimination of faces.

Discrimination

Infants' ability to discriminate faces is important, particularly so that they can recognize the important people in their environment. During the first year, infants' face processing changes from a general ability with all face types to specialization with a restricted range of faces. One of the most important people for infants to learn is their mother and, within a few hours after birth, infants can recognize their mother (Bushnell, 2001). It is not, however, until few months later, they can recognize their father (Ward, 1999). In addition to being able to discriminate their caregiver's face, infants also show an ability to discriminate the faces of other individuals. At 3 months, infants are surprisingly flexible – showing an ability to discriminate faces of all races (D. J. Kelly, Quinn, et al., 2007). This is despite their preferential attention to own-race faces at this age (D. J. Kelly et al., 2005). This pattern of face 'generalist', discriminating amongst faces regardless of prior experience, does not persist. At 6 months, however, they continue to show discrimination of own-race faces, but their ability to discriminate other-race faces is reduced in scope (i.e., discriminating between only some other-race faces, (D. J. Kelly, Quinn, et al., 2007). Despite this differential discrimination, they show no race-based visual preference at this age (Fassbender et al., 2016; Liu et al., 2015). At 9 months infants' ability to discriminate faces has narrowed to exclusively own-race faces (D. J. Kelly, Quinn, et al., 2007), even though infants show a greater preference for other-race faces at this age (Fassbender et al., 2016; Liu et al., 2015). Similarly, at 3 months, infants are able to discriminate faces of many difference species at both behavioural (e.g., preference looking) and neural levels, but at 9 months, their ability to discriminate faces of other species is reduced or even eliminated at behavioural level (e.g., monkey faces, Pascalis et al., 2005), although neural activity, as measured by event-related potentials (ERP), still shows discrimination (Scott, Shannon, & Nelson, 2006). The way in which infants develop their preference for and ability to discriminate between faces of particular types suggests that experience is driving this early skill. This change in discrimination has been characterized as perceptual narrowing: maintenance or improvement in the discrimination of the face types to which infants have the most exposure and stagnation or reduction in ability to discriminate between face types to which they likely have little or no exposure (Scott, Pascalis, & Nelson, 2007).

Equally possible is a more nuanced relationship, contingent on the type of exposure. While the clearest results for the effects of experience exist for other-race, gender, and other-species faces, changes in processing of faces based on face orientation and face age that likely relate to experience have also been documented. It has been suggested that we receive exposure to faces primarily in a canonical, upright orientation, which leads to the “inversion effect” (i.e., greater facility with upright than inverted faces; Yin, 1969). However, we encounter inverted faces relatively more frequently in childhood (e.g., through play) which may explain how our ability to recognize inverted faces is superior in childhood relative to infancy and adulthood (for review, see Valentine, 1988). Similar to the other-race effect, an experience-dependent other-age effect has been described in children (>5 years old) and adults whereby ability with faces of different ages relates to either early or recent exposure with faces of those types (for review see Rhodes & Anastasi, 2012; Wiese, Komes, & Schweinberger, 2013). Across multiple ages and face types, evidence suggests that exposure drives processing. At the extremes of no exposure and 100% exposure, it only makes sense that exposure would predict discrimination. Within these boundaries the relationship is less clear and has not been measured. It is possible that exposure and ability have a 1:1 relationship.

Neurological indices of face processing

The ability to discriminate between faces of different types is not uniquely evident behaviourally. Given the challenges with working with infants and the challenges infants have evidencing their early capacities, a second method that has been used to explore differences in infants' processing has been the use of electroencephalogram (EEG). Methods with higher spatial resolution (e.g., functional magnetic resonance imaging) that would provide specificity of the brain areas active during face processing are typically not tolerated by infants. EEG is a non-invasive measure of infants' electrical brain activity recorded from electrodes placed on the scalp. It has excellent temporal resolution, measuring millisecond-by-millisecond changes in brain activity. EEGs can also be tied to specific events, in which case the EEG signals are termed Event-Related Potentials (ERPs). Both infants and adults demonstrate components indicative of exposure to a visual stimulus, component P1 (Itier & Taylor, 2004; Macchi Cassia, Kuefner, Westerlund, & Nelson, 2006). Further, both infants and adults evidence face-related ERP components (the adult N170 and the infant N290 and P400) that differentiate faces from other visual stimuli (de Haan & Nelson, 1999; Ganis, Smith, & Schendan, 2012). Both the N290 and the P400 have been argued to be precursors of the adult N170 (de Haan, Johnson, & Halit, 2003). They occur over occipital and temporal regions of the scalp, however the area(s) of the brain from which they originate is unclear. The adult N170, which is also typically measured from occipital and temporal scalp electrodes and has been localized to the fusiform gyrus, differentiates upright from inverted faces and familiar from unfamiliar faces (Balas et al., 2010; Bruno Rossion & Gauthier, 2002). Infant face-specific ERP components, N290 and P400, differ between familiar and unfamiliar face types (Balas, Westerlund, Hung, & Nelson, 2011), suggesting a role for experience in shaping infants' brain response to faces.

Changes in face processing

There is evidence that a change in experience may change the face types with which we show facility. Natural exposure in later life has been found to change children's ability to discriminate between faces that were previously infrequently-experienced. Korean children adopted from Korea by Caucasian families in France when they were between 3 to 9 years old show a facility with Caucasian faces, but not with Korean faces; their lack of ability to discriminate between Korean faces and superior ability discriminating Caucasian faces was comparable to that of Caucasians born in France (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). This suggests that there is some flexibility, in that narrowing can be reversed by substantial changes in face exposure in childhood.

Experimentally changing the types of faces to which infants are exposed can also change the typical trajectory of narrowing. Experimental enhancement of infants' exposure to otherwise infrequently-experienced faces (i.e., other-species faces through the use of a picture book) led to a continuing ability to discriminate between other-species faces at 9 months of age (Pascalis et al., 2005). More importantly, this was not a function of exposure alone. The typical trajectory of behavioural and ERP indices of narrowing only changed when the parents read the picture-book to the infants using individual-level labels (i.e., each face was given their own name; e.g., 'Preston', 'Ragnar', 'Wilmot'…), not category-level labels (i.e., all faces were labeled as 'monkey') (Scott & Monesson, 2009, 2010). Early individual-level training with unfamiliar face types has lasting effects. Tested 3-5 years later, children who received training on unfamiliar category types evidenced a behavioural advantage and more mature electrical brain response to faces (Hadley, Pickron, & Scott, 2015). It suggests that the brief training that they received re-organized how they processed faces at the neural level, an effect that persisted despite their having discontinued training long before.

Mechanisms of development.

We know that infants receive a lot of experience with faces and that experience can be used to alter the typical developmental trajectory of face processing, but what we do not know is how infants' typical, natural experience with faces relates to their face-processing abilities, as indexed by attention and discrimination. Further, we do not know how attention, discrimination, and electrical brain activity in response to certain face types relate to each other and to infants' natural exposure to faces. Finally, we do not know what types of natural experiences are most powerful in shaping infants' face processing. The relation between attention and discrimination has been proposed but evidence for it is still missing. Studies have shown that infants' likely exposure to faces (e.g., to females if they have a female primary caregiver) relates to their preference (Quinn et al., 2008). Similarly, studies have shown that this exposure relates to their discrimination of faces (Pascalis et al., 2005). Very little is known about the relation between these metrics of face processing. We don't have a good characterization of how attention mediates relation between exposure and discrimination ability because these two measures are not typically both used in the same study with the same infants. One of the goals of the current dissertation is to explore the relationship between attention and discrimination. Several theoretical perspectives suggest that there should be a relationship between exposure and discrimination. Some of these theories also argue that exposure and discrimination should relate to attention.

The contact hypothesis. The contact hypothesis argues that face discrimination depends on infants' exposure to faces (e.g., Harrison & Hole, 2009; Wright, Boyd, & Tredoux, 2003). It assumes that the amount of exposure received to faces predicts ability with faces. Indirect evidence for the contact hypothesis comes from three streams of evidence: research documenting exposure, differential abilities, and computational models of exposure and ability. Research documenting infants' face exposure has found that infants are exposed primarily to own-race, female, and adult-age faces (Rennels & Simmons, 2008; Sugden et al., 2014), all face types that infant have been found to best discriminate (e.g., females, Ramsey-Rennels & Langlois, 2006). More directly, Bushnell (2001) found that exposure and face processing ability correlate, with greater exposure to mom's face relating to a stronger preference for mom's face in newborn infants. In adulthood, there is evidence that exposure relates to ability (Hancock & Rhodes, 2008) . Although the contact hypothesis is not developmental, per se, the third line of evidence comes from computational modeling. Modeled systems that receive skewed early experience show infants' typical pattern of general ability to discriminate all face types followed by restriction in the type of faces they can discriminate; by contrast, providing diversity early and homogeneity later resulted in superior unfamiliar face processing (Furl, Phillips, & O'Toole, 2002). The contact hypothesis, as conceived, assumes all types of exposure are equal. Although possible, we believe this is unlikely to be true because we do not believe that all faces in the environment are or can be equally attended or processed.

Perceptual narrowing. Perceptual narrowing builds on the contact hypothesis to specify the mechanism by which exposure would influence face processing. It argues that exposure plays a foundational role in determining face processing through its influence on perceptual processes, not restricted to faces (Scott et al., 2007). In faces, language, and other domains, exposure tunes the perceptual system to best discriminate the frequently-experienced types which, consequently, allows these frequently-experienced types to be best processed. Infrequently-experienced types show either stagnation or decline in perceptual processing. There is strong evidence that perceptual processing is tuned by exposure. This mechanism has been well supported with faces (e.g., Anzures et al., 2012; D. J. Kelly, Quinn, et al., 2007) and in other domains (e.g., language, Elsabbagh et al., 2013; multi-sensory processing, Lewkowicz, 2014; for a comparison of faces and language see Maurer & Werker, 2014). Perceptual processing is clearly changing with age and for frequently-experienced types. As with the contact hypothesis, perceptual narrowing does not address the question of how different type(s) of exposure might differentially impact perceptual processing.

Face space. Face space describes a theoretical matrix in which faces encountered are represented, stored, and used to process faces (Valentine, 1991, 2001; Valentine, Lewis, & Hills, 2015). It has gone through several iterations since its inception. As with perceptual narrowing and the contact hypothesis, face space builds on experience to shape processes used to recognize faces. Experienced faces are used to build either a 'norm' or exemplars. The density of the exemplars in any section or area of the space determines how well similar faces can be discriminated. The density of face space within a given area is determined by the number of faces of that type that were experienced. Within a norm-based matrix, the distance from this central 'norm' quantifies the ability to discriminate a new face. Within an exemplar-based system, the distance from near exemplars sums to quantify the ability to discriminate a new face. As conceived by Valentine, the face space explains the pattern of results for upright and inverted, own- and other-race, and other types of faces (Valentine, 1991). In their proposed development of face space, Nishimura, Maurer, and Gao (2009) posit that face space develops in childhood, but is less refined than that of adults; 8-year-olds and adults use similar cues to conceptualize identity, supporting the norm-based model (Nishimura, Maurer, Jeffery, Pellicano, & Rhodes, 2008). With the most recent update, Valentine and colleagues postulate that some experiences are more powerful than others, with social and attentional mechanisms potentially gatekeeping face space and consequently face processing ability.

Social influences. Social perspectives aim to delineate the aspects of exposure that determine later ability. Scherf and Scott (2012) conceive the necessity of learning about the important caregivers in their world as shaping the faces and face types that infants will preferentially process. Face space similarly posits that social interactions are likely playing a role in determining which faces are preferentially processed (Valentine et al., 2015). What aspect of social congress is critical to determining whether a face is processed is still unclear. Individuation may be one path. As discussed above, providing individual names for faces, a common social occurrence with caregiver faces in the first year of life, prevents perceptual narrowing for infrequently-experienced faces while unnamed or category-level labelled experience does not (Scott & Monesson, 2009). A second path may be contingent responding. Within the auditory domain, social interactivity is required to prevent perceptual narrowing for non-native languages (Kuhl et al., 2003). Twelve interactive, social sessions with a non-native speaker maintained infants' capacities with the non-native language; merely hearing the audio or watching the audio-visual interactions was insufficient to prevent perceptual narrowing for the non-native language. The author could find no comparable study with visual recognition. Individuation and social interaction are both common to caregivers' faces. Both individuation and social interactivity likely draw attention to the faces to be processed, although whether there is an attentional mechanism operating in early face processing has yet to be tested.

Attentional influences. Face space, in its recapitulation, proposes that attention-capturing faces are better processed and consequently more likely to be integrated into face space (Valentine et al., 2015). Interaction and social congress serve to highlight some faces from experience. Similarly, the way in which some faces are experienced (e.g., near, alone in the field of view, and in a frontal viewpoint) may be effective in capturing infants' early attention (Sugden & Moulson, 2016).

Attention seems to presage discrimination. Eye tracking studies have documented differing developmental trajectories in the way in which infants attend to and scan faces between familiar (i.e., own-race) and unfamiliar (i.e., other-race) faces (W. S. Xiao, Xiao, Quinn, Anzures, & Lee, 2013). How infants scan faces predicts their ability to discriminate the faces (N. G. Xiao et al., 2015). Although indirect, this suggests that what exposure is influencing is attention and that this attention is then influencing whether infants can discriminate the faces. Recent research has tested this directly. Markant and colleagues (Markant, Oakes, & Amso, 2016) directed infants' visual attention through the use of visual cues. Some of the cues were informative, whereby they directed infants' attention to other-race faces, and others were not. Nine-month-old infants, who received informative cues that directed their attention to the other-race face discriminated other-race faces. Infants who did not receive informative cues behaved like 9-month-olds in other studies, showed no discrimination. This finding suggests attention is moderating the impact of experience on infants' ability to discriminate individual faces.

What builds infants' face processing system?

Experience is required for visual processing and face processing, however the mechanisms and salient features of that experience are unclear. We don't know which aspects of exposure matter. One reason for this is that the majority of research was indirect and did not measure infants' early experiences. If it is measured, it is by asking the parent a few questions about infants' exposure to familiar and unfamiliar face types, excluding infants who have regular contact with the face type to be 'unfamiliar' in the study. It is unclear how well parent-report represents infants' typical experiences, given the differences between an adult and a developmental perspective (Smith et al., 2011). No studies examine relations between exposure and ability and, critically, none measure it from the infant's own perspective.

Many studies on early face preferences for familiar and unfamiliar face types are with homogenous populations (i.e., in China), preventing more nuanced understanding of the role of experience. There is undoubtedly value in establishing trajectories of development within a sere experience, concluding that infants who receive no exposure to unfamiliar face types show typical patterns of narrowing. Now that this has been well established, of greater value, particularly given the increasing diversity of the world, is understanding more nuanced relationships between exposure and ability.

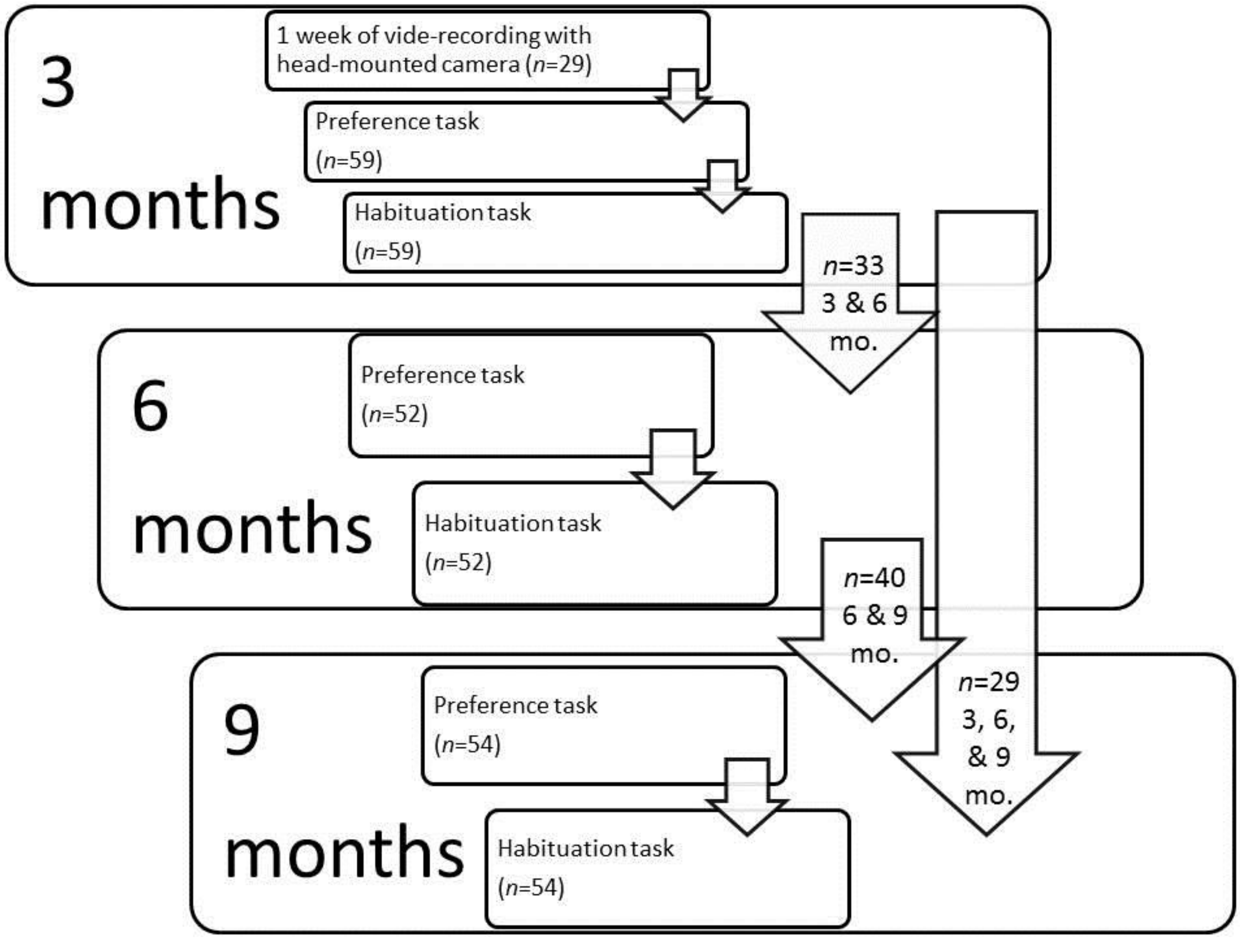
A third issue is that most studies only examine one aspect of development, at a single point in time. Studies typically report experience *or* attentional preference *or* discrimination *or* ERP. The majority of the studies cited here and that the author could source used only a single method to examine infants' face processing capacity. Very few used two and none used more than two measures. Consequently, no study yet has been able to consider how experience, attention, and ability relate in early life. Given the parallels in typical trajectories it is not unreasonable to expect that they do, however there is no extant evidence to directly support this assertion. Understanding these relationships and trajectories provides a powerful way to truly appreciate how the infant learns and builds the capacities that are likely necessary to achieve adult-level expertise.

The current dissertation.

The studies included in this dissertation marry multiple methodologies to test the relationship between experience, attention, and ability. The goal of the study is to understand how natural experience, behavioural indices of face processing (i.e., preference and discrimination) and neurological measures of face processing (i.e., ERP) relate in infants at 3, 6, and 9 months of age. More generally, we ask what predicts development and learning in infancy. Using the face processing system as a model system, we can better understand the basic principles upon which face learning is built.

Design and hypotheses. We conducted a longitudinal study of infants' exposure to, attention to, discrimination of, and brain response to different types of faces at 3, 6, and 9 months of age. To understand infants' typical, daily exposure to faces, at each age, infant-perspective video was recorded using head-mounted cameras in the infant's home for a period of approximately 1 week (results described in Chapter 2; see Figure 1 for flow-chart of study design). We hypothesize that the faces to which infants will be exposed will be primarily caregivers, relatives, and other own-race, adult-age, and female, replicating Rennels and Simmons (2008) and our previous research (Sugden et al., 2014). After their week of recording, infants visited the lab where they completed three tasks. All three tasks used face types that varied in familiarity (i.e., own-race female, own-race male, other-race female, and other-race male). The first task, designed to assess infants' visual attention to faces of different types, was a visual preference task (results described in Chapter 3). We hypothesize that infants' attention will be initially captured by the most familiar face types (e.g., female), but this preference for familiar will decline in favour of an unfamiliar face-type preference with increasing age. The strength of this preference (i.e., how much infants attend to the familiar over the unfamiliar face type) will relate to infants' exposure to caregivers' (e.g., mom and dad's) faces and not to other relatives' or strangers' faces. The second task was a face discrimination task where we measured infants' ability to discriminate individual faces of each type (results described in Chapter 4). As predicted by perceptual narrowing, we hypothesize that infants will best discriminate faces they experience most often. The third task was an ERP task which measured infants' electrical brain activity in response to faces of each type (results described in Chapter 5). We hypothesize that infants' neurological response will differ between the familiar and unfamiliar face types. Finally, in Chapter 6, we link exposure, attention, and ability. We hypothesize that ability to discriminate faces will be modulated by how the faces are experienced and infants' pattern of attention to faces. This study has the potential to provide a description of the basic learning principles that may apply for the rest of our learning lives.

Figure 1: Flow-chart of methods and sample size



Chapter 2: Exposure to faces

William James famously said that "the baby, assailed by eyes, ears, nose, skin, and entrails at once, feels it all as one great blooming, buzzing confusion (W. James, 1980)." Although poetic, infants' visual experience is not clear. Previous research suggests that what likely assails infants' eyes are faces, with one quarter of their typical daily experience including faces (Sugden et al., 2014) most of whom are family members and caregivers (Jayaraman et al., 2015; Rennels & Simmons, 2008). This is not surprising; altricial infants' intense caregiving requirements demands caregiver attention. This creates an opportunity to differentiate important faces (e.g., caregivers, relatives) from faces that are not important (e.g., strangers) through the frequency and qualities of their presentation.

Infants are statistical learners. At the most basic level, the habituation-dishabituation paradigm, in which infants are exposed to a single stimulus until they no longer show an interest in it and then are shown a new stimulus to which they show recovery of interest, highlights their ability to track the relative novelty and familiarity of events. Newborn infants show this basic sensitivity (Slater, Morison, & Rose, 1984). They are able to track the statistical probabilities of a series of stimuli. If they are habituated to a visual sequence of shapes in which the sequence is defined by the transitional probabilities between shapes, they show renewed interest when shown a novel sequence that did not follow the transitional probabilities (Bulf, Johnson, & Valenza, 2011). At 2, 5, and 8 months, infants habituated to a slightly more complex sequences of shapes defined by their transitional probabilities; as with the newborns, infants habituated to the pattern showed renewed interest to a novel pattern (Kirkham, Slemmer, & Johnson, 2002). By 9 months, they can track the statistical frequencies and co-occurrences of visual objects in scenes, separating the pattern from extraneous information (Fiser & Aslin, 2002). At 12 and 14 months of age, infants leverage their sensitivity to the statistical co-occurrence of bimodal, visual and auditory, stimuli across many trials to learn object labels (Smith & Yu, 2008). They also show strong statistical learning for language across the first two years of life (Maye, Weiss, & Aslin, 2008; McRoberts, McDonough, & Lakusta, 2009; Pelucchi, Hay, & Saffran, 2009; Saffran, Aslin, & Newport, 1996; Saffran & Wilson, 2003). Statistical co-occurrence and contextual clues both matter for learning.

Multiple types of contexts can influence early learning. For example, location of training and test both influence memory. If 3-month-old infants are asked to remember a visual object, they can only do so if the training occurs in the same location as the test (Rovee-Collier & Dufault, 1991). The exception to this is that if they are trained in multiple different locations, then their memory is not tethered to any one context and they are able to show memory in a novel context. Similarly, auditory context can facilitate or disrupt 3-month-olds' memory (Fagen et al., 1997). Infants trained with conjugate mobile reinforcement showed retention of the training only if the same and not if different music was played during a memory test that occurred 7 days later. Face experience appears to provide cues of frequency, co-occurrence, and context, all found to facilitate statistical learning. Early face experience provides repeated presentations of single face types, typically female, own-race, and adult-aged (Sugden et al., 2014). Furthermore, it represents few people, primarily infants' mother and other family members, who are encountered often (Jayaraman et al., 2015; Rennels & Simmons, 2008). It is likely that typical rules of early learning apply to and are operating with faces to help infants learn about the important people in their environment.

The influence of early experience in learning

Early face learning is likely driven by differences in exposure, although what aspects of exposure are likely to be most prognostic are unclear. From birth, infants evidence a sensitivity to the frequency of exposure to their mother's face, showing a greater preference for their mother with greater exposure to their mother (Bushnell, 2001). It is not, however, until 4 months after birth that infants show a preference for their father over the face of another male stranger (Ward, 1999). By comparison, at 3 months, they show an overall preference for female over male faces (Quinn et al., 2002), but only for faces of their own race (Quinn et al., 2008), likely as a consequence of their greater exposure to female and own-race faces. Similarly, they show a greater preference for own-race over other-race faces, a preference not shown by newborns (D. J. Kelly et al., 2005). By 6 months, they show differential ability by face race – discriminating between individual faces of their own race and some but not all faces of other races – despite equal facility 3 months prior (D. J. Kelly, Quinn, et al., 2007). When tested on the same task, 9-month-old infants show discrimination of only own-race faces and a failure to discriminate other-race faces. A similar trajectory of perceptual narrowing—gradual loss or stagnation of ability with unfamiliar, as compared to familiar, face types (Scott et al., 2007)—has been found for other-species faces (Heron-Delaney, Wirth, & Pascalis, 2011b; Pascalis, de Haan, & Nelson, 2002; Scott & Monesson, 2009). In fact, in all of these cases the 'familiar' face type, the one they prefer and best discriminate, is the one that most resembles the infant's mother (e.g., own-species, own-race, female) and not their father. This may suggest that the frequency with which or the way in which they encounter their father's face is different from the frequency or quality of experience they receive to their mother's face.

We note, however, that not all infants have a female primary caregiver and/or a mom. Some infants are raised by single fathers, two partnered or married dads, or parented by a male primary caregiver. Although no studies have yet examined the typical exposure to faces of male primary caregivers, one infant being equally co-parented by both a mother and father was found to have greater male face than female face exposure (Sugden et al., 2014). Infants who typically see fewer female faces would be expected to show greater preference for and discrimination of male faces, the reverse pattern from infants with female primary caregivers. Quinn and colleagues' research supported this, finding that the pattern of preference for infants with a male primary caregiver is for male over female faces (Quinn et al., 2002). This emphasizes that although females are usually the primary caregiver for infants, gender does not necessarily make a face particularly special to an infant. The face of the primary caregiver, regardless of gender, is processed in a qualitatively different way than all of the other faces that the infant experiences.

Social importance – it's who you know!

It is hard to disentangle the influence of the identity of a face from its probability in the infant's environment. An infants' mother is likely to represent a majority of their face exposure, occurring in multiple contexts, and co-occurring with the majority of other relatives or familiar face types. If statistical learning is occurring with faces, as studies of infants' visual preference and discrimination of faces of different types suggest, it would be expected that the metrics of familiar, important faces would differentiate caregivers and relatives from strangers in the infant's early visual environment across multiple contexts. Akin to the argument of cross-situational word learning (Smith & Yu, 2008), consistency across contexts may be another cue which disambiguates the important faces in the infants' early environment from faces that are not, for example, caregivers. Caregivers are also likely to have qualitatively different social interactions with the infant, potentially facilitating face learning through this social congress (Scherf & Scott, 2012). For example, mothers are more likely to engage in caretaking while fathers are more likely to play with the infant (Lamb, 1977). During play episodes, mothers show more sensitive behaviour than do fathers; mothers are less likely to try to change infants behaviour, present objects when the infant is inattentive, and interfere with infant behaviour during a play episode (Power, 1985). It is likely that differences in behaviour influence what and how infants learn during their interactions with different people.

The importance of the infant perspective

Although there are many ways to capture infants' early experience, the infant perspective is unique and important. Furthermore, to truly appreciate that perspective requires a method that captures the rich wealth of infant-perspective information with high fidelity. Head-mounted infant-perspective cameras provide this data. There is a growing body of research that uses child-perspective head-mounted cameras to capture, describe, quantify, and relate experience to learning (for a review, see Smith, Yu, Yoshida, & Fausey, 2015). Importantly, an adult or bird's eye view are not predictive of learning whereas the child perspective predicts what the child will learn (Pereira et al., 2014; Yurovsky et al., 2013). One notable difference between the adult and developmental perspective is in exposure to faces. In toddlerhood, during a play task, the child perspective includes far fewer faces than does the adult perspective (Smith et al., 2011). Conversely, in infancy, face exposure quantified from natural recordings of infants' typical daily experiences found more than double or triple (28.9% at 1 month of age and 34.0% at 3 months of age) adult levels (i.e., 11.4%) of face exposure (Sugden, 2012). When infants experience faces, these are presented in a way that promotes attention and learning (Sugden & Moulson, 2016). Growing from this methodology, there is an understanding of the uniqueness of an infant's perspective, the importance of that perspective, and how the natural visual statistics of their environment distinguish the familiar from the unfamiliar, the important from the unimportant, and the learned from the unlearned.

Research questions and hypotheses

Infants quickly learn important faces, but how familiar are important faces? Does their frequency, consistency within context, or consistency across contexts differentiate them from faces that are not as personally important to the infant? We hypothesize yes on all fronts. We expect that important faces, like mom and dad, differentiate themselves through their relatively greater statistical probability in the environment overall, within a single experience of a face, and across multiple contexts. We posit that there are likely degrees to this, radiating out from the primary caregiver, to other caregivers, to relatives, and to strangers.

Method

Participants

Twenty-eight (13 female) 3-month-old participants were recruited from a database of families who had previously expressed an interest in developmental research. Infants were 88 days old (*M*=87.68 days, *SD*=10.52) when they began the study and 100 days (*M*=99.54 days, *SD*=12.38) when they ended their participation. The infants all lived in a large, diverse metropolitan area and reflected that diversity; parents reported infants' background as: 17 White, 3 Black, 2 East Asian, 3 East Asian-White, 2 Black-White, and 1 South Asian-South-East Asian. Although all infants had a female primary caregiver, the family members with whom they lived were also highly heterogeneous: Only 16 infants were single children living with both parents, eight infants lived with siblings, three infants lived with extended family members, and one infant lived with boarders. Two infants did not live with a male caregiver, living with extended family or two female parents.

Equipment

Parents were provided with two miniature inconspicuous cameras with which to record. The camera was in the shape of a yellow happy-face pin (see Figure 2), with the recording aperture concealed in the black-coloured left eye of the face. The light-weight camera was 5cm in diameter. This camera was chosen because it looked more like an infant clothing accessory than a camera. The camera was clipped onto a fuzzy elasticized headband, which was worn on the infant's head. In a few cases, parents chose to clip the camera onto a hat, hairband, or other head accessory (e.g., balaclava in the winter). To be able to best capture the infant's field of view the camera was placed at or slightly above the bridge of the infants' nose, between the infant's eyebrows. Small sponges on the back of the camera were used to adjust the camera angle to best capture the infant's field of view. The camera was oriented upside-down, to ensure that the eye of the camera was as near as possible to the infant's eye. The camera recorded at either 8 or 30 frames per second with an image resolution of 1536 X 2048 pixels. Video was recorded in .AVI to a 16GB microSD memory card. The video included audio and was in full colour. Parents were also provided with a charging cable with which to recharge the battery, a small bag in which to store the equipment, printed instructions for the camera (see Appendix F), and a photograph of an infant wearing a properly placed camera as an exemplar for camera placement.

Parents were also given a 'daily diary' (see Appendix G), which included a series of questions to be answered about each day they spent with the camera. The questions inquired about the number of times they recorded with the camera, the people the infant saw, the locations the infant visited, a brief description of the infant's activities, and any notes about the camera or recording. The daily diary also included reminders about privacy concerns related to recording.

Figure 2: Infant wearing upside-down-smiley-face head-mounted camera on a fuzzy red headband

Procedure

Parents were contacted by telephone or email and invited to participate in the study. If they were interested, two visits were booked. The first visit was at the parent's home, lab, or another location convenient to the parent (e.g., spouse's place of work, grandparent's home). The second visit was in the lab. If an additional visit was necessary (e.g., lost equipment, see below), this always occurred at the family's home.

At the first visit, the parent provided informed consent for participation (see Appendices A-C for consent agreements), answered a brief questionnaire that included demographics questions (see Appendix D), and was trained in the operation of the camera in four steps: 1) The researcher would show the parent how to operate the camera by following printed step-by-step instructions (see Appendix F). Parents kept the instructions for the duration of their participation. 2) The researcher supervised the parent following the same instructions, to ensure they were able to operate the camera. 3) If the baby was available, the researcher would place the camera on the baby's head and record a small sample of video during which they would place their face directly in front of the baby's face and say 'The baby is looking at me.'. The researcher also highlighted, for the parent, where the camera should be placed, referring to a printed exemplar photograph. (The parents also kept this exemplar during the week of recording.) After the researcher had recorded, they removed the memory card and showed the video to the parent. This step also served to ensured accurate placement of the camera because the researcher could determine, from the section of video during which they indicated that the baby was looking at their face, whether the camera placement needed to be adjusted. If it did need to be adjusted, the researcher would place small sponges on the back of the camera to change the camera angle. The researcher would then repeat step 3 to check the adjustment. Theoretically, this would repeat until the researcher assessed that the camera was capturing the infant's field of view. In practice, this was repeated a maximum of twice for any child. If, however, during this step the child was not available, the researcher would demonstrate on themselves; camera angle adjustments were not made in this case. 4) The researcher had the parent place the camera on the baby or, if the baby was unavailable, the researcher's, their own, or a plush toy's head to demonstrate camera placement. If the baby was available, the researcher and parent would check this video as well. Throughout camera training, the researcher provided guidance and feedback to the parent.

Parents were instructed to charge the cameras overnight every night and, if possible, to plug them in to charge after each recording session (e.g., while the child was napping). They were asked to record as much as possible, with an encouraged minimum of twice per day. To facilitate participation with an infant population, parents were not given a schedule for recording. Parents were asked to record at any time of the day, provided the infant was awake. If the infant fell asleep during a recording session, parents were asked to end recording. They were told to record during any of the infant's activities, with the goal of best representing their typical, daily experiences. With respect to out-of-the-home recording, they were told they could record in public places, with the proviso that they not record in locations where there is a reasonable expectation of privacy (e.g., doctor's office, restroom). If they wished to record in semi-public locations (e.g., baby yoga, church) or in another person's private home or office (e.g., aunt's home), they were asked to ask the person in charge (e.g., instructor, pastor, aunt) whether they could record.

One to 2 days after receiving the camera, parents were contacted by the researcher to ensure recording was going well. If the parent identified any issues, the researcher would trouble-shoot with the parent over the telephone. If the parent filled the SD card, a piece of equipment was broken (e.g., dropped in a bath, gummed by an infant, act of dog), a piece of equipment was lost or the parent had an issue that could not be resolved over the telephone, a researcher would return to visit the parent to replace the equipment and/or resolve the issue. One to 2 days after this second visit, a researcher would again contact the parents to inquire about recording. The day before the family was scheduled to visit the lab, they were again contacted to ensure that recording had gone well and that the appointment was still convenient for them.

The family returned to the lab to return the camera. At this appointment, the infant participated in a preference task (see Chapter 3), a discrimination task (see Chapter 4) and an ERP task (see Chapter 5). The parents completed a final questionnaire (see Appendix H), documenting their time recording and experience with the camera. To thank them for their participation, the family received a $25 honorarium, a copy of all of the videos recorded from their infant's perspective, a 'baby scientist award', and, for the infant, a toy. Although some families did record at 6 and/or 9 months of age, this data will not be reported here because the current dissertation aims to understand the influence of *early* experience (i.e., at 3 months) on concurrent and later face-processing ability.

Data coding

Infant looking was coded frame-by-frame using Datavyu 1.3 (Datavyu Team, 2014). All coders completed an extensive training with a senior coder. They then coded 1 – 2 videos independently. On the last video, coding reliability was assessed, as measured against a highly-experienced senior coder. All coders achieved a minimum of 85% reliability. Coders were assigned to infants, so that the same coder coded all of the videos for each infant. In the cases of male coders, a senior female coder first viewed all of the videos to ensure the family's privacy was respected and to be sensitive to parents' possible concerns about a male coder (e.g., breast-feeding videos). If the videos contained any materials that the researcher deemed of concern, the male coder was assigned to a different infant.

Face identification. During video coding, faces were identified at the individual level when this was possible. In no particular order, coders identified faces by utilizing any of a combination of: 1) the questionnaire completed at the home visit, which included a list and description of frequently-experienced people; 2) the daily diary, which included a list and description of people experienced each day; 3) the questionnaire completed at the lab visit, which included a list and description of the people the infant experienced during the week; 4) the knowledge of research assistants who had met the family; 5) videos recorded from tasks completed as part of the larger study in which the family participated on the second visit, which typically included the parent's and always included the infant's face; 6) other infant-perspective videos recorded by the infant at 3 months of age; 7) infant-perspective video recorded from the perspective of the infant when they were 6- and 9-months-old; 8) self- or other-person- identification that occurred in videos (e.g., 'Put your brother down.'); 9) the camera itself (diagnostic of whether an infant was the participant); and 10), where possible, the person coding the video met the family in-person when the family visited the lab. For every infant, a minimum of one other researcher who had met the family reviewed all of the faces coded as relatives to ensure accuracy within the relatives the researcher had met (two to six relatives' faces per infants). They then used the participant video to assess the relationship of the other faces coded as relatives. Inter-rater reliability for both measures was 100%.

We also classified non-relatives' faces as strangers. By default, strangers were people that could not be certainly identified as relatives. These people ranged from family friends to passers-by on the street. We took a conservative approach in identifying relatives, omitting any person for whom the relationship could not be ascertained; consequently, these people were identified as strangers. Although we recognize that some of these faces may be relatives, we reasoned that because we wish to faithfully characterize relative face experience and that the group of potential relatives is smaller than the group of potential strangers, including non-relatives as relatives would be more problematic. From this perspective, strangers may be more likely to resemble relatives, however we can be certain that the relatives we have identified are not strangers.

Location coding. Video recording locations were classified as home, car, outdoors, and public space. Homes included any home environment, including the homes of relatives and friends, in addition to the infant's own home. We classified the location home in this way for two reasons: 1) in some videos it was unclear whose home it was, and 2) infants visiting any home are likely to be in contact only with close friends and relatives, which speaks to our research question. Car included any private vehicle, however in all cases here the car was driven by a family member. Outdoors included activities such as walks in the stroller, playing with siblings in the park, a street barbeque with neighbours, and a picnic. Public places were all non-home, indoor locations (e.g., offices, malls, recreation centres, summer camp mess hall, restaurants, and Ikea).

Results

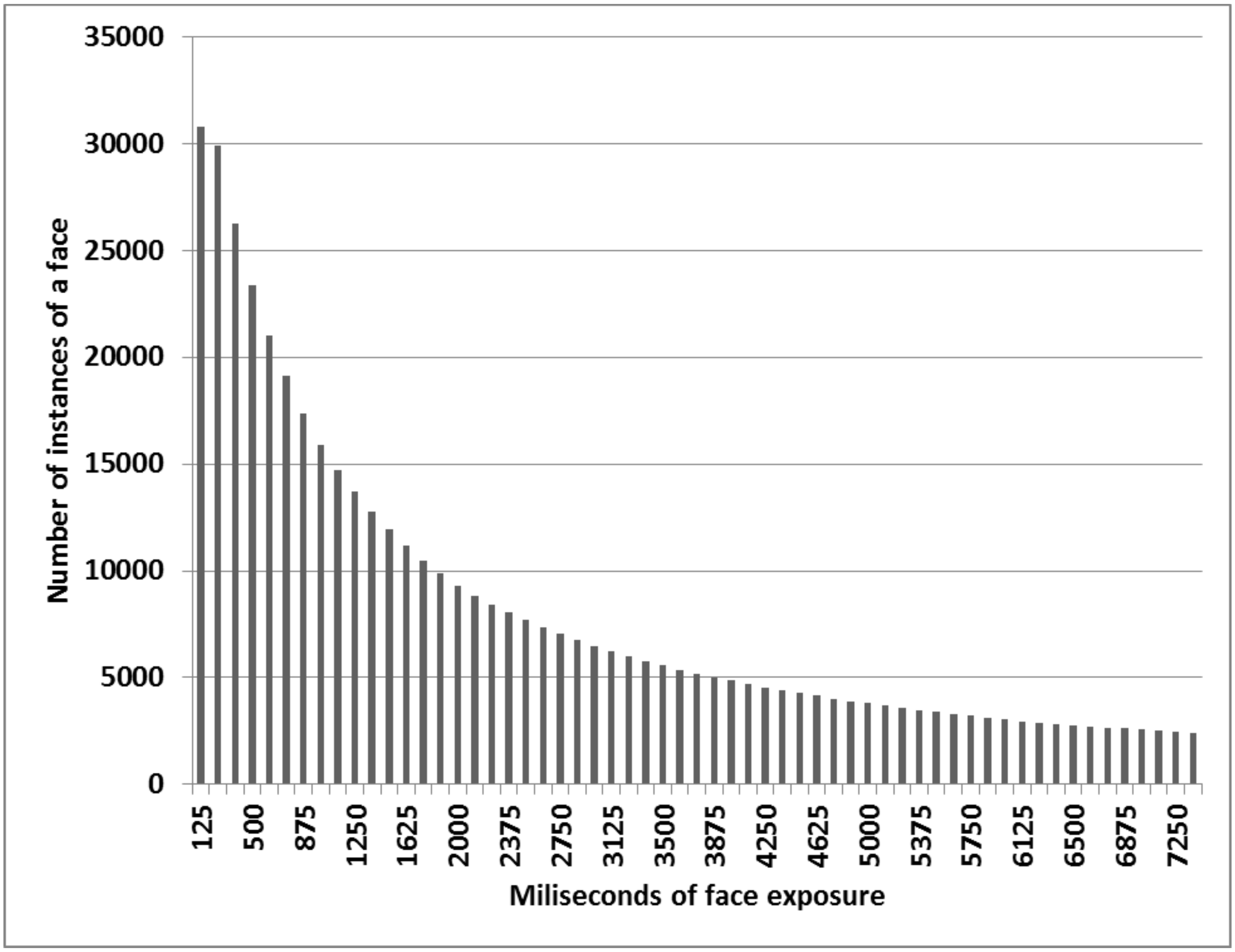
Total video

A total of 89 hours, 14 minutes, and 33 seconds of video were recorded. Infants averaged a little over 3 hours of video each (*M*=3 hours 11 minutes and 14 seconds, *SD*=2 hours 22 minutes and 44 seconds per infant). Within this, some of the video could not be coded because the camera was occluded, technical issues with the camera, or other concerns that the video did not accurately represent the perspective of the video; omitting this ruined video left a total of 85 hours, 5 minutes, and 14 seconds of video (*M*=3 hours 2 minutes and 20 seconds, *SD*=2 hours 18 minutes and 38 seconds per infant) that could be coded.

Metrics of face exposure

All infants were exposed to faces. On average, infants spent 27.9% (*SD*=11.4, Range: 3.7%-48.5%) of their time, or 17 minutes per hour, exposed to faces. Previous studies with this age group have reported comparable metrics of exposure (e.g., Jayaraman et al., 2015; Sugden et al., 2014). Infants saw an average of 26 individual faces during their time recording, which averaged to 13 individuals per hour (*M*=13.4 individuals per hour, *SD*=20.5). Individual faces per hour is not a straight-forward division of individual faces over time recorded because faces repeat, with any number of the 26 individuals occurring within an hour (e.g., if hour 1 includes mom, dad, and, hour 2 includes mom, dad, and Sachi, the infant has seen 4 individuals in 2 hours and 3 individuals' faces per hour). Irrespective of the individual, faces occurred in the field of view an average of 7 times per minute (*M*=7.6 times per minute, *SD*=5.3). The mean exposure length of any given face was 3 seconds (*M*=2.80 seconds, *SD*=0.90 seconds; see Figure 3).

Figure 3: Survival curve of face exposure in milliseconds



Familiar faces – caregivers, self, and relatives

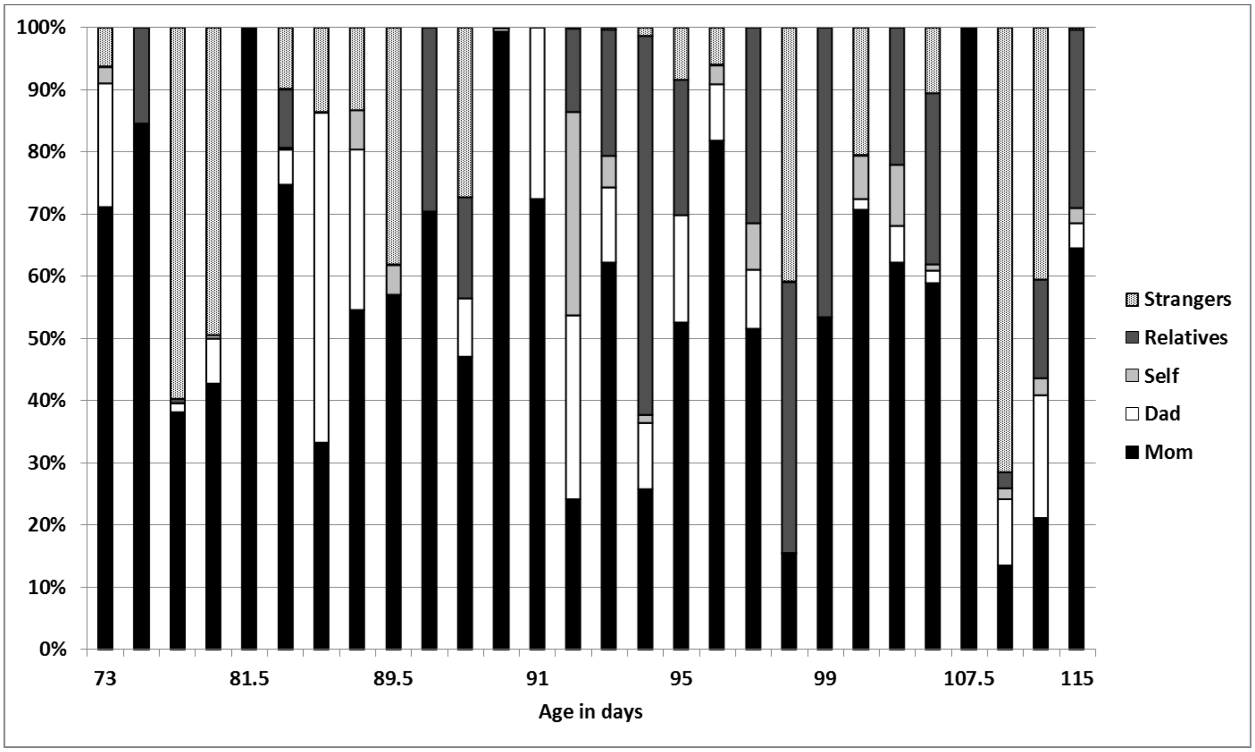
Mom and dad. All infants had a female primary caregiver and one infant had two female primary caregivers. Two infants did not have a male caregiver living at home. We included all infants with experience with mom in the analysis of mom but excluded infants with no dad experience from the analysis of dad.

Mom was the most frequently experienced single face of the majority of infants (26 of 28 infants), with the exception of one infant who saw their own reflection and one infant who saw their father's face more than their mother's face. Mom represented an average of 57% (*M*=57.4%, *SD*=24.6) of all face exposure (see Figure 4). Omitting the infant with two moms barely changes the average, *M*=57.4%, *SD*=25.0. On average, each experience of mom's face lasted for 3 seconds (*M*=3.1 seconds, *SD*=1.1).

Dad was the second most frequently experienced face for 12 of the 26 infants. In the remaining cases, siblings (*n*=6), grandparents (*n*=5), the infant's own face (*n*=1), an uncle (*n*=1), or a cousin (*n*=1) were more frequent. Dad represented an average of 11% (*M*=10.9%, *SD*=12.5) of all of the infant's face exposure (see Figure 4). On average, each experience of dad's face lasted for 2 seconds (*M*=1.9 seconds, *SD*=1.6).

There were significant differences between infants' experience of dad's face as compared to mom's face. All but two infants had more experience with mom's than with dad's face, $Z(25)=4.2$, $p<.001$. When it occurred, dad's face was present for shorter periods (*M*=2.4, *SD*=1.6, *Mdn*=1.9) than was mom's face (*M*=3.1, *SD*=1.1, *Mdn*=3.0), $Z(21)=2.5$, $p=.013$; this was true in 17 of 22 infants.

Figure 4: Percent exposure to caregivers, siblings, other relatives, and strangers, by infant



Self. One notable feature of the videos was that infants were often exposed to their own face. This occurred when parents presented them to a mirror and, because many infant toys and accessories included mirrors (e.g., activity mat with a mirror in its peak), when babies were playing independently. In a previous study, one infant's face exposure was nearly exclusively to their own face (Sugden et al., 2014). We expected that own-face exposure would differ from adult face exposure, since infant behaviour is generally different from that of adults. In this sample, 18 of 28 infants had some exposure to their own face. Excluding the infants with no own-face exposure, 4.0% (*SD*=7.5, Range: 0.0 – 32.7%) of all exposure was to their own face (see Figure 4). On average, infants' own faces persisted in their field of view for 2.4 seconds (*SD*=1.3).

Relatives. Some infants also had experience with relatives, such as siblings, grandparents, aunts, uncles, and cousins. Infants who had no such exposure are omitted from this section of analysis. Since some infants had relatives living with them at home and others did not, we considered exposure to relatives in two ways. First, we present the overall data on exposure to relatives' faces. Second, we consider differences in the pattern of exposure between infants who do and who do not have relatives living at home with them.

After parents' and the infant's own face, a relative was the next-most frequently experienced face for 2 infants (i.e., grandmother and brother). Of the 28 infants, 17 were exposed to relatives' faces. Infants experienced 2.6 individual (*SD*=1.5) relatives. When they occurred, relatives represented an average of 23.8% (*SD*=15.6) of all face exposure (see Figure 4). On average, each experience of a relative's face lasted for 2.4 seconds (*SD*=6.2).

Relatives living at home vs. not-at-home. Ten infants who experienced relatives lived with relatives. Eight were siblings. On average, and excluding parents and the infants themselves, infants lived with 1.9 individual relatives (*M*=1.9, *SD*=1.7, Range: 1-6). At-home relatives represented an average of 18.8% (*SD*=14.3) of all face exposure, although one infant's brother's face did not appear on camera. Not-at-home relatives were only encountered in one of the 10 infants' recordings of daily life. On average, each experience of an at-home relative's face lasted for 2 seconds (*M*=2.3 seconds, *SD*=2.0) and that of a not-at-home relative was also 2 seconds (*M*=2.6 seconds, *SD*=1.5). For the seven infants who did not have relatives living with them at home, overall exposure to relatives (*M*=23.0%, *SD*=19.2) was not significantly different than exposure to relatives who did live at home, $t(15)=0.52$, $p=.612$.

Unfamiliar faces - strangers

Strangers. As a group, strangers represented an average of 14.9% (*SD*=20.6) of all face exposure (see

Figure 4), however this was highly variable with seven infants having no stranger face exposure and two having more than 50% of their face exposure represented by strangers. More than half of strangers occurred only once or twice (53.0% of all strangers' faces) and 80% occurred a dozen times or fewer. Infants experienced 21 strangers each, however this varied widely (*SD*=35.3, *Mdn*=2, Range: 0-123).

Strangers relative to relatives. As compared to relatives (i.e., family members who are not mom, dad, or the infant themselves), strangers represented comparable exposure: 12 infants received more exposure to relatives and 13 received more exposure to strangers, $Z(25)=0.53$, $p=.595$. The number of strangers experienced was also not significantly greater than the number of relatives experienced, $Z(27)=0.70$, $p=.486$. The number of strangers experienced surpassed the number of relatives experienced in 11 of the 28 infants. There was high variability in both groups; a non-parametric Friedman test of differences did not find the variability significantly different, $X^2=1.3$, $p=.257$. When they did occur, strangers' faces dwelled for significantly shorter times (M=1.8 seconds, SD =1.1) than did relatives' faces (M=3.0 seconds, SD =1.6), $t(12)=2.9$, $p=.014$.

Consistency and context

Since infants are sensitive to statistical probabilities, we considered that measures of central tendency may not fully capture face exposure. To capture metrics of consistency within and across contexts, we took a corpus approach and analyzed the full dataset, irrespective of the individual participants.

Consequently, we tested the survival functions of the persistence over time of each type of face. Our survival cut-off was 10 seconds (representing >90% of self and >95% of faces of each other type) and, as illustrated in Figures 5, 6, and 7 there were significant differences in the probability that the face would persist in the infant's field of view. Considering only the last third of the distribution (Figure 6), those that represents the faces that persisted for the longest times in the infant's field of view, infant's own face persisted for the longest (7.8 seconds), parents were next-longest and approximately equal (mom and dad=5.4 seconds), relatives persisted for slightly less than parents (5.3 seconds), and strangers persisted for the shortest time (4.9 seconds), $X^2(4)=10.2$, $p=0.17$.

We considered probability of exposure in a second way, by examining the number of videos in which faces of a given type would occur. Since videos were taken on different days and at different times throughout the day, we consider them to be snapshots of various periods within the infant's week with the camera. Consequently, this measure was intended to represent the probability, across time, activities, and days, that any given face would recur.

Figure 5: Standardized survival curve by for parents, self, relatives, and strangers

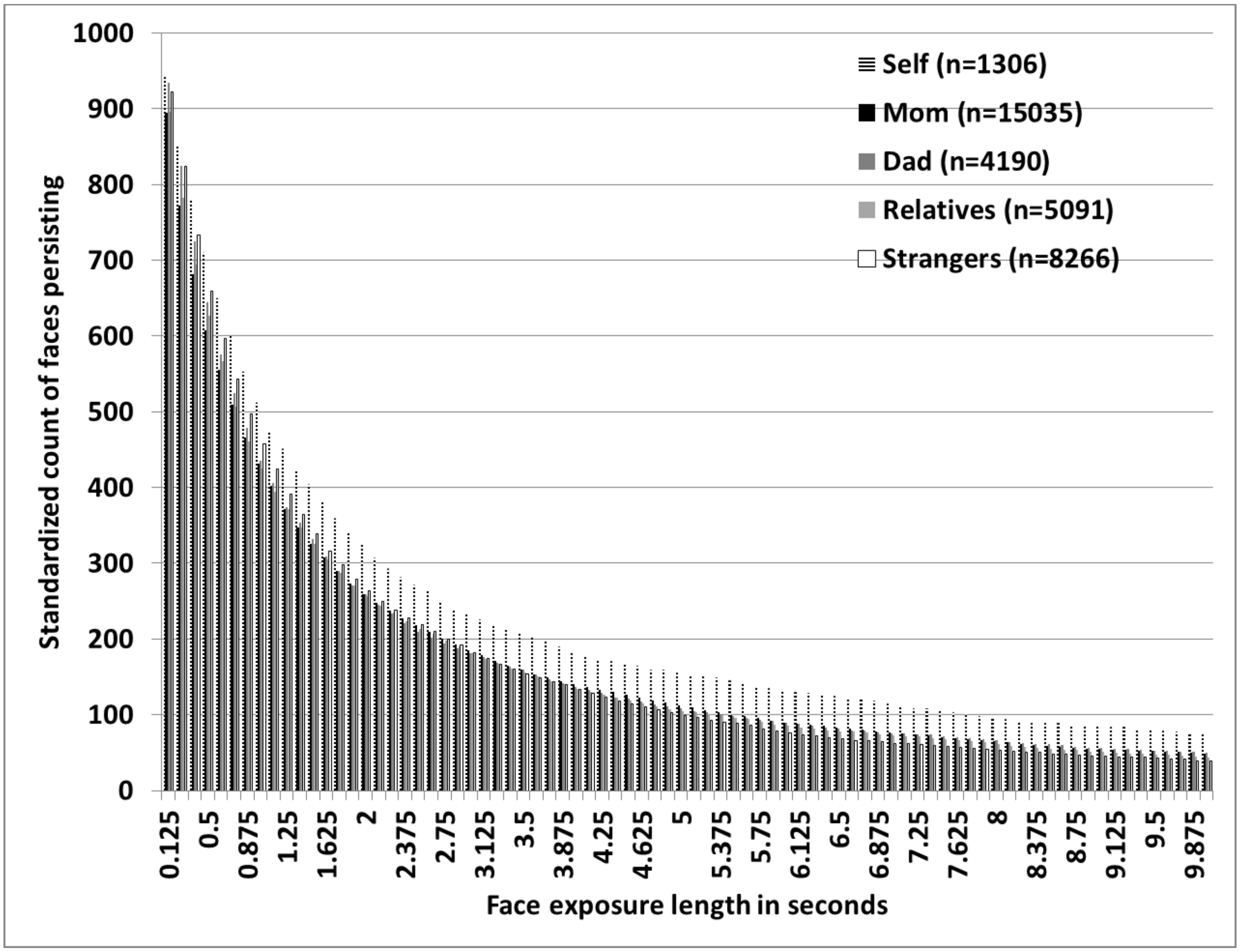


Figure 6: First 3 seconds of the standardized survival curve

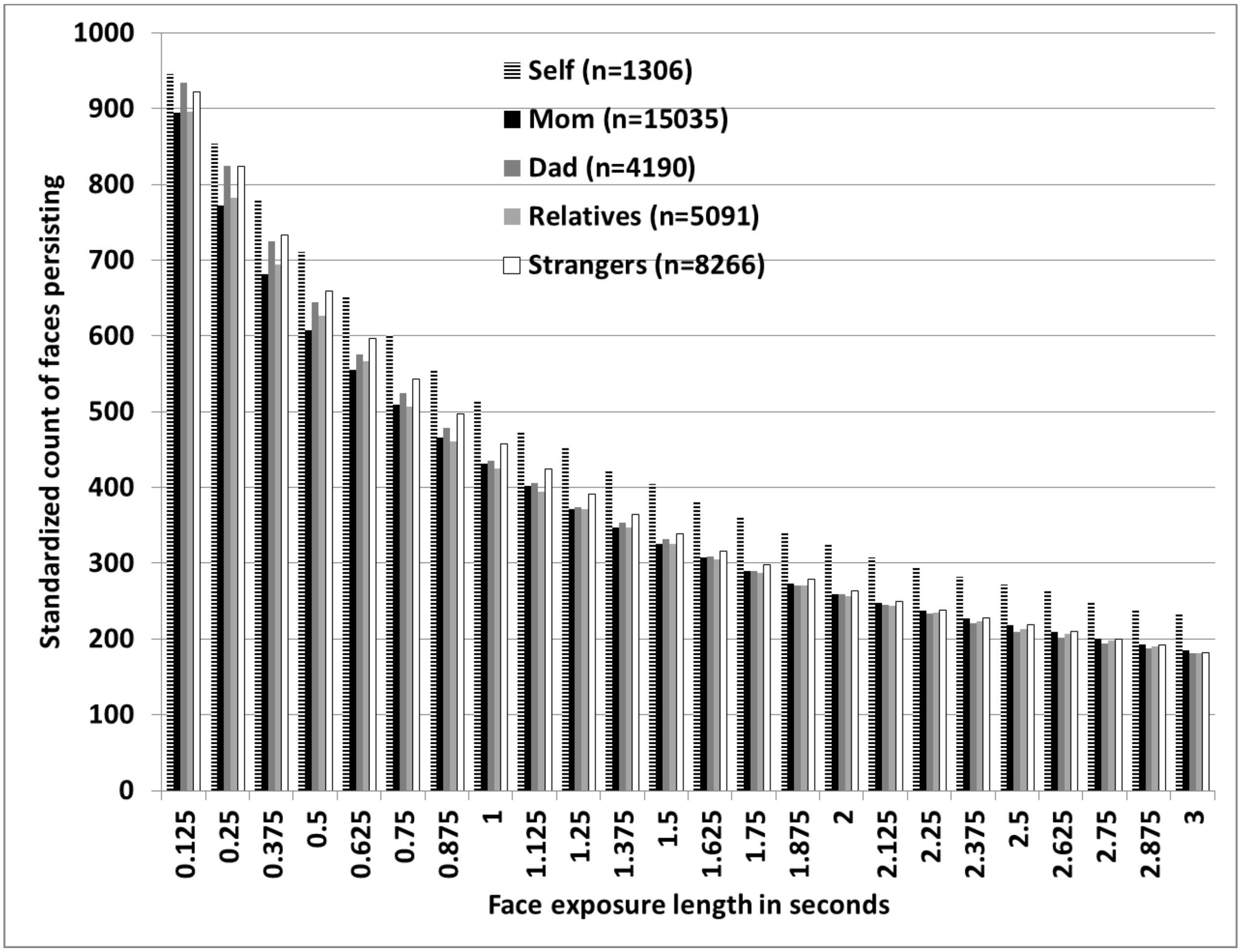
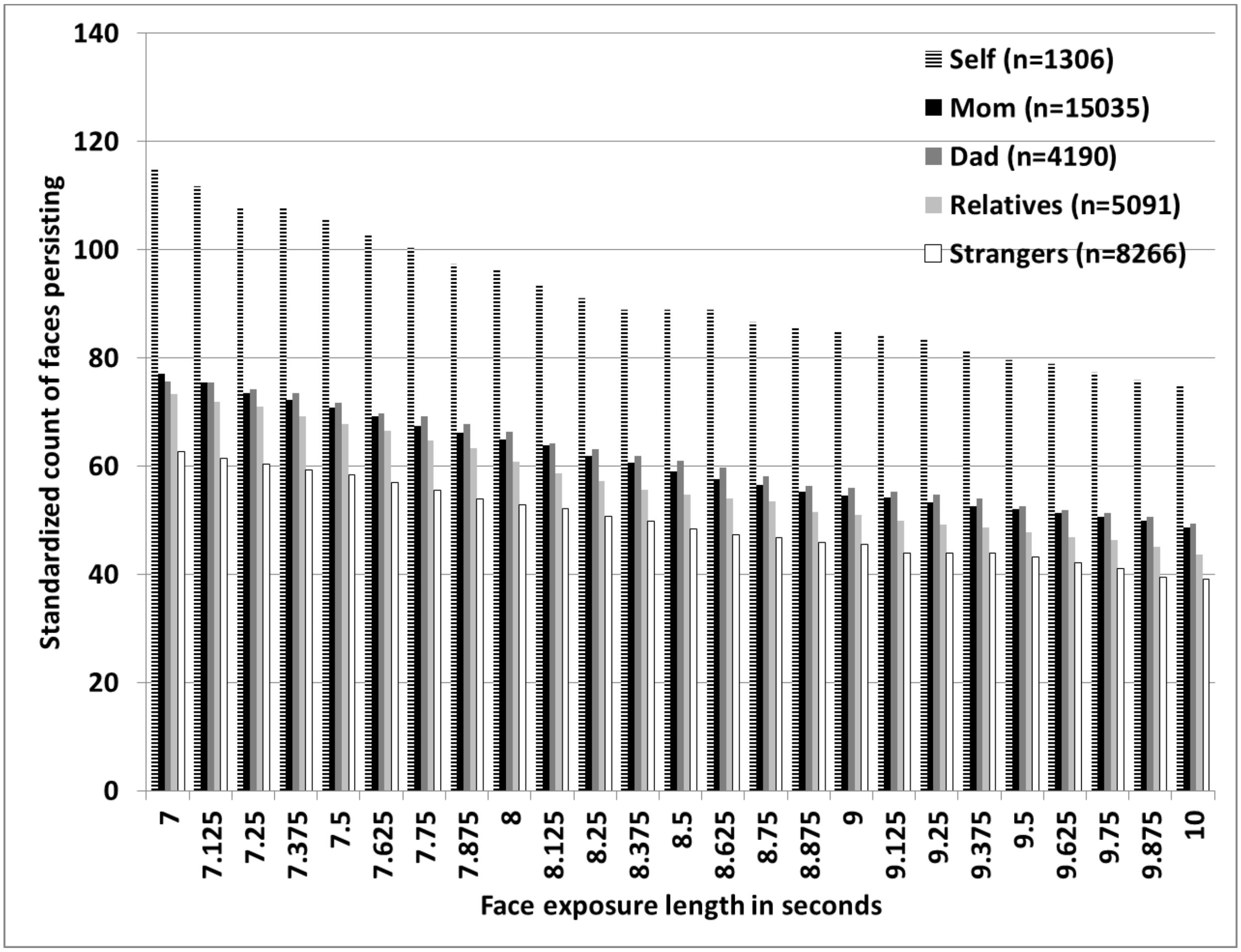


Figure 7: Last 3 seconds of the standardized survival curve



Of the 238 videos containing faces, mom's face was still the most likely to occur in any given video, present in 264 (90.2%) of videos. Put another way, the odds of mom occurring in any given video are 9.2 to 1. Dad was second-most frequent, in 93 (35.2%) of videos; the odds of dad appearing are only 0.54 to 1. The odds were higher than the infant themselves would appear in any given video (0.35 to 1, appearing in 68 videos, 25.8% of all videos) as compared to a stranger (0.25 to 1, with strangers appearing in only 53 or 20.1% of videos). Siblings and relatives were approximately equally frequent, with siblings appearing in 30 (11.4%, 0.13 to 1 odds) and relatives appearing in 39 (14.8%, 0.17 to 1 odds) of videos. Videos in which relatives occurred were not significantly more frequent than videos with strangers, $Z(27)=0.7$, $p=.486$.

Lastly, we considered consistency across locations. As with different videos, different locations were taken to represent different types of activities. Omitting instances where the location was not clear (e.g., the infant could only see the ceiling, the infant was in a stroller with the top down), the majority of recordings (80.4%) and faces (60.9% of instances and 60.9% of time) occurred in the home. Similarly, 12.8% of recordings and 20.3% instances of (17.6% of exposure time to) faces occurred outside or on the street (e.g., walks in the stroller). Indoor public places (e.g., malls, restaurants) represented only 5.7% of all recordings, but 3-4x that proportion in terms of instances of face exposure (17.8%; 21.4% of exposure time). Car rides were infrequent (1.1% of video) and there were nearly no faces experienced in car rides (0.1% of instances and 0.01% of exposure).

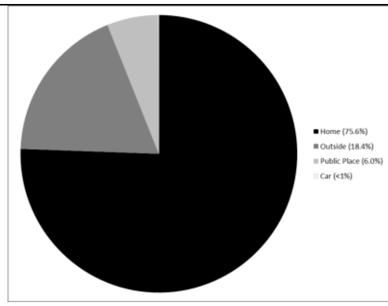
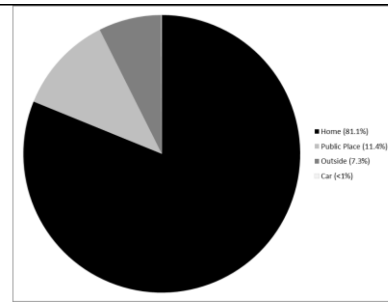
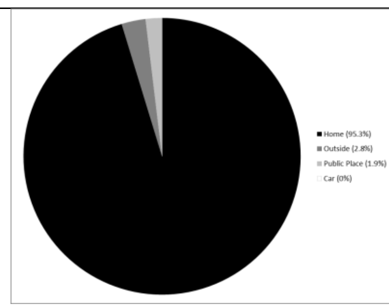
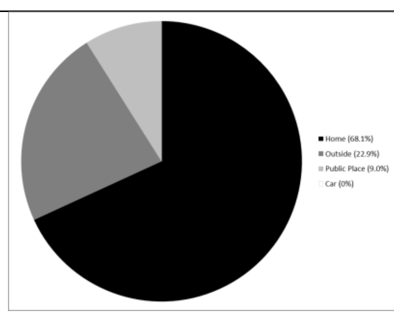
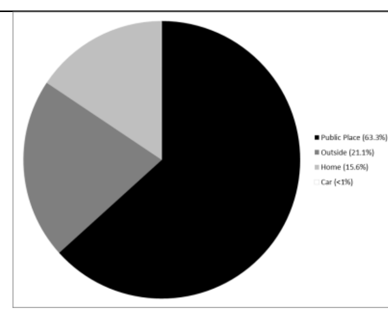
With these baseline metrics in mind, we then considered the way in which faces of different types were distributed across these different environments. Infants are sensitive to contextual cues, with context aiding memory (e.g., Jones, Pascalis, Eacott, & Herbert, 2011). We anticipated that mom would be consistent throughout, expected dad to occur at home but were agnostic as to his presence in other venues, anticipated relatives would occur inside and outside of the home equally, and expected strangers to be primarily an outside-of-the-home phenomenon.

Mom and dad were ubiquitous, appearing in all location types considered. They were the most consistent faces and generally represented the most frequent face(s) in these locations. Mom was the most frequent face seen in two of the four locations (home, 53.1% and outside, 47.6%) and second most frequent, after strangers, in public places (12.8%). She also represented the most face exposure time at three locations, home (55.6%), outside (47.6%), and in the car (69.9%), and was second-most exposed outside (47.6%). Although dad was never the most frequently experienced face, he often took second place. He was second-most-frequent at home in terms of total time exposed to his face (15.5% of time, but second to relatives in terms of instances of his face, 16.4%) and in the car, in terms of instances of faces seen (35.7%; see Figure 8).

The infant him/herself was never frequent, representing 6.3% of all faces seen at home (0.5% in public and 0.8% outside). Most of infants' total own face exposure time occurred at home (7.7%, as compared to outside, 0.7% and in the car, 0.4%). Relatives were second-most-frequent faces seen at home (16.8% instances; third in terms of time, 15.3%) and frequently seen outside (19.6% of instances and 18.1% of time). Relatives never occurred in a car and rarely in public (4.5% of instances and 6.1% of time; see Figure 8).

Strangers were most or second-most frequent in all non-home locations. They represented the most frequent instances of a face when the infant was in a car (40.5%) and in a public places (76.6%). In outside locations, instances of strangers' faces were second-most-frequent (26.0%), after mom. This was also true when considered in term of the proportion of total time spent exposed to faces in each location represented by strangers, with strangers' faces being the most frequent again in public places (76.6%) and second-most, after mom, in the car (17.8%) and outside (28.5%; see Figure 8).

Figure 8: Proportion of time spent exposed to Mom's, Dad's, Self, Relatives', and Strangers' face by location

Face Types	Face Identities	
Parents	Mom	Dad
		
Self	Self	
		
Other faces	Relatives	Stranger
		

Discussion

Mom was the most frequent and consistent face within infants' environments. She was the most frequent face for all but two infants, whereas dad was only most frequent for one infant and second-most-frequent for 12 of 28 infants. Mom represented 57% of infants' face exposure, whereas dad was 11%. When mom's face appeared, it persisted for longer than dad's face. The odds that she would appear in any given context were higher than 9 to 1. By comparison, the odds of dad were only slightly better than 0.5 to 1. Mom and dad appeared in every environment classified; mom was the most frequent face in the majority of these environments whereas dad and strangers often jockeyed for second place. Other relatives were far less consistent. If infants were exposed to relatives, relatives represented 24% of face exposure, however 11 infants had no exposure to relatives. When a relative's face occurred, it persisted for longer than did strangers', but not longer than parents'. Across contexts, exposure to relatives was spotty. Siblings were only present in two and relatives were only present in three of four possible location types. They had comparable probabilities of being present in any given context, of approximately 0.2 to 1. Strangers had a comparably low probability of occurrence across contexts, 0.3 to 1, but were present in all location types and were the most frequent type of face experienced when infants were in a public place. They represented 15% of all face exposure; however they were more likely to disappear sooner than were other face types.

Why does frequency of exposure matter? Across multiple modalities and definitions of 'frequency', infants demonstrate sensitivity to the statistical regularity of events. Within hours of birth, the amount of exposure infants receive to their mother's face predicts their preference for their mother's face (Bushnell, 2001). Similarly, infants with female primary caregivers are exposed to female faces more than male faces (Sugden et al., 2014) and, as we found, mom more than dad. Infants with female primary caregivers show a preference for female faces whereas those with male primary caregivers show a preference for male (Quinn et al., 2002). This female preference that only appears for faces that resemble the infant's mother (i.e., own-race) but not those that do not (i.e., other-race) (Quinn et al., 2008). It is not just attention that is tuned by frequency of exposure. Infants' ability to discriminate faces is also shaped by exposure: ability to discriminate familiar face types improves with age while ability with unfamiliar types does not (D. J. Kelly, Quinn, et al., 2007; D. J. Kelly et al., 2009). Familiarity and continued ability to discriminate, however, can be maintained by minimal experimental exposure (Anzures et al., 2012; Scott & Monesson, 2009).

It was not just frequency of exposure that differentiated parents from other faces, it was also their consistency within and across contexts. Within context, when their faces occurred, they were more likely to persist in the infant's field of view, as compared to strangers' or other relatives' faces. This has two implications. First, if infants are learning about and processing faces, providing them with a longer period of time in which to encode the face would be beneficial because it makes it more likely that they will process it sufficiently to allow them to evidence learning (Hunter et al., 1983). This is particularly true since faces are complex stimuli, which typically take longer for infants to process (Richards, 2010), and one for which infants show developmental trajectories of attention (Frank, Vul, & Johnson, 2009) and learning (Bhatt, Bertin, Hayden, & Reed, 2005; Schwarzer, Zauner, & Jovanovic, 2007; W. S. Xiao et al., 2013) within the first year.

Across a longer time-span, familiar faces were more likely to recur. This was true across video recording occasions, but not across locations where strangers were just as likely to occur as mom and dad. In our analysis, mom, dad, the infant themselves, and relatives represented only one or a few people. The category of stranger, however, represented up to 123 different individuals, any one of whom was unlikely to recur more than twice. Strangers were consistently seen in all locations, but the same stranger was unlikely to be seem in multiple locations (e.g., more than half of the individuals occurred only once or twice). Consistency across contexts can be considered as distributed learning opportunities for infants, a learning type more successful than massed learning for faces (Cornell, 1980). Furthermore, the combination of longer exposure times and distributed practice suggest a qualitatively superior type of experience.

Strangely, infants' exposure to their own faces also points to a higher quality experience. Eighteen infants experienced their own face, with own-face exposure representing 4% of their face experience. The persistence of self-faces was higher than that of all other faces, including mom and dad. Infants of this age have been found to smile and look at their own image (Rochat & Striano, 2002), and to engage with the mirror as if it were another infant with whom to play (Amsterdam, 1972). From the metrics provides here, it does seem to be a potentially powerful learning experience. The implication of this early mirror exposure on learning is an open question.

The way in which infants are exposed to faces is, in many respects, monotonous. They are exposed to a highly homogenous pool of potential faces, repeatedly, and across multiple locations and contexts. Most of their experience is to a single face, mom or dad. This parallels the findings of other studies that found comparably low diversity in infants' face experience (Rennels & Simmons, 2008; Sugden et al., 2014). The implications of this are not boring. Faces are a complex stimulus that are difficult to learn, as evidenced by the long trajectory of the development of face perception (e.g., slow trajectory of configural processing, Mondloch, Le Grand, & Maurer, 2002). Additionally, infant memory and recognition are sensitive to context (Fagen et al., 1997; Haaf, Lundy, & Coldren, 1996). Thus, providing distributed practice that recurs across contexts likely facilitates early face learning. This distributed, simplified practice with faces likely works in concert with social (Scherf & Scott, 2012), perceptual (Sugden & Moulson, 2016), and attentional (Palermo & Rhodes, 2007) mechanisms to allow very young infants to quickly and efficiently achieve the capacity to recognize important faces in their environment. In Chapter 5, we will examine how this early exposure links to later attention and ability. This has the potential to disentangle the contributions of different aspects of experience from ability.

Chapter 3 Visual attention to familiar and unfamiliar face types

Early visual experience is full of faces. More than one quarter of 1- and 3-month-old infants' waking experience, or 15 minutes of every hour, is spent exposed to faces (see Chapter 2; Sugden et al., 2014). Nearly all faces are own-race; most faces are female and adult-aged. In other words, the faces infants see are primarily mom-like. In fact, as described in Chapter 2, most are mom. Throughout the first year, infants spend the majority of their time with their primary caregiver and other mom-like faces (see Chapters 2 and 6 for descriptions of face types experienced by infants). Although face experience declines over the first year of life, by 12 months of age infants have amassed approximately 500 hours of experience with faces and more than 60% of this is to their two most frequently-experienced faces (Jayaraman et al., 2015).

Fortunately, babies like faces. From birth, infants show a visual preference for faces over other visual stimuli: they will look longer at them (Fantz, 1965) and will work harder, by turning their head and eyes, to maintain faces in their field of view (Goren et al., 1975; Johnson et al., 1991). This may be due to their general preference for top-heavy patterns, with more elements or greater contrast in the upper visual field than the lower visual field (Farroni et al., 2005; Macchi Cassia, Turati, & Simion, 2004, but see Chien, 2011; Chien, Hsu, & Su, 2010). Face-like visual stimuli also hold newborn infants' visual attention more than other visual stimuli (Mondloch et al., 1999). From 3 to 9 months, infants allocate increasing attention to faces over other visual stimuli when these are presented in complex visual scenes (Frank et al., 2009).

Not all faces are equal. As described in Chapter 1, very early infants show a pattern of preferential attention to some face types over others, which is likely influenced by familiarity. For example, newborns with more exposure to their mother's face show a greater visual preference for their mother's face over the face of an unfamiliar female (Bushnell, 2001). At 3 months infants show a pattern of preference not evident at birth, preferring human faces over other-species faces (Heron-Delaney et al., 2011), faces of the gender of their primary caregiver (typically female) over other-gender faces (Quinn et al., 2002, but only if the female face is own-race, Quinn et al., 2008), faces of their own race over other-race faces (D. J. Kelly et al., 2005) and dad's face over that of another man (Ward, 1999).

Face preference is not static. Two recent studies explored the development of visual face preferences in 3-, 6-, and 9-month-old infants living in homogeneous, mono-racial environments. One was longitudinal and examined preference for uniquely female own- (Caucasian) and other- (African) race faces (Fassbender et al., 2016). The other used male and female own- (Chinese) and other- (Caucasian) race faces for a cross-sectional sample of 3-, 6-, and 9-month-olds, however they found no gender preference (Liu et al., 2015) despite infants' having shown a preference for female in studies with similar designs (e.g., Quinn et al., 2002). Both studies found that 3-month-olds preferred own-race faces, 9 month-olds preferred other-race faces, and 6-month-olds showed no preference. Understanding how infants develop with a restricted range of face experience is highly informative, however it does not provide any information about the role of experience, per se. It also fails to take into account the fact that increasing numbers of infants live in diverse, multi-racial communities and families. How does face processing change if exposure to other races isn't absolute zero?

Although no study has yet drawn the link between infants' preferential attention to faces of particular types and their discrimination of these face types, it is not unlikely that infants' visual attention to faces would presage their discrimination of faces. As reviewed in the General Introduction (Chapter 1), perceptual narrowing is a phenomenon where infants show continued ability to discriminate familiar face types and either a loss or stagnation of ability with unfamiliar face (Scott et al., 2007), which is seen with faces that differ by race, (D. J. Kelly, Quinn, et al., 2007), species (Scott & Monesson, 2009) and age (Macchi Cassia, Bulf, Quadrelli, & Proietti, 2014). It is also found in other domains (e.g., faces and language; Maurer & Werker, 2014). According to perceptual narrowing, infants' capacities are more broadly tuned and become more specialized with age, based on what is present in the infant's environment.

In addition to potentially presaging discrimination, infants' attentional preferences provide information about their developing attention and how the face processing system develops. Understanding infants' attentional preference for particular types of faces provides information about their developing attention and suggests a role for exposure in this attentional development. Infants' ability to deploy their attention matures over the first year of life (e.g., Hood et al., 1996). Attention is heavily influenced by their experience with the visual stimulus and stimulus complexity (Hunter et al., 1983; Richards, 2010). Classic infant memory studies suggest that age, stimulus complexity, and exposure interact, even on the short timescales of a single research study (e.g., Houston-Price et al., 2009; Hunter, Ames, & Koopman, 1983; Miranda, Hack, Fantz, Fanaroff, & Klaus, 1977; Roder, Bushnell, & Sasseville, 2000). If infants have received sufficient exposure to the stimulus, so that they have built a representation of it, they are likely to show a preference for the novel stimulus that is unfamiliar to them; conversely, if their exposure to the familiar stimulus was insufficient to permit them to adequately process it, they will show a continued preference for the familiar (Hunter et al., 1983). This likely operates on multiple timescales, including longer developmental ones.

Faces are arguably complex stimuli and, although infants receive a large amount of exposure to faces in early life, their exposure is fairly homogenous, reflecting few face types and few people (Jayaraman et al., 2015; Rennels & Simmons, 2008; Sugden et al., 2014). Even with highly familiar faces, it is not until approximately the middle of the first (de Haan & Nelson, 1997) or second (Carver et al., 2003) year of life or later that infants' behavioural preference for their mother's face over that of a stranger changes. Based on their visual experience with faces of particular types, it would be expected that infants would commence with a familiarity preference, attending more to familiar face types, followed by a novelty preference, attending more towards the unfamiliar face types (e.g., Fantz, 1964).

Infants' developing visual attention also informs theories of face processing. According to a schema-based model, faces that are moderately discrepant from the schema receive maximal attention whereas faces that are highly discrepant or not discrepant from the schema receive lower levels of attention (Fantz & Nevin, 1967; Kagan, 1970; M. Lewis, 1969; Wilcox, 1969). According to this model, familiar face types belonging to strangers would receive maximal attention when the infant is 3 months because they are moderately discrepant from the caregiver-schema that the infant is developing. At approximately 4 months, the schema for human faces is tentatively established and by 9 months it is entrenched, resulting in greater attention only to optimally discrepant stimuli (Kagan, 1970).

The above-proposed pattern would be also consistent with a the face space theory of face processing (Valentine, 2001) described in Chapter 1, which argues that the greater the number of exemplars of faces of a particular type that an individual experiences the greater the capacity to process faces of that type. Applied to development, as infants' face processing abilities grow with increases in their experience with faces, face processing latency for unfamiliar face types would be expected to increase, relative to processing latency for familiar face types, with increasing infant age (Slater et al., 2010). In other words, 3-month-olds would show a preference for familiar faces because they are building their face space for familiar face types. At 6 and 9 months of age, infants' face space for familiar faces would be more mature and consequently they would show greater attention towards the novel face types in an attempt to process these within their sere face space for this unfamiliar type.

Despite the congruence between these two recent studies, the state of the literature is less clear for race than for gender. A meta-analytic review completed by the author and a co-author (Marquis & Sugden, in preparation) found that infants' preference for female faces across the first year of life is robust, with a significant adjusted mean preference of 5.11% over chance. By comparison, infants' preference for faces of different races was inconclusive, with an adjusted mean preference of -2.88% over chance that was not significant. Furthermore, there was a substantial publication bias within the infant face race processing literature, leading meta-analysis to conclude that more research was necessary to disentangle infants' attention to own- and other-race faces within the first year of life.

The current study aims to evaluate the pattern of infants' visual attention to familiar and unfamiliar face types at 3, 6, and 9 months of age. As has previously been reported in the literature, we anticipate that 3-month-olds will exhibit a preference for familiar female own-race over unfamiliar male own-race faces, which will be attenuated at 6 and 9 months. We do not expect to find this gender preference with male and female other-race faces (Quinn et al., 2008). With female faces, we expect to replicate the previously-reported finding of a preference for own-race at 3 months, no preference at 6 months, and a preference for other-race at 9 months. For male faces, however, we are agnostic. If infants' attention to male own- and other-race faces depends on establishment of and degree of discrepancy from their face schema, then they should show a preference for own-race as their schema is being established at 3 or 6 months and for other race once it has been established, at 6 or at 9 months. If their attention to faces depends on the maturity of their face space for males, then the relative preference for male faces should show the same pattern as for females with a delay due to reduced male face exposure: a preference for male own-race faces should decrease while the relative preference for male other-race faces should increase with increasing infant age.

Method

Participants

Fifty-nine infants participated when they were 3 months old, 56 participated when they were 6 months old, and 54 participated when they were 9 months old (for demographic details, please see Table 1). Approximately two thirds of the infants (42 3-month-olds and 48 6-month-olds) were contacted to participate longitudinally. Twenty-nine infants participated at all three ages (3, 6, and 9 months of age; for full details of participation, please see Table 1 and Figure 1). Twenty-nine of these infants contributed data to the head-mounted camera study described in Chapter 1.

Table 1: Demographic details of infants who participated in the attentional preference task

Visits	Age	Demographic information by age and group			Group Demographics
		3 months	6 months	9 months	
Participated once	3 months	98.68 days old (*SD*=11.34; Range: 82-123)			22 infants (11 males; 9 White, 4 Asian, 2 Black, 1 South Asian, 6 Bi-racial)
	6 months		194 days old (*SD*=9.79; Range: 178-194)		12 infants (4 males; 9 White, 2 Bi-racial; 1 Multi-racial)
	9 months			282.67 days old (*SD*=11.76; Range: 261-304)	15 infants (9 males; 6 White, 9 Bi-racial)
Participated twice	3 and 6 months	104 days old (*SD*=18.02; Range: 88-122)	186.00 days old (*SD*=8.00; Range: 178-194)		4 infants (3 males; 2 White, 1 Black, 1 Bi-racial)
	3 and 9 months	102.25 days old (*SD*=6.45; Range: 93-108)		274.25 days old (*SD*=12.45; Range: 260-290)	4 infants (3 males; 2 White, 1 Asian, 1 Bi-racial)
	6 and 9 months		195.55 days old (*SD*=9.29; Range: 175-209)	275.50 days old (*SD*=14.30; Range: 258-300)	11 infants (2 males; 7 White, 2 Asian, 1 Black, 1 Bi-racial)
Participated three times	3, 6, and 9 months	97.45 days old (*SD*=10.89; Range: 80-121)	182.67 days old (*SD*=8.82; Range: 169-198)	276.88 days old (*SD*=9.80; Range: 266-302)	29 infants (10 males; 20 White, 1 Asian, 2 Black, 6 Bi-racial)
		3 months	6 months	9 months	All infant participators
Visits By Age and Overall		59 infants (27 males) 98.68 days old (*SD*=11.24) 34 White, 6 Asian, 5 Black, 2 South Asian, 12 Bi-racial)	52 infants (19 males) 187.98 days old (*SD*=10.64) 38 White, 3 Asian, 4 Black, 1 South Asian, 9 Bi-racial, 1 Multi-racial)	54 infants (24 males) 278.04 days old (*SD*=11.51) 35 White, 4 Asian, 3 Black, 17 Bi-racial)	98 infants (42 males) 165 total visits (summed across all age groups) 55 White, 8 Asian, 6 Black, 2 South Asian, 25 Bi-racial, 1 Multi-racial

Equipment

Infants were seated in their parent's lap in a darkened room. Parents were asked to wear a sleep mask during the task, to prevent their responses from influencing the infant's response. In a few cases where wearing the mask proved to be problematic (e.g., the infant was particularly fussy or squirmy, the infant was distracted by the mask, or the infant removed it from their parent's head) the parent was asked to close their eyes. The researcher and control computers were separated from the parent and infant by a heavy fabric curtain. A small lamp provided minimal illumination, to allow the research assistant to assess whether the infant was looking at the screen. The parent and infant sat approximately 30 centimeters from a Viewsonic VX2450 series LED 1080p full HD computer monitor with 1920 x 1080 resolution and 5ms response time, upon which the faces were presented. A matte black card-board frame was mounted to the front of the monitor to cover the reflective surfaces and lights of both the monitor and camera. The monitor sat on a small table, covered in a matte black curtain, against a wall, that was also covered in a matte black curtain. The curtains and frame ensured that there were no other visually interesting surfaces or objects to distract the infant. The infant preference task was programmed in E-Prime 2.0 (Psychology Software Tools, Inc.). Infant looking during all lab tasks was recorded using a Logitech HD Pro Web-Camera, which recorded 1080p video at 15 or 30 frames per second. The camera was situated on top of the viewing monitor and pointed down at the infant.

Stimuli

Infants were presented with four pairs of faces; each pair was presented twice with their left-right positions reversed. The pairs were: female own-race and female other-race, male own-race and male other-race, male own-race and female own-race, and male other-race and female other-race. Faces were 10-14 centimeters in height and 7-10 centimeters in width, sized so that the central face area of the eyes, nose, and mouth was always in approximately the same position. Faces were presented at a visual angle of 18.93-26.27 degrees by 13.31-18.93 degrees. The distance between the faces was 22-24 centimeters (or 40.27-43.60 degrees), varying depending on the size of the head of each face. The faces were full colour photographs of attractive adults presenting a closed-mouth smile, sourced from the SuMo Face Database

(Sugden & Moulson, 2013). The faces were determined to be positively valenced, happy, and attractive, scoring at least a 7 on a 10-point scale, where 10 would be most positive/happy/attractive. They were also rated as no more than 3 on a 10-point scale for distinctiveness (with 10 being most distinctive). The faces were presented on an off-white background (see Figure 9).

Race was determined by parents' self-identification. Since the city from which the participants were recruited is highly multicultural, many infants and parents were multi-racial. Own-race was always determined to be the race of the mother. Other-race was determined to be the race of neither parent. For example, if the mother self-identified as Asian and the father self-identified as Black and South Asian then own-race faces would be Asian and other-race faces would be White. Infants who participated more than once always saw the same races of faces during the task, but they never saw the same individuals more than once. This was accomplished by changing the individual faces that were used in this task every 3 months once the study commenced.

To orient or re-orient infants to the screen when faces were not being presented, an attention-grabber was displayed. The attention grabber was a red ball that appeared to expand and contract on the screen.

Procedure

Families were recruited from a database of parents who expressed an interest in participating in developmental research with their infant, as described in Chapter 2. A researcher then visited the family in their home to explain the study and deliver the camera, as described in Chapter 2 Approximately 1 week later, after recording the world from their infant's perspective, the parent and infant visited the lab. Once they were comfortably seated in an infant-friendly lounge, a researcher re-explained the task and answered any questions the parent had. While the parent was speaking to the researcher, another researcher would play with the infant, with the goal of acclimating the infant to the new environment and people.

Figure 9: Exemplar of face pairs from the preference task

*Photo on right published with permission. Photo on left is of the author and was not used in the study.

If the parent assessed the baby was ready, the parent, infant, and researcher moved to the testing room and the task commenced. Throughout the task, both the parent and researcher monitored the infant to ensure that the infant remained happy and engaged in the task. The task began with the attention-grabber. Once the infant attended to the screen, a research assistant presented a pair of faces. Presentation of the pairs was fully randomized. The pair remained on the screen for 10 seconds, regardless of infant looking behaviour, after which the attention-grabber reappeared. This repeated until either the infant saw all 8 presentations (4 pairs, each presented twice) or until the baby needed a break. If the baby took a break, the parent determined whether the baby wished to continue or discontinue the task altogether. All infants completed the task.

After they completed the task, infants and parents took a break. During this break, the researcher explained the next task, the face discrimination task. Subsequent to completing the attentional preference task, infants completed up to four discrimination tasks (see Chapter 4) and then the ERP task (see Chapter 5).

Video coding

All coders were trained to code infant looking to 85% reliability, measured against a highly-experienced senior coder. Infant looking was coded frame-by-frame from the video-recording of the infant during the preference task. Coding was conducted using Datavyu 1.3 (Datavyu Team, 2014). Determination of when the infant was oriented to the screen was done during the task by senior coders who had reached reliability criterion during training, spent several months assisting with the study, and acquired extensive experience coding infant looking behaviour from videos of the tasks from the study. Twenty percent of all video was coded by a second experienced coder to ensure inter-rater reliability. Only the results from the first coder are presented here.

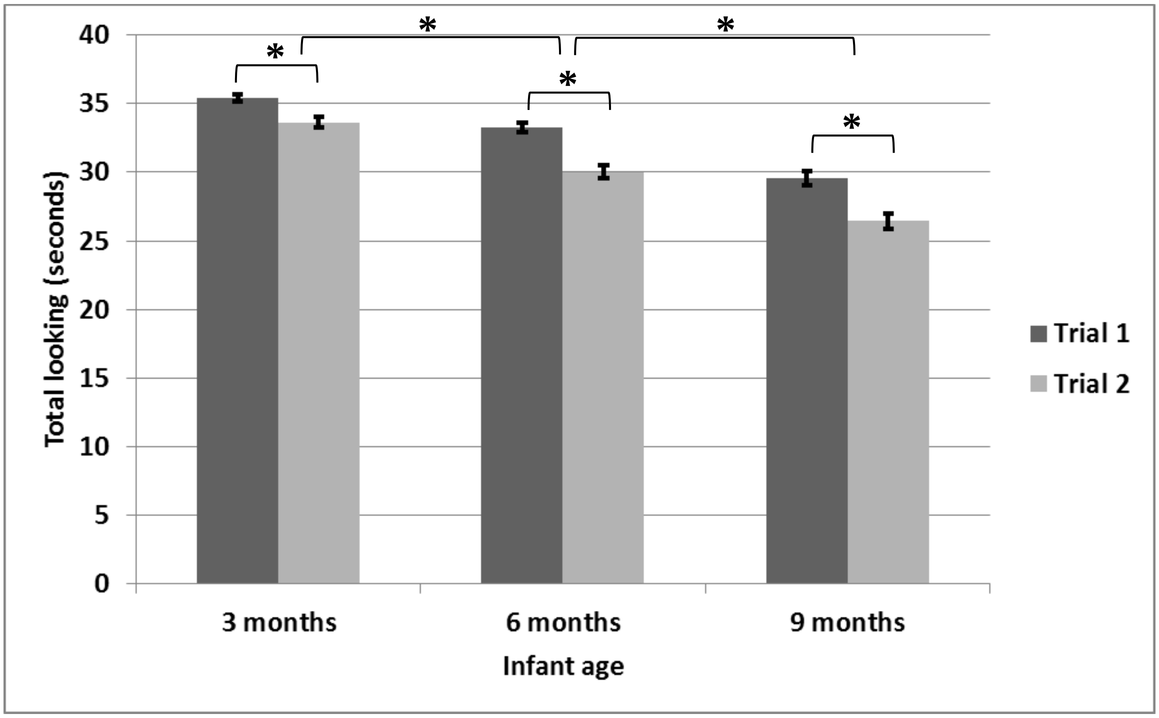
Results

Since infants saw each pair twice and looking behaviour may be expected to change between the first and second presentation (Roder et al., 2000), for all metrics of attention we present results for the first and second trials separately. In rare instances where infants did not look at the pair presented, these trials were omitted since assigning a value of 0 would be inaccurate; as a consequence, the sample size varies in a minority of cases.

Overall looking metrics

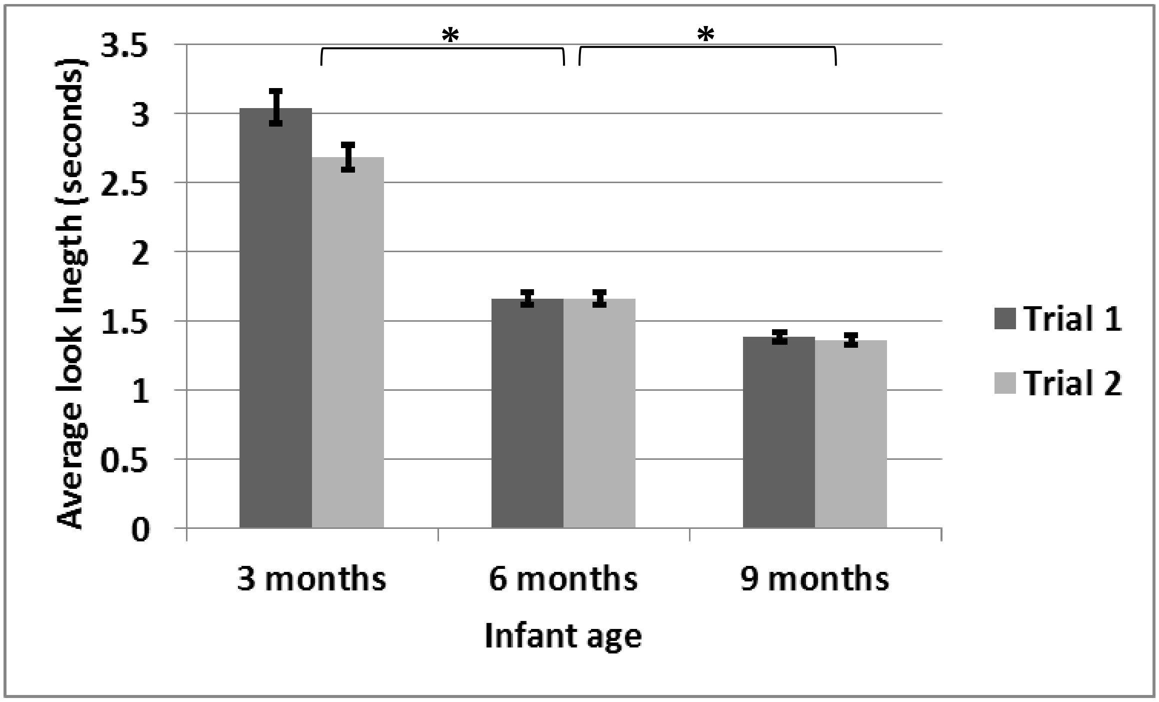
We examined infants' overall looking metrics to understand infants' overall patterns of attention and looking during the task before examining changes in these patterns based on familiarity. Since infant attention to faces is expected to decline over the first year of life (Goren et al., 1975; Johnson et al., 1991; M. Lewis, 1969), we first examined infants' overall attention to faces in terms of the amount of the 80 seconds of total trial time (i.e., 10 seconds per 4 pairs each presented 2 times = 10 x 4 x 2 = 80) they spent looking at the faces. This provides us with a measure of the total amount of attention infants were allocating to the faces, when they were available. We anticipated that this would decrease with increasing age, since older infants would need less time to process a face, and from trial 1 to trial 2, as the faces become less novel. Three-month-olds did look longest to the stimuli, spending 66.31 (SD=8.47) of the available 80 seconds (trial 1 M=33.84, SD=4.69, trial 2 M=32.47, SD=5.55); 6-month olds spent 59.46 (SD=10.18) of the available 80 seconds (trial 1 M=31.26, SD=4.69, trial 2 M=28.20, SD=6.64); 9-month-olds spent 52.08 (SD=13.89) of the available 80 seconds (trial 1 M=27.38, SD=7.01, trial 2 M=24.69, SD=8.01). The age-related decline was significant, $F(2, 162)=18.67$, $p<.001$, $n^2_p=0.19$, as was the decline over trials, $F(2, 162)=38.90$, $p<.001$, $n^2_p=0.19$; trial and age did not interact, $F(2, 162)=1.22$, $p=.297$, $n^2_p=.02$ (see Figure 10).

Figure 10: Total amount of time 3-, 6-, and 9-month-olds spent looking at the face pairs on trials 1 and 2 during the preference task



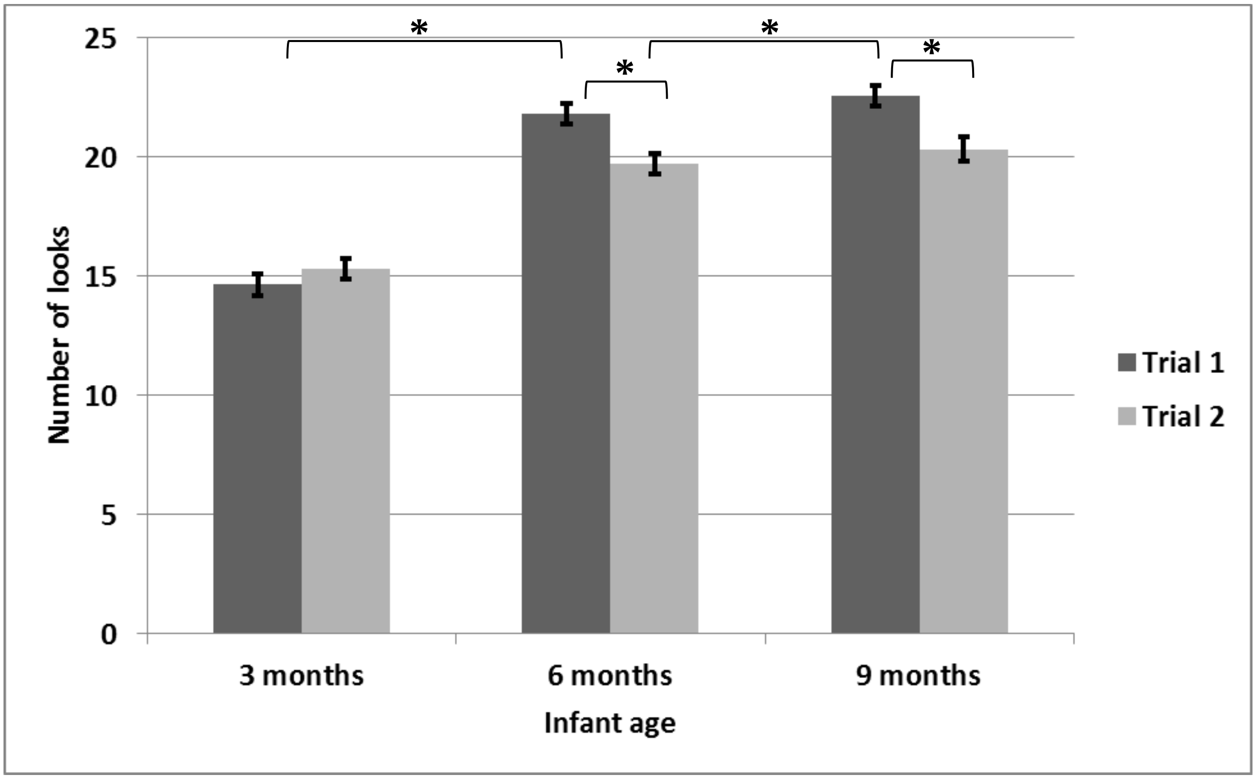
Since total time spent looking may represent few or several looks, we also examined to the average look length at each age and from trial 1 to trial 2. We anticipated that average look length would decline from trial 1 to trial 2 as the novelty of the faces decreased, and as infants aged. We did find an age-related decline in infants' overall look lengths, but not a decline from trial 1 to trial 2: 3-month-olds' 2.6-second looks (*SD*=1.08; trial 1 *M*=2.95, *SD*=1.73, trial 2 *M*=2.60, *SD*=1.40) were the longest, followed by 6-month-olds at 1.55 seconds (*SD*=0.54; trial 1 *M*=1.57, *SD*=0.60, trial 2 *M*=1.58, *SD*=0.63), and 9-month-olds at 1.27 seconds (*SD*=0.43; trial 1 *M*=1.29, *SD*=0.47, trial 2 *M*=1.27, *SD*=0.46). The age-related decline was significant, $F(2, 162)=49.55$, $p<.001$, $n^2_p=0.38$, but not the decline over trials, $F(1, 162)=1.88$, $p=.172$, $n^2_p=0.01$ or trial by age interaction, $F(2, 162)=1.74$, $p=.179$, $n^2_p=.02$ (see Figure 11).

Figure 11: Average look length for 3-, 6-, and 9-month-olds during the preference task



Lastly, we looked at total number of looks across all pairs of faces. We expected that younger infants would have fewer looks, as compared to older infants, since younger infants have difficulty disengaging their attention (Frick, Colombo, & Saxon, 1999). Indeed, 3-month-olds had the fewest looks (M=29.97, SD=6.11, trial 1 M=14.59, SD=7.06, trial 2 M=15.37, SD=6.55), as compared to 6-month-olds (M=41.54, SD=10.90, trial 1 M=21.83, SD=6.11, trial 2 M=19.71, SD=6.10) and 9-month-olds (M=42.89, SD=13.08, trial 1 M=22.50, SD=6.65, trial 2 M=20.39, SD=7.44). The age-related increase was significant, $F(2, 162)=19.44$, $p<.001$, $n^2_p=0.19$, as was the increase over trials, $F(1, 162)=8.81$, $p=.004$, $n^2_p=0.05$. Trial and age interacted, $F(2, 162)=5.32$, $p=.006$, $n^2_p=.06$, due to greater increases in number of looks on trial 1 as compared to trial 2 at 6 and 9 months (see Figure 12).

Figure 12: Number of looks on trials 1 and 2 for 3-, 6-, and 9-month-olds during the preference task



Preferential looking metrics

Since different types of looking behaviour differ in what they represent, we present two different metrics intended to capture different aspects of infant attention. Since infants saw each pair twice and looking behaviour may be expected to change between the first and second presentation, we considered first and second trials separately (Roder et al., 2000). As a measure of *attentional preference*, we present the proportion of time (measured in milliseconds) spent looking towards the familiar face over all time spent looking at either face during the trial, irrespective of the total amount of time available to look. This is taken to represent infants' attentional preference for one over another face, and is the metric usually reported in paired-preference studies (e.g., Quinn et al., 2002). To test our original hypotheses of greater looking towards female and own-race faces early and a reversal of this trend within the race comparisons at later ages, we ran one-sample t-tests against a nil of 50%.

As a measure of infants' *attentional orienting*, we present persistence or length of infants' first looks to each image in the pair (e.g., we measure the first look to the male face and also first look to the female face in a male-female face pair, not just the first look to one of the pair). We chose to use the first look to each picture (i.e., 2 first looks) and not to use only the first look to one of the pair (i.e., 1 first look), since the first look to the pair has been found to be randomly distributed (e.g., DeNicola, Holt, Lambert, & Cashon, 2013). The logic here is that even if the first saccade is randomly distributed between the two faces, they may yet distribute differential attention to faces of different types within their first look to each face within a pair of faces. In this case, we use paired-sample t-tests to determine whether infants' first looks are diagnostic of a pattern of preference.

To examine change over time, we conduct separate analyses on infants who only visited once and infants who visited multiple times. This is for three reasons. First, statistical models of change over time including all infants failed to converge. Second, statistical tests appropriate for the non-longitudinal samples assume independence of measurement, an assumption violated by the longitudinal babies. Third, and relatedly, statistical tests appropriate for the longitudinal samples either exclude (pair-wise or list-wise deletion) non-longitudinal infants or replace the missing values (e.g., with the mean); we did not view either option as appropriate since this would mean that nearly half of our sample would be deleted or estimated. To increase the power of our analyses, we include all infants' first visits (both those who visited only once and those who visited multiple times) in our analysis of the one-visit infants. Consequently, for the one-visit analyses, we include 59 3-month-olds, 22 6-momth-olds, and 15 9-month-olds; some tests, however, have fewer infants due to a lack of infant looking during a particular face or pair.

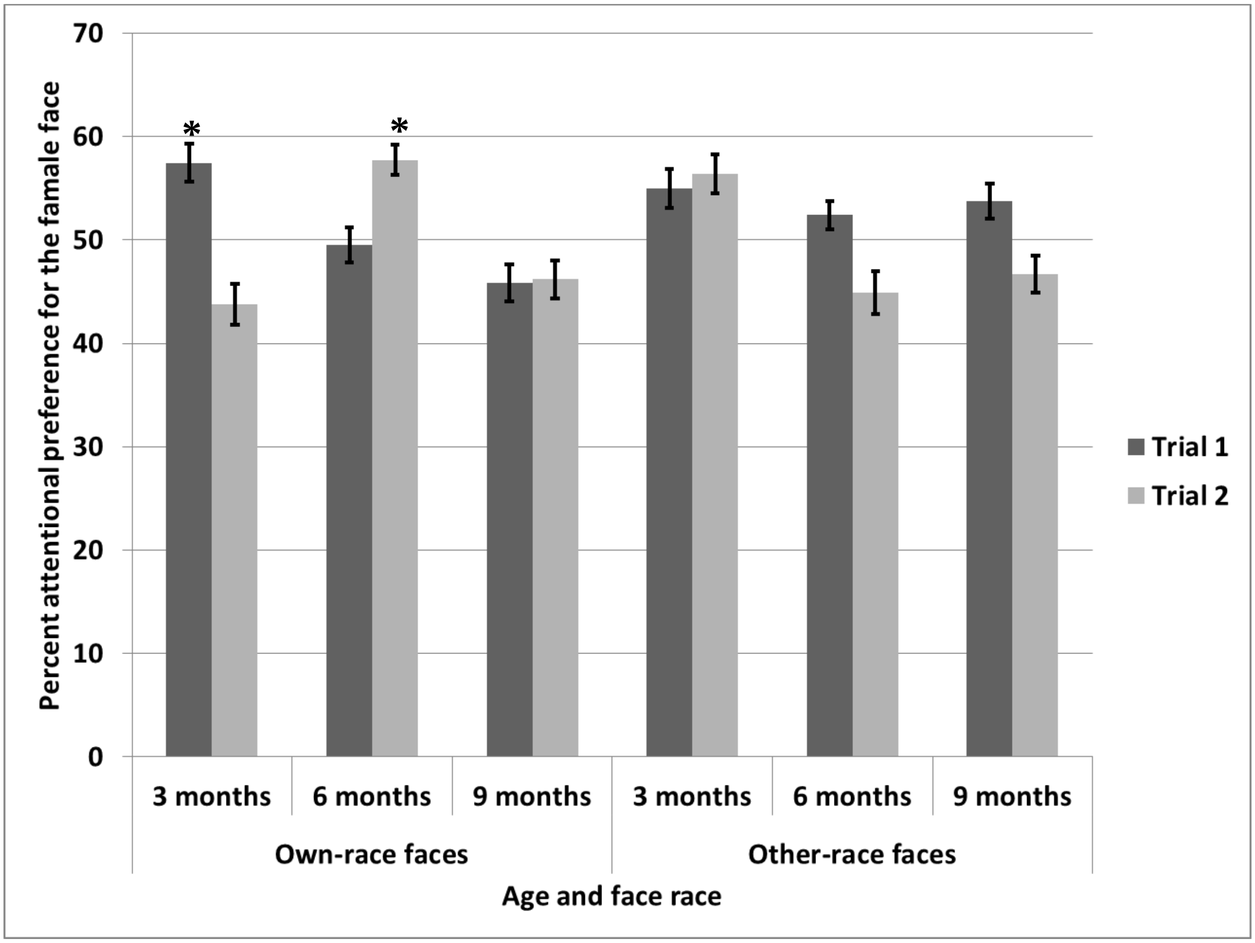
For each comparison for these infants, we used a repeated-measure model. In the preferential attention model, we included trial as a repeated-measure and age as a covariate. For attentional orienting, we additionally use face type as a repeated measure because attentional orienting encompasses two values (i.e., one for each face type) whereas attentional preference provides only one (i.e., a proportion of the familiar over the unfamiliar face type). For the longitudinal infants (n=28), we used the same strategy, with the only difference being that all of the infants visited more than once and age became a within-subject factor.

Gender preferences: own-race

Attentional Preference. We anticipated that infants would show a preference for female over male faces across all ages within the own-race pair, with the preference at 3 months being stronger than the preference at later ages. When considered as the proportion of all looking to the female as compared to all looking towards the male, infants did evidence the expected preference for female at 3 months on trial 1(t(58)=2.03, p=.047; ΔM=7.44%) and a non-significant preference for male on trial 2 (t(58)=-1.56, p=.121, ΔM=-6.24%). They exhibited a preference for female at 6 months on trial 2 (t(51)=2.73, p=.009, ΔM=7.75%) and no significant preference on trial 1(t(51)=-0.15, p=.882, ΔM=-0.05%). There was also no significant preference on either trial at 9 months (trial 1: t(53)=-1.17, p=.247, ΔM=-4.18%; trial 2: t(53)=-1.04, p=.304, ΔM=-3.80%; see Figure 13).

Within infants' first or only visits, there was no significant effect of trial, age, or a trial by age interaction (trial, F(1, 94)=1.27, p=.263, η_p^2=.013; age, F(1, 94)=0.003, p=.959., η_p^2<.001., trial X age, F(1, 94)=0.13, p=.715, η_p^2=.001). Similarly, within the longitudinal infants, there were no main effects or interactions (trial, $F(1, 23)=0.78$, $p=.386$, $\eta_p^2=.033$; age, $F(2, 22)=1.25$, $p=.307$., $\eta_p^2=.102$., trial X age, $F(2, 22)=2.00$, $p=.159$, $\eta_p^2=.154$).

Figure 13: Attentional preference towards the female face within the own- and other-race gender pairs by trial and age

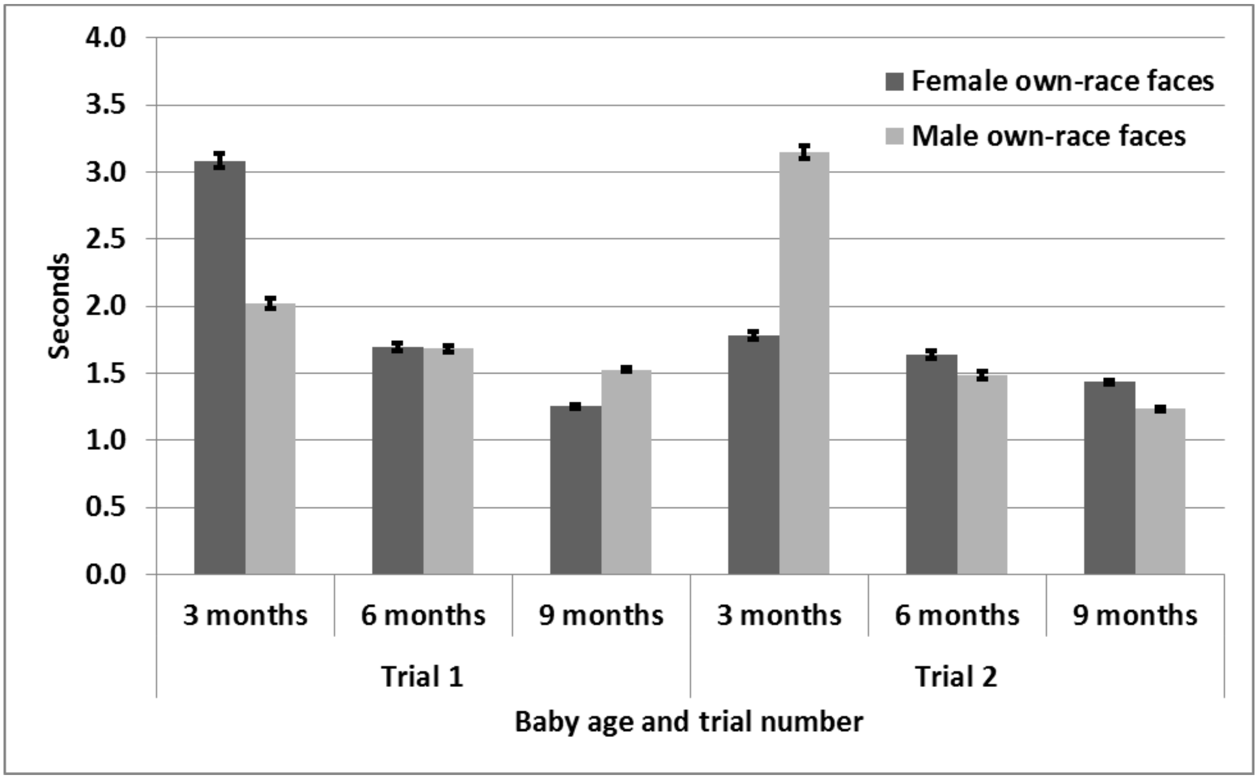


Attentional orienting. Although the pattern of greater looking to female on trial 1 and greater looking to male on trial 2 appeared similar to the results of attentional preference at 3 months, the duration of infants' first looks was only significantly different between the male and female face pairs at 3 months on trial 2, with a preference for male ($t(58)=-2.70$, $p=.009$, $\Delta M=-1.37$ seconds), and not on trial 1 ($t(58)=1.904$, $p=.062$, $\Delta M=1.07$ seconds). There were no other significant differences at 6 months (trial 1, $t(51)=0.045$, $p=..964$, $\Delta M=0.01$ seconds; trial 2, $t(51)=0.49$, $p=.628$, $\Delta M=0.16$ seconds), or 9 months (trial 1, $t(53)=-1.25$, $p=.218$, $\Delta M=-0.27$ seconds; trial 2, $t(53)=1.71$, $p=.094$, $\Delta M=0.20$ seconds; see Figure 14).

Within infants' first or only visits, there was a significant interaction of face type by trial ($F(1, 94)=7.72$, $p=.007$, $\eta_p^2=.076$), due to decreased looking towards the female and increased looking towards the male from trial 1 to trial 2 (for female faces, trial 1-2: $\Delta M=1.01$ seconds, $SE=0.33$, $t(95)=3.096$, $p=.003$; for other-race faces, trial 1-2: $\Delta M=-0.67$ seconds, $SE=0.34$, $t(95)=-1.95$, $p=.054$). There were no other significant main effects (face gender, $F(1, 94)=0.32$, $p=.576$, $\eta_p^2=.003$; trial ($F(1, 94)=.003$, $p=.955$, $\eta_p^2<.001$) or interactions (face gender X age, $F(1, 94)=0.34$, $p=.563$, $\eta_p^2=.004$; trial X age, $F(1, 94)=0.23$, $p=.631$, $\eta_p^2=.002$; face race X trial X age, $F(1, 94)=2.95$, $p=.091$, $\eta_p^2=.030$).

Within the longitudinal infants, there were no main effects or interactions (age, $F(2, 22)=3.32$, $p=.055$, $\eta_p^2=.232$; face gender, $F(1, 23)=1.95$, $p=.176$, $\eta_p^2=.078$; trial, $F(1, 23)=.023$, $p=.638$, $\eta_p^2=.010$; age X face gender, $F(2, 22)=0.63$, $p=.540$, $\eta_p^2=.054$; age X trial, $F(2, 22)=1.11$, $p=.348$, $\eta_p^2=.091$; face gender X trial, $F(1, 23)=0.46$, $p=.505$, $\eta_p^2=.020$; age X face gender X trial, $F(2, 22)=0.55$, $p=.586$, $\eta_p^2=.047$).

Figure 14: Attentional orienting towards the female face within the own-race gender pairs by trial and age



Gender preferences: Other-race

Attentional preference. We anticipated that infants would show no preference for female over male faces across all ages within the other-race pair. Within the proportion looking to the familiar face over all looking in the other-race gender comparison pair there was a different pattern than that of the own-race pair. Although the means on trial 1 suggested a preference for female, this was not significant at any age (3 months, $t(58)=0.86$, $p=.392$, $\Delta M=4.98\%$; 6 months, $t(51)=1.72$, $p=.091$, $\Delta M=2.40\%$; 9 months, $t(53)=1.12$, $p=.267$, $\Delta M=3.78\%$). Similarly, infants did not show a significant preference on the second trial (3 months, $t(58)=1.72$, $p=.091$, $\Delta M=6.41\%$; 6 months, $t(51)=-1.23$, $p=.226$, $\Delta M=-5.07\%$; 9 months, $t(53)=-0.95$, $p=.549$, $\Delta M=-3.30\%$; see Figure 13, above).

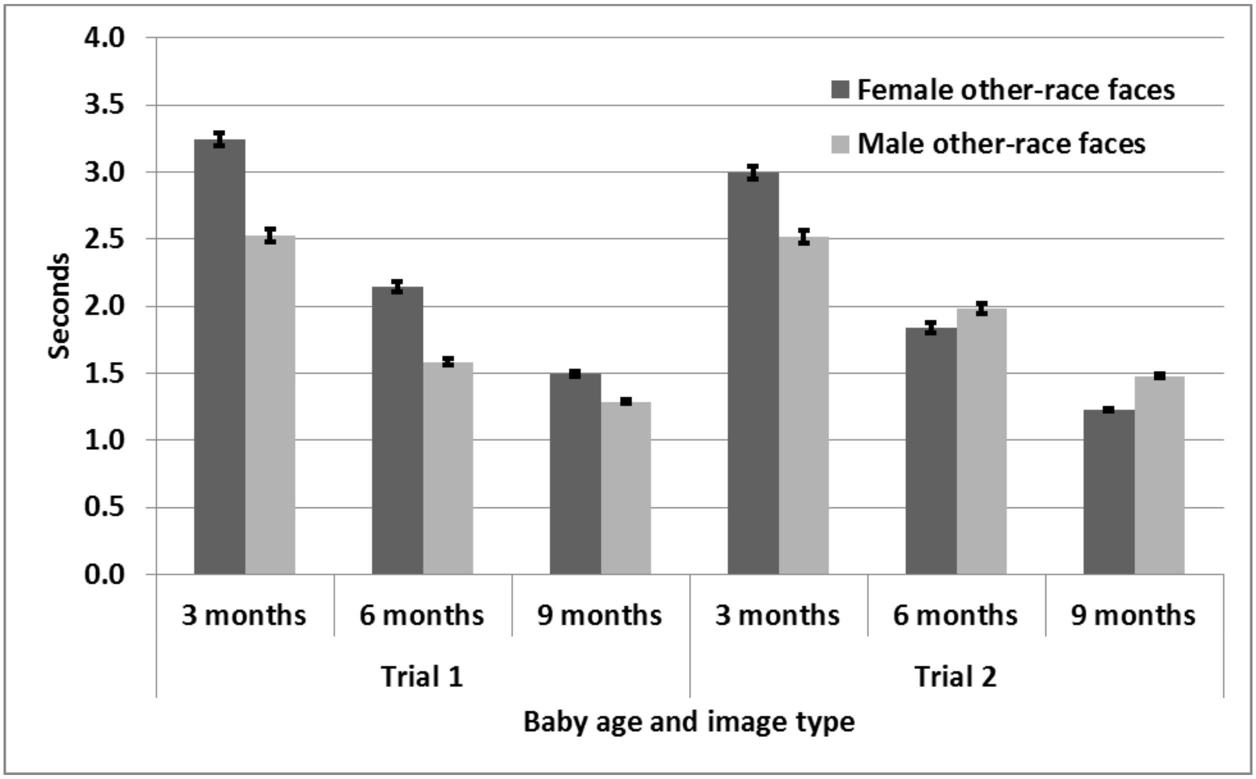
Within infants' first or only visits, there was no significant effect of trial, age, or a trial by age interaction (trial, $F(1, 94)=0.10$, $p=.748$, $\eta_p^2=.001$; age, $F(1, 94)=0.65$, $p=.421$, $\eta_p^2=.007$, trial X age, $F(1, 94)=0.09$, $p=.765$, $\eta_p^2=.001$). Within the longitudinal infants, there was a main effect of age ($F(2,22)=4.04$, $p=.032$, $\eta_p^2=.268$), with a significant decrease in preference from 3 to 6 months ($\Delta M=8.9\%$, $SE=3.4\%$, $p=.045$; but not from 6 to 9 months $\Delta M=-6.6\%$, $SE=4.0\%$, $p=.335$; or 3 to 9 months, $\Delta M=2.3\%$, $SE=4.8\%$, $p>.999$). There were no other main effects or interactions (trial, $F(1, 23)=2.14$, $p=.157$, $\eta_p^2=.085$; trial X age, $F(2, 22)=0.33$, $p=.725$, $\eta_p^2=.029$).

Attentional orienting. Consistent with our hypothesis, we found no preference for female at 3 months (trial 1, $t(58)=1.20$, $p=.236$, $\Delta M=0.72$; trial 2, $t(58)=0.75$, $p=.456$, $\Delta M=0.48$), 6 months (trial 1, $t(51)=1.76$, $p=.085$, $\Delta M=0.56$; trial 2, $t(51)=-0.38$, $p=.708$, $\Delta M=-0.14$), or 9 months (trial 1, $t(53)=0.98$, $p=.331$, $\Delta M=0.20$; trial 2, $t(53)=-1.50$, $p=.141$, $\Delta M=-0.25$; see Figure 15).

Within the infants' first or only visits, we found no significant main effects or interactions (face gender, $F(1, 94)=2.28$, $p=.134$, $\eta_p^2=.024$; trial, $F(1, 94)=0.16$, $p=.688$, $\eta_p^2=.002$; face gender X age, $F(1, 94)=0.39$, $p=.534$, $\eta_p^2=.004$; trial X age, $F(1, 94)=0.02$, $p=.893$, $\eta_p^2<.001$; face gender X trial, $F(1, 94)=0.01$, $p=.907$, $\eta_p^2<.001$; face gender X trial X age, $F(1, 94)=0.14$, $p=.709$, $\eta_p^2=.001$).

Within the longitudinal infants we found a similar pattern as with the own-race face gender pair. There was a main effect of age ($F(2, 22)=15.03$, $p<.001$, $\eta_p^2=.577$) due to significant decreases in looking with age from first to last and second to last testing visit (3 to 9 months, ΔM=1.06 seconds, *SE*=0.20, *p*<.001; 6 to 9 months, ΔM=0.56 seconds, *SE*=0.22, *p*=.038; 3 to 6 months, ΔM=0.47 seconds, *SE*=0.27, *p*=.291). There were no other main effects or interactions (face gender, $F(1, 23)=0.60$, $p=.447$, $\eta_p^2=.025$; trial, $F(1, 23)=0.04$, $p=.852$, $\eta_p^2=.002$; age X face gender, $F(2, 22)=0.12$, $p=.884$, $\eta_p^2=.011$; age X trial, $F(2, 22)=0.16$, $p=.855$, $\eta_p^2=.014$; face gender X trial, $F(1, 23)=1.29$, $p=.268$, $\eta_p^2=.053$; age X face gender X trial, $F(2, 22)=0.54$, $p=.592$, $\eta_p^2=.047$).

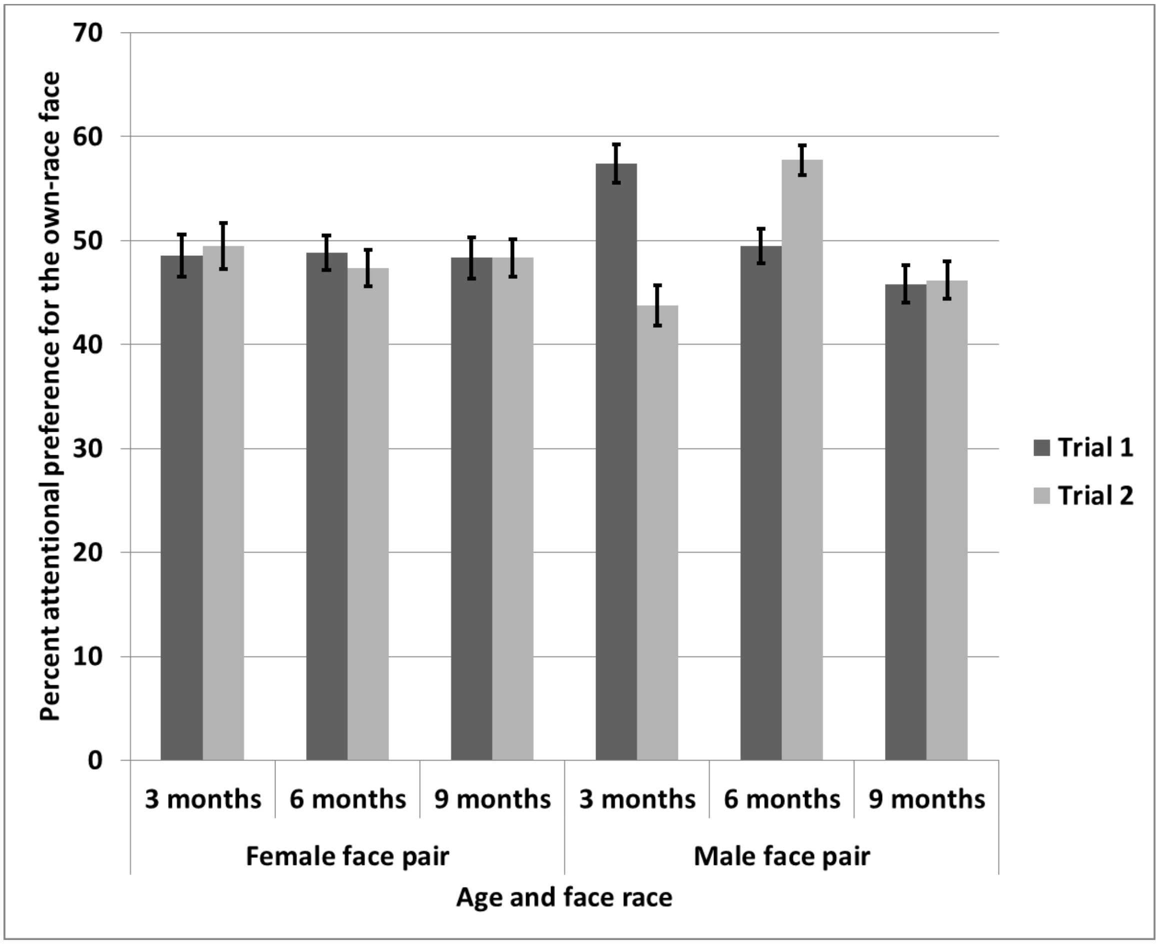
Figure 15: Attentional orienting towards the female face within the other-race gender pairs by trial and age



Race preferences: Female faces

Attentional preference. Previous research has documented infants' preference for own-race faces at 3 months, no preference at 6 months, and an other-race preference at 9 months using uniquely female faces (Fassbender et al., 2016); we expected to replicate these findings. Infants evidenced a non-significant preference for the other-race face at all ages and on all trials (3 months, trial 1: $t(58)=-0.35$, $p=.727$, $\Delta M=-1.41\%$; trial 2: $t(56)=-0.11$, $p=.910$, $\Delta M=-0.50\%$; 6 months, trial 1: $t(51)=-0.34$, $p=.733$, $\Delta M=-1.13\%$; trial 2: $t(51)=-0.74$, $p=.463$, $\Delta M=-2.60\%$; 9 months, trial 1: $t(53)=-0.42$, $p=.674$, $\Delta M=-1.66\%$; trial 2: $t(53)=-0.46$, $p=.651$, $\Delta M=-1.67\%$; see Figure 16). Given the lack of a significant preference and consistency in findings across the three ages and two trials at each age, we did not conduct any further analyses.

Figure 16: Attentional preference towards the own-race face within the male and female race pairs by trial and age

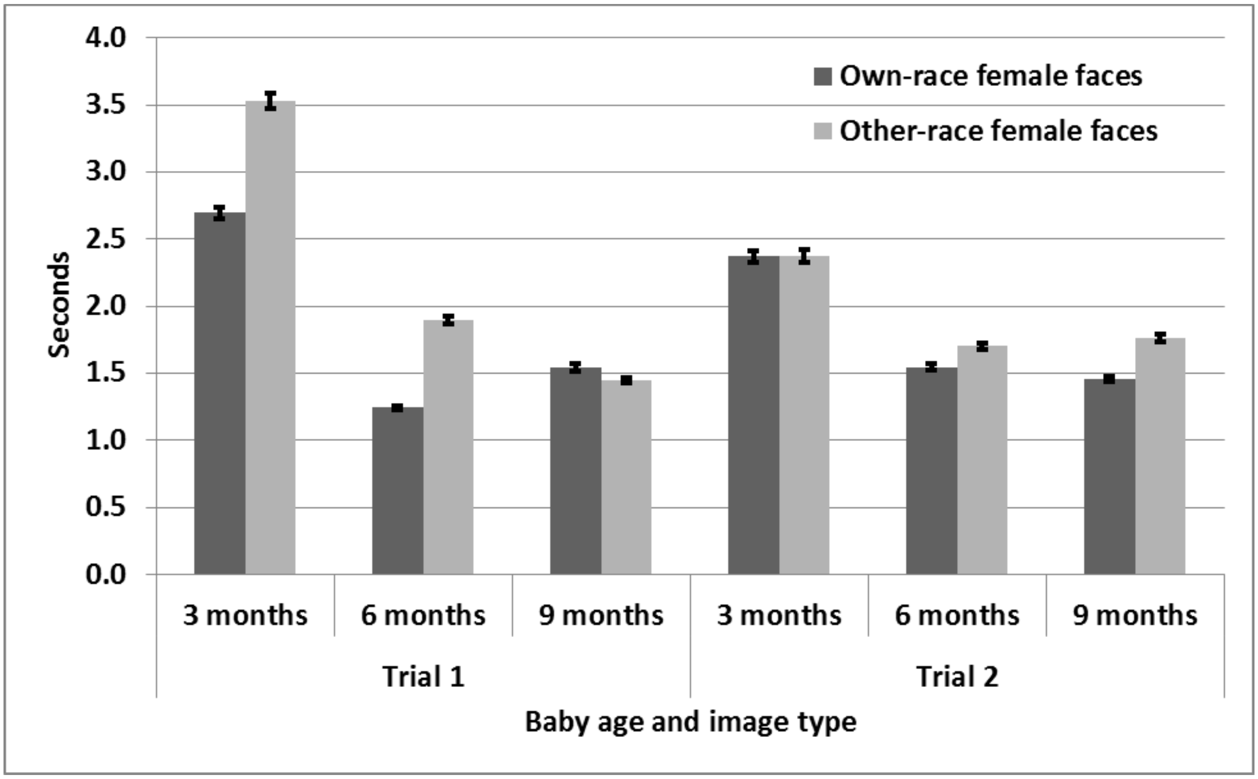


Attentional orienting. When considering the duration of the first looks within the female pair, there was significantly greater looking towards the other-race face on trial 1 at 6 months (t(51)=-3.17, p=.003, ΔM=-0.65), but not on trial 2 (t(51)=0.67, p=.509, ΔM=-0.16). There was also no significant difference at 3 months (trial 1, t(58)=1.17, p=.245, ΔM=-0.84; trial 2, t(58)=0.01, p=.992, ΔM=-0.01) or 9 months (trial 1, t(53)=-0.36, p=.720, ΔM=0.10; trial 2, t(52)=-1.23, p=.224, ΔM=-0.31; see Figure 17).

Within the infants' first or only visits, there was a significant main effect of trial (F(1, 92)=10.84, p=.001, η_p^2=.105), with significantly greater looking on trial 1 than trial 2 across all ages, ΔM=0.51 seconds, SE=0.16, p=.002). There was also a significant interaction of trial with age (F(1, 92)=4.46, p=.038, η_p^2=.046). There were significant changes with age only on trial 1 (own-race faces, F(2, 93)=4.61, p=.012; other-race faces, F(2, 93)=4.93, p=.009) but not trial 2 (own-race faces, F(2, 93)=2.01, p=.139; other-race faces, F(2, 93)=2.56, p=.083), due to a decrease in looking from trial-to-trial with increased age. This difference was significant at nearly all ages (own-race faces, 3 to 6 months, ΔM=1.37 seconds, SE=0.42, p=.004, 3 to 9 months, ΔM=1.51 seconds, SE=0.42, p=.001, 6 to 9 months, ΔM=0.52 seconds, SE=0.29, p=.860; other-race faces, 3 to 6 months, ΔM=1.47 seconds, SE=0.57, p=.033, 3 to 9 months, ΔM=2.22 seconds, SE=0.48, p<.001, 6 to 9 months, ΔM=0.76 seconds, SE=0.42, p=.185). There were no other main effects or interactions (face race, F(1, 92)=0.77, p=.383, η_p^2=.008; face race X age, F(1, 92)=0.22, p=.638, η_p^2=.002; face race X trial, F(1, 92)=0.50, p=.483, η_p^2=.005; face race X trial X age, F(1, 92)=0.05, p=.824, η_p^2=.001).

Within the longitudinal infants there was a main effect of age (F(2, 22)=4.06, p=.032, η_p^2=.269) due to significant decreases in looking with age from first to second testing visit (3 to 6 months, ΔM=0.62 seconds, SE=0.21, p=.025; 3 to 9 months, ΔM=0.70 seconds, SE=0.30, p=.091; 6 to 9 months, ΔM=0.08 seconds, SE=0.21, p>.999). There was also a significant interaction of test age with trial (F(2, 22)=10.40, p=.001, η_p^2=.486), due to a decrease in looking from trial 1 to trial 2 at 6 months (ΔM=-0.81 seconds, SE=0.34, p=.023). The decrease was not significant at 3 or 9 months ((ΔM=-0.75 seconds, SE=0.88, p=.039; ΔM=-0.19 seconds, SE=0.32, p=.553, respectively). There were no other main effects or interactions (face race, F(1, 23)=0.23, p=.637, η_p^2=.010; trial, F(1, 23)=2.06, p=.165, η_p^2=.082; age X face race, $F(2, 22)=1.76$, $p=.196$, $\eta_p^2=.138$; face race X trial, $F(1, 23)=0.37$, $p=.548$, $\eta_p^2=.016$; age X face race X trial, $F(2, 22)=0.84$, $p=.447$, $\eta_p^2=.071$).

Figure 17: Attentional orienting towards the own-race face within the female face race pairs by trial and age



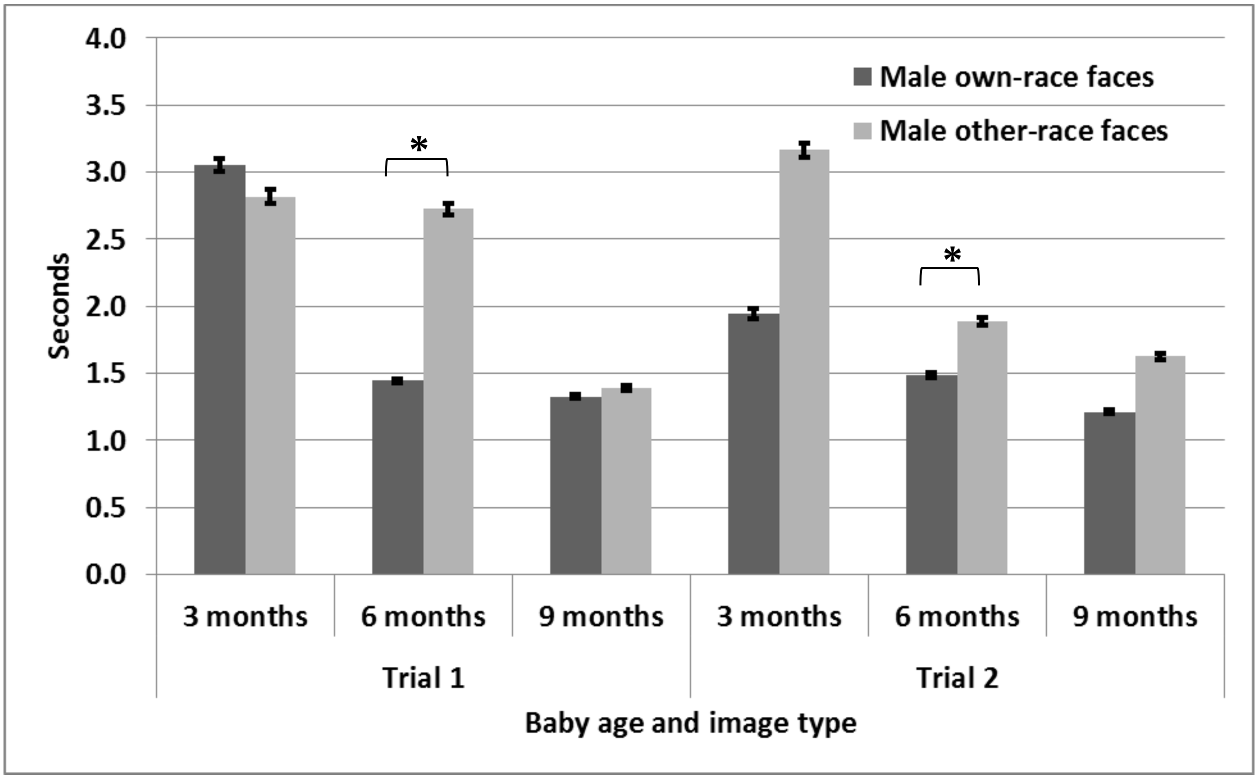
Race preferences: Male faces

Attentional preference. As above-discussed, infants' pattern of preference for own-race faces at 3 months, no preference at 6 months, and an other-race preference at 9 months, has been demonstrated with female faces (Fassbender et al., 2016) and with a combination of male and female faces (Liu et al., 2015), but not with uniquely male faces. We were agnostic as to whether infants would show this pattern with male faces. Infants' proportion looking showed a consistent preference for other-race faces amongst the male pairs, however this was not significant at any age (3 months, trial 1: $t(58)=-1.11$, $p=.270$, $\Delta M=-4.63\%$; trial 2: $t(58)=-1.85$, $p=.070$, $\Delta M=-7.22\%$; 6 months, trial 1: $t(51)=-0.32$, $p=.749$, $\Delta M=-1.07\%$; trial 2: $t(51)=-1.63$, $p=.109$, $\Delta M=-6.50\%$; 9 months, trial 1: $t(53)=-1.26$, $p=.215$, $\Delta M=-4.09\%$; trial 2, $t(53)=-1.97$, $p=.054$, $\Delta M=-6.96\%$; see Figure 16, above). Given the lack of a significant preference and consistency in findings across the three ages, we did not conduct any further analyses.

Attentional orienting. There were no differences in the length of first looks to either face at 3 (trial 1: $t(37)=0.52$, $p=.609$, $\Delta M=-0.24$ seconds, and trial 2: $t(35)=-1.56$, $p=.129$, $\Delta M=1.22$ seconds) or 9 months (trial 1: $t(47)=-1.40$, $p=.169$, $\Delta M=0.07$ seconds, and trial 2: $t(42)=-0.47$, $p=.644$, $\Delta M=0.41$ seconds). At 6 months, infants looked longer at the other-race faces on both trials (trial 1: $t(43)=-3.19$, $p=.003$, $\Delta M=1.28$ seconds, and trial 2: $t(38)=-257$, $p=.014$, $\Delta M=0.40$ seconds; see Figure 18),

In examining change over time, there were no significant main effects or interactions within the infants' first or only visits (face race, $F(1, 94)=1.44$, $p=.234$, $\eta_p^2=.015$; trial, $F(1, 94)=2.29$, $p=.134$, $\eta_p^2=.024$; face race X age, $F(1, 94)=0.04$, $p=.837$, $\eta_p^2<.001$; trial X age, $F(1, 94)=0.68$, $p=.413$, $\eta_p^2=.007$; face race X trial, $F(1, 94)=2.81$, $p=.097$, $\eta_p^2=.029$; face race X trial X age, $F(1, 94)=2.21$, $p=.141$, $\eta_p^2=.023$) or within the longitudinal infants (age, $F(2, 22)=0.32$, $p=.727$, $\eta_p^2=.029$; trial, $F(1, 23)<.001$, $p=.989$, $\eta_p^2<.001$; age X trial, $F(2, 22)=2.31$, $p=.122$, $\eta_p^2=.174$)

Figure 18: Attentional orienting towards the own-race face within the male face race pairs by trial and age



Discussion

Our data present an interesting pattern of results. For faces of different genders, the data suggest that infants do show an attentional preference for female over male own-race faces at 3 months and not for female over male other-race faces at any age. The preference for female in the current study is consistent with previous results finding a preference for own-race female as compared to male faces at 3 months of age (Quinn et al., 2002) and for female as compared to male other-race faces (Quinn et al., 2008). This is surprising because the infants in this sample were drawn from a large metropolitan city in which there is a large diversity of faces (Statistics Canada, 2011). Consequently, these infants have experience with other-race faces (e.g., when parents' friends visit, see Chapter 6). In the previously-cited research, the infants had limited contact with other-race faces due to their being born in a highly racially homogenous city.

Gender preferences

Although infants did not exhibit a statistically significant preference for female faces in the other-race pairs, they evidenced a pattern of greater looking towards the female on trial 1 as compared to trial 2 at 6 and 9 months. This is also the pattern they showed for own-race faces at 3 months, the only age at which they showed a preference for female. It has been well established that infants show a preference for novel relative to familiar stimuli (Fantz, 1964), however this is only true in certain conditions. Infants show a preference for the familiar until they have fully processed the stimulus, at which point they will prefer the novel, with factors such as stimulus complexity influencing the trajectory of this change in preference (Hunter & Ames, 1988; Hunter et al., 1983; Richards, 2010; Roder et al., 2000; Shinskey & Munakata, 2010). We argue that infants may be developing a preference for other-race female faces. Although they have some experience with this face type, they have not received sufficient experience to show a robust female face preference.

This can also be cast within the framework of face space (Valentine, 1991, 2001; Valentine et al., 2015). We would argue that by 3 months infants have acquired sufficient exposure to female own-race faces to have built a dense face space for faces of this type. This rich face space permits them to briefly look at the novel female face, easily process the face, and then, on the second trial, turn their attention to male own-race faces. Since other-race female faces are rarer in the infant's early visual environment (Sugden et al., 2014; see Chapters 2 and 6), their other-race female face space is too sparse at 3 months to allow them to fully process the face within the short task trials, leading to their continued interest in the face. The question then becomes when might infants have acquired sufficient exposure to other-race female faces to show the pattern of looking they presented for own-race faces at 3 months? It is possible that it is emerging from 6 to 9 months in the other-race faces, however it may not be fully evident until later in development.

The contrast here between infants' preferential attention to own- and other-race faces provides further evidence for the role of experience in shaping infants' early visual attention. As gender roles and the diversity of caregiving and parental leave amongst different populations change, this would be expected to drive differences in infants' preference for faces of different genders (Quinn et al., 2002). This suggests the need to accurately quantify this early face exposure and relate it to infants' developing capacities, as we do in Chapter 6.

Race preferences

The findings from own- and other-race comparisons across faces of different genders are less consistent with previous research. We find no attentional preference for other-race faces at any age for any face gender. We only find differences in attentional orienting, regardless of face gender, at 6 months; at 6 months infants spend longer time oriented to the other-race face. These findings are at odds with previous literature (Fassbender et al., 2016; D. J. Kelly et al., 2005; Liu et al., 2015). Although inconsistent with the perceptual narrowing literature, studies that have provided infants with experimental exposure to other-race faces have found that minimal exposure can reverse or prevent perceptual narrowing (Anzures et al., 2012; Heron-Delaney et al., 2011, p.). As described in Chapter 6, infants in the current study have some exposure to other-race faces, which has potentially provided them with sufficiently regular, but limited exposure to encourage them to attend to the other-race face. Here we suggest that they may experience other-race faces in a way that is akin to interrupting habituation or sufficient face processing – a process which results in a strong preference for the yet-unprocessed stimulus type (Hunter et al., 1983). Interactions that do not allow for adequate processing would fit with the face space model, in that the representations of these facieum interrumpitur would be sparser or less well developed than faces for which processing was adequate.

Given the increasing diversity within Canada (Government of Canada, Citizenship and Immigration, 2014), it may not be reasonable to expect that these infants see exclusively own-race faces. Finding a population with truly homogenous experience may become more and more challenging, further mudding the waters in the relationship between experience and ability. Attentional preference is influenced by infants' understanding of, familiarity with, and recent experience with familiar and unfamiliar face categories (Colombo et al., 2010; DeNicola et al., 2013; Shaddy & Colombo, 2004). Within a diverse population, race may no longer be salient (Anzures et al., 2010).

Conclusion

The results from combining infants' preference for gender and race allows for a better understanding of how different types of familiarity may differentially influence infants' patterns of attention. Within this context, infants' preference for face gender or race is not as straightforward. On some metrics, infants show the expected pattern of preferential looking, whereas on other metrics they do not. An infant-perspective view of natural experience with particular face types may offer a clearer view of the push and pull of novelty and familiarity on their attention (please see Chapter 6 for this analysis).

Chapter 4 Discrimination of familiar and unfamiliar face types

Just as preference changes over development, so does discrimination. Very early infants show an ability to discriminate between individual faces, such as between their mother's face and a stranger's face (Field, Cohen, Garcia, & Greenberg, 1984) or between two strangers' faces (Pascalis & de Schonen, 1994; Turati, Macchi Cassia, Simion, & Leo, 2006). They also discriminate faces from non-face stimuli (Easterbrook, Kisilevsky, Muir, & Laplante, 1999). When discriminating faces, newborns are able to use the diagnostic inner components (Turati & Simion, 2002), although removing face contour and hair cues disrupts recognition (Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995) suggesting that newborns cannot yet rely on internal cues alone. Despite their reliance on multiple cues, newborns' ability is surprisingly robust to changes in viewpoints (Turati, Bulf, & Simion, 2008), spatial-frequency filtering (de Heering et al., 2008), and occlusion (Gava, Valenza, Turati, & Schonen, 2008). They also show memory for and discrimination of faces over both short (i.e., 2 minute) and long (i.e., 24 hour) intervals at 6 months of age and, for male infants, also at 3 months of age (Pascalis & de Schonen, 1994).

Discrimination, like preference, changes over age and is shaped by the faces to which infants are exposed. Infants' ability to discriminate between faces shows a pattern that is the opposite of what has been documented for preference. Kelly and colleagues found that, across the first year of life, infants show a decline in their ability with other-race faces (D. J. Kelly, Quinn, et al., 2007). At 3 months, they can discriminate equally between own- and other-race faces. Despite being tested on the same task, at 6 months they are only able to discriminate between own-race faces and a few other-race face types and at 9 months they can only discriminate between own-race faces. Other studies, however, have found that 3-month-olds are only able to discriminate between other-race faces when they are provided with more information (i.e., a diversity of exemplars) and not when they were provided only with a single image of the familiar face (Sandy Sangrigoli & De Schonen, 2004). Although gender and race represent two possible dimensions by which a face can be familiar or not, these co-occur and it's unclear how infants process faces that include varying levels of familiarity.

Infants may have a better representation of female faces, as a consequence of infants' greater exposure to female faces (Rennels & Simmons, 2008; Sugden et al., 2014), which potentially explains superior processing of female over male faces (Ramsey-Rennels & Langlois, 2006). Also like own- and other-race faces, infants show differential processing of faces by gender. Infants typically show discrimination and a robust preference for female faces over male faces (Quinn et al., 2002), similar to their preference for own-race faces over other-race faces (D. J. Kelly et al., 2005). These two different types of novel and familiar face interact: infants' preference for female may not extend to female faces that are not the same as that of infants' primary caregiver (Quinn et al., 2008). Whether they show differential visual processing of own- and other-race male and female faces, however, is still an open question.

Training studies have found that experimental exposure can alter the typical trajectory of other-race face discrimination, preserving or regaining the ability. When infants are provided with other-race training with picture-books from 6 to 9 months of age, they do not evidence the typical decline in other-race face processing (Heron-Delaney et al., 2011). Furthermore, providing infants with training on other-race faces allows them to regain their ability to recognize other-race faces, despite their being unable to do so prior to training (Anzures et al., 2012). This retention of ability with faces for which infants typically show declines in discrimination has also been found when infants were provided regular training with other-species faces (Scott & Monesson, 2009), a face type for which infants show a pattern of declining discrimination ability similar to that seen with other-race faces (Pascalis et al., 2002).

Previous studies have found that race and gender discrimination abilities interact (Tham, Bremner, & Hay, 2015). Infants' ability to discriminate between two individuals depended on both gender and race at 3 to 4 months of age, but only on race at 8 to 9 months of age. Although the younger infants performed best with own-race female faces, the older infants performed best with both male and female own-race faces. Departing from the findings of Kelly, however, Tham and colleagues (2015) did not find that the younger infants could discriminate own- and other-race faces with equal facility: only own-race faces were discriminated at both ages.

Mechanisms

Several mechanisms by which the differential processing of familiar and unfamiliar face types develops have been proposed. These theories are not mutually exclusive and all are well supported. All theories underscore the difference in early exposure to faces of different types (e.g., greater exposure to female, own-race, and adult-age faces as documented by several researchers: Rennels & Simmons, 2008; Sugden, Mohamed-Ali, & Moulson, 2014) as girding the emergence of differential processing. None, however, directly addresses the multiple competing influences of different types of familiarity and how these different types of familiarity may interact.

Scott and colleagues have proposed perceptual narrowing, a process by which infants' perceptual system improves with frequently-experienced face types and either declines or fails to improve with infrequently-experienced face types (Scott et al., 2007). This perceptually-driven theory is supported by empirical studies of changes in infants' visual discrimination of faces from 3 to 9 months, whereby infants maintain or improve in their ability to discriminate familiar and not unfamiliar face types (D. J. Kelly, Quinn, et al., 2007; Macchi Cassia et al., 2014; Simpson, Varga, Frick, & Fragaszy, 2011).

Although not addressing development, per se, Valentine's face space theory argues that increased experience with own-race faces creates a superior representation of that face type in face space which allows better processing faces of this type and that face types with which they have a paucity of experience creates a sere face space against which discrimination is far more challenging (Valentine, 1991, 2001; Valentine et al., 2015). There is evidence that this is operating in infancy and childhood, suggesting that it represents an age-invariant mechanism for learning faces (Nishimura et al., 2009; Slater et al., 2010). In this view, with greater experience with familiar face types, infants should show greater ability with faces of these types. Conversely, a sere face space would make face discrimination challenging. In his recent recapitulation of face space, Valentine and colleagues (2015) argue that the way in which infants are exposed to faces may play a role in determining which faces make it in to the representational face space.

An exemplar-based model is congruent with research that found that maintenance of infants' ability with infrequently-experienced faces depended on their individuation with a unique name (e.g., 'Preston', 'Ragnar', and 'Nicole' instead of 'Monkey', 'Monkey', and 'Monkey'; Scott & Monesson, 2009). This marker for individuation may shape how infants process the face and thereby store it in their face space. Similarly, Scott has also suggested that developmental tasks and social interactions may play a role in differences in trajectories of face processing for faces of different types (Scherf & Scott, 2012). Individuation is just one way in which the caretakers and other important people in infants' lives are explicitly differentiated from strangers. Infants may know several female own-race faces (e.g., mom, grandma) that interact with them in sensitive ways, but this may be true for fewer male own-race faces. Similarly, it is conceivable that mom's friends would be more likely to interact with the infant than would be dad's friends, potentially resulting in social female other-race face exposure for the infant and not male other-race face exposure. Social interaction may itself also mark faces for differential processing, with familiarity being an influence on the likelihood of social interaction with faces of different types.

In a recent paper, Markant and colleagues (2016) argued that the deployment of attention may be at the root of infants' failures to discriminate. On a task on which 9-month-old infants typically show an inability to discriminate other-race faces, she found that experimentally changing how infants' deploy their attention causes the other-race effect to disappear (Markant et al., 2016). This is consistent with the other theories, but provides a more basic perceptual mechanism by which they may operate. Infant attention may be shaped by social or other markers, which then determines whether or how a face will be processed. At present, it is difficult to tease apart the contributions of each of these mechanisms to the development of the gender and race processing in infancy, particularly since the mechanisms and face types are not mutually exclusive. For example, how might faces that draw from both familiar and unfamiliar categories (e.g., own-race male or other-race female) be attended in a discrimination task?

It might be expected that types of familiarity may interact. Some familiar face types may be more generally better attended or processed than other face types, even when combined with unfamiliar face types. For example, familiar faces are processed better than unfamiliar faces: older infants typically show superior processing of own-race over other-race infants, a dichotomy not present in younger infants (D. J. Kelly, Quinn, et al., 2007). However, own-race female faces are likely to be more familiar to the infant than other-race female faces. Own-race female faces are also likely to be more familiar than own-race male faces. Other-race male faces are likely to be the least familiar, within race and gender comparisons. How might this combination of levels of familiarity impact infants' ability to discriminate between individual faces of that type?

No study has compared infants' discrimination of faces of different genders beyond 3 months of age or how this changes with age. Furthermore, no study has directly compared differences in discrimination between different types of familiarity and how discrimination of faces that vary along dimensions of familiarity change with age. Is familiarity represented in a way that is dichotomous, requiring faces to be familiar on all dimensions for successful discrimination, or nuanced, with degree and type of familiarity considered? The goal of the current study was to understand how infants' discrimination of faces differed by levels of familiarity, gender and by race, across the first year of life. We hypothesized that infants' discrimination of faces of varying degrees of familiarity would be graded. The most familiar face type (i.e., female own-race; most mom-like) was expected to be discriminated at all ages. The face type that least resembled mom or dad (i.e., male other-race) faces was expected to be discriminated at 3 but not at 6 or 9 months. The second most familiar face types (i.e., male own-race, most dad-like; and female other-race, mom-like in gender but not race) were expected to be equally discriminated at 3. We anticipated discrimination of female other-race faces, but were agnostic on male own-race faces.

Method

Participants

Fifty-nine infants participated when they were 3, 56 participated when they were 6, and 59 participated when they were 9 months old (for demographic details, please see Table 2). These were the same infants who participated in the preferential attention task (Chapter 3). Additionally, the head-mounted infant-perspective data from a sub-set of the 3-month-olds who participated in this task is described in Chapter 1. A minority of infants did not complete any habituation tasks during their visit (for full details of participation, please see Table 3 and Figure 1).

Stimuli and equipment

Infants participated as part of a large-scale longitudinal study. For this task, infants were seated in their parent's lap, in front of a computer monitor, in a darkened room. To prevent parents from inadvertently influencing the infant's responses, they were asked to wear a sleep mask throughout the task. If an infant was particularly fussy or squirmy, distracted by the mask, or removed the mask from their parent's head the parent was directed to keep their eyes closed for the duration of the task. The researchers who were controlling the presentation of stimuli were separated from the parent and infant by a heavy fabric curtain that prevented the control computers from illuminating the testing area. A small lamp provided minimal illumination, to allow the researcher to assess infant looking during the task.

Parent and infant sat approximately 30 centimeters away from the computer monitor upon which the face stimuli were presented, a Viewsonic VX2450 series LED 1080p full HD computer monitor with 1920 x 1080 resolution and 5ms response time. The small table on which the monitor sat and wall against which the monitor was placed were covered in a matte black curtain. Reflective surfaces and lights on the monitor and camera were covered by a black card-board frame. The goal of covering these surfaces was to ensure that the images presented on the screen were the only visually interesting objects available to the infant. The task was programmed in presentation (Neurobehavioralsystems, www.neurobs.com). Infant looking during all lab tasks was recorded using a Logitech HD Pro Web-Camera which recorded 1080p video at 15 or 30 frames per second.

Table 2: Demographic details of infants who participated in the discrimination task

Visits	Age	Demographic information by age and group			Group Demographics
		3 months	6 months	9 months	
Participated once	3 months	100.08 days old (*SD*=11.67; Range:82-123)			22 infants (11 males; 9 White, 4 Asian, 2 Black, 1 South Asian, 6 Bi-racial)
	6 months		195.14 days old (*SD*=9.16; Range:182-212)		12 infants (4 males; 9 White, 2 Bi-racial; 1 Multi-racial)
	9 months			282.67 days old (*SD*=11.76; Range:261-304)	15 infants (9 males; 6 White, 9 Bi-racial)
Participated twice	3 and 6 months	98.82 days old (*SD*=12.34; Range:84-121)	191.53 days old (*SD*=12.39; Range:175-217)	274.82 days old (*SD*=13.46; Range:258-300)	4 infants (3 males; 2 White, 1 Black, 1 Bi-racial)
	3 and 9 months				4 infants (3 males; 2 White, 1 Asian, 1 Bi-racial)
	6 and 9 months				11 infants (2 males; 7 White, 2 Asian, 1 Black, 1 Bi-racial)
Participated three times	3, 6, and 9 months	97.09 days old (*SD*=10.52; Range:80-120)	182.30 days old (*SD*=8.77; Range:169-198)	276.04 days old (*SD*=10.60; Range:260-302)	29 infants (10 males; 20 White, 1 Asian, 2 Black, 6 Bi-racial)
Overall		3 months	6 months	9 months	All infant participators
		n=54 infants (26 males) 98.11 days old (*SD*=11.31; Range:80-123)	*n*=52 infants (19 males) 188.42 days old (*SD*=11.35; Range:169-217)	*n*=49 infants (21 males) 278.10 days old (*SD*=11.70; Range:258-304)	97 individual infants (42 males) 161 total visits (summed across all age groups) 55 White, 8 Asian, 6 Black, 2 South Asian, 25 Bi-racial, 1 Multi-racial

Table 3: Number of trials attempted and completed in the discrimination task

Visits	Age at task		
	3 months	6 months	9 months
Participated once	Attempted: 57 (*n*=25) Completed: Female own: 5 Female other: 13 Male own: 12 Male other: 2	Attempted: 33 (*n*=14) Completed: Female own: 0 Female other: 13 Male own: 10 Male other: 4	Attempted: 45 (*n*=15) Completed: Female own: 8 Female other: 10 Male own: 10 Male other: 5
Participated twice	Attempted: 24 (*n*=11) Completed: Female own: 2 Female other: 5 Male own: 6 Male other: 1	Attempted: 40 (*n*=15) Completed: Female own: 5 Female other: 13 Male own: 9 Male other: 5	Attempted: 32 (*n*=11) Completed: Female own: 6 Female other: 11 Male own: 10 Male other: 6
Participated thrice	Attempted: 45 (*n*=24) Completed: Female own: 0 Female other: 18 Male own: 16 Male other: 1	Attempted: 70 (*n*=24) Completed: Female own: 11 Female other: 20 Male own: 19 Male other: 10	Attempted: 64 (*n*=24) Completed: Female own: 10 Female other: 21 Male own: 21 Male other: 6
Overall	Attempted: 126 (*n*=59) Completed: Female own: 7 Female other: 36 Male own: 34 Male other: 4	Attempted: 143 (*n*=52) Completed: Female own: 16 Female other: 46 Male own: 38 Male other: 19	Attempted: 137 (*n*=49) Completed: Female own: 24 Female other: 42 Male own: 41 Male other: 17

Stimuli

Infants were presented with two faces during each task: the familiar face to which they were habituated and a novel face. Each task was with one of four face types: female own-race, female other-race, male own-race, and male other-race. Each face type had at least three versions with unique faces, to ensure that infants who participated in the study at more than one time point saw different faces each time. For the purposes of this task, infants' own-race was determined to be the race of their mother.

Faces were presented at a visual angle of between 18.9 to 22.6 degrees in height and between 13.3 to 17.06 degrees in width. Height and width varied because faces were sized to ensure that the facial features (i.e., level and width of the eyes and position of the nose) were consistent from face to face. The faces were full colour photographs of attractive adults presenting a closed-mouth smile, sourced from the SuMo Face Database (Sugden & Moulson, 2013). The faces were determined to be positively valenced, happy, and attractive, scoring at least a 7 on a 10-point scale, where 10 would be most positive/happy/attractive. They were also rated as no more than 3 on a 10-point scale for distinctiveness (with 10 being most distinctive).

In addition to the faces, infants were also presented with an attention-grabber between trials, to re-orient the infant to the screen. The attention grabber was either a red or blue ball that loomed and retracted, appearing to bounce forward and back on the screen.

Procedure

After infants completed the attentional preference task (see Chapter 3), they were given a break while the researcher explained the discrimination task to their parent(s). Once the parent determined that the baby was ready, the family and researcher moved to the testing room. To ensure that the infant remained happy and engaged in the task, both the parent and the researcher monitored the baby. If the baby became fussy or the parent felt that the baby needed a break, the task was discontinued either temporarily or permanently. If the reason for the break was sufficiently minor to not require the parent and infant to move, the task was resumed after the temporary discontinuation. Temporary discontinuation was primarily due to infants' dropping their soother during the task. If the infant required feeding, changing, or other attention (e.g., one infant undressed themselves), the task was permanently discontinued. Although the infant was permitted to return to complete other tasks, they were not shown the same face pair again.

Once the researcher initiated the task, infants were presented with the attention-grabber. Once the infant attended the attention-grabber, a research assistant presented the first face. While faces were on the screen, the researcher monitored infants' looking to the screen through a live video-feed of the video recording the infant's looking behavior, recorded with a small web-camera that was pointed at the infant (as described in Chapter 2). The researcher would depress a button while the infant was looking to the screen and release the button once the infant disengaged from the screen. If the infant looked away from the screen for at least 2 seconds, the trial ended. This repeated until the infants' total looking towards the image during the last three trials decreased to 50% or less than the total looking towards the image during the longest consecutive three trials (e.g., (trial4 + trial5 + trial6)/(trial1 + trial2 + trial3) < 0.5), with the caveat that the longest three trials and last three trials were mutually exclusive. As a consequence, all infants saw a minimum of six habituation trials (i.e., longest consecutive three trials were the sum of 1, 2, and 3, more than double the sum of trials 4, 5, and 6). The task was programmed to show infants a maximum of 30 trials, however no infants reached this acme.

After reaching habituation criterion, infants entered three test trials. During the test trials infants were shown two faces in the following pattern: a novel face, the familiar face, and the novel face again. Each face was presented for a total of 10 seconds, irrespective of infant looking. As during habituation, infants were presented with an attention-grabber between test trials and a researcher determined the onset of each test trial, based on whether the infant was attending to the screen.

After each completed habituation task, parents and infants took a small break during which infants played with their parent, a research assistant, and/or toys. During this break, parents were encouraged to feed or change the baby, as needed. Parents were then asked to assess whether infants would like to complete another task. If the parent assessed the infant was willing to continue, the task repeated with a different pair of faces, until infants had completed all 4 tasks. If infants did not complete a habituation task and the cause of their failure to complete was not readily identified by the parent as state-related (e.g., hungry, soiled diaper) or the parent asked to discontinue a task, they were not invited to complete another task. The order of tasks was quasi-random. The first two tasks were randomized to be either own-race male or other-race female faces. The last two tasks were randomized to be either other-race male or own-race female. After the discrimination tasks were completed, the parent and infant were given another break. The infant subsequently completed the ERP task (see Chapter 5).

Infant looking coding

All coders were trained to 85% inter-rater reliability on previously-recorded videos, as measured against a highly-experienced senior coder. They were then required to gain experience coding previously-recorded videos prior to being permitted to code infants' looking during the task. Infant looking was coded off-line, frame-by-frame using Datavyu 1.3 (Datavyu Team, 2014). All coders were blind to the trial (e.g., habituation or test) and the type of face pair (e.g., own-race or other-race) being displayed.

Results

Overall, infants attempted 406 habituation tasks, an average of 2.54 (SD=0.94) habituation tasks per infant. Fifty habituation attempts were unsuccessful (see Table 3: Number of tasks completed by age and by number of visits). Although this number may seem high, it represents only 12.2% of all task attempts. Anecdotally, this often occurred because parents typically encouraged infants to complete as many tasks as they could, resulting in infants becoming fussy after having already completed 1 or more tasks.

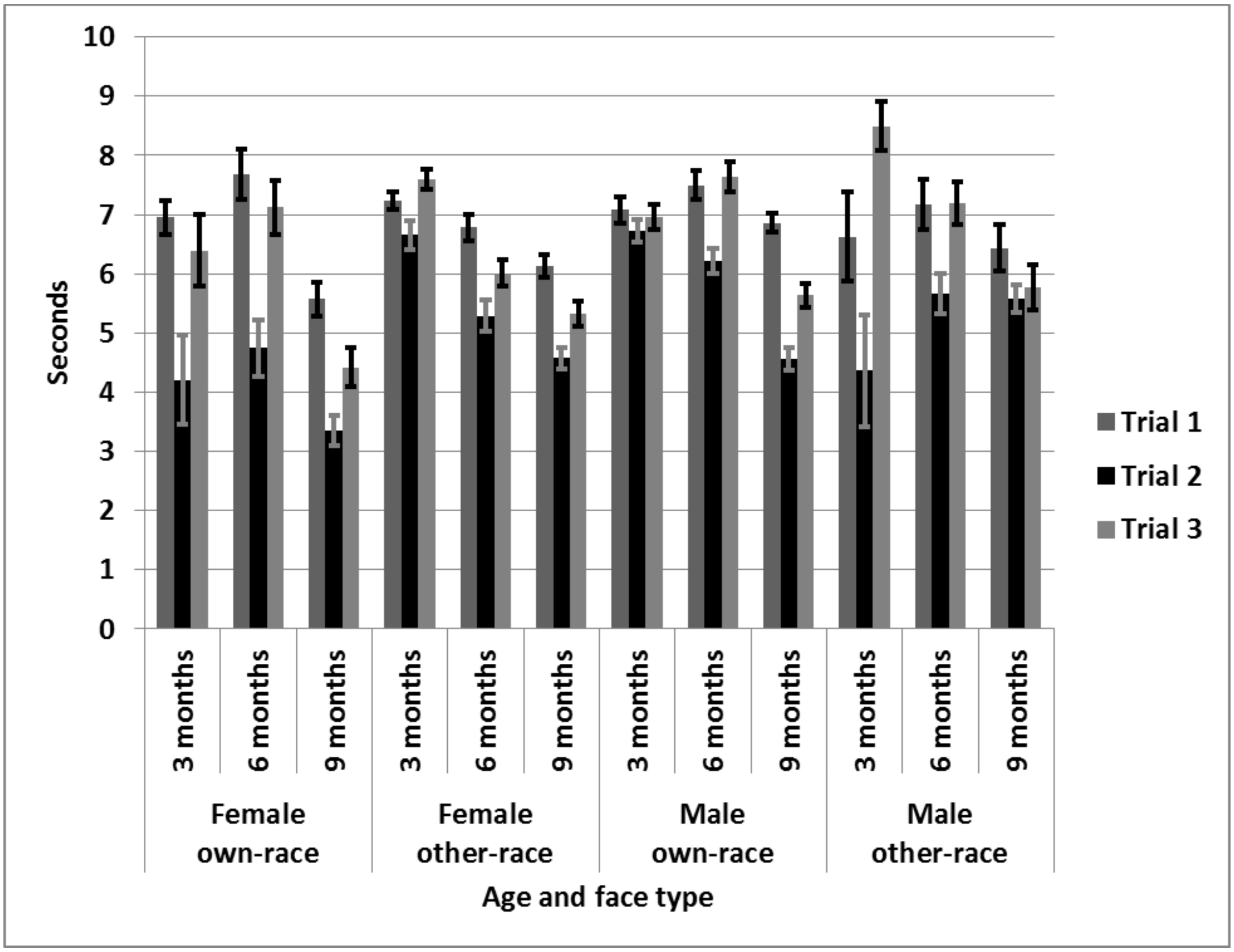
Habituation metrics

Although we had no prior hypotheses about face types impacting infants' looking behaviour during the habituation portion of the task, we checked whether infant looking differed during habituation, prior to the test trials, between face types. To evaluate whether infants' looking behaviour during habituation differed on the habituation trials, we ran a repeated measures general linear model with within-subject variables of face race (2 levels: own and other) and face gender (2 levels: female and male), with age as a between-subject factor. There was a significant effect of age, $F(1, 20)=5.80$, $p=.010$, partial η^2=.37. This reflected overall greater looking at 3 months (*M*=110.24, *SE*=11.55 seconds) as compared to 6 and 9 months (*M*=83.56, *SE*=8.17 seconds and *M*=65.11, *SE*=6.97 seconds, respectively).

There was also a significant effect of face gender, $F(1, 20)$=7.18, p=.014, partial η^2=.26, and a face gender by age interaction, $F(1, 20)$=5.07, p=.017, partial η^2=.34. Not unexpectedly, this was due to overall more looking at 3 months to female faces (*M*=138.54 seconds, *SE*=11.81) than to male faces (*M*=81.93 seconds, *SE*=16.04). This was also true at 6 months (female faces, *M*=84.86 seconds, *SE*=8.35; male faces, *M*=81.41 seconds, *SE*=11.34). There was no difference in looking to female and male faces during habituation at 9 months (female faces, *M*=64.11 seconds, *SE*=7.12; male faces, *M*=66.10 seconds, *SE*=9.67). This change in looking between faces during habituation relates to the time that the infants took to reach habituation criteria, which is not typically considered to be a preference. There was no effect of face race on looking during the habituation trials, $F(1, 20)$=0.26, p=.617, partial η^2=.13.

Raw looking time across the three (i.e., novel, familiar, novel) test trials revealed an interesting pattern (see Figure 19). The faces that were familiar at only one dimension (i.e., own-race males and other-race females) showed a decline in overall attention to the familiar face during test trial 2 from 3 to 6 to 9 months of age. Infants' attention to the familiar other-race male face, however, increased across this age range. Overall looking to the familiar own-race females face during the test trial did not change from 3 to 6 months, and declined at 9 months. Accordingly, we ran four exploratory regressions, one on each face type, with each of the three test trials as independent variables (see Table 4). The only test trial that was consistently predictive of the proportion preference was the test trial 2, with the familiar face. Although this metric is not typically reported, we include it here due to its predictive power.

Figure 19: Raw looking scores in seconds on the face discrimination task for each face type on test trials 1 (novel), 2 (familiar), and 3 (novel) for 3-, 6-, and 9-month-olds



Discrimination

Discrimination was defined as greater looking towards the novel than the familiar face during the test trials. This was calculated by averaging the total looking towards the novel face (i.e., novel face test trial 1 + novel face test trial 3 / 2) and dividing that by an average of the average looking towards the novel and total looking towards the familiar on test trial 2 (i.e., average looking towards the novel + total looking towards the familiar / 2), then multiplying by 100 to get a percentage. In instances where the infant only completed 1 test trial with a novel stimulus and 1 with the familiar (e.g., due to inattention during 1 test trial or because they became fussy during the last trial), the percentage looking towards the novel was calculated as total looking towards the novel divided by all looking on the two good test trials, multiplied by 100. We used the percentage looking towards the novel as our metric because it controls for infants' overall rates of looking, which we know differs by age, and because this is the metric typically reported in the literature (e.g., Anzures et al., 2012), allowing us to compare our results to the results of other studies using similar paradigms. Because a first goal for this study is to determine whether the infants are able to discriminate each type of face at 3, 6, and 9 months of age, we tested this by using single-sample t-tests to compare the percent looking to the novel face against a chance level of 50%. If infants showed a novelty preference that was significantly greater than chance, it could be concluded that they could discriminate the face.

In reporting our effects, we use two measures of effect size. First, we use Cohen's *d* as a measure of effect size because it provides a statistical measure of effect with quasi-standardized levels by which the size of the effect can be evaluated. Typically, d=.2 is considered a small effect, d=.5 a medium effect, and d=.8 a large effect, although Cohen himself advocates using these guidelines as rough guides only and to consider the balance of the data as well (Cohen, 1992). Second, we also provide the number of children that showed discrimination of the face, defined as infants who evidenced a novelty preference greater than 55%. We use this benchmark of 55% for discrimination based on a recent meta-analytic review by the author and a colleague which found typical adjusted effect sizes for face discrimination in infants to be 5.24%. It also represents 1 second greater looking towards the novel face on the test trials, of the total 20 seconds in which the novel face is available. We use this because it is a clear, objective measure of effect size that is uninfluenced by measures of central tendency of the group (Cohen, 1990). Moreover, providing a count of the number of children that showed the effect has an advantage in that this metric that can be understood by all audiences (Cohen, 1990). It also high-lighting potential changes in the proportion of infants who show and do not show discrimination, a figure that would be obscured within the measures of central tendency. In providing both, we hope to more fairly illustrate infants' early discrimination capacities and the variability within these capacities.

Table 4: Regression models predicting overall proportion looking towards the novel over the familiar as predicted by test trials 1, 2, and 3 during the discrimination task

Face Type	**Predictors**	**B**	***SE***	**β**	***t***	R^2	R^2a *(SE)*
Female Own- race	Intercept	.784	.077		10.15***	.366	.301 (.19)
	Test Trial 1	<.001	.000	.397	1.86[a]		
	Test Trial 2	<.001	.000	-.715	-4.04***		
	Test Trial 3	<.001	.000	-.003	-.013 [f]		
Female Other-race	Intercept	.600	.053		11.28***	.188	.166 (.20)
	Test Trial 1	<.001	.000	.015	.13 [e]		
	Test Trial 2	<.001	.000	-.467	-4.47***		
	Test Trial 3	<.001	.000	.429	3.70***		
Male Own-race	Intercept	.680	.069		9.81***	.150	.124 (.20)
	Test Trial 1	<.001	.000	.094	.91 [c]		
	Test Trial 2	<.001	.000	-.431	-4.06***		
	Test Trial 3	<.001	.000	.228	2.01*		
Male Other-race	Intercept	.641	.109		5.89***	.249	.147 (.19)
	Test Trial 1	<.001	.000	.368	1.51 [b]		
	Test Trial 2	<.001	.000	-.627	-2.56**		
	Test Trial 3	<.001	.000	.217	.84 [d]		
***p<.001; **p=.018, *p=.047, [a]=.073, [b]=.145, [c]=.367, [d]=.409, [e]=.898, [f]=.989							

Own-race female faces. We anticipated that infants would be able to discriminate own-race female faces at all ages. All age groups evidenced greater than chance discrimination. This was true at 3 months (*M*=71.02%, *SD*=27.09, *t*(6)=2.05, *p*=.086, *d*=.18), 6 months (*M*=82.79%, *SD*=20.15, *t*(15)=6.51, *p*<.001, *d*=3.36), and 9 months (*M*=74.24%, *SD*=21.28, *t*(22)=5.46, *p*<.001, *d*=2.33) of age (see Figure 20). The number of infants showing greater attention to the novel face similarly evidences infants' capacities with this familiar face type. At 3 months 57.14% of infants could discriminate the faces (4 of 7 infants); this jumps to 87.5% at 6 months (14 of 16 infants) and 82.6% at 9 months (19 of 23 infants; see Figure 21).

Own-race male faces. Since male faces represent one 'step' away from the most familiar face type (i.e., own-race females, like mother), we anticipated that infants would discriminate them at 3 months. We were unsure how this would change with age. Three-month-old infants failed to show discrimination of own-race male faces (*M*=56.57%, *SD*=18.27, *t*(32)=2.10, *p*=.044, *d*=.74). At 6 months and 9 months infants did show discrimination of own-race male faces (6 months, *M*=66.22%, *SD*=20.46, *t*(37)=4.89, *p*<.001, *d*=1.61; 9 months, *M*=69.76%, *SD*=22.66; *t*(40)=5.58, *p*<.001, *d*=1.77, see Figure 20). At 3 months, only 32.4% of (11 of 34) infants showed greater attention to the novel. By 6 months, 71.1% of infants (27 of 38) and at 9 months 70.7% of infants (29 of 41) evidenced discrimination of the novel from the familiar face (see Figure 21).

Figure 20: Discrimination of faces by type as measured by percent looking towards the novel as compared to all looking on the test trials at 3-, 6-, and 9-month-olds during the discrimination task

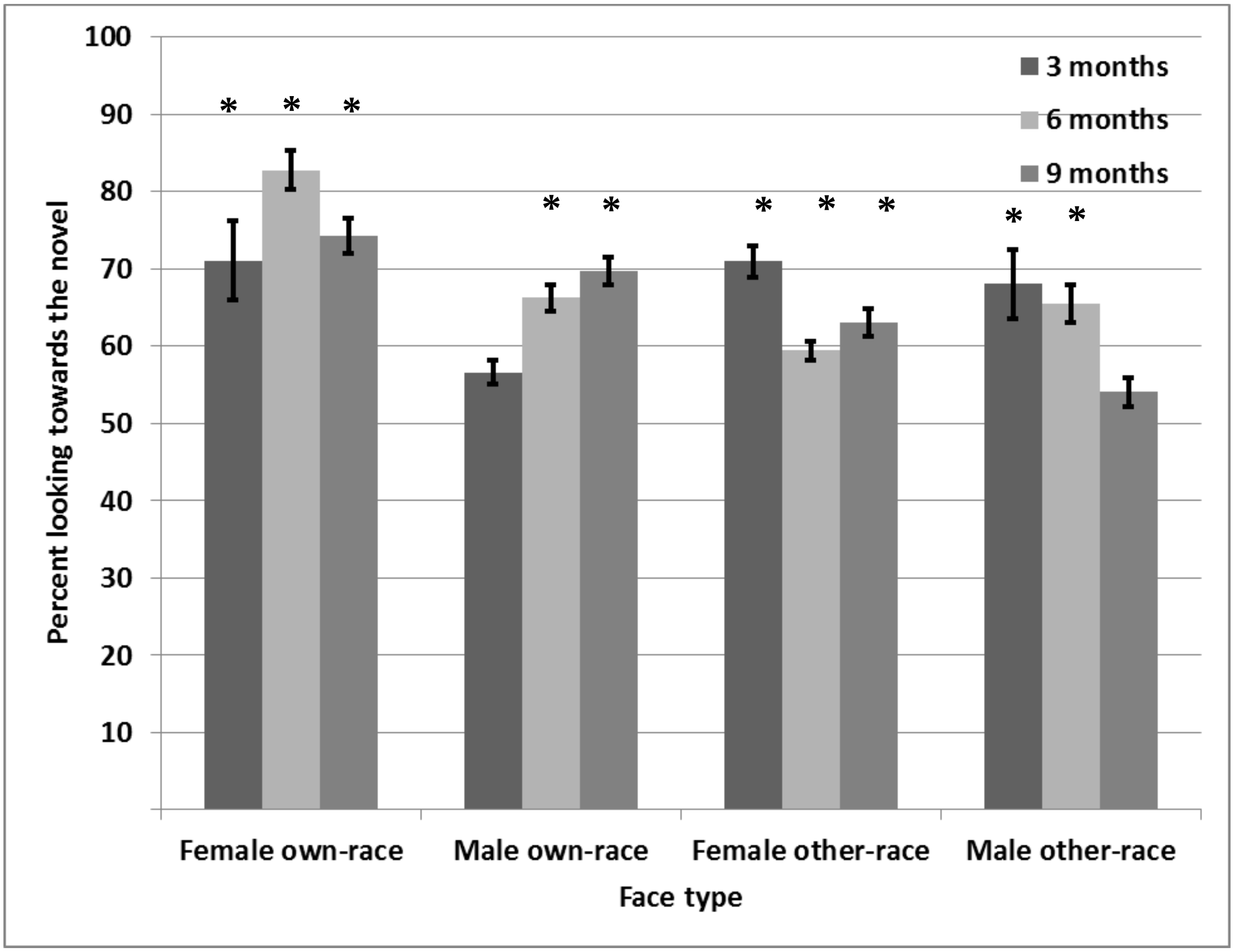
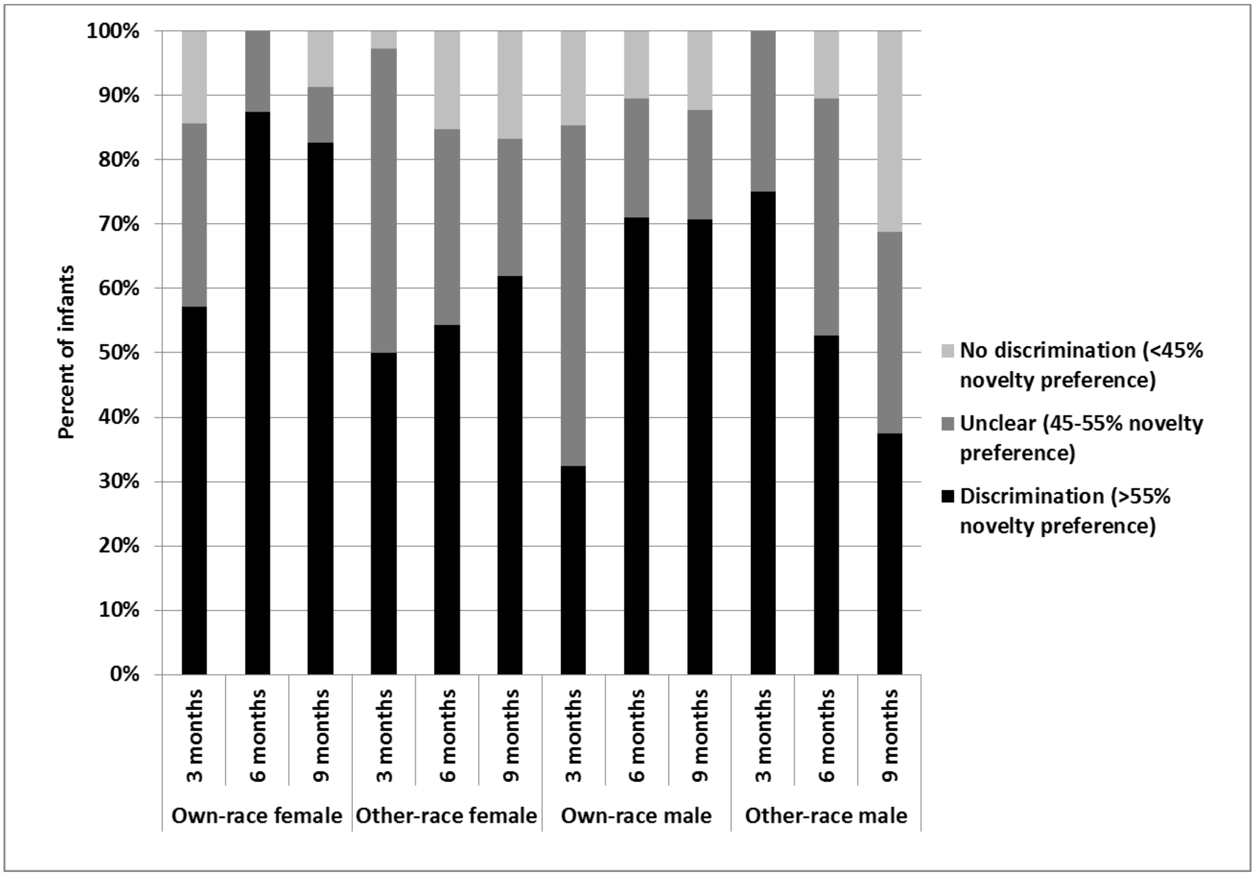


Figure 21: Percent of infants of each age showing discrimination



Other-race female faces. Like own-race male faces, other-race female faces represent one 'step' away from the most familiar face type, however they are also likely to be less familiar since they are unlike father or other family members. Given the typical trajectory of other-race face discrimination, we anticipated that fewer infants would be successful in discriminating these faces, with increasing age. Consistent with our predictions, 3-month-old infants' evidenced discrimination of other-race female faces (M=70.95%, SD=23.89, t(35)=5.26, p<.001, d=1.78). Infants continued to discriminate these face types at 6 months (M=59.42%, SD=16.95, t(45)=3.77, p<.001, d=1.12) and at 9 months (M=63.05%, SD=22.56, t(41)=3.75, p=.001, d=1.17; see Figure 20). The number of infants evidencing discrimination was not consistent with this pattern.

Mean values and their effect size (i.e., Cohen's d) were not always consistent with our second measure of effect size (i.e., a count of infants showing discrimination). More infants evidenced discrimination, with increasing age. Exactly half of infants (18 of 36 infants) showed greater looking to the novel at 3 months; from this we must conclude that the infants in the half of the sample that did show discrimination drove the significant effect. At 6 months 54.3% (25 of 46 infants) showed greater looking to the novel; combined with the measures of central tendency, this again suggests that a slim majority are driving the significant effect. Unlike at earlier ages, at 9 months nearly two-thirds (61.9%; 26 of 42 infants) showed greater looking to the novel, suggesting a more robust effect at this age (see Figure 21).

Other-race male faces. Other-race male faces represent the least familiar face-type and, as a consequence, we anticipated that infants would have the greatest difficulty discriminating them beyond 3 months of age. Further, we anticipated that the number of infants able to discriminate them would remain consistently below that of other faces, potentially declining with increasing age. Three-month-old infants failed to show significant discrimination of male other-race faces according to the alpha-level of .05 (M=68.00%, SD=18.15, t(3)=1.98, p=.141, d=2.29), although this finding is inconsistent with our two measures of effect size: Cohen's d indicated a large effect and 75% of infants evidenced discrimination (see below). We address this inconsistency in the discussion. Infants failed to discriminate male other-race faces at 9 months (M=54.02%, SD=15.47, t(15)=1.04, p=.314, d=.54). Infants were able to do so at

6 months (*M*=65.42%, *SD*=21.41, *t*(18)=3.14, *p*=.006, *d*=1.48; see Figure 20). In contrast to the mean looking values, three quarters of 3-month-olds (75.0% or 3 of 4 infants) discriminated the male other-race face. By 6 months, roughly half showed this capacity (52.6% or 10 of 19 infants). By 9 months, only 37.5% (6 of 16 infants) evidenced discrimination (see Figure 21).

Developing discrimination

Since we are interested in the development of these capacities over time, we aimed to characterize the increase or decrease in capacity with each face type with a change in age. To this end, we ran four separate regressions with proportion looking for each face type. Although female face discrimination was not predicted by infant age, with R^2_a values of .01 for own-race and other-race, male face discrimination was, with R^2_a values of .06 and .08 for own- and other-race faces, respectively (see Table 5). When infants' looking towards the familiar face on test trial 2 was analyzed in the same way, the models were more successful at predicting other-race female (R^2_a =-.065), own-race male (R^2_a=-.116) and other-race male (R^2_a =-.024) age-based change, but no better with own-race female (R^2_a=-.002; see Table 5).

Table 5: Age-based regression models predicting face discrimination by type using proportional preference and looking to the familiar on test trial 2 of the discrimination task

Metric of Discrimination	Face Type	Predictors	B	*SE*	β	*t*	R^2	R^2_a *(SE)*
Percent looking to the novel over all test trial looking ++	Female Own-race	Intercept	82.02	10.85		7.56***	.006	-.017 (21.99)
		Age in days	-0.02	0.05	-.07	-.51[c]		
	Female Other-race	Intercept	72.84	5.46		13.35***	.024	.016 (21.26)
		Age in days	-0.05	0.03	-.16	-1.73[a]		
	Male Own-race	Intercept	50.30	5.35		9.395***	.069	.060 (20.57)
		Age in days	0.07	0.03	.26	2.865** [d]		
	Male Other-race	Intercept	82.92	11.07		7.49***	.102	.078 (18.55)
		Age in days	-0.10	0.05	-.32	-2.05*		
Looking towards the familiar 1 on test trial 2+	Female Own-race	Intercept	5.44	1.62		3.37** [a]	.021	-.002 (3.22)
		Age in days	-0.01	0.01	-.14	-.96[b]		
	Female Other-race	Intercept	7.64	.76		10.05***	.072	.065 (2.96)
		Age in days	-0.01	0.004	-.27	-3.08**[b]		
	Male Own-race	Intercept	8.12	0.64		12.74***	.124	.116 (2.44)
		Age in days	-0.01	0.003	-.352	-3.97***		
	Male Other-race	Intercept	4.96	1.61		3.08** [c]	.056	-.024 (2.65)
		Age in days	0.002	0.007	.06	0.34 [d]		

+ in milliseconds out of a possible 10 seconds
++ [(Novel trial 1 + Novel trial 3)/2]/({[(Novel trial 1 + Novel trial 3)/2]+Familiar trial 2}/2)
***$p<.001$, ** [a] $p=.002$, ** [b] $p=.003$, ** [c] $p=.004$, ** [d] $p=.005$, ***[a]=.002, *=.047, [a]=.086, [b]=.342, [c]=.611, [d]=.740

Discussion

Infants demonstrated a robust ability to discriminate faces of nearly all types across nearly all ages. Using the raw number of babies who showed discrimination, more babies were able to discriminate own-race female, own-race male, and other-race female faces at 6 months, as compared to 3 months. The proportion of babies who could discriminate each face type remained high (>=70%) or increased from 3 through to 9 months of age for all face types except for male other-race faces. Although three quarters of infants discriminated male other-race faces at 3 months, only half showed this capacity at 6 months and only one third could do so at 9 months. Looking at their proportion preference of the novel over the familiar, the only ages and face types for which infants did not show discrimination were other-race male faces at 9 months and, surprisingly, own-race male faces at 3 months. On proportion looking to the novel on the test trials and raw values of looking towards the familiar on the second test trial, age was not predictive of looking at female own-race faces. There was, however, an age-related increase in male own-race face discrimination and age-related decreases in female other-race and male other-race face discrimination on these same data.

We posit two potential reasons for the lack of change in infants' ability to discriminate female own-race faces. First, because our participants are infants, there may be a maximal proportion of infants that are able to, at any given point, clearly display their discrimination capacity. Infants are notoriously labile and this may place constraints on the number of infants who are able to perform any given task. Moment-to-moment changes in infant state prevent some infants' from displaying their capacities. Further, the cross-sectional component may be particularly vulnerable to individual differences. We provide multiple measures to illustrate infants' performance, both measures of central tendency and individual metrics, so as to carefully illustrate infant performance. We argue that where these measures converge provides greater evidence for a reliable effect whereas where these measures fail to converge may suggest an area in which infants' capacity is more fragile, not developed in all infants, or may not have yet developed.

Second, there actually is development that is not captured by the metric of proportional looking towards the novel, as evidenced by the increase in number of babies who can do the task at 6 and 9 months and corresponding, for female own-race faces, decrease in mean proportions. From this perspective, group measures of central tendency may be problematic. The reason for the discrepancy could be because babies are labile or due to individual differences. For example, some infants within our sample may not identify female own-race faces as most familiar; they may have equal or more contact with male or other-race faces, and therefore show reduced female own-race face discrimination. Thus, we argue that it is important to use multiple measures of infant discrimination to fully capture infants' abilities, since measures of mean proportion looking towards the novel for the group may be obscuring important individual differences in performance.

The increase in infants' ability to discriminate male own-race faces likely represents greater exposure to male faces (e.g., dad) with increasing infant age, although the authors must acknowledge that this comparison had a smaller sample size, particularly at 3 months. This finding, however, is consistent with other studies that have found that infants' ability to discriminate their father's face does not emerge until after 3 months (Ward, 1999).

The most interesting pattern, from the author's perspective, is that of other-race males and females. Both show declining ability with increasing age, however both are superior to male own-race face discrimination at 3 months of age. Additionally, at 6 months discrimination performance for male other-race faces is almost identical to performance for within 1% of male own-race faces. This finding is in keeping with the work on the emergence of the other-race effect by Kelly and colleagues (D. J. Kelly et al., 2009; D. J. Kelly, Liu, et al., 2007; D. J. Kelly, Quinn, et al., 2007). It offers further support to the position that infants undergo a change in their capacity to discriminate. With female other-race faces, however, it does not appear that they lose their ability to perform the task at either 6 or 9 months. The novelty preference is attenuated at these later ages, but still significantly greater than chance. The number of infants showing a novelty preference continues to rise with age whereas the number of infants showing a novelty preference for other-race male faces falls over this same period. Within the female own- and other-race comparison, at older ages, a greater number of babies are able to discriminate the faces, however the mean proportion looking to the novel over the familiar for the group is smaller. This strange result means that measures of central tendency show a decline whereas the effect size of total number of babies capable of doing the task shows an increase in ability. We interpret this as showing clear development of infants' ability to discriminate these face types, as indicated by the greater number of infants who show this ability and large Cohen's *d*. In comparing the seconds looking on each of the test trials between female other-race and other face types, we argue that what is happening is that infants' attention to the familiar face is attenuating more slowing in the quasi-familiar (i.e. female other-race and male own-race) face categories. This is happening as infants show a general age-related decline in looking. Consequently, the degree of magnitude of novelty preference is also being attenuated. This suggests that a task appropriate for the most familiar face types (i.e., female own-race) may benefit from adjustment (e.g., increase the decrement requirement to 60% or greater, increase the length of the test trial) so as to show the same magnitude of effect. This may suggest that it is infants' looking on test trial 2 (i.e., the familiar face and not on test trials 1 and 3 where the novel face was shown) that is most diagnostic in this task. Again, this argues for the need to report more than one metric to fairly capture the effect.

One concern, however, is whether this pattern is evident in the infants who participated at multiple ages. Despite the small sample sizes within each face type and age, the overall pattern from the full sample persisted within the longitudinal sample across every face type. Female own-race faces were discriminated at the two ages for which 8 longitudinal infants contributed data (6 months, *M*=67.8%, *SD*=23.2, 5; 9 months, *M*=59.0%, *SD*=21.8; 5 infants showed discrimination at both ages). Female own-race faces showed a decline in discrimination at the three ages for which 13 longitudinal infants contributed data, but an increase in the number of individual infants evidencing discrimination (3 months, *M*=59.1%, *SD*=20.3; 6 months, *M*=57.2%, *SD*=13.1; 9 months, *M*=55.2%, *SD*=17.9; 5, 6, and 7 infants showed discrimination, respectively). Male own-race faces showed an increase in discrimination in the 12 longitudinal infants contributed data at all 3 ages, and an increase in the number of individual infants evidencing discrimination from 3 months to the older ages (3 months, *M*=51.8%, *SD*=7.3; 6 months, *M*=56.9%, *SD*=8.4; 9 months, *M*=58.9%, *SD*=17.1; 3, 8, and 6 infants showed discrimination, respectively). Only 1 infant completed the male other-race face task at 3 and 6 months; they showed discrimination at 3 months (55.2% novelty preference) but not at 6 months (49.9% novelty preference). Within the four infants who completed the male other-race face task at 6 and 9 months, there was also a decline in discrimination and number of individual showing discrimination (6 months, *M*=63.5%, *SD*=14.0; 9 months, *M*=55.4%, *SD*=12.4; three and one infants showed discrimination, respectively).

Own- and other-race discrimination patterns, along with the increase in ability with own-race male faces with increasing age, suggests that competing types of familiarity and novelty both may be influencing infants' ability to process faces. This has several interesting theoretical implications. First, it suggests that perceptual narrowing, infants' gradual loss or stagnation of capacity to discriminate unfamiliar face types and increased ability to discriminate familiar face types (Scott et al., 2007), may be operating by degrees. For example, here we found that the least familiar face type (i.e., male other-race) showed full loss of ability whereas face types that are of middling familiarity saw increasing (i.e. male own-race) and decreasing but not to zero (i.e., female other-race) trajectories of change in ability.

Putting this into the lens of the face space theory (Valentine, 1991, 2001; Valentine et al., 2015), infants' wealth of experience with female own-race faces may have increased the density of this area of their face space so that they can easily discriminate faces of this type already by 3 months of age. Similarly, an environment in which male other-race faces are highly infrequent has resulted in a sere face space, with few exemplars, which makes discrimination of these unfamiliar face types challenging. Although female other-race faces are also likely less familiar, it is possible that infants are leveraging their wealth of knowledge of female own-race faces to be able to discriminate, albeit less well, female other-race faces. It may also be possible, however, that they see female other-race faces, given that they are likely to see more female than male faces (Rennels & Simmons, 2008; Sugden et al., 2014).

Both theories posit that experience is shaping infants' face processing abilities. We suggest that the changes in infants' ability with own-race male faces support this position. Although males are infrequent in infants' early experience (Rennels & Simmons, 2008; Sugden et al., 2014), infants who have a male parent are likely to have ongoing, albeit lesser, experience with that parent and potentially that parent's male friends. Consequently, it would be expected that the infants would accrue greater experience with male faces with age. If true, then what these data are showing is that it takes longer for infants to accrue the hours of exposure necessary to show discrimination because male faces are less frequent in the environment. Just as infants can recognize their mother within hours of birth (Bushnell, 2001) whereas recognizing father does not occur until months later (Ward, 1999), the trajectory of recognition of own-race males shows a similarly lengthier process to achieve female-level ability with male faces. This position is consistent with our results in Chapter 6.

What aspects of experience may be most predictive is an empirical question, one on which the current study is silent. There are several aspects of experience which may be playing a role. Social interaction (Scherf & Scott, 2012), markers of individuation (Scott & Monesson, 2009), perceptual properties (Sugden & Moulson, 2016), or attentional mechanisms (Markant et al., 2016) have all been suggested and empirically supported. What is necessary to answer this question is a measure of infants' experience with and attention to different types of faces. To inform this question, we mate multiple methods to be able to better appreciate the factors that lead to infants' ability to recognize individuals in Chapter 6.

Chapter 5 Electrical brain response to familiar and unfamiliar face types

Experience changes the system. For example, although most adults are face experts, not all faces are equal. Adults' face expertise is limited to the face types with which they have had the most exposure (Herlitz & Lovén, 2013; Meissner & Brigham, 2001). This expertise is supported by specialized neuroarchitecture (Itier, Van Roon, & Alain, 2011; Kanwisher, McDermott, & Chun, 1997) which is sufficiently plastic to be changed by brief, targeted experience (Tanaka & Pierce, 2009). Arguably the most plastic system and the system most fundamentally changed by experience is the newborn infant. From birth, infants show greater attention to this highly salient feature of the environment, faces (Fantz, 1963; Goren et al., 1975; Johnson et al., 1991). Newborns' perceptual system has been tuned to caregivers and the degree of that tuning correlates with the amount of experience they receive (Bushnell, 2001). Specialization that is likely experience-driven persists well beyond the first few hours of life (Quinn et al., 2002) and there is evidence for experience-driven changes in the brain (Scott & Monesson, 2010). It is likely that infants' experience-based behavioural tuning reflects neurological tuning, but it is currently unknown when and how this neurological tuning develops. From this perspective, the face processing system, with its known experience-driven plasticity, typical developmental trajectory, discrete brain response to faces, and rapid changes within the first year, can serve as a model system for the impact of experience on the development of specificity in the brain.

Face specificity in the brain in adulthood

The majority of adults are face experts. Undergirding this expertise are face-specific areas of and responses in the brain. One area of the brain that has received particular attention is the fusiform gyrus, an area of the visual cortex. The fusiform gyrus has been called the fusiform face area (FFA) because it has been argued to exclusively processes faces (Grill-Spector, Knouf, & Kanwisher, 2007; Kanwisher et al., 1997; Kanwisher & Yovel, 2006). It typically shows greater right hemisphere activation in response to faces than to other non-face stimuli, including cars or scrambled faces. This may be because faces are processed at the individual-level, and not due to a face specificity, per se (Gauthier, Tarr, et al., 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999). Studies on individuals with inter-cranial electrodes (which were implanted for medical reasons, to monitor seizure activity) find three types of face-specific ERPs (Allison, Puce, Spencer, & McCarthy, 1999). A negative-going component that occurs at approximately 200ms after a face is presented, the N200, is found in the ventral occipitotemporal cortex. A second N200 occurring is found in the middle temporal gyrus. A positive-going component, the P350, occurs approximately 350ms after the face is presented and is measured from posterior ventral occipitotemporal, posterior lateral temporal, and anterior ventral temporal regions. Face-specificity is also evident in electrical brain activity recorded at the scalp, using electroencephalogram (EEG), and temporally tied to discrete events (i.e., event-related potentials, ERPs). A negative-going component that occurs approximately 170 milliseconds after a face is presented, which is most prominent over occipital and temporal scalp regions, called the N170, has been found to differentiate faces from other objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bötzel, Schulze, & Stodieck, 1995). It is larger in amplitude and shorter in latency (i.e., occurs sooner or responds more quickly) to faces than to other non-face objects (Bentin et al., 1996; Bötzel & Grüsser, 1989; Ganis et al., 2012). The N170 also responds to features diagnostic of a face (Martin Eimer, Kiss, & Nicholas, 2010). Arguably there may be other face-sensitive components (e.g., the P1, occurring100 ms after image onset; Dering, Martin, Moro, Pegna, & Thierry, 2011). This face specificity in the adult brain is used to support the position that faces are a 'special' stimulus, one for which we have innate, experience-independent capacities evident from birth (Kanwisher & Yovel, 2006). The debate over whether faces are special is far from settled (Diamond & Carey, 1986; Want et al., 2003, Gauthier, Tarr, et al., 2000; Gauthier et al., 1999). What is special is that most typically developed adults have an uncanny ability to process faces, but only those face types with which they likely have the most experience (e.g., Meissner & Brigham, 2001). This likely builds on earlier capacities and brain development.

Early brain development

From birth, our brains undergo substantial change. The brain nearly doubles in size, from approximately 36% to approximately 72% of adult brain size, within the first 12 months of life (Knickmeyer et al., 2008). During this time, it also increases in volume by 101%; this varies by area, with cerebellum increasing by 240% and subcortical areas increasing by 130% (Knickmeyer et al., 2008). Neurons continue to be born (i.e., neurogenesis; Huttenlocher, 1990) and cortical grey matter growth is highest during the first year of life (Knickmeyer et al., 2008). These newly created neurons migrate from their birthplace to their cortical home and, once there, they elaborate, growing dendrites, synapses, and spines at a nearly logarithmic expansion (Andersen, 2003). Over the first year, local connectivity decreases while long-range connectivity increase (Fair et al., 2007; A. M. C. Kelly et al., 2009). This proliferation is balanced by pruning of synapses, dendrites, and spines, or neuron death (Cowan, Fawcett, O'Leary, & Stanfield, 1984; Lossi & Merighi, 2003). Different areas of the brain develop at different rates. Within the infant primary visual cortex, there is a high rate of synapse formation within the first 8 months of life (Huttenlocher, de Courten, Garey, & Van der Loos, 1982). Synaptic density in this area reaches its acme, of approximately 150% of adult levels, before infant's first birthday, after which synaptic density declines (Huttenlocher et al., 1982). Pruning and apoptosis occur earlier for the visual areas than other areas of the brain (Levitt, 2003).

Face-specificity in brain development

As with adults, infants' brains show face specific responding. The fusiform gyrus is part of a cortical network that is activated when 2-month-old infants view faces (Tzourio-Mazoyer et al., 2002). Like the adult N170 ERP component (Bentin et al., 1996). The adult N170, infants also show two electrical brain responses, a negative-going component called the N290 which occurs at approximately 140 to 380 ms after stimulus onset and a positive-going component called the P400 which occurs at approximately 300-585 ms after stimulus onset, that differentiate faces from other objects (de Haan & Nelson, 1999). As with the N170, the infant N290 and P400 are sensitive to facial feature changes within the face (Key, Stone, & Williams, 2009). It is unclear whether these early components develop into an adult N170 (de Haan et al., 2003). An adult-like N170 response to isolated eyes is evident in children at approximately 11 years of age, although an adult-like N170 to full faces has not been found before adulthood (Taylor, Edmonds, McCarthy, & Allison, 2001). Other components may also relate to face processing in infancy (e.g., P1, (Macchi Cassia et al., 2006). If faces are special in the adult brain, this may develop in infancy and potentially relate to face-type-specific experience.

Familiar and unfamiliar face types in the adult brain

Brain responses to faces are moderated by familiarity of the face in infancy and in adulthood. Although the N170 is likely indexing the face, per se, both it and later components have been found to be diagnostic of different aspects of face processing. Recognition of facial identity has been related to a negative-going component approximately 300-500 ms after stimulus onset, the N400, and a positive-going component approximately 600-800 ms after stimulus onset, the P600, which occur at midline, temporal, and occipital electrode sites (Martin Eimer, 2000). Facial familiarity, measured with different types of faces, leads to slightly different electrical brain responses. One of the more common manipulations is inverting the face, which leads to greater amplitude of the N170 as compared to upright faces (de Haan, Pascalis, & Johnson, 2002; B. Rossion et al., 2000; Bruno Rossion & Gauthier, 2002). This is likely because adults require greater processing capacities to process inverted faces (Sadeh & Yovel, 2010). Adults' N170 response to inverted human faces was comparable to their response to upright and inverted monkey faces (with no difference found between upright and inverted monkey faces), suggesting differential processing of upright human faces as compared to other less familiar face categories (de Haan et al., 2002). However, it may be that any object of expertise may evidence differential processing if it is upright as compared to if it is inverted regardless of whether the expertise was naturally (Gauthier, Skudlarski, Gore, & Anderson, 2000; Tanaka & Curran, 2001) or experimentally (Gauthier et al., 1999; Scott, Tanaka, Sheinberg, & Curran, 2006) acquired. Other types of familiarity, such as own- and other-race face familiarity, may also impact the N170. Some studies have shown greater N170 response to other-race faces (Stahl, Wiese, & Schweinberger, 2010; Wiese, Kaufmann, & Schweinberger, 2012), but in some cases this was contingent on race being made salient through a categorization task (Stahl et al., 2010, but see Herrmann et al., 2007). The N170 is smaller in amplitude for human, as compared to non-human species faces (Itier et al., 2011; Yamada et al., 2015). Some studies have found no difference in own- and other-race face processing at the N170 (Caldara et al., 2003), but differences in processing at later components instead (Caldara, Rossion, Bovet, & Hauert, 2004). The N170 may also show gender effects, if these are made salient through the use of an oddball task (Choi et al., 2015). The development of differential processing likely begins in infancy, as infants begin to learn about and show behavioural differences to familiar and unfamiliar face types.

Familiar and unfamiliar face types in the infant brain

Infants' electrical brain response is also sensitive to the familiarity of the face, with a larger amplitude negative component (termed the NC, occurring 500 to 800 ms after stimulus onset over central, frontal electrodes), as compared to novel, faces (de Haan & Nelson, 1999). Even in infants who evidenced no behavioural indices of discrimination of their mother's face, 6-month-olds' ERP components were found to discriminate between infants' mother's face and a stranger's face (de Haan & Nelson, 1997). This difference in neural response to mother as compared to a stranger continues from 1 to 5 years (Carver et al., 2003). Similar to adults, infants show differential processing of familiar and unfamiliar face types, such as inverted, other-species, and other-race faces. Different components may or may not respond to different types of familiarity. The infant N290 is larger for human than for monkey faces (Scott, Shannon, et al., 2006). Although it discriminates species, the N290 shows no difference between upright and inverted faces of either species whereas the P400 is larger for upright than inverted faces of either species (de Haan et al., 2002). This is congruent with behavioural results that find infants prefer (Heron-Delaney et al., 2011) and are better able to discriminate (Pascalis et al., 2002) faces of their own species as compared to other-species (i.e., monkey) faces and upright as compared to inverted faces (Chien, 2011; Slater, Quinn, Hayes, & Brown, 2000). If, however, infants are provided with experimental exposure to monkey faces prior to 9 months of age, their electrical brain response shows more human-like processing of monkey faces (Scott & Monesson, 2010), a finding that is reflected in the experimental group's superior behavioural ability to recognize individual monkey faces after training (Scott & Monesson, 2009).

A similar result has been found with other-race faces. Own-race and female are the most familiar face types in infancy, as compared to other-race and male (Sugden et al., 2014). Infants prefer own-race faces and, in the second half of the first year of life, are better able to discriminate own-race as compared to other-race faces (D. J. Kelly et al., 2005, 2009; D. J. Kelly, Liu, et al., 2007; D. J. Kelly, Quinn, et al., 2007). They also show differential N290 and P400 response to own- and other-race faces at 9 months of age (Balas et al., 2011). Similar to other-species faces, other-race face training can prevent developmental changes in own- and other-race face processing (Heron-Delaney et al., 2011). Race is not the only dimension on which human face types are likely to differ in familiarity. Infants also show a preference for female over male faces (Quinn et al., 2002), a preference that is specific to own-race faces (Quinn et al., 2008). The authors, however, could find no study that explored whether face-specific ERP components differed in response to male and female faces, suggesting that this empirical question has yet to be tested. Further, to our knowledge, no study has examined whether face-specific ERP components differed in response to real images of own- and other-race faces, although this question has been asked with computer-generated faces (Balas et al., 2011). Understanding how brain response differs in response to faces of varying degrees of familiarity would provide a more fulsome appreciation of how variable experience shapes the developing system.

The current study

The goal of this study was to understand the impact of experience on the development of specificity in the infant brain, using the face processing system as a model system. To this end, we examined infant' electrical brain components of face processing (P1, N290, and P400) to face types that varied by familiarity (i.e., gender and race) across the first year of life. We anticipated that differentiation between familiar and unfamiliar face types would change with increasing infant age. With respect to the P1, we did not anticipate any differences between familiar and unfamiliar face types, since this component likely reflects low-level visual features of the stimulus. We hypothesized that differences between faces of different types would be present for the N290 and P400, since these represent face-specific processing. Using female, male, own-race, and other-race faces, we anticipated that the difference between own- and other-race face processing would increase, particularly at ages at which infants show differential processing. Conversely, we anticipated an early difference in female and male face processing, with this difference disappearing at older ages.

Method

Participants

Thirty-three 3-month-olds (18 females, *M*=97.03 days old, *SD*=11.58), 43 6-month-olds (28 females, *M*=188.05 days old, *SD*=11.06), and 36 9-month-olds (22 females, *M*=275.67 days old, *SD*=10.80) participated in the ERP task (for demographic details, please see Figure 1). Additional babies were recruited, but did not participate in the ERP task due to researcher unavailability (three 3-month-olds, seven 6-month-olds, and ten 9-month-olds), infants declining to wear the cap (one 3-month-old and four 9-month-olds) and infants not completing a minimum of 10 trials (22 3-month-olds, two 6-month-olds, and four 9-month-olds). If the infant did wear the cap and perform the task, but had fewer than 10 good trials overall, they were excluded from further analysis. Similarly, infants with fewer than 10 good trials for faces of each type (e.g., fewer than 10 good female face trials) were excluded from secondary analyses. Consequently, 19 3-month-olds, 28 6-month-olds, and 21 9-month-olds completed sufficient trials in the race comparison and 20 3-month-olds, 30 6-month-olds, and 21 9-month-olds completed sufficient trials in the gender comparison. Including only the infants who successfully contributed at least 10 trials, 19 infants participated thrice (3, 6, and 9 months of age), 33 participated twice, and 60 participated once.

Stimuli and equipment

The testing room was a small, quiet room with a table, chair, and computer monitor. Parent and infant sat approximately 30 centimeters away from the computer monitor, which sat on a small table against a wall. The monitor was a HD 3470 Dell Optiplex ATI Radeon monitor with a 60hz refresh rate. The researcher who was controlling the stimulus presentation sat in an adjoining room; a small window directly behind the infant-parent pair allowed the researcher to view the back of the pair from the adjoining room. The researcher also monitored the pair through a live video-feed from a camera placed on top of the stimulus-presentation monitor. A light in the adjoining room provided minimal, indirect illumination, to allow the researcher to assess infant looking during the task. The task was programmed in E-Prime (Psychology Software Tools, Inc.). Infant looking during the task was recorded using a Logitech HD Pro Web-Camera which recorded 1080p video at 15 or 30 frames per second. EEG was recorded from a 128-channel Hydrocel Geodesic Sensor Net (Electrical Geodesics Inc).

Infants were presented with 10 individuals of each of four types of faces: female own-race, female other-race, male own-race, and male other-race. Since the task involved comparing own- and other-race face processing, infants' own race was determined by race of their mother (e.g., if the mother self-identified as White, own-race was White, regardless of baby or father race). The faces were passively presented to the infant in blocks, with one face of each type presented per block. Faces were approximately 15 centimeters in height and 14 centimeters in width (+/- 1.5 centimeters) subtending to a visual angle of 28.07 degrees. The faces were colour images of undergraduate students from the SuMo Face Database (Sugden & Moulson, 2013). The faces were smiling, attractive, and non-distinctive, scoring at least a 7 on a 10-point scale for each (10 would be most positive/happy/attractive/non-distinctive). Between trials, infants were re-oriented to the screen with an attention-grabber, a red or blue ball (colour randomized) that grew and shrank in size to mimic bouncing.

Procedure

During the break after the discrimination task, parents were: re-explained the ERP task; shown, explained, and invited to touch an infant ERP cap; had any questions they had about the task or the cap answered; and provided oral consent to the ERP task. During this time, a researcher and the infant would play together. After the parents agreed to complete the ERP task, a researcher measured the infant's head to ensure the correct ERP cap size was used. The researcher then marked the centre of the infant's head with an 'X' in grease pencil, to be used to guide the placement of the ERP cap. The cap was soaked for a minimum of 10 minutes in warm saline solution prior to the cap being applied to the infant.

Once parents assessed that the infant was ready to participate, they were invited to the testing room. Once the baby was seated on the parent's lap in the testing room, a research assistant distracted the baby with engaging, fun toys (e.g., a tiger-shaped xylophone, a giraffe-shaped rattle, blowing soap bubbles for the baby to pop). A senior researcher assessed the baby's engagement with the toys and, once the baby was fully engaged, quickly placed the ERP cap on the infant's head. If the baby fussed, the parent was instructed to do whatever they would normally do to distract or soothe the baby. Once the cap was on and the baby was again playing with the toys, the parents were invited to take photos with the baby while the researcher set up the task and checked electrode impedances. (Photographs of infants wearing the ERP cap were subsequently posted to or shared with the lab website by parents; please see www.facebook.com/ryersonbeelab for examples.)

Once everything was ready, the parent was asked to close their eyes during the task, to prevent their responses from influencing the responses of their infant. This was chosen in place of a sleep mask to avoid infants becoming distracted by the sleep mask and to allow the parent to quickly respond, should the infant catch the wires on the parent's clothing, move suddenly, or become fussy. The lights in the room were dimmed and the task was projected onto the computer monitor.

The parent was asked to alert the researchers should they notice non-visible signs that their infant becoming fussy or bored (e.g., squirming, distressed vocalizations). To ensure that the infant remained happy and engaged in the task and that they did not grab the ERP cap, at least two researchers monitored the baby: one or more through a live video-feed and by standing behind the parent and one out of the field of view of the infant. If the baby did grab the cap, the researcher stationed behind the parent would gently remove their hand from the cap.

All infant looking was coded online by an experienced senior coder who presented the stimuli to the infant when the infant was oriented towards the screen. If the infant did not look at the screen during stimulus presentation (e.g., they blinked or looked away momentarily), the researcher was given up to 2 seconds after stimulus onset to press a button that marked the trial as void. Each face was presented for 500ms. The face was followed by a blank screen, presented for 1 second. After this blank screen, the attention-grabber reappeared.

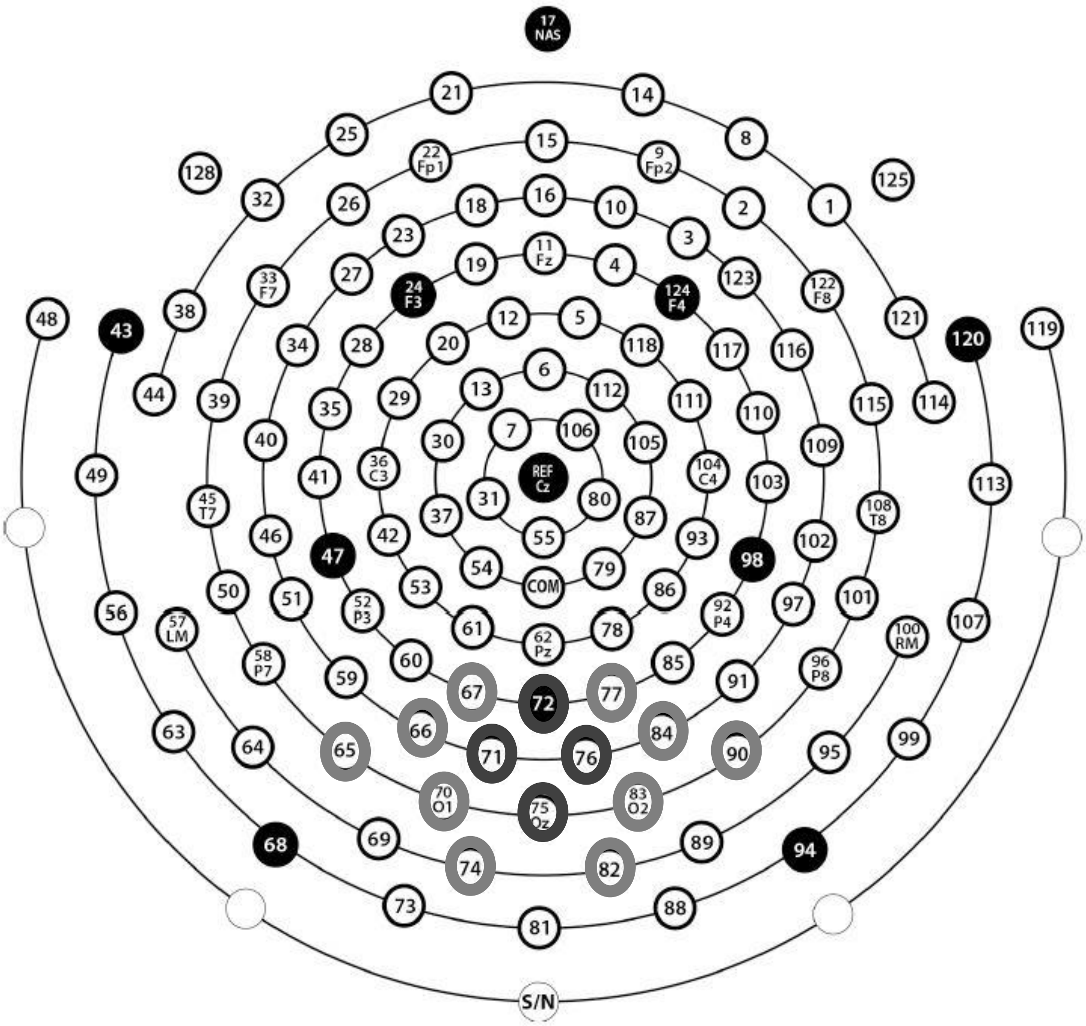
If the baby became fussy or the parent felt that the baby needed a break, the task was discontinued either temporarily or permanently. If the reason for the break did not necessitate removal of the ERP cap and the parent decided that the baby still wished to continue the task, the task was resumed after the temporary discontinuation. Some reasons for short breaks were: moving the infant into a more comfortable position, temporary fussing, concerning that the infant may become fussy, and needing a snack. If the reason for the break required that the ERP cap be removed, the task was permanently discontinued. The task was also discontinued if the infant fell asleep, became fussy and did not settle during a break, or if the parent indicated that the infant wished to discontinue. After the task ended, the cap was quickly removed from the infant's head and parents were provided with a warm, damp, soaped cloth with which to remove the grease-pencil 'x' from the top of the infant's head. Parents were also provided with a small cloth with which to dry the infant's damp scalp and hair. The cap was rinsed and disinfected after each use. The ERP task was the last task that they completed during their visit to the lab.

ERP processing and analysis

All ERP data was recorded, processed, and extracted using NetStation (EGI). The raw Electroencephalogram (EEG) was recorded referenced to Cz. The display presented during recording was filtered using a 0.1Hz highpass filter and a 30Hz lowpass filter, however this filtered signal was not recorded. The recording was sampled at 500 Hz. After data collection, the continuous EEG recording was first filtered using a 0.1Hz highpass and then a 30Hz lowpass filter. It was next segmented into 1.1 second segments, with a baseline period of 100ms before stimulus onset and a recording period of 1000ms after stimulus onset. The data were then baseline corrected, using the 100ms baseline within the segment. A senior researcher with extensive ERP experience then manually edited the segments. Bad channels were identified and marked as bad. Trials were rejected if more than 10% of channels were marked as bad (i.e., more than 12 of the 126 sensors). Trials were also rejected if they contained an eye blink, eye movement, or other artefacts. Bad channels in remaining trials were then interpolated using a spherical spline interpolation. The data was then averaged across each trial type within each participant and rereferenced to an average reference.

The grand average data were visually inspected to determine which time windows and electrodes best captured the P1, N290, and P400 components. The P1 was analyzed to check for visual effects unrelated to face race processing per se. The N290 and P400 were analyzed because they are face-specific and previous research has found that these components showed differential responding to own- and other-race computer-generated faces (Balas et al., 2011). Previous literature suggested that the P1, N290 and P400 would be found between 90-170ms, 120-450ms and 350 and 690ms, respectively, in 3-month-olds (Halit, de Haan, & Johnson, 2003; Macchi Cassia et al., 2006; Peykarjou & Hoehl, 2013; Peykarjou, Westerlund[2], Cassia, Kuefner, & Nelson, 2013; Webb, Long, & Nelson, 2005), between 90-170ms, 170–340ms and 250–730ms, respectively, in 6-month-olds (Balas et al., 2010; de Haan & Nelson, 1999; de Haan et al., 2002; Quinn, Doran, Reiss, & Hoffman, 2010; Scott & Monesson, 2010; Snyder, Garza, Zolot, & Kresse, 2010; Webb et al., 2005), and between 90-170ms, 120-410ms and 220-730ms, respectively, in 9-month-olds (Balas et al., 2010, 2011; Scott & Monesson, 2010; Scott, Shannon, et al., 2006; Webb et al., 2005; Wiebe et al., 2006). Based on these readings and our current data, the time-window selected for the P1 was 90-170ms in all age groups. The window for the N290 was 250-450ms in 3-month-olds, 200-340ms in 6-month-olds, and 200-350ms in 9-month-olds. The window for the P400 was 350-690ms in 3-month-olds, 300-600ms in 6-month-olds, and 270-600ms in 9-month-olds. Based on the cited literature, we anticipated that these would be present in the occipital and temporal cortices. We further visually inspected each infant's averaged data for each face type to ensure that the time window and sensors selected were appropriate. For all infants these were: left hemisphere sensors 65, 66, 67, 70, and 74, medial 71, 72, 75, and 76, and right hemisphere sensors 77, 82, 83, 84, and 90 (see Figure 22).

Figure 22: Schematic of ERP sensors selected for P1, N290, and P400 component (left hemisphere sensors 65, 66, 67, 70, and 74; medial sensors 71, 72, 75, and 76, and right hemisphere sensors 77, 82, 83, 84, and 90)



Results

Overall, infants completed an average of 31 artifact-free ERP trials (*SD*=18.91) with approximately equal number of good trials per condition (Female own-race faces *M*=7.64, *SD*=4.73 trials; Female other-race faces *M*=8.10, *SD*=5.14 trials; Male own-race faces *M*=7.50, *SD*=4.90 trials; Male other-race faces *M*=7.79, *SD*=4.97 trials). In our analyses, we present mean amplitudes for each component (Kappenman & Luck, 2011; Luck, 2005). Mean amplitude was chosen because, as Luck argues, a particular peak's amplitude and latency may represent multiple components, sensitive to changes within each of these and to filtering. Mean amplitude captures a range of time-points, potentially providing a more robust measure of the underlying component. Consequently, measurements of peak amplitude/latency are not directly comparable with mean amplitude.

All face types elicited a positive-going component that peaked between 90-170 ms after stimulus onset. The mean amplitude was 12.38μV (*SD*=9.30, Range: -44.02-31.51). We did not expect to find any effect of familiarity of the face type for the P1. All face types elicited a negative-going component, the N290, that peaked maximally 200-450ms after stimulus onset (with a mean amplitude of 8.03μV, *SD*=10.88, Range: -12.42-68.92), and a positive-going component that peaked maximally 300-690 ms after stimulus onset (with a mean amplitude of 12.47μV, *SD*=12.23, Range: -11.96-64.04). We hypothesized both gender and race effects for both components, with gender differences manifesting at earlier ages (i.e., 3 and 6 months) and race differences manifesting later (i.e., 6 and 9 months).

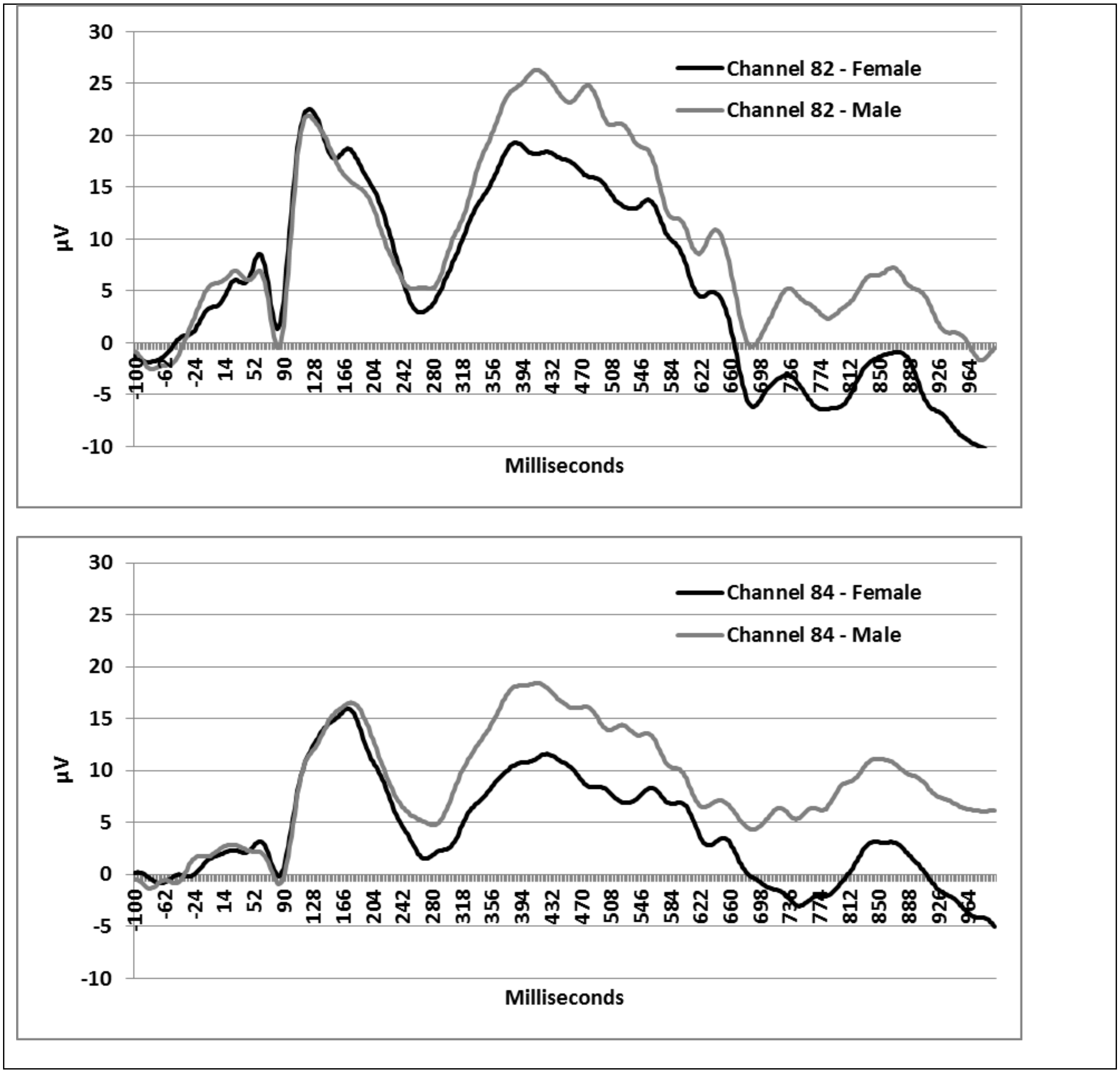
Separate repeated-measures MANCOVAs were conducted for each age (i.e., 3, 6, and 9), comparison (i.e., gender and race), and component (i.e., P1, N290, and P400). The independent variables involved in each model were the 2-level comparison of interest (i.e., male and female for gender) and 3 levels of hemisphere (i.e., left, right, and central). Age was included as a covariate to include an analysis of the smaller scale effects of time within each age group. For each significant effect, we conducted follow-up tests using paired sample t-tests for race and gender effects and, for significant effects or interaction with age, simple correlations. If the omnibus test was not significant, no further analyses were conducted.

Gender comparisons

P1. We did not expect to find any differences for the P1 between faces of different genders and hemispheres. We were agnostic as to the effect of age. Consistent with our hypotheses, there were no main effects of gender at 3 (*F*(1, 18)=0.01, *p*=.914, n_p^2=.001), 6 (*F*(1, 28)=0.53, *p*=.472., n_p^2=.019), or 9 (*F*(1, 19)=0.14, *p*=.712, n_p^2=.007) months nor of hemisphere at 3 (*F*(1, 18)=1.47, *p*=.258, n_p^2=.147), 6 (*F*(1, 28)=1.58, *p*=.225., n_p^2=.105), or 9 (*F*(1, 19)=0.74, *p*=.490, n_p^2=.076) months. Similarly, age did not interact with gender (3 (*F*(1, 18)=0.004, *p*=.950, n_p^2<.001), 6 (*F*(1, 28)=0.62, *p*=.439, n_p^2=.022), or 9 (*F*(1, 19)=0.15, *p*=.699, n_p^2=.008) months) or with hemisphere (3 (*F*(1, 18)=0.93, *p*=.416, n_p^2=.098), 6 (*F*(1, 28)=1.00, *p*=.380., n_p^2=.069), or 9 (*F*(1, 19)=0.08, *p*=.983, n_p^2=.009) months; see Figure 23).

N290. We hypothesized that the N290 would be sensitive to face gender, particularly at younger ages. Gender was marginally significant at 6 months (*F*(1, 28)=3.64, *p*=.067, n_p^2=.115; mean amplitude of female, *M*=9.68μV, *SE*=1.91, and male *M*=9.35μV, *SE*=2.12) as was the interaction of gender with age (*F*(1, 28)=3.71, *p*=.064, n_p^2=.117). Gender was not significant at 3 months, *F*(1, 18)=0.56, *p*=.464, n_p^2=.030, or 9 months, *F*(1, 19)=0.13, *p*=.727, n_p^2=.007, neither was the interaction of gender and age (at 3 months, *F*(1, 18)=0.73, *p*=.405, n_p^2=.039, and at 9 months *F*(1, 19)=0.15, *p*=.705, n_p^2=.008). Hemisphere was not significant at any age (3 months, *F*(1, 18)=0.22, *p*=.803, n_p^2=.025; 6 months, *F*(1, 28)=0.46, *p*=.637., n_p^2=.033, or 9 months, *F*(1, 19)=0.83, *p*=.451, n_p^2=.085) nor did it interact with age (at 3 months, *F*(1, 18)=0.10, *p*=.907, n_p^2=.011; 6 months *F*(1, 28)=0.19, *p*=.826., n_p^2=.014; or 9 months, *F*(1, 19)=0.84, *p*=.449, n_p^2=.085; see Figure 23).

Figure 23: Grand average of 6-month-olds' ERP response in μV to male and female faces over right hemisphere sensors 82 and 84



P400. We hypothesized that the later infant component sensitive to faces would be sensitive to face gender, particularly at younger ages. As with the N290, there was a significant effect of gender at 6 months (F(1, 28)=6.50, p=.017, n_p^2=.188) as well as a gender by age interaction (F(1, 28)=6.11, p=.020, n_p^2=.179). The mean amplitude in response to female faces was smaller (M=14.87μV, SE=1.81) than to male faces (M=17.00μV, SE=2.16). Increasing age was associated with a decline in mean amplitude for male faces (at mid, r_s=-.41, p=.023, and marginally at left, r_s=-.36, p=.053, and right r_s=-.32, p=.087, electrodes). These effects were not present at 3 months (gender, F(1, 18)=0.83, p=.375, n_p^2=.044; gender by age, F(1, 18)=0.82, p=.378, n_p^2=.043) or 9 months (gender, F(1, 19)=346, p=.563, n_p^2=.018; gender by age, F(1, 19)=0.39, p=.538, n_p^2=.020) months. Hemisphere was not significant at any age (3 months, F(1, 17)=0.06, p=.946, n_p^2=.007; 6 months, F(1, 27)=0.88, p=.427, n_p^2=.061; and 9 months, F(1, 18)=1.78, p=.197, n_p^2=.165, months), nor did it interact with age at 3 months, F(1, 17)=0.07, p=.937, n_p^2=.008; 6 months, F(1, 27)=0.59, p=.583, n_p^2=.042; or 9 months, F(1, 18)=1.87, p=.182, n_p^2=.172 (see Figure 23).

Race comparisons

P1. We did not expect to find any differences for the P1 between faces of different races or hemisphere. We were agnostic as to the effect of age. In line with hypotheses, there was no effect of race (at 3, F(1, 17)=0.03, p=.871, n_p^2=.002, 6, F(1, 26)=0.57, p=.456, n_p^2=.022, or 9, F(1, 19)=0.32, p=.578, n_p^2=.017, months), race by age interaction (at 3, F(1, 17)=0.01, p=.925, n_p^2=.001, 6, F(1, 26)=0.46, p=.503, n_p^2=.017, or 9, F(1, 19)=0.32, p=.767, n_p^2=.029, months), effect of hemisphere (at 3, F(1, 16)=1.37, p=.281, n_p^2=.147, 6, F(1, 25)=1.73, p=.198, n_p^2=.121, or 9, F(1, 18)=0.32, p=.735, n_p^2=.034, months), or age by hemisphere interaction (at 3, F(1, 16)=0.89, p=.431, n_p^2=.100, 6, F(1, 25)=1.22, p=.311, n_p^2=.089, or 9, F(1, 18)=0.27, p=.767, n_p^2=.029, months).

N290. We hypothesized that the component found to be sensitive to faces in previous studies would be sensitive to face race, particularly at younger ages. We found no evidence of this in any of our comparisons. There was no effect of race (at 3, F(1, 17)=0.61, p=.444, n_p^2=.035, 6, F(1, 26)=0.32, p=.574, n_p^2=.012, or 9, F(1, 19)=0.01, p=.906, n_p^2=.001, months), race by age interaction (at 3, F(1, 17)=0.89, p=.358, n_p^2=.050, 6, F(1, 26)=0.23, p=.632, n_p^2=.009, or 9, F(1, 19)=0.02, p=.889, n_p^2=.001, months), effect of hemisphere (at 3, F(1, 16)=0.19, p=.828, n_p^2=.023, 6, F(1, 25)=0.46, p=.639, n_p^2=.035, or 9, F(1, 18)=0.16, p=.856, n_p^2=.017, months), or age by hemisphere interaction (at 3, F(1, 16)=0.09, p=.332, n_p^2=.129, 6, F(1, 25)=0.23, p=.796, n_p^2=.018, or 9, F(1, 18)=0.17, p=.848, n_p^2=.018, months).

P400. We hypothesized that the later infant component sensitive to faces would be sensitive to face race, particularly at younger ages. As with the N290, we found no evidence of this in any of our comparisons. There was no effect of race (at 3, F(1, 17)=0.31, p=.585, n_p^2=.018, 6, F(1, 26)=1.13, p=.297, n_p^2=.042, or 9, F(1, 19)=0.57, p=.459, n_p^2=.029, months), race by age interaction (at 3, F(1, 17)=0.55, p=.469, n_p^2=.031, 6, F(1, 26)=0.96, p=.335, n_p^2=.036, or 9, F(1, 19)=0.61, p=.444, n_p^2=.031, months), effect of hemisphere (at 3, F(1, 16)=0.07, p=.931, n_p^2=.009, 6, F(1, 25)=0.43, p=.652, n_p^2=.034, or 9, F(1, 18)=0.94, p=.408, n_p^2=.095, months), or age by hemisphere interaction (at 3, F(1, 16)=0.08, p=.928, n_p^2=.009, 6, F(1, 25)=0.29, p=.754, n_p^2=.022, or 9, F(1, 18)=1.02, p=.380, n_p^2=.102, months).

Discussion

Infants demonstrated clear P1, N290, and P400 components at all ages. We had anticipated that they would show differential gender processing, particularly at 3 and 6 months, and race processing, particularly at 6 and 9 months, for N290 and P400 mean amplitude. At 6 months, infants evidenced the hypothesized gender differences for P400 and, marginally, for N290 mean amplitude. For both the P400 and (marginally) the N290 gender also interacted with age at 6 months. Neither the other gender nor the race main effects or interactions were significant. At no age or comparison were there any P1 effects.

The corpus of literature examining infants' electrical brain response to familiar and unfamiliar face types is small, but growing. Some findings are contradictory, reflecting the novel and exploratory nature of infant ERP research. Further, when examining familiar and unfamiliar face types, many of the studies use non-human faces (i.e., monkeys) and objects to compare to human faces, often including an orientation manipulation (e.g., Peykarjou & Hoehl, 2013; Scott et al., 2006). Alternatively, they use caregivers' faces (de Haan & Nelson, 1997). Few have directly examined face race and none, that the author could find, have examined face gender. Consequently, the novelty of the current study challenges the author to situate it within the extant literature.

The P1 likely reflects low-level features of the visual stimulus and not face processing or stimulus processing, per se (de Haan et al., 2002). Although it may be sensitive to the difference between faces and objects (Halit et al., 2003), no study has reported a difference in processing of different types of faces at the P1. The lack of differential responding to familiar and unfamiliar face types is consistent with previous research and our hypotheses. Given P1's relation to differences in low-level features of the visual stimuli, this could be argued to suggest that any effects at later ERP components are likely related to processing of the stimulus type itself.

Significant gender effects were found at 6 months for N290 and P400. There were no effects of race at this age. There were no significant effects of gender or race for N290 and P400 at 3 or 9 months. We consider three potential reasons for this pattern of results. First, the categories of race and gender may not be sufficient to elicit differences in face-specific ERP components within the first year of life. Second, ongoing brain development may be obscuring any true effects in differential processing. Third, differential ERP response between faces of different types may only occur at times during which infants' face processing systems are undergoing reorganization *specific to the face type under investigation*. We consider evidence for each of these arguments, including how these may relate to the gender effect evidenced at 6 months.

Degrees of difference

It is possible that the failure to find an effect of face race on infants' ERP response represents a true null effect. Infant face processing has been an active area of investigation, particularly since the seminal articles of Kelly and colleagues that described the development of an own-race preference and an other-race effect (superior processing of own- as compared to other-race faces) in infancy (D. J. Kelly et al., 2005; D. J. Kelly, Quinn, et al., 2007). Given the similar differences in adults' processing of familiar and unfamiliar face types (e.g., own- and other-race, Meissner & Brigham, 2001) and their associated differences in electrical brain response (Stahl et al., 2008; Wiese et al., 2012), we anticipated that infants would show a similar differential response to familiar (i.e., female and own-race) and unfamiliar (i.e., male and other-race) faces. No study that the author could find has documented differences in ERP response between images of real own- and other-race faces. Only one study has found differential ERP response to own- and other-race computer-generated faces (Balas et al., 2011). Typically ‘other’ category faces are monkeys and, with this category, infants’ differential ERP response of own- and other-species faces (de Haan et al., 2002; Halit et al., 2003; Scott & Monesson, 2010; Scott, Shannon, et al., 2006). Simian and computer-generated faces differ from actual human faces. The human-simian differentiation is not nearly as nuanced as that of gender or race. This suggests that infants’ ERP response to faces requires substantial deviation to elicit N290 or P400 changes. The single study to find a neurological ERP effect is consistent with this position as infants’ only showed differential processing when presented with faces where physiognomic and pigmentation cues were clearly own- and other-race (Balas et al., 2011). In a well-controlled manipulation of pigmentation and physiognomy, ERP response was no different between own-race faces and own-race faces coloured to be other-race; ERP response was also not different between other-race faces and other-race faces coloured to be own-race. Similarly, infants also show differential processing of upright and inverted faces, although this inversion effect is not face-specific (de Haan et al., 2002; Halit et al., 2003). I posit that clear category differences are necessary to elicit differences in face-specific components. Faces for which category boundaries are less clear or more nuanced, such as natural images of faces of different genders and races, would therefore fail to show an effect. By this logic, further development is necessary before infants show differences in processing to photographs of real own- and other-race faces.

That there was an effect of gender at 6 months could also be considered within this framework. It is not until 6 months that a caregiver’s face is discriminated from a stranger’s face at the P400 (but not at the N290, Balas et al., 2010), despite showing behavioural discrimination of their mother hours after birth (Bushnell, 2001). Extending the above argument, caregiver and gender may be clearer categories for infants than is race, potentially due to greater exposure to female, as compared to male, faces within the first year of life (Rennels & Simmons, 2008; Sugden et al., 2014) and consequentially greater capacities with female as compared to male faces (Ramsey-Rennels & Langlois, 2006). The development of these capacities earlier may reduce the degree of cue salience needed for category discrimination at the neurological level, with infants showing generalized gender differences across faces of different races. That they did not show gender differences at 9 months may be due to precisely this inclusion of own- and other-race faces, with emerging race category capacity differences (D. J. Kelly et al., 2009; D. J. Kelly, Quinn, et al., 2007) obfuscating gender differences. If true, then the use of uniquely own-race faces of different genders at 9 months or measurement at older ages would be expected to result in the re-emergence of gender effects at the N290 or P400.

Development obscures ERP effects of face type

Infancy is a time of change and instability. Infant face processing (e.g., face preference, Johnson, Dziurawiec, Ellis, & Morton, 1991; discrimination, D. J. Kelly, Quinn, et al., 2007) and brain development show long developmental trajectories (Nelson, 2001). This is true of many developmental processes. Although the N290 or P400 may be diagnostic of face processing per se (de Haan et al., 2003), similar to the adult N170 (Bentin & Deouell, 2000), it is unclear whether they share the same underlying neural mechanisms or processing responsibilities (de Haan et al., 2003). If it is not a precursor the N170, not truly face-specific, is in the process of developing face specificity, or is responsive to faces alone and another component is responsive to face type would all be potential reasons for a lack of ERP difference to race and gender. As well argued by de Haan and colleagues (de Haan et al., 2003), there are more open questions than answers about ERP components in infancy and what they represent.

Differential ERP response may suggest instability in face category processing

In conceptualizing this study, it was assumed that ERP components found to differentiate faces from objects and human faces from non-human faces would also differentiate race and gender. Categorization, per se, or familiarity are not the only potential paths to differential processing. That infants only show differential processing of faces of different genders at 6 months suggests to the author that differential responding may reflect a stage in which infants are attending specifically to this gender comparison. Within Chapter 4, a fuller sample of these infants evidenced a novel capacity to discriminate own-race male faces and continued but reduced capacity with other-race male faces at 6 months. Similarly, they continued to show discrimination with own-race female and, although slightly reduced, other-race female faces. From this perspective, 6 months is the only age at which infants show a clear ability to process male and female faces of all types. It may be that infants' electrical brain response to faces relates to their ability to discriminate these faces.

A similar argument can be applied to own- and other-race face processing. Infants evidenced no P400 difference in own- and other-race face processing at any age. This finding is incongruent with that reported by Balas and colleagues (Balas et al., 2011). Following the same logic as with gender, infants receive far more exposure to own-race than to other-race faces and this difference is greater than their difference in exposure to female and male faces, with approximately 97 own-race faces to every 3 other-race faces as compared to 7 female faces to every 3 male faces (Sugden et al., 2014). As described in Chapter 6, infants in the current sample received little other-race face exposure in early life despite living in a large multi-cultural metropolis in which their own-race is by definition not the majority. (To clarify, visible minorities account for more than 50% of the population in the metropolis from which the infants were recruited and, consequently, no single race or ethnic group represents 50% or more of the population (Bélanger & Caron-Malenfant, 2005). Given this disparity in experience, I argue that race processing likely lags behind gender processing, potentially by several months. It may be that the age at which infants show differential P400 processing is the age at which the categories have coalesced sufficiently to allow for differential processing, but are still not yet stable enough to have reached a stable plateau or ability. This would be in keeping with current theoretical conceptions of how exposure drives ability through perceptual (Scott et al., 2007), memory and attentional (Want et al., 2003), and cognitive (Valentine, 2001) changes to the face processing system. It would, however, be a novel way of conceptualizing infant ERP components.

The current study arguably suggests that infants' electrical brain response may be diagnostic of the age at which they are acquiring, coalescing, or becoming fluent in this particular category. There is no doubt that different capacities develop at different rates (Mondloch et al., 2002) as does the maturing brain (Andersen, 2003; Knickmeyer et al., 2008; Levitt, 2003). This is an empirical question yet-to-be-answered. If true, it would suggest a tight link between behavioural and neurological measures of visual processing. It may suggest ERPs as a measuring of instability, or sensitive periods, within development, periods during which support or insult may have substantive down-stream implications.

Chapter 6 The influence of exposure on preference and discrimination

Evidence for learning based on experience with particular types of faces persists throughout the first year of life, during which infants undergo substantial changes in their face processing capacities. These changes are evident both in their early attentional biases for faces, as measured by visual preferences, and in their capacity to discriminate between faces of particular types. At 3 months, infants evidence a visual preference for face types (e.g., female, (Quinn et al., 2002); own-race, (D. J. Kelly et al., 2005) with which they have the most experience (Sugden et al., 2014). At this age, they can discriminate between many types of faces, even face types to which they likely have had limited or no exposure. This ability undergoes perceptual narrowing over the next 6 months until, at 9 months of age, infants no longer show an ability to discriminate between infrequently experienced face types (e.g., other-race: (D. J. Kelly et al., 2005; D. J. Kelly, Quinn, et al., 2007).

The current literature suggests three non-mutually-exclusive aspects of early experience that are likely influencing how and what infants learn about faces: 1) the number of individual faces of a particular type that the infant experiences; 2) the amount of exposure to faces; and 3) the quality of experience with faces. These three different features of face experience suggest different pathways to the development of face perception and may account for different aspects of infants' later attention to and discrimination of faces.

The number of individual faces experienced by an observer has builds their Face Space, the theoretical matrix within which face properties are encoded (Nishimura, Maurer, & Gao, 2009; Valentine, 1991, 2001; Valentine, Lewis, & Hills, 2015). As individuals are experienced, the relevant dimensions by which the face can be recognized are encoded. The center of the face space represents the average of the individuals experienced and the dimensions of the space are those that allow discrimination between faces. The greater the number of individual exemplars reflecting the population of faces of the observer, the better the face recognition for these faces. Development of face space tunes to the population represented in the infant's environment. Consequently, one might expect that the greater number of individuals experienced by an infant will allow them to develop a more fulsome Face Space. With a superior Face Space within which to encode new faces, the infant would be expected to exhibit greater ability to discriminate faces from the population they have experienced. The system would operate optimally with faces nearer to the center of the Face Space and less optimally with faces and face types that fall further away from the center or origin of Face Space. This might be one way in which frequency of experience, specifically experience with socially relevant individuals, tunes the early system.

Alternatively (or in addition), it may be that infants are sensitive to the natural statistics of their world and use their quantity of experience with faces, and not just socially-relevant individuals, to shape how and what they learn. To put it another way, it may be that the greatest quantity of experience with faces of a particular type marks these faces as important. This contact hypothesis has been put forward by several researchers working in different domains (Harrison & Hole, 2009; Sporer, 2001). Logically, it is reasonable to expect that face types with which infants have experience will be better processed than face types with which they have no experience. If this is true, this would suggest that frequency of exposure provides a very simple and straight-forward metric by which to measure the face types infants will prefer and later continue to discriminate.

Early studies that provided infants with experimental exposure to face types with which they are unlikely to have natural experience support the position that exposure results in maintained ability whereas no exposure results in loss of ability. For example, exposing infants to monkey faces experimentally, through training with six images of monkey faces presented in a picture book, allows infants to continue to discriminate monkey faces at 9 months of age when their untrained peers no longer show the ability (Pascalis et al., 2005). Critically, infants generalized their training to novel instances of monkey faces. This suggests that very limited exposure to a few individual exemplars of a face category with which infants would otherwise have no experience holds open the perceptual window that would otherwise narrow in absence of this experience.

More recent studies of the influence of different types of exposure support the position that exposure alone may be insufficient to explain ability. Scott and Monesson (2009) found that the way in which the face is experienced is also important. In their study, two groups of infants received regular exposure to monkey faces presented in a picture book. For one group of infants, the monkeys were all labeled "monkey;" for the other group of infants, the monkeys were labeled with individual names. Only infants who heard individual names for the monkey faces retained their ability to discriminate monkey faces at 9 months of age, suggesting that mere exposure is not sufficient. Rather, individuation of faces was key to retaining ability.

Naming may not be the only marker of face importance. There may be multiple ways in which particular faces draw infants' attention and thereby increase infants' processing of faces of that type. Scherf and Scott (2012) argue that the development of face processing depends on the developmental level of the infant. Face-processing skills are self-organizing through periods of developmental and task change. Within this framework, the timing and quality of experience with faces is expected to shape ability. During the first year of life, infants are developing an attachment relationship with a caregiver and, under this framework, would be predicted to show a preference for caregiver-type faces irrespective of the frequency of exposure to faces of different or similar types. Infants would be expected to have more frequent and different interactions with caregivers than with strangers (Rennels & Simmons, 2008), potentially facilitating their ability to process their caregiver's face.

A more perceptually-based explanation of how the quality of experience may influence ability can also be drawn from the object learning literature. When learning object names, toddlers are sensitive to how the objects are presented. In seminal work using infant-perspective cameras to describe how infants experience objects and how this relates to learning, Smith and colleagues found that objects viewed from a toddler's perspective were more likely to be larger, alone, and central in their field of view (Smith et al., 2011) and only the toddler's first-person perspective, not the adult or a bird's eye view perspective, predicted learning (Pereira et al., 2014; Yurovsky et al., 2013). Similarly, one might predict that early face learning also benefits from these viewing conditions. For example, faces that are presented near to the infant to compensate for their poor acuity will be better resolved and thereby better learned. Faces that are viewed in a frontal orientation are better discriminated by infants, suggesting that this is likely the viewpoint that provides them with the greatest information and should also facilitate learning

(Turati et al., 2008). Finally, faces viewed alone in the field of view, without other competing faces, would likely reduce the demands on infants' attention, which would then facilitate learning.

Ultimately, what is necessary to tease apart how different features of experience influence learning about faces is an understanding of how infants experience faces and how this relates to their early preferences for and ability with faces. The infant's perspective of his/her typical, daily visual environment, as captured by head-mounted camera, provides this precisely. This method has been used effectively to capture infants' natural, daily experience with faces (Jayaraman et al., 2015; Sugden et al., 2014) and toddlers' word learning. Infant-perspective video recording provides a rich source of data from which to better appreciate their experience (Pereira et al., 2014). As previously mentioned, this perspective is substantially different from either the parent perspective or a bird's eye view perspective of the same situation (Smith et al., 2011). Most importantly, it is only the infant's perspective that is predictive of learning (Yurovsky et al., 2013).

The goal of the current study was to understand how infants' natural, daily experiences predict learning. Specifically, we investigated whether and how face exposure predicts face preferences and discrimination of frequently experienced (i.e., own-race and female) and less frequently experienced (i.e., other-race and male) face types at 3 months of age. Given that 3-month-olds prefer frequently over infrequently experienced face types (D. J. Kelly et al., 2005), we expect that the influence of experience will manifest in infants' preference, with greater exposure predicting greater preference. Building on current theories of how exposure may relate to learning, it is possible that different features of experience may be more or less predictive of preference. If the raw statistics of the infants' visual world drive improvements in processing, then the frequency of exposure to faces or to faces of a particular type will drive their preferences. Finally, if the way in which a face is experienced influences learning about faces, we expect that frequency of experience with close family members (i.e., mom and dad), who likely engage in face-to-face interactions with their infants, will best predict infants' preferences. In contrast to our prediction that greater exposure relates to greater preference, we do not predict that exposure will influence discrimination ability at this age, since 3-month-old infants are likely to be able to discriminate between both frequently- and infrequently- experienced face types. Given that studies have found differential discrimination performance at later ages, we have included a discrimination task to fairly evaluate both types of visual processing that mark infants' developing ability with faces.

Method

Participants

Twenty nine 3-month-old infants participated in this study. 14 were female. Infants' ethnicities were highly varied, with 18 Caucasian, 3 Black, 3 East Asian and Caucasian, 2 East Asian, 2 Black and Caucasian, and 1 South East Asian. The average age at which infants began recording was 87 days (*M*=87.17 days, *SD*=10.69 days). They recorded for an average of 11 days (*M*=10.69 days, *SD*=7.33 days), returning to participate in the lab tasks at an average age of 99 days (*M*=98.86 days, *SD*=12.68 days; see Figure 1). All of the infants included in the analysis in this Chapter were also included in Chapters 2-5.

Procedure

In brief, families recorded infants' typical, daily experience from an infant-perspective for approximately 1 week (for full description, see Chapter 2). After their week with the camera, infants came to the laboratory where they performed a visual preference (for full description, see Chapter 3) and discrimination (for full description, see Chapter 4) tasks with face types that varied by familiarity. These were, organized by decreasing familiarity, own-race female, own-race male, other-race female, and other-race male.

Results

Due to the variable number of infants who completed each habituation task and who had relatives or a male caregiver, the sample sizes change between comparisons. The below-reported statistics for exposure, preference, and discrimination are drawn from Chapters 2 – 4. We refer the reader to these Chapters for more information on exposure, preference, and discrimination results in isolation.

When examining the relationship between exposure and preference, we ran simple binomial spearman's correlations in all cases for three reasons: 1) correlation between some of the metrics used below (e.g., female face exposure and mom face exposure), 2) violations of assumptions of parametric tests for the number of individuals, and 3) so that the values reported would be directly comparable. Although we would have liked to use regressions for our first analysis, reasons 2 and 3 would have made the results of any regression suspect, at best. Correlations were the next-best option available. Fortunately, reasons 2 and 3 were not an issue in the variables used to predict the relationship between exposure, preference, and discrimination. Consequently, we used regression to model the relationships.

What is the relationship between exposure and preference?

Does overall exposure predict overall looking? We did not expect that overall exposure (irrespective of face type) would predict overall looking, however we ran a simple correlation to ensure that any subsequent findings were not due simply to overall rates of exposure in any particular infant. Overall, infants spent 26.5% (*SD*=10.9) of their time exposed to faces and, within the preference task, 69.9 seconds (*SD*=9.5) of the available 80 seconds looking at the stimuli. There was no significant relationship between overall exposure and infants' overall looking during preference r_s=-.03, *p*=.869.

Does face-type exposure predict preference? If statistical frequency is the only metric influencing preference, we would hypothesize that infants would show the strongest preference for the face types with which they had the most experience, irrespective of identity. Overall, infants saw more female faces (*M*=75.8%, *SD*=19.8) than male faces (*M*=24.2%, *SD*=19.8), *t*(28)=7.02, *p*<.001. They also experienced more own-race (*M*=88.5%, *SD*=22.6) than other-race faces (*M*=11.5%, *SD*=22.6), *t*(28)=9.18, *p*<.001. Broken down even further, the majority of face experience was with own-race female faces (*M*=66.7%, *SD*=22.8), followed by own-race male faces (*M*=21.8%, *SD*=19.8), other-race female faces (*M*=8.4%, *SD*=17.6), and other-race male faces (*M*=3.1%, *SD*=6.4). Infants saw significantly more female than male own-race faces, *t*(28)=5.50, *p*<.001. This was also true for other-race faces, *t*(28)=2.05, *p*=.049. In considering preference, we considered only preferential attention and not attentional orienting. As analyzed in Chapter 3, we consider trials 1 and 2 separately. We expected that greater exposure to faces of a particular type (e.g., own-race female) would relate to attentional preference for faces of that type (e.g., own- over other-race female and female own- over male own-race). The only measure of preference found to be related to exposure time was infants' preference for male own- over other-race faces on trial 1 (see Table 6). Specifically, both greater overall female face exposure and greater overall own-race female face exposure related to greater preference for the male own-race over the male other-race face. Conversely, greater overall male own-race face exposure related to lower preference for the male own-race over the male other-race face pair. No other correlations were significant (see Table 6).

Table 6: Correlation between preference and exposure to faces of different types

Measure		Preference for female over male faces				Preference for own- over other-race faces			
		Own-race pair trial 1	Other-race pair trial 1	Own-race pair trial 2	Other-race pair trial 2	Female gender pair trial 1	Male gender pair trial 1	Female gender pair trial 2	Male gender pair trial 2
Face exposure time	Overall female	r_s=.23 p=.239	r_s=.08 p=.681	r_s=-.22 p=.252	r_s=.16 p=.413	r_s=-.12 p=.526	r_s=.40 * p=.032	r_s=-.09 p=.650	r_s=.21 p=.273
	Overall own-race	r_s=.23 p=.240	r_s=-.06 p=.744	r_s=-.06 p=.747	r_s=.08 p=.684	r_s=.20 p=.298	r_s=.16 p=.398	r_s=-.04 p=.842	r_s=-.13 p=.506
	Own-race female	r_s=.27 p=.152	r_s=.12 p=.554	r_s=-.21 p=.273	r_s=.16 p=.422	r_s=-.11 p=.564	r_s=.38 * p=.042	r_s=.04 p=.836	r_s=-.23 p=.232
	Own-race male	r_s=-.21 p=.286	r_s=-.10 p=.591	r_s=.135 p=.492	r_s=-.12 p=.542	r_s=.13 p=.492	r_s=-.42* p=.024	r_s=-.10 p=.620	r_s=.23 p=.241
	Other-race female	r_s=-.13 p=.519	r_s=.08 p=.687	r_s=-.02 p=.922	r_s=-.10 p=.627	r_s=-.16 p=.401	r_s=-.04 p=.846	r_s=-.03 p=.865	r_s=.12 p=.552
	Other-race male	r_s=-.19 p=.328	r_s=-.04 p=.830	r_s=.19 p=.323	r_s=-.17 p=.376	r_s=-.14 p=.484	r_s=-.28 p=.146	r_s=.23 p=.224	r_s=.12 p=.540

Note: Overall male and overall other-race are not included as these are the proportional inverse of overall female and overall own-race, respectively

Does the number of individuals of a given type predict preference? If preference depends on the adequacy of the individual variability to build a face-space, then preference would best be predicted by the number of individuals of a particular type. Excluding caregivers, infants experienced an average of 13.0 (*SD*=17.9) females; of these, 9.7 (*SD*=13.7) were own-race and 3.2 (*SD*=7.4) were other-race females. Infants experienced an average of 8.8 (*SD*=13.0) males; of these 6.5 (*SD*=9.5) were own- and 2.4 (*SD*=5.3) were other-race.   We found no relation between the number of individuals to which infants were exposed, including overall female, male, own-race, other-race, own-race female, own-race male, other-race female, and other-race male, and any metric of attentional preference (see Table 7).

Table 7: Correlation between preference and the number of individuals to which infants were exposed

Measure		Preference for female over male faces				Preference for own- over other-race faces			
		Own-race pair trial 1	Other-race pair trial 1	Own-race pair trial 2	Other-race pair trial 2	Female gender pair trial 1	Male gender pair trial 1	Female gender pair trial 2	Male gender pair trial 2
Face exposure number of individuals	Overall female	r_s=.04 p=.827	r_s=-.01 p=.969	r_s=.22 p=.258	r_s=-.16 p=.423	r_s=-.25 p=.192	r_s=-.06 p=.746	r_s=.03 p=.868	r_s=-.19 p=.323
	Overall male	r_s=-.10 p=.592	r_s=-.05 p=.811	r_s=.25 p=.200	r_s=-.14 p=.478	r_s=-.08 p=.675	r_s=-.02 p=.906	r_s<.01 p=.998	r_s=-.23 p=.227
	Overall own-race	r_s=.01 p=.949	r_s=-.02 p=.928	r_s=.25 p=.202	r_s=-.12 p=.557	r_s=-.13 p=.507	r_s=-.03 p=.897	r_s<-.01 p=.991	r_s=-.23 p=.232
	Overall other-race	r_s=-.14 p=.474	r_s=.01 p=.942	r_s=.14 p=.491	r_s=-.20 p=.321	r_s=-.12 p=.552	r_s<-.01 p=.971	r_s=.07 p=.701	r_s=-.06 p=.759
	Own-race female	r_s=.09 p=.644	r_s=-.02 p=.908	r_s=.26 p=.187	r_s=-.13 p=.512	r_s=-18. p=.356	r_s=-.04 p=.829	r_s=.03 p=.864	r_s=-.23 p=.229
	Own-race male	r_s=-.08 p=.673	r_s=.04 p=.842	r_s=.27 p=.172	r_s=-.14 p=.480	r_s=-.17 p=.394	r_s=-.07 p=.720	r_s=-.04 p=.826	r_s=-.18 p=.348
	Other-race female	r_s=-.17 p=.366	r_s=.10 p=.591	r_s=.12 p=.538	r_s=-.26 p=.188	r_s=-.20 p=.296	r_s=.02 p=.925	r_s=.04 p=.849	r_s=.04 p=.822
	Other-race male	r_s=-.07 p=.737	r_s=-.10 p=.603	r_s=.229 p=.247	r_s=-.16 p=.411	r_s<.01 p=.993	r_s=-.03 p=.869	r_s=.12 p=.546	r_s=-.14 p=.455

Does social relevance predict preference? If preference depends on the quality of inputs, then the highest quality interaction would best predict learning. Since the highest quality of interaction would be between infants and relatives, and particularly mom and dad, then the relationship between gendered face preference and experience would be best predicted by relatives and parent face experience. We anticipated that exposure to mom would predict female face preference within the gender comparison and female own-race preference within the race comparison. We expected that exposure to dad would influence male face preference within the gender comparison and male own-race preference within the race comparison.

As reported in Chapter 2, infants spent the majority of their time exposed to their mother's face (*M*=55.7%, *SD*=25.6), and dad next-most frequently (*M*=9.7%, *SD*=12.3). Non-caregiver females represented 8.1% *(SD*=13.6) and non-caregiver males represented 5.9% *(SD*=9.1) of infants' face exposure. All relatives were own-race. Strangers were rare. In descending order they were female own-race (*M*=8.2%, *SD*=11.5), male own-race (*M*=3.4%, *SD*=7.0), female other-race, (*M*=2.6%, *SD*=4.9), and male other-race (*M*=1.4%, *SD*=4.6). The only significant finding here, however, was that exposure to make own-race stranger faces correlated positively with own-race female face preference on trial 2, in that infants with greater male own-race stranger face preference showed a stronger preference for own-race female faces on the second trial of the face gender preference task.

Table 8: Correlation between preference and exposure to relatives and strangers

Measure		Preference for female over male faces				Preference for own- over other-race faces			
		Own-race pair trial 1	Other-race pair trial 1	Own-race pair trial 2	Other-race pair trial 2	Female gender pair trial 1	Male gender pair trial 1	Female gender pair trial 2	Male gender pair trial 2
Face exposure time with relatives and strangers	Mom	r_s=.03 p=. 895	r_s=-.14 p=. 455	r_s=-.13 p=. 511	r_s=.04 p=. 826	r_s=.24 p=.203	r_s=.27 p=.151	r_s=.18 p=.339	r_s=-.02 p=.911
	Dad	r_s=-.29 p=.127	r_s=-.10 p=.611	r_s=.03 p=.892	r_s=-.09 p=. 660	r_s=.06 p=. 754	r_s=-.30 p=111	r_s=-.09 p=.632	r_s=.25 p=.196
	Female relatives	r_s=.08 p=.665	r_s=.22 p=.242	r_s=.17 p=.384	r_s=-.09 p=.653	r_s=-.20 p=.301	r_s=.24 p=.214	r_s=-.31 p=.102	r_s=-.33 p=.083
	Male relatives	r_s<.01 p=.991	r_s=-.24 p=.220	r_s=.14 p=.483	r_s=.10 p=.626	r_s=.28 p=.143	r_s=-.13 p=.493	r_s=-.34 p=.069	r_s=-.21 p=.281
	Female strangers	r_s=-.13 p=.506	r_s=.07 p=.735	r_s=.08 p=.679	r_s=-.17 p=.402	r_s=-.35 p=.062	r_s=-.34 p=.072	r_s=.24 p=.217	r_s=.10 p=.594
	Male strangers	r_s=-.28 p=.145	r_s=-.02 p=.923	r_s=.28 p=.154	r_s=-.12 p=.557	r_s=-.21 p=.273	r_s=-.09 p=.649	r_s=.16 p=.395	r_s=-.08 p=.690
	Female own-race strangers	r_s=-.06 p=.743	r_s=.01 p=.944	r_s=.29 p=.140	r_s=-.20 p=.303	r_s=-.23 p=.228	r_s=-.28 p=.136	r_s=.24 p=.217	r_s=-.10 p=.615
	Female other-race strangers	r_s=-.20 p=.301	r_s=.16 p=.420	r_s<01 p=.988	r_s=-.22 p=.260	r_s=-.36 p=.055	r_s=-.07 p=.716	r_s=.09 p=.644	r_s=.17 p=.372
	Male own-race strangers	r_s=-.16 p=.397	r_s=-.08 p=.667	r_s=.137 p=.487	r_s=-.01 p=.956	r_s=-.14 p=.464	r_s=-.01 p=.968	r_s=.13 p=.509	r_s=-.13 p=.500
	Male other-race strangers	r_s=-.13 p=.158	r_s=.11 p=.563	r_s=.39 * p=.043	r_s=-.29 p=.129	r_s=-.20 p=.297	r_s=-.15 p=.443	r_s=.13 p=.505	r_s=.04 p=.827

Exposure did not relate to preference for female faces, except for a surprising positive correlation between male other-race stranger exposure and female face preference on trial 2 of the own-race face gender preference task. Exposure only related to preference in a few cases for male faces. For male faces, with respect to infants' preference for male own- over other-race faces on trial 1, greater overall female face exposure and greater overall own-race female face exposure related to greater preference for the male own-race over the male other-race face, whereas greater overall male own-race face exposure related to lower preference for the male own-race over the male other-race face pair.

What is the relationship between exposure, preference, and discrimination?

If discrimination depends on experience, overall measures of exposure should predict discrimination. If discrimination depends on clear, predictable exposure (as described in Chapter 2), then discrimination would best be predicted by caregivers' faces. We use both overall percent exposure and caregiver exposure in our models. It may also be predicted by infants' overall levels of attention, as measured in the preference task. Given the results of Chapter 3, we used overall proportion looking as our metric of preference in our models. For our measures of discrimination, given the results of Chapter 4, the correlation between the ratio score and looking on test trial 2, and limited variability within the ratio score, we used test trial 2 (in seconds) on the discrimination task as our metric.

We only used the female other-race and male own-race discrimination tasks as outcomes to our model. We chose these two face types for two reasons. First, because they are both familiar and unfamiliar in face type. Female and own-race are familiar. Male and other-race are unfamiliar. Second, as a consequence of their being the first or second discrimination task completed by the participants, we had sufficient power to test our hypotheses with only these two face types. We did not have sufficient power to test our hypotheses for the other two types, male other-race and female own-race.

Since this is exploratory, we used a backwards method including all variables in the first step and removing non-significant variables (p=>.100) in subsequent step(s).

Female other-race face discrimination. We hypothesized that other-race female discrimination at 3 months would be predicted by infants' exposure to faces overall, exposure to their mother's face, and preference for female other-race faces over male other-race and female own-race faces at 3 months; this was supported by the model, R^2_A=.620 (see Table 9). Further, we hypothesized that other-race female discrimination at 6 months would still be predicted by infants' exposure and attention to faces at 3 months of age. After 6 iterations, the model was not successful in predicting discrimination at 6 months; all variables were removed from the model (see Table 10). As with 6 months, we anticipated that exposure and attention to faces at 3 months would predict discrimination at 9 months. After 6 iterations, the model was not successful in predicting discrimination (see Table 11).

Table 9: Regression model predicting 3-month-olds' other-race female face discrimination from preference and exposure

Model	Variable	*t*	*p*	*B (SE)*	95% CI for *B*	*Beta*	R^2	R^2_A	ΔR^2_A
1	Constant	2.29	.043	4795.03 (2090.99)	[192.80 – 9397.26]		.737	.594	
	Face exposure: overall	2.11	.058	10415.39 (4932.45)	[-440.87 – 21271.65]	.419			
	Face exposure: Mom	2.87	.015	5164.92 (1800.34)	[1202.40 – 9127.44]	.562			
	Pref. T1: Female other- over own-race	-0.48	.638	-52.11 (107.71)	[-184.96 – 289.17]	.080			
	Pref. T2: Female other over own-race	4.38	.017	494.63 (112.99)	[-743.32 – -245.95]	-.759			
	Pref. T1: Female over male other-race	-2.82	.001	-240.24 (85.27)	[-427.91 – -52.57]	-.455			
	Pref. T2: Female over male other-race	-3.03	.011	-423.45 (139.84)	[-731.23 – -115.66]	-.488			
2	Constant	2.60	.023	5069.78 (1947.09)	[827.43 – 9212.13]		.732	.620	.026
	Face exposure: overall	2.13	.055	9989.81 (4695.92)	[-241.72 – 20221.34]	.402			
	Face exposure: Mom	3.05	.010	5270.95 (1728.98)	[1503.84 – 9038.07]	.573			
	Pref. T2: Female other over own-race	4.64	.001	502.17 (108.28)	[738.09 – 266.26]	-.770			
	Pref. T1: Female over male other-race	-2.99	.011	-245.22 (81.90)	[-423.66 – -66.78]	-.464			
	Pref. T2: Female over male other-race	-3.19	.008	-429.32 (134.79)	[-723.011 – -135.63]	-.495			

Table 10: Regression model predicting 6-month-olds' other-race female face discrimination from preference and exposure

Model	Variable	*t*	*p*	*B (SE)*	95% CI for *B*	*Beta*	R^2	R^2_A	ΔR^2_A
1	Constant	2.84	.018	10226.89 (3604.22)	[2198.18 – 18257.59]		.196	-.287	
	Face exposure: overall	-1.14	.282	-8836.61 (7769.45)	[-26148.02 – 8474.80]	-.366			
	Face exposure: Mom	-0.49	.634	-1615.09 (3287.05)	[-8939.09 – 5708.92]	-.161			
	Pref. T1: Female other- over own-race	0.86	.408	181.79 (210.33)	[-650.45 – 286.86]	.276			
	Pref. T1: Female over male other-race	-0.91	.387	-264.24 (292.13)	[-490.37 – 468.80]	-.306			
	Pref. T2: Female other- over own-race	0.05	.961	10.79 (215.24)	[-915.13 – 386.66]	.015			
	Pref. T2: Female over male other-race	0.01	.996	1.77 (331.38)	[-736.60 – 740.14]	.002			
2	Constant	3.03	.011	10230.58 (3372.33)	[2808.136 – 17653.03]		.196	-.170	.117
	Face exposure: overall	-1.20	.257	-8838.88 (7396.78)	[-25119.087 – 7441.33]	-.366			
	Face exposure: Mom	-0.58	.608	-1611.17 (3055.03)	[-8335.246 – 5112.90]	-.161			
	Pref. T1: Female other- over own-race	-0.91	.384	-181.79 (200.55)	[-623.192 – 259.61]	-.276			
	Pref. T1: Female over male other-race	-1.0	.340	-264.71 (265.51)	[-849.092 – 319.68]	-.307			
	Pref. T2: Female other- over own-race	-.053	.959	-10.83 (205.07)	[-462.193 – 440.54]	-.015			
3	Constant	3.21	.008	10255.60 (3197.14)	[3289.62 – 17221.58]		.195	-.073	.097
	Face exposure: overall	-1.31	.214	-8944.87 (6816.99)	[-23797.82 – 5908.08]	-.371			
	Face exposure: Mom	-0.59	.567	-1655.92 (2810.54)	[-7779.55 – 4467.71]	-.165			
	Pref. T1: Female other- over own-race	-0.95	.362	-182.05 (191.976)	[-600.33 – 236.23]	-.276			
	Pref. T1: Female over male other-race	-1.08	.300	-267.92 (247.47)	[-807.10 – 271.26]	-.311			
4	Constant	4.03	.001	8932.01 (2217.01)	[4142.45 – 13721.56]		.172	-.019	.054
	Face exposure: overall	-1.21	.248	-7486.75 (6190.35)	[-20860.18 – 5886.69]	-.310			
	Pref. T1: Female other- over own-race	-1.01	.331	-188.49 (186.79)	[-592.02 – 215.05]	-.286			
	Pref. T1: Female over male other-race	-1.10	.292	-264.93 (241.12)	[-785.84 – 255.98]	-.307			
5	Constant	4.07	.001	7803.74 (1915.66)	[3695.06 – 11912.42]		.107	-.020	.001
	Face exposure: overall	-1.05	.312	-6390.92 (6098.33)	[-19470.53 – 6688.68]	-.265			

	Pref. T1: Female over male other-race	-0.74	.473	-160.56 (217.95)	[-628.02 – 306.90]	-.186			
6	Constant	4.09	.001	7410.20 (1811.40)	[3549.28 – 11271.12]		.073	.011	.031
	Face exposure: overall	1.08	.295	-6507.76 (6002.61)	[-19302.03 – 6286.51]	-.270			
7	Constant	8.75	.001	5570.18 (636.48)	[4220.90 – 6919.45]		.000	.000	.011

Table 11: Regression model predicting 9-month-olds' other-race female face discrimination from preference and exposure

Model	Variable	*t*	*p*	*B (SE)*	95% CI for *B*	*Beta*	R^2	R^2_A	ΔR^2_A
1	Constant	0.18	.864	641.15 (3643.67)	[-7601.41 – 8883.71]		.181	-.365	
	Face exposure: overall	0.61	.556	4476.76 (7321.60)	[-12085.84 – 21039.35]	.229			
	Face exposure: Mom	0.57	.583	1597.92 (2809.98)	[-4758.71 – 7954.54]	.212			
	Pref. T1: Female other- over own-race	0.63	.546	136.34 (217.57)	[-355.85 – 628.52]	.222			
	Pref. T1: Female over male other-race	0.99	.351	229.11 (232.70)	[-297.31 – 755.52]	.370			
	Pref. T2: Female other- over own-race	0.57	.581	123.52 (215.97)	[-365.05 – 612.08]	.192			
	Pref. T2: Female over male other-race	0.46	.657	134.86 (206.36)	[-530.18 – 799.91]	.162			
2	Constant	0.22	.829	774.56 (3485.71)	[-6992.09 – 8541.22]		.162	-.257	.108
	Face exposure: overall	0.68	.511	4769.13 (599.94)	[-10827.70 – 20365.96]	.244			
	Face exposure: Mom	0.74	.480	1918.54 (2612.02)	[-3901.40 – 7738.48]	.254			
	Pref. T1: Female other- over own-race	0.76	.466	155.34 (204.99)	[-301.40 – 612.08]	.253			
	Pref. T1: Female over male other-race	0.92	.378	195.274 (211.82)	[-276.68 – 667.23]	.315			
	Pref. T2: Female other- over own-race	0.64	.534	132.78 (206.36)	[-327.02 – 592.58]	.206			
3	Constant	0.22	.833	731.60 (3390.98)	[-6731.88 – 8195.09]		.127	-.190	.067
	Face exposure: overall	0.81	.436	5439.36 (6735.10)	[-9384.50 – 20263.22]	.278			
	Face exposure: Mom	0.96	.359	2350.64 (2456.06)	[-3055.10 – 7756.69]	.311			
	Pref. T1: Female other- over own-race	0.64	.538	123.03 (193.37)	[-302.59 – 548.64]	.200			
	Pref. T1: Female over male other-race	1.08	.302	219.47 (202.82)	[-226.94 – 665.88]	.354			
4	Constant	0.66	.522	1859.59 (2817.94)	[-4280.16 – 7999.35]		.095	-.131	.059
	Face exposure: overall	0.63	.539	3858.66 (6102.84)	[-9438.28 – 17155.61]	.197			
	Face exposure: Mom	0.86	.408	2002.78 (2334.28)	[-3083.18 – 7088.73]	.265			
	Pref. T1: Female over male other-race	0.93	.370	170.15 (182.72)	[-227.95 – 568.26]	.274			
5	Constant	2.44	.030	3396.18 (1393.07)	[386.65 – 6405.72]		.065	-.079	.052
	Face exposure: Mom	0.67	.518	1369.56 (2059.27)	[-3079.22 – 5818.35]	.181			

	Pref. T1: Female over male other-race	0.79	.445	133.17 (169.06)	[-232.06 – 498.40]	.215			
6	Constant	5.62	.000	4173.65 (742.44)	[2581.28 – 5766.02]		.033	-.036	.043
	Pref. T1: Female over male other-race	0.69	.500	112.88 (162.64)	[-236.59 – 462.34]	.182			
7	Constant	8.23	.000	4512.75 (548.47)	[3343.76 – 5681.78]		.000	.000	.036

Male own-race face discrimination. We hypothesized that male own-race face discrimination at 3 months would be predicted by exposure to faces overall, exposure to their dad's face, and their preference for male own-race faces over male other-race and female own-race faces at 3 months. After 6 iterations, the most predictive model, model 3, did not include any of the metrics of exposure, but three measures of attention to male own-race faces; the final model included only one metric of attention, R^2_A=.231 (see Table 12). Further, we hypothesized that own-race male face discrimination at 6 months would still be predicted by infants' exposure and attention to faces at 3 months of age, Overall face and dad face exposure but no measures of preference predicted male own-race discrimination at 6 months, R^2_A=.191 (see Table 13). As with 6 months, we hypothesized that own-race male discrimination at 9 months would be predicted by infants' exposure to face at 3 months and preference at 3 months. After 6 iterations, the model retained no variables and was not predictive of discrimination at 9 months (see Table 14).

Table 12: Regression model predicting 3-month-olds' own-race male face discrimination from preference and exposure

Model	Variable	*t*	*p*	*B (SE)*	95% CI for *B*	*Beta*	R^2	R^2_A	ΔR^2_A
1	Constant	3.86	.004	12145.03 (3147.91)	[5023.96 – 19266.11]		.479	.132	
	Face exposure: overall	-1.20	.262	-11715.6 (9795.43)	[-33874.41 – 10443.21]	-.425			
	Face exposure: Dad	1.06	.316	8117.55 (7650.44)	[-9188.96 – 25424.05]	.417			
	Pref. T1: Male own- over other-race	-0.80	.446	-47.82 (60.06)	[-183.69 – 88.05]	-.258			
	Pref. T2: Male own over other-race	-1.50	.169	-589.07 (393.89)	[-1480.11 – 301.98]	-.547			
	Pref. T1: Male over female own-race	-1.95	.083	-434.77 (222.76)	[-938.68 – 69.14]	-.614			
	Pref. T2: Male over female own-race	-0.84	.424	-126.65 (151.25)	[-468.80 – 215.50]	-.248			
2	Constant	4.59	.001	10448.52 (2274.31)	[5381.04 – 15516.00]		.442	.163	.031
	Face exposure: overall	-0.93	.376	-7467.55 (8063.03)	[-25433.09 – 10497.99]	-.271			
	Face exposure: Dad	0.81	.436	5498.13 (6779.31)	[-9607.11 – 20603.36]	.283			
	Pref. T2: Male own over other-race	-1.29	.226	-427.63 (331.46)	[-1166.16 – 310.90]	-.397			
	Pref. T1: Male over female own-race	-1.82	.099	-361.96 (199.36)	[-806.17 – 82.25]	-.511			
	Pref. T2: Male over female own-race	-0.85	.417	-125.76 (148.45)	[-456.53 – 205.01]	-.247			
3	Constant	4.60	.001	10073.11 (2191.79)	[5249.01 – 14897.22]		.406	.189	.026
	Face exposure: overall	-0.62	.549	-4292.07 (6938.01)	[-19562.51 – 10978.38]	-.156			
	Pref. T2: Male own over other-race	-1.02	.328	-273.71 (267.48)	[-862.43 – 315.02]	-.254			
	Pref. T1: Male over female own-race	-1.69	.120	-319.31 (189.29)	[-735.93 – 97.31]	-.451			
	Pref. T2: Male over female own-race	-1.28	.229	-172.02 (134.91)	[-468.95 – 124.90]	-.337			
4	Constant	8.45	.000	8893.53 (1052.66)	[6599.98 – 11187.09]		.385	.231	.042
	Pref. T2: Male own over other-race	-1.17	.264	-301.18 (256.90)	[-860.91 – 258.56]	-.280			
	Pref. T1: Male over female own-race	-1.62	.132	-284.37 (175.96)	[-667.74 – 99.01]	-.401			
	Pref. T2: Male over female own-race	-1.54	.149	-194.77 (126.42)	[-470.21 – 80.68]	-.382			
5	Constant	9.62	.000	8140.62 (845.98)	[6312.99 – 9968.25]		.314	.209	-.022
	Pref. T1: Male over female own-race	-1.40	.184	-245.82 (175.33)	[-624.59 – 132.96]	-.347			

	Pref. T2: Male over female own-race	-1.33	.205	-168.17 (126.14)	[-440.69 – 104.35]	-.330			
6	Constant	9.81	.000	7639.36 (778.59)	[5969.46 – 9309.26]		.221	.165	-.044
	Pref. T1: Male over female own-race	-1.99	.066	-332.90 (167.16)	[-691.43 – 25.62]	-.470			

Table 13: Regression model predicting 6-month-olds' own-race male face discrimination from preference and exposure

Model	Variable	*t*	*p*	*B (SE)*	95% CI for *B*	*Beta*	R^2	R^2_A	ΔR^2_A
1	Constant	2.58	.027	5762.08 (2232.69)	[787.34 – 10736.82]		.450	.120	
	Face exposure: overall	0.31	.763	2086.19 (6745.83)	[-12944.45 – 17116.82]	.115			
	Face exposure: Dad	-1.83	.097	-10728.90 (5867.03)	[-23801.45 – 2343.65]	-.713			
	Pref. T1: Male own-over other-race	0.99	.347	46.07 (46.65)	[-57.86 – 150.00]	.294			
	Pref. T1: Male over female own-race	1.47	.172	192.43 (130.81)	[-99.04 – 483.90]	.479			
	Pref. T2: Male own over other-race	1.14	.283	359.86 (316.87)	[-346.18 – 1065.90]	.423			
	Pref. T2: Male over female own-race	-0.31	.762	-33.19 (106.66)	[-270.84 – 204.46]	-.083			
2	Constant	6.44	.000	6374.24 (989.41)	[4196.56 – 8551.92]		.445	.192	.072
	Face exposure: Dad	-2.16	.053	-9619.69 (4448.05)	[-19409.79 – 170.41]	-.640			
	Pref. T1: Male own-over other-race	1.01	.334	38.59 (38.20)	[-45.50 – 122.67]	.246			
	Pref. T1: Male over female own-race	1.71	.115	167.00 (97.45)	[-47.49 – 381.48]	.416			
	Pref. T2: Male own over other-race	1.17	.266	313.33 (267.17)	[-274.70 – 901.35]	.368			
	Pref. T2: Male over female own-race	-0.25	.809	-24.42 (98.51)	[-241.23 – 192.38]	-.061			
3	Constant	7.70	.000	6246.52 (811.03)	]4479.43 – 8013.60]		.442	.256	.064
	Face exposure: Dad	-2.24	.045	-9545.67 (4260.94)	[-18829.46 – -261.87]	-.635			
	Pref. T1: Male own-over other-race	1.12	.284	40.37 (36.02)	[-38.12 – 118.85]	.258			
	Pref. T1: Male over female own-race	1.77	.103	164.37 (93.01)	[-38.28 – 367.02]	.409			
	Pref. T2: Male own over other-race	1.31	.216	327.35 (250.69)	[-218.86 – 873.56]	.385			
4	Constant	8.64	.000	6581.01 (761.50)	[4935.89 – 8226.12]		.383	.241	-.015
	Face exposure: Dad	-2.04	.062	-8614.35 (4220.05)	[-17731.22 – 502.51]	-.573			
	Pref. T1: Male over female own-race	1.56	.144	143.09 (91.94)	[-55.54 – 341.72]	.356			
	Pref. T2: Male own over other-race	1.00	.338	239.06 (240.32)	[-280.13 – 758.24]	.281			
5	Constant	8.99	.000	6721.44 (748.02)	[5117.11 – 8325.78]		.336	.242	.001
	Face exposure: Dad	-1.80	.093	-6123.01 (3395.21)	[-13405.01 – 1159.00]	-.407			

	Pref. T1: Male over female own-race	1.42	.179	128.29 (90.70)	[-66.23 – 322.81]	.319			
6	Constant	11.60	.000	7329.72 (632.14)	[5982.34 – 8677.10]		.242	.191	-.051
	Face exposure: Dad	-2.19	.045	-7391.47 (3382.13)	[-14600.32 – -182.62]	-.491			

Table 14: Regression model predicting 9-month-olds' own-race male face discrimination from preference and exposure

Model	Variable	*t*	*p*	*B (SE)*	95% CI for *B*	*Beta*	R^2	R^2_A	ΔR^2_A
1	Constant	3.47	.008	6977.94 (2009.01)	[2345.15 – 11610.73]		.262	-.292	
	Face exposure: overall	-1.15	.282	-6180.58 (5359.37)	[-18539.32 – 6178.16]	-.415			
	Face exposure: Dad	1.12	.295	4925.18 (4399.19)	[-5219.38 – 15069.73]	.432			
	Pref. T1: Male own- over other-race	-0.19	.855	-7.77 (41.18)	[-102.72 – 87.19]	-.071			
	Pref. T1: Male over female own-race	-0.46	.657	-148.61 (322.13)	[-891.44 – 594.23]	-.186			
	Pref. T2: Male own over other-race	-0.90	.396	-221.62 (247.10)	[-791.44 – 348.19]	-.359			
	Pref. T2: Male over female own-race	0.13	.897	26.13 (194.79)	[-423.04 – 475.31]	.054			
2	Constant	3.98	.003	7071.58 (1778.12)	[3049.19 – 11093.98]		.260	-.151	.141
	Face exposure: overall	-1.25	.242	-6279.40 (5010.54)	[-17614.04 – 5055.23]	-.422			
	Face exposure: Dad	1.19	.263	4758.86 (3983.99)	[-4253.56 – 13771.28]	.418			
	Pref. T1: Male own- over other-race	-0.23	.820	-8.91 (38.03)	[-94.93 – 77.11]	-.081			
	Pref. T1: Male over female own-race	-0.49	.639	-126.19 (259.96)	[-714.26 – 461.88]	-.158			
	Pref. T2: Male own over other-race	-0.95	.369	-220.33 (233.05)	[-747.54 – 306.87]	-.356			
3	Constant	5.00	.001	6825.69 (1365.78)	[3782.54 – 9868.85]		.256	-.042	.109
	Face exposure: overall	-1.34	.210	-5783.18 (4320.89)	[-15410.71 – 3844.36]	-.388			
	Face exposure: Dad	1.24	.243	4463.73 (3596.53)	[-3549.84 – 12477.30]	.392			
	Pref. T1: Male over female own-race	-.46	.658	-107.03 (234.81)	[-630.21 – 416.15]	-.134			
	Pref. T2: Male own over other-race	-.97	.353	-199.15 (204.39)	[-654.56 – 256.27]	-.322			
4	Constant	5.43	.000	6584.18 (1212.64)	[3915.18 – 9253.18]		.240	.033	.075
	Face exposure: overall	-1.35	.205	-5573.72 (4138.78)	[-14683.11 – 3535.66]	-.374			
	Face exposure: Dad	1.22	.247	4162.37 (3405.55)	[-3333.20 – 11657.95]	.365			
	Pref. T2: Male own over other-race	-.91	.385	-167.65 (185.30)	[-575.50 – 240.19]	-.271			
5	Constant	5.50	.000	6616.67 (1202.91)	[3995.75 – 9237.58]		.184	.048	.015
	Face exposure: overall	-1.55	.147	-6262.66 (4037.26)	[-15059.08 – 2533.77]	-.420			

	Face exposure: Dad	0.94	.365	2909.12 (3087.51)	[-3817.99 – 9636.23]	.255			
6	Constant	5.56	.000	6659.36 (1196.86)	[4073.71 – 9245.01]		.123	.056	.008
	Face exposure: overall	-1.35	.200	-5227.30 (3868.04)	[-13583.69 – 3129.08]	-.351			
7	Constant	11.93	.000	5144.27 (431.18)	[4219.49 – 6069.05]		.000	.000	.056

Discussion

Our results find two arguably distinct patterns, differing by face type. No measures of female face exposure were significantly correlated with infants' preference for female faces at 3 months of age. Three-month exposure to mom and preferential attention to other-race female faces significantly predicted infants' discrimination of female other-race faces at 3 months, explaining 62% of the variance. Exposure and preference at 3 months did not predict discrimination at 6 or 9 months. For the male faces, exposure and preference at 3 months did relate and only preference, not exposure, was predictive of own-race male face discrimination at 3 months. It was not until 6 months that exposure to dad at 3 months, independent of preferential attention, was predictive of own-race male face discrimination (see Table 13). Dad face exposure at 3 months explained 11% of the variance in own-race male face discrimination at 6 months (see Table 12).

Exposure, preference, and discrimination

This pattern is consistent with a perspective whereby exposure shapes attention and discrimination. We interpret this as indicating that infants' early face exposure tunes infants' early attention to faces and, only after exposure has had its effect on attention, does this cumulative experience and attentional preference combine to predict discrimination. This is why infants show a relationship between exposure to and preference for male but not for female faces and exposure and preference predict discrimination at 3 months for female and only later, at 6 months, for male faces. These infants have primarily female face exposure and this was likely also true at 1 month (Sugden et al., 2014). If infants require a certain amount of experience to tune preference and then further experience to be able to perform a discrimination task, then they would be expected to show a female face experience-preference link early and have experience and preference predict discrimination later. Similarly, since they are getting less exposure to male faces at 3 months and this likely was also true at 1 month (Sugden et al., 2014), they would be expected to require more time to show the link between exposure and preference, which is what emerges in this sample at 3 months. Further, exposure and preference may require some time to operate to tune face discrimination, which would be why the link between exposure and preference does not emerge until 6 months for male faces. This is consistent with our current results and with extant research.

Infants' early experience is female-dominated, as demonstrated by several previous studies (Jayaraman et al., 2015; Rennels & Simmons, 2008; Sugden et al., 2014) and Chapter 2. As was demonstrated by Bushnell (2001), exposure to mom's face predicts preference for mom's face after mere hours of exposure. What was unknown is how much more exposure would be required to predict preference and discrimination for mom-like faces and for dad-like faces. It is logical to expect that female and male face capacities would emerge at differing latencies since infants have far more opportunity to learn about female than male faces. Viewed from this perspective, it is understandable that infants show an early preference for female and own-race face types, since these are the types with which they have the most experience and are currently learning. Schema theory (Lewis, 1969) predicted this in that it argued that infants titrate their visual attention to provide themselves with an optimal amount of novelty. In this case, if infants are learning about female faces and own-race faces at 3 months, then they would be expected to show a visual preference for these face types. After they have learned about these face types, this preference would decline and would direct their attention to the somewhat less familiar types (e.g., male and other-race). Furthermore, if attention indexes learning, then infants should not be expected to show a capacity with particular types of faces until after they have shown declining attention to these types of faces—i.e., after they have sufficiently categorized or learned about the face type.

Theories of face processing: importance of mom and other caregivers

Current theories of face processing tend to predict discrimination from experience, but leave out the role of attention. The current study is consistent with statistical learning, in that infants learned the most frequent types of stimuli that were also most likely to co-occur across locations and contexts (see Chapter 2). It is also consistent with social theories, since caregiver face experience and attentional preference predicted discrimination (Scherf & Scott, 2012). That preference was retained, with experience, in the model suggests a role for attention in focusing infants' early capacities that has potentially developed from earlier visual experience (Markant et al., 2016).

It is less easy to reconcile the contact hypothesis and face space with the current results. The author does not doubt that experience matters and that greater experience with particular types of faces likely results in greater ability, however this was not borne out here as precisely. Exposure seemed to be influencing preference and its effect on discrimination included preference. As a consequence, it may be that exposure cannot operate on discrimination without the intervening role of attention. Furthermore, here we find that it is only one (i.e., mom or dad), not a multitude of different faces, that tunes the system. Face space would require a greater number of exemplars, even if these are sensitive and socially engaging, to create sufficient density to show capacity, a consideration we did not test due to the restricted number of individual numbers experienced by each infant. Similarly, the contact hypothesis assumes contact with more than one individual of a particular type. Here, we find that caregiver face exposure is the most predictive of infants' early learning. It may be that infants' require simple or not-too-novel input and it is not until later that they are developmentally ready to extract lessons about face processing from more than one or a few faces. Consequently, it may be that face space and the contact hypothesis apply only after infants' have completed fully processing and potentially categorizing mom-like and dad-like faces.

What influences infants' early male face discrimination?

That preference and not exposure was predictive of discrimination at 3 months suggests that infants are using other face experience in their attempts to discriminate own-race male faces. This is particularly notable since only a third of infants were able to discriminate own-race male faces at 3 months of age (see Chapter 4). There may be several reasons for that. First, it may be that the videos are not adequately capturing infants' experiences with dad. Although dads did report placing the cameras on infants’ heads and, in some cases, being involved in caregiving, it is possible that dad was simply not a frequent enough person in the infants' early visual environment to be adequately captured by a single week of recording experience. However, dad face exposure at 3 months was predictive of ability at 6 months, arguing against the possibility that the data represented dad face exposure with low fidelity. Alternatively, we might suggest that it is here, again, mom that could be driving infants' ability. Given the influence of their mother's face, which is an own-race face that is familiar, it may be that this own-race, adult face exposure provides the infant with rudimentary capacities to discriminate between other own-race faces, but not to the same degree. We tested this by adding mom to the model – mom face exposure explained the least variance and was removed in the second iteration of the model. Thus, exposure to mom's face does not influence infants' ability to discriminate own-race male faces.

The importance of multiple methods and measurement periods

This paper further highlights the need to consider multiple metrics of early capacities measured in the same way at multiple time-points to truly measure the *development* of infants' abilities. It is insufficient to document the ages at which infants can and cannot do a potential task by itself. Development is a dynamic process during which multiple capacities are maturing concurrently, potentially influencing each other. Measuring infants' ability on a single capacity fails to consider how it may relate to (in this case) similar or (potentially) disparate other capacities (e.g.,Cashon et al., 2013). In the current study, we would have failed to note any effect of experience on ability had we measured exposure and preference alone or exposure and discrimination alone. It was the confluence of these three measures that allowed the more nuanced understanding of how infants' early experiences shape the developing system.

The importance of an infant perspective

Infant-perspective cameras capture infants' typical, daily, experiences at home and with their families. This socially-situated, rich, and natural data provides a powerful method by which to document natural experiences and opportunities for learning. All of the video represents actual infant life experiences. Although we concede that we cannot definitively know for certain our data is representative, that we were able to predict up to 62% of the variance in infants' female other-race face discrimination performance using the video-recorded experiences and preference and 19% of the variance in infants' male own-race face discrimination using a potentially incomplete picture of infants' experience is even more impressive. If we found these relations with an incomplete picture of the infant's visual world, it is difficult to imagine how much more predictable infants' behaviour would be with complete documentation of infants' visual experience (which is, of course, impossible to get). In this light, our findings are actually a conservative estimate of the role of experience in shaping the developing system.

Longitudinal measurement – how might exposure, attention, and discrimination change?

Although the current study did not consider infants' exposure to faces beyond 3 months, the author would argue that it likely continues to have an effect, particularly on preference for and ability with infrequently-experienced faces. Other-race faces are so infrequent that they may show an even later development of preference and discrimination that would not be related to exposure until potentially 6 or 9 months. How exposure changes at later ages and how exposure links to preference and discrimination at later ages are still open questions. We might suggest that later experience with the least familiar face types (i.e., other-race males) would eventually predict ability, after infants acquire cumulatively sufficient experience. How much experience would be required is still unclear. Although this question is beyond the scope of the data presented, it is an empirical question that can be answered by using multiple methodologies at multiple longitudinal time-points.

Why mom? Why dad?

Mom and dad are the most frequent faces in the infant's early environment. Consequently, it is not unreasonable to expect that they exert a heavy influence on infants' early face processing capacities. These may be the exemplars that tune the system. If infants are developing a face space, it may be that mom's face is at the origin during the first few months of life. This is consistent with female face biases (Ramsey, Langlois, & Marti, 2005; Ramsey-Rennels & Langlois, 2006). At approximately the half-year mark, however, the face that is next-most-frequent in the infant's environment (i.e., dad or another caregiver) has likely been experienced sufficiently to have had an effect on this early mom-centric face space. Dad may represent another face cluster (e.g., male faces), which is why his influence on discrimination does not occur until later. This has interesting implications for infants who have no male primary caregiver, only male primary caregivers, or other non-traditional caregiving arrangements (e.g., grandparents). Consistent with this is the finding that infants with male primary caregivers attend preferentially to male over female faces (see Chapter 3) and that infants do not show a capacity to discriminate male own-race faces until 6 months whereas they can do so with female own-race faces at 3 months (see Chapter 2). How communal living or deprivation may change, upset, or delay this trajectory would be an interesting study.

Conclusion

The current results argue for stepped learning that is exposure-dependent. If infants receive sufficient exposure to faces of a particular type, they show preference and then discrimination of these faces. Indeed, preference and exposure predict this later discrimination *but only after they have accrued sufficient exposure***.** Before they have reached the exposure threshold, exposure may only influence preference and not discrimination. These three measures are three pieces of the same learning puzzle. Infants learn from socially-engaging, attention-capturing input, such as that provided by their parents, to determine how to deploy their attention in their new environment. Exposure and attention then combine to help infants understand and individuate the people in their world. From this perspective, caregiving moments are all teaching moments, from which infants are well equipped to learn.

Chapter 7 General Discussion

Infant's environment represents an early opportunity for learning and they take full advantage of this opportunity. The open question that this dissertation aimed to answer is: how do they do it? Faces represent a model system by which to consider how infants are able to learn so quickly, efficiently, and typically successfully. In this final Chapter, I will review the findings from this dissertation, relate them to the larger literature on infant learning, and discuss the implications of this type of learning system.

Exposure to faces is highly homogenous and predictable at 3 months

Infants are provided with predictable input. As detailed in Chapter 2, the early infant environment is awash with faces. Faces are present in over a quarter of infants' typical, daily experiences. There is a lack of variability or diversity in early face inputs. This was highlighted in Chapters 2 and 6, in addition to replicating previous studies that have found that infants' face diets are tightly constrained (Jayaraman, Fausey, & Smith, 2015; Rennels & Simmons, 2008; Sugden, Mohamed-Ali, & Moulson, 2014; Sugden & Moulson, 2016). The faces that infants see are mostly caregivers' faces and these faces recur across contexts and environments. Although other faces do occur, other faces tend to be infrequent and far less consistent across contexts. Stranger and relative face exposure was highly variable, with some infants receiving no and other infants receiving substantial non-caregiver face exposure. Unlike strangers or other relatives, caregivers' faces are more likely to persist in the infant's field of view. This sets up an early learning environment in which the signal – caregivers' faces – can be more easily identified from the noise of all of the other faces in the environment through its statistical frequency and its cross-context reliability. But how do infants use this predictable, clear signal?

Implications of this pattern of exposure. There is no question that a clear, redundant input is helpful to learn a new skill. Per schema-theory, it is important to reduce the level of complexity of an input to only slightly above the current capacities of the infant (e.g., Lewis, 1969). As greater mastery is achieved, greater complexity can be added. This seems to be a general rule of learning (e.g., in childhood Azevedo, Cromley, & Seibert, 2004). Both adults and children show superior learning from the clear input of infant-perspective environments whereas they fail in the cluttered adult-perspective ones

(Yurovsky, Smith, & Yu, 2013). This is true in many other domains, not just visual perception (e.g., language, Liu, Kuhl, & Tsao, 2003). Computer modeling simulations corroborate this finding: systems that start with limited, restricted, but clear input show developmental-type learning trajectories whereas those that start with more adult-like inputs fail in this task (Elman, 1993). Once they have learned, they can adaptively use the adult-like inputs.

Early experience may have far-reaching impacts. As was detailed in the introduction, deprivation through obscured visual input (i.e., cataracts) or neglect (i.e., infants raised in orphanages) has substantial down-stream impacts on later visual and facial processing (Maurer, Mondloch, & Lewis, 2007; Parker, Nelson, & The Bucharest Early Intervention Project Core Group, 2005). After deprivation, years or decades of visual input cannot remediate the system to reach typical levels of face processing. Conversely, early inputs can facilitate face processing in adulthood of face types with which the adult typically does not have extensive experience. Within typical development, early face experience predicts later capacity with face types that are typically unfamiliar, potentially by reactivating the obsolesced skill (e.g., with child faces, Macchi Cassia, Kuefner, Picozzi, & Vescovo, 2009). But when are these early inputs important?

Simplified, clear inputs may only be adaptive at very early ages. It is unclear the ages at which different types of input are most beneficial. If contact-based hypotheses (e.g., Face space, the contact hypothesis, perceptual narrowing) are accurate, then diversity is required to develop expertise in face processing. However, how many faces or exemplars constitute "diversity" is an open question with limited empirical study outside of studies of severe deprivation, which are valuable but which also conflate face deprivation with other types of deprivation or neglect (e.g., Pennsylvania, Nelson, Zeanah, & Fox, 2007). Exposure to a continued lack of diversity, by being raised in a very small hometown, resulted in reduced memory for faces and less face-specific electrical brain response (N170; Balas & Saville, 2015).

As detailed in Chapter 2, infants receive reduced diversity in face exposure, relative to that likely received by adults or children. A large proportion of infant face exposure is to caregivers, particularly mom. Caregiver and caregiver-type faces (e.g., female own-race) are highly familiar whereas faces that resemble caregivers less (e.g. male other-race) are less familiar. It is likely that infants' attention to faces relates to their degree of familiarity with the face type. If there are more than a few faces in their visual environment, how does their visual attention differ by face familiarity?

Infants' attention to familiar and unfamiliar face types

Young infants show greater attention to the face types that occur most often in their early experience. In the preference task (see Chapter 3), infants showed an initial (trial 1) preference for female over male own-race faces only at 3 months and a later (trial 2) preference for male at 6 months. Gender preference was not evident in the female and male other-race face comparisons at any age. These findings of a preference for female at 3 months in own- but not in other-race faces replicate the work of Quinn and colleagues (Quinn et al., 2008, 2002) and extend them to describe infants' later pattern of preference for male. Contrary to hypotheses, when shown own- versus other-race face pairs infants of all ages had no preference. Unlike other studies that examined preferential visual attention of infants raised in homogenous environments, infants in the current study were raised in a highly multicultural city and diverse home environments. Although the overall trends and means for trial 1 within the pair of male faces of different races were consistent with other studies, with declining attention towards the own-race face, this was not true of the female face pair where infants evidenced no hint of a preference at any age. The diversity of infant experience may be one possible reason for their diverse performance.

The pattern of results for the face gender pairs is consistent with previous literature, however the pattern of results for the face race pairs is not. As discussed in Chapter 3, there are several potential reasons for these discrepancies. First, unlike most samples (e.g., Liu et al., 2015), our infants were recruited from a large multi-cultural city in which no race or ethnicity makes up 50% or more the population (Bélanger & Caron-Malenfant, 2005) and consequently infants' exposure to other-race face types rivals their exposure to dad's face (see Chapters 2 and 6). Other-race faces are not novel; they are instead less familiar than are own-race face types. Their other-race face space may be sparser than own-race face space, but it is likely not empty. Although face space makes no predictions about infants' attentional preferences, it might be expected that infants who are learning about both own- and other-race faces deploy their attention to both types, in contrast to the skewed attention pattern seen when infants encounter a face type that is totally novel (i.e., early and declining attention to own-race). Consistent with schema theory, they are titrating their exposure to novelty by deploying their attention to maximize learning of visual stimuli that are slightly, but not too far, beyond their ken.

Attention or preference? Preferential looking paradigms are often conceptualized as infant preference. The term preference is problematic. In lay terms, it implies that infants have a greater liking or affinity when this cannot truly be assumed from visual attention alone. Throughout this document the author has attempted to disambiguate this by more clearly describing infants' looking behavior as attentional orienting or attentional preference. A visual bias or attentional bias might be a fairer or more honest conception of infants' behavior in the task described in Chapter 3.

Implications of differential attention. Infants' visual attention, particularly how long they spend attending to a visual stimulus, has been related to the speed and strategy with which they process a visual stimulus (Colombo, Mitchell, Coldren, & Freeseman, 1991; Colombo, Mitchell, & Horowitz, 1988). Infants who show shorter fixation durations are more successful at face processing than are longer lookers (Colombo et al., 1988; Frick, Colombo, & Saxon, 1999). What typically captures infants' attention is likely their ability to resolve the stimulus, whereas what maintains their attention is its complexity (Cohen, 1972) in addition to its familiarity (Cohen, DeLoache, & Rissman, 1975; Hunter, Ames, & Koopman, 1983). We argue that the duration of individual infants' attention to faces may be influenced by experience. If so, we would posit that it would relate to how faces are presented in their visual environment.

Understanding what shapes individual infants' attention has important cognitive implications. Measures of infant attention have been found to relate to their developing cognitive abilities at 5 years (Rose, Feldman, Wallace, & McCarton, 1989) and young adulthood (Fagan & Detterman, 1992; Fagan, Holland, & Wheeler, 2007). Indices of attention or speed of processing have been found to predict later outcomes within other domains as well (e.g., language, Benasich & Tallal, 2002). This suggests that whatever is tuning infants' early attention has far-reaching consequences which is why it is important to explore what shapes early attention. If experience does relate to attention, this suggests a mechanism by which parents can help infants' adaptively deploy attention to benefit later cognitive outcomes.

Relationship between exposure and attention?

Given the evidence, it is not unreasonable to posit that experience predicts attention. This has previously been found by relating infants' exposure to their mom with their attention to their mother over a stranger's face (Bushnell, 2001) and implied in the finding that infants preferentially attend to familiar over unfamiliar face types (e.g. female faces, Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). Here, we further suggest that not only does experience tune attention, but attention will shape subsequent experience. This creates a mutually-reinforcing cycle of attention and experience. In that case experience matters only inasmuch as it is attended to. Without the critical factor of attention to the experience, learning does not occur. This makes logical sense at the extremes, whereby it would be impossible to learn from things that were allocated no attention. Now that we have clearly described how 0 and 100% experience shape attention, we can consider what happens to attention when experience rates fluctuate to understand how differing amounts and types of input shape learning.

What comes first? Attention and exposure are the chicken and the egg. There are multiple things that shape infants' attention to faces and, in particular, to mom's face. Some of these occur prior to infants' experience with faces. In early development infants show greater visual attention face-like stimuli (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991), suggesting that there are early visual system biases that result in greater attentional capture by face-like stimuli (e.g., potentially due to their having more items in the upper than lower half). Providing infants with a sweet taste can also shape their attentional preferences (Blass & Camp, 2001), pointing to the relationship between vision and other modalities. Mother's voice captures infants' attention at birth (Sai, 2005). This may be due to in utero exposure to their mother's and other voices. Without this face-voice pairing experience, infants fail to show a preference for their mother's face (Sai, 2005). Since faces are inextricably linked to voices, this early attentional orienting to the source of the vocalizations may itself also shape infants' visual attention to faces. Similarly, although exposure to mom's face correlates with preference for mom's face (Bushnell, 2001), vocalizations by mom during these face exposures are a necessary component to facilitate the attentional capture by mom's face (Sai, 2005). This is not to say that mothers are passive in this, mothers actively use language to engage infants' visual attention (Waxman & Spencer, 1997). Although there are bi-directional influences in their interactions, this strategy is used ubiquitously, even when their infants are hearing impaired. A bi-directional relationship is arguably most likely between exposure and attention.

Changes in patterns of natural exposure would be expected to change infants' typical patterns of attention. For example, if infants are raised in an environment with greater variability in face types, for example by biracial or multiracial caregivers, they may be expected to show a less narrow pattern of racial preferences with development. Although there are differences in face scanning between bi- and mono-racial infants (Gaither, Pauker, & Johnson, 2012), the author could find no evidence of differential preferences between bi- and mono-racial infants in the extant literature. A second area in which changes in exposure may be expected to change infants' attention is with families where caregivers are uniquely single-sex or there is only one primary caregiver. Infants' attention to female faces is influenced by the gender of the primary caregiver, with greater attentional preference towards faces that match the gender of the caregiver (Quinn et al., 2002). This typically changes with development, as detailed in Chapter 3. An open question, however, is whether and how this changes if there are no male caregivers (as occurred with two infants in this sample), only one caregiver (as was the case with 1 infant in this sample), no female caregivers (which did not occur in this sample), or if primary caregivers change with development (as occurred at 9 months with 2 of the infants in this sample). The current data highlights differences that are potentially important. Although pursuing these differences is beyond the scope of the current research question (in addition to the ethical concerns of reporting on n=1 samples), it suggests a fertile avenue for further research, to fully understand how these changes in exposure may influence infants' attention.

Implications of an exposure-attention relationship. If there is a bidirectional relationship between exposure and attention, this implies that a change in experience would result in a change in attention and vice versa. Consequent to the change in experience and/or attention, there should be a change in later capacities. There is evidence for both the impact of experience and attention on infants' face processing skills. Bahrick has argued that it is inter-sensory redundancy, per se, that is directing attentional and cognitive development (Bahrick, Lickliter, & Flom, 2004). Providing infants with experimental experience to unfamiliar face types, such as monkey faces or other-race faces, results in a change in infants' ability to process these unfamiliar face types (Heron-Delaney, Anzures, et al., 2011; Pascalis et al., 2005; Scott & Monesson, 2009). Similarly, changing infant attention by drawing it towards unfamiliar face types within a short experimental task, without changing infants' prior exposure, also results in infants showing an ability to discriminate face types with which they typically fail to show discrimination (Markant, Oakes, & Amso, 2016). Attention can operate without the need for changes in experience. This suggests that experience may only be one of the potential ways in which attention can be shaped and changed.

Theories of exposure and attention. The author could find no theories that predicted infants' preferential attention to familiar over unfamiliar face types, per se. Theories that predicted discrimination were informative in that they often included or alluded directly or indirectly to a role for attention. Face space, in its more recent revision, has been enlarged to incorporate the role of attention and type of visual experience in shaping whether the face is encoded into face space (Valentine, Lewis, & Hills, 2015). This is also consistent with arguments made by Scott and colleagues (Scherf & Scott, 2012; Scott & Fava, 2013) as well as other researchers (DeNicola, Holt, Lambert, & Cashon, 2013; Markant et al., 2016) and the author in a previous paper (Sugden & Moulson, 2016). The attention-experience link is also present in more socially driven theories, whereby infants' face processing capacities are related to both their developmental stage and the social interactivity of the face (Scherf & Scott, 2012). Ultimately, attention suggests a mechanism by which experience can influence ability, a mechanism by which perceptual narrowing or statistical learning could operate (Kirkham, Slemmer, & Johnson, 2002; Scott, Pascalis, & Nelson, 2007) to tune discrimination.

Infants' processing of familiar and unfamiliar face types

Infants were able to discriminate, at all ages, female faces. As detailed in Chapter 4, although a majority were able to do this for female own-race faces at all ages, fewer infants were able to do this with female other-race faces. Discrimination performance for male faces was less clear. Male own-race faces were only discriminated at 6 and 9 months, but not at 3 months. Male other-race faces showed the opposite pattern: 3 of the 4 infants could discriminate male other-race faces at 3 months, slightly more than half could do so at 6 months, and they were no longer able to do so at 9 months. Infants' natural brain activity in response to faces at early visual (i.e., P1) and early face-specific (i.e., N290, P400) components did not discriminate between face gender or face race.

With age, more individual infants were able to discriminate own-race female, own-race male, and other-race female, despite some decreases in metrics in central tendency. Only male other-race faces showed a decline, consistent with a decline in metrics of central tendency for discrimination of male other-race faces. There was also an age-related decrease in the group mean for discrimination of female other-race faces. The continued capacity with own-race faces and decline with male other-race faces is consistent with current theories of the development of face processing (e.g., perceptual narrowing, contact hypothesis, face space). The increase in number of infants showing discrimination and decline in group mean discrimination score for female other-race faces is not entirely consistent with current theories. As discussed above, this may reflect infants' ongoing familiarity with other-race faces, a consequence of their living in a diverse metropolis. Infants may be successful with other-race female faces because their female face space is highly populated as a consequence of their greater female face exposure. The tactic of using own- for other-race female discrimination may be slightly less stable or robust leading to successful, improving, and slightly lower levels of novelty preference. It may also suggest that perceptual narrowing (Scott et al., 2007), at least in this case, speaks only to the degree of and not success in discrimination. Teasing apart these potential mechanisms would clarify the way in which infants are using their experience to succeed at discriminating faces.

Implications of familiar and unfamiliar face discrimination. Given the overall success of infants on the discrimination task, it is unclear what the implications are of superior or inferior face discrimination. In a recent meta-analytic review, although Sugden and Marquis (in preparation) found evidence of the other-race effect in face discrimination, which predicted 7-9% of the variance in face discrimination, this was far eclipsed by methodological decisions that predicted 20% or more of the variance in infant face discrimination. While certainly serving as a marker of early ability there is evidence that narrowing may only be a lag in processing or attentional bias: unfamiliar face discrimination shows recovery at 12 months if the infant is given sufficient time to process the stimulus (Fair, Flom, Jones, & Martin, 2012) and at 9-months if their attention is directed towards the stimulus (Markant et al., 2016). In an adult population, the other-race effect accounts for 15% of the variance in discrimination accuracy (Meissner & Brigham, 2001), although gender bias is even smaller (Herlitz & Lovén, 2013). Meissner and Brigham (2001) suggest real-world forensic implications of the own-race bias, particularly in eye-witness testimony. How this relates to earlier face processing skill is still an open question.

Electrical brain response to familiar and unfamiliar faces

Infants evidenced a clear P1, N290, and P400 in response to faces at 3, 6, and 9 months of age. The P1 was entirely unrelated to face race or face gender. We anticipated that this would be true of the P1, since this component has been hypothesized to measure low-level visual features of the stimulus (de Haan et al., 2002). At the P400 and marginally at the N290, gender interacted with age at 6 months. There were no other effects of gender or race at the N290 or P400. We had hypothesized that the N290 and P400 would index face familiarity. This was because although the N290 has been argued to indicate face perception, per se, independent of face type (de Haan et al., 2002), other studies have found differences by face familiarity at this component (e.g., female faces, Righi, Westerlund, Congdon, Troller-Renfree, & Nelson, 2014). Similarly, the P400 has been argued and found to index face type or familiarity (Balas et al., 2010).

As discussed in Chapter 5, we consider possible reasons why we failed to find the expected pattern of differences in the N290 and P400. First, the components themselves may not be familiarity-specific yet. This is at odds with other studies that have found differences in own- and other-species processing (Scott & Monesson, 2010) and own- and other-race processing (Balas, Westerlund, Hung, & Nelson, 2011). No study has yet found familiarity effects with images of different types of real human faces, which is what infants were shown in our study, and consequently it may simply be that infants require larger differences between familiar and unfamiliar face types (i.e., human vs. monkey or computer-generated faces created to high-light differences in race) to show this discrimination in their electrical brain response.

Second, it is possible that a difference at these components may only visible when the system is undergoing re-organization, which is why it is evident in 6-month-olds for gender only. Three-month-olds show a preference for female that 6-month-olds do not. At 6 months, however, infants show a capacity to discriminate male own-race faces that was not evident at 3 months. This may also relate to infants' eventual accrual of sufficient male or dad face exposure, something with which they only had limited experience at 3 months. If true, then these findings suggest substantial reorganization that may be indexed by the N290 and P400. Further, that there were no differences in race may suggest that race-based re-organization occurs at a different developmental time. Other-race faces were even less frequent than dad's face, suggesting that the own-/other-race face discrimination at these components may not occur until much later in development.

A third possible reason for a failure to find the expected pattern is that face familiarity in the infant brain may be better indexed by attentional (e.g., infant Nc component) instead of face-specific components (i.e., infant ERP components N290, P400). If exposure is shaping infants' early attention to faces of different types, then it may also be shaping infants' attentional response to these face types. If true, then we would expect to find differences by face type at the negative component (e.g., Nc) or at later slow-wave components (de Haan et al., 2003). This finding would provide support for the experience-attention relationship described earlier.

Exposure, attention, and discrimination – how do these relate?

Early exposure to faces related to discrimination of male faces at 3 months. Exposure combined with attention (i.e., visual preference) predicted infants' discrimination of female other-race faces at 3 months. Both overall exposure to faces and to mom's face, specifically, were significant factors in predicting infants' ability to discriminate between the faces of individual females. Preference predicted discrimination at 3 months for male faces, however it was not until 6 months that infants' experience at 3 months predicted discrimination of male own-race faces. Here, it was uniquely dad's face, and not overall exposure, that was diagnostic. How and what infants learn depends on their attention to the relevant stimuli in their environment and what is relevant to them may be determined by their own attention.

This link between exposure, attention, and ability is novel and important. No study has yet examined how these three factors relate, likely because few previous studies have measured infants' experience with faces. That infants' overall face experience, experience with mom's face, and visual preference predicts 62% of the variance in discrimination of other-race female faces a substantively significant finding. Further, the results of Chapter 6 not only describe how experience, attention, and discrimination relate at 3 months, they also high-light the importance of early exposure and attention in continuing to influence ability at 6 months. Despite half of infants' life experiences happening after the point at which we measured their exposure and attention, our model was still able to predict 19% of the variance in infants' discrimination of own-race male faces based on exposure to dad's face. This finding highlights the primacy of caregivers' faces in shaping infants' attention and ability. It further argues for the importance of very early experience in shaping later capacities, at least within the first 6 months of life.

Theories of discrimination. As above-discussed, theories of face discrimination may either implicitly or explicitly leave wide the door for an attentional mechanism to explain the link between experience and ability. Face space has explicitly identified an attentional component as necessary for integration of a face into face space (Valentine et al., 2015). Under this conception of face space, the faces added to face space still create a norm-based or exemplar-based space, with infants best discriminating face types that are similar to those integrated into face-space. The contact hypothesis (Harrison & Hole,

2009) argues for the role of experience, however it fails to take into account the nuance of experience itself. Consequently, it is unclear whether the attention-experience relationship would be captured under the umbrella of the contact hypothesis. Perceptual narrowing (Scott et al., 2007) similarly leaves open the door for a more nuanced view of experience in determining how experience may influence perceptual processes. Ultimately, while each theory captures the phenomenon it attempts to explain, the lack of a full understanding of the infant experience makes it difficult to truly appreciate what may be changing in the early input.

Development of exposure, attention, and ability

The author argues that what is developing in infants' early development is first and foremost attention. There are two reasons for this. First, infants' exposure to the faces that are most diagnostic of infants' later capacities and attention are presented in ways that may be prolonging infants' visual attention to these faces (as described in Chapter 2). These are the most persistent faces, representing the tail-end of the distribution of face exposure lengths. Second, these are the faces that are most reliable across contexts. As discussed above, infants should attend to these faces preferentially over more novel visual stimuli as they are learning about the faces. Providing these faces in multiple contexts distributes this learning and untethers it from a single locale, a strategy that is more effective in producing robust, context-independent learning. Third, if infants' preferential attention to these face types translates into real-world deployment of attention, then exposure and attention should evidence a bi-directional relationship if measured on an ongoing basis. Although this third point cannot be tested with the current data, it does predict that there should be a relationship between changes in attention and experience at later ages.

Despite arguing for particular patterns of attention, these patterns are not fixed across the first year of life. What is being described herein are emerging patterns, likely to occur as the infant is learning about familiar visual stimuli in their environment. After learning has occurred, the landscape of exposure and attention is likely to change. Consistent with schema theory, we anticipate that attention and exposure to familiar learned visual stimuli will decline once the stimulus has been processed and encoded.

Consequently, infants should show capacity for things that they have already learned without any preferential attention to them.

Familiar and unfamiliar face processing

Face gender processing. Infants receive massive early exposure to female faces, and mom's face in particular (see Chapter 2). They receive far less male face and dad face exposure. Their limited attention to male (see Chapter 3) and delay in capacity to discriminate own-race male (see Chapter 4) faces is likely due to this limited exposure to dad's face. This might have important implications beyond face processing. Infants take more time to process male than female faces (e.g., 5- to 12-month-olds, Leinbach & Fagot, 1993), potentially suggesting that the way in which they deploy their attention to or the way in which they process these faces is less efficient. Inferior attention allocation may be due to exposure whereas inefficient processing may be due to exposure, attention, or both.

Implications. Early exposure may shape brain development and early brain changes may have large down-stream effects. If neural architecture is being reserved by early experience, this suggests an underlying mechanism whereby early exposure would predict much later (i.e., beyond infancy) face processing skills because exposure has allowed the system to claim the neural architecture necessary for those skills. This is not a novel argument and has been made and well supported in other areas, such as by Maurer and colleagues on infants born with congenital cataracts (e.g., de Heering & Maurer, 2014; Geldart, Mondloch, Maurer, De Schonen, & Brent, 2002; Maurer, Mondloch, & Lewis, 2007; Mondloch et al., 2013; Robbins, Nishimura, Mondloch, Lewis, & Maurer, 2010). They show a delay in attention to and ability to discriminate male faces, likely due to limited exposure to dad's face. If early exposure is required to reserve the neural architecture for faces, to “buy the lot” on which face processing will be built, this early architecture is being shaped by nearly exclusively single gender, female faces. For most infants, male faces are rare and don't tend to show attentional capture until after 3 months (see Chapter 3). This may suggest why researchers find gender biases in face processing, particularly in females (Herlitz & Lovén, 2013; Ramsey-Rennels & Langlois, 2006). That males tend to show attenuated female bias or no gender bias has been argued to be due to ongoing plasticity in the system that allows them to use their larger exposure to male faces later in life (e.g., to male friends) to attenuate the bias (Herlitz & Lovén, 2013). Without large changes in exposure and attention to male faces, as in the case of females, the system remains behaviorally and neurologically tuned to female faces. As their exposure to male faces exceeds that of female faces, we would expect that attention changes concurrent with exposure. We would expect both behavioural and neurological consequences to this change. This is an empirical question for future research.

Face race processing. The relationship between exposure, attention, and ability with faces of different races is less clear-cut. As detailed in Chapter 2 and 6, the majority of infant's exposure was to own-race faces. Their preference was nearly ubiquitously for other- over own-race face types (see Chapter 3), contrary to previous research (Fassbender, Teubert, & Lohaus, 2016; S. Liu et al., 2015). Moreover, these infants were able to discriminate female faces of all races at all ages and only showed deficits in male other-race processing at 9 months. (They did not show significant ability at 3 months, although 75% of infants could do the task.) This was the reverse pattern to male own-race faces where infants were able to discriminate at 6 and 9 months, but not 3 months. The development of differences in own- and other-race face processing has been found across multiple labs and multiple studies (for review, see Anzures, Quinn, Pascalis, Slater, & Lee, 2013), although few consider the layered familiarity of race and gender. Where faces of different genders were used, these were typically not considered separately (e.g., Liu et al., 2015).

Implications. As previously discussed, the majority of other-race effect studies with infants recruited infants from highly homogenous environments (e.g., Chinese infants living in China, S. Liu et al., 2015). While informative in detailing how an almost totally novel stimulus is processed by infants, there is an increasing global trend towards diversity and multiculturalism. It is unclear how long mono-racial enclaves will persist. Studies of infants from these enclaves provide a good measure of behavior at the extremes of experience – all or none. Although some infants still had no other-race face exposure, the current study suggests how some infants may behave when given some, albeit minimal, potential experience with unfamiliar face types. It is this variability that allowed the exploration of how exposure relates to attention and ability, a relationship that could not have been understood without infants who received different amounts of exposure. It is anticipated that the emphasis on a more nuanced view of experience, attention, and ability will flesh out the interstitial space between 0 and 100%.

Face processing of other species faces. As briefly described in the introduction, gender and race are not the only two categories for which infants show differential exposure, attention, and discrimination. Other-species faces are another category of face for which infants show a typical trajectory of narrowing, likely due to their total lack of experience with these unfamiliar face types. Faces of other species also show early differences. At birth, newborns show equal attention to and equal capacity to discriminate between human and non-human primate faces (Di Giorgio, Leo, Pascalis, & Simion, 2012; Heron-Delaney, Wirth, & Pascalis, 2011). At 3.5 and 6 months of age, infants show a preference for human over non-human primate faces (Heron-Delaney, Wirth, et al., 2011). This is likely due to exposure, since most infants typically do not have exposure to non-human primate faces in their typical, daily environment. Infants show perceptual narrowing for other-species faces, both primate (Pascalis et al., 2005; Pascalis, de Haan, & Nelson, 2002; Scott & Monesson, 2009) and non-primate (Simpson, Varga, Frick, & Fragaszy, 2011). Older infants, however, are still able to discriminate between monkey faces, provided they are given sufficient time with these faces (Fair et al., 2012), which suggests that perceptual narrowing is not absolute at 9 months.

Measuring development – the importance of multiple measures at multiple time points

There are structured visual inputs in the infant's early environment. As seen here, infants experience a lot of faces. Moreover, they experience them in ways that are likely to force infants to attend (e.g., near, alone in the field of view, and frontally oriented; Sugden & Moulson, 2016). Although there may be early biases that result in newborns' greater attention to face-like over non-face-like stimuli (e.g., Macchi Cassia, Turati, & Simion, 2004), this tunes to faces in a short amount of developmental time. Why they might continue to attend to faces and to some faces over other faces is likely due to their ongoing experience with faces and the continued inter-relationship between exposure and attention.

A more holistic conception of development is needed to truly appreciate the changes that are occurring and what or how the infant is learning. This is not a novel proposal. Smith and Thelen argued that: “development can only be understood as the multiple, mutual, and continuous interactions of all the levels of the developing system […, (1996, pg. 258)].” The data compiled within this dissertation highlights the mutual interactions of experience, attention, and learning. This appreciation of their relationship, however, could not be achieved without the different types of measurements used.

To continue to quote Smith and Thelen “development can only be understood as nested processes that unfold over many timescales from milliseconds to years (1996, pg. 258).” Although not within this framework, this multiple timescale approach has been used throughout this dissertation to highlight differences that can only be fairly captured on multiple timescales. Within infant looking we discuss the differences that occur in infants' preferential attention on the first as compared the second trial. This is informative. Their looking changes within a single attentional task, suggesting that infants' looking depends on very proximal experience. This is also true within the habituation task where we consider the overall metrics (i.e., proportion looking to the novel over the familiar) of the test trials as well as just the proportion looking towards the familiar. Both tell subtly different stories. The ERP data is the smallest timescale, describing events that occur within a second within the infant brain. The longitudinal component is the largest timescale, spanning 6 of the first 9 months of infants' lives. The developmental component captured by taking multiple measurements across the first year of life cannot be understated. Development is, by definition, change. Understanding this change cannot be fully accomplished by capturing a snap-shot of a single moment in early life just as it cannot be captured by a single measure of early capacities. Multiple measurements on multiple timescales provide an understanding of what is developing within infant development.

The impact of changing inputs or attention at different stages of development

Continued exposure would be expected to be necessary to maintain the system. Minor variations would be expected to impart minor changes. Major disruptions would be expected to reorganize or otherwise disrupt the system. Major disruptions may occur because of external or internal changes. For example, they may be due to a change in environment (e.g., moving to a different country with a different culture and diversity of population) or due to a change in an infant's capacities (e.g., motor or language development). Both have been shown to influence infants' capacities.

Early visual deprivation. Maurer and colleagues' work in infants born with congenital cataracts suggests that later deficits are due to a failure to reserve the underlying neural structure which adults typically use for visual processing (e.g., Maurer, Mondloch, & Lewis, 2007). There is clear and unequivocal evidence in support of this position. The author might add a mechanism for this that is simple and perceptual – when infants are presented with the visual world again, this is likely not the simplified, homogenous, face-heavy world of the younger infant. The perceptual experience is most probably not the same. Their visual diet is suddenly that of an older infant or child, instead of that of a newborn. If the visual system requires the clear, monotonous inputs of early life to tune itself, this may be another reason why these children fail to adequately recover. Investigating this by providing older infants recently recovered from cataract surgery with newborn-like exposures would be an interesting test of the role of experience in tuning early attention.

Childhood changes to experience. There is evidence that even adults past the stage at which they would be expected to show plasticity or flexibility within a domain can learn from infant-directed input. This has been found in two areas: speech phoneme perception and label learning. If children are adopted into a novel monoracial society (i.e., Korean children into a Caucasian environment), they show flexible adaptation to the new face types such that, by adulthood, they show an other-race effect for the face type to which they belong and which they experienced during infancy and early childhood (Sangrigoli, Pallier, Argenti, Ventureyra, & De Schonen, 2005). As highlighted above, changes in exposure need not be as substantial as a change in content but may be a change in the statistical distribution of different faces. With more fathers taking paternity leave, infants' face experience may change over the first year of life through increased father face experience. Measuring the outcomes of this change on infants' attention and ability would be of interest to understand whether and how infants learn from this change in input.

Experimental changes to experience. Multiple studies have used picture-book exposure to change infants' experience with face types that would otherwise be unfamiliar. Experience with other-species (Pascalis et al., 2005) and other-race (Heron-Delaney, Anzures, et al., 2011) have found that the minimal exposure provided by a book of six pictures of faces is sufficient to, at least temporarily, delay perceptual narrowing. The key to this appears to be how the faces are presented. Labeling the faces at the individual level (e.g., 'Ragnar', 'Preston' and 'Sachi') results in continued discrimination of the face type whereas providing category-level labels (e.g., 'monkey', 'monkey', and 'monkey') or no labels at all does not (Scott & Monesson, 2009). The differences between levels of training are also apparent in infants' electrical brain response to faces (Scott & Monesson, 2010). Scott and colleagues argue that labeling faces at the individual label highlights differences between the two visual stimuli (Scott & Fava, 2013; Scott & Monesson, 2009, 2010). They are changing how they attend to the individually labeled, as compared to the category-level labeled, face. This is consistent with our interpretation, whereby experience-related factors, but not simple experience per se, influence attention (and vice-versa) and thereby ability.

Limitations

Although the current study captures infants' visual experience, attention, discrimination, and electrical brain response using multiple measures at multiple time points, no study is perfect. The largest limitation to the current study is the failure to capture infants' looking within their visual environment. Currently, this is due to the limitations of head-mounted eye tracking technology, which could not be used at home by parents in the same inconspicuous way as the head-mounted camera. Consequently, although the current rich, natural video data provides an infant's-eye view of the early visual environment, it does not reveal infants' deployment of attention within this environment. To include this level of analysis in the study, we are currently conducting follow-up visits with infants at 12 and 18 months at which infants wear head-mounted eye-tracking to document how they deploy their attention during a series of quasi-natural in-lab tasks. Ideally, should the technology become more accessible, the current study should be replicated with an eye-tracking component.

A second concern is how representative the data are of infants' typical, daily experiences. Although we are sensitive to the concern that the videos miss some of the infants' typical experiences, the results from Chapter 6 in which we account for 62% of the variance in infants' performance on an other-race female and 19% of the variance on an own-race male face discrimination task further supports the idea that the video is capturing a core truth of each baby's typical face experience. These are likely conservative estimates of the influence of experience, since the data is unlikely to be absolutely representative of infants' total face experience. The reader is left to imagine how much more of the variance we may have been able to predict had we captured the entirety of infants' face experience.

A third concern is with the tasks themselves. Infants are notoriously labile, as are their capacities when these are measured with a single task (Colombo et al., 1988). Although we attempted to measure multiple capacities in multiple ways (i.e., with 2 trials in the preference task; with up to 4 potential habituation tasks), these were all measured at a single visit. If the infant was not having a good day, they may have done few of or struggled with the tasks. Ideally, future studies should include more than one preferential looking and more than one of each discrimination task, potentially by having infants complete these tasks at the initial home visit. Alternatively, more than one metric of attention and discrimination (i.e., not just preferential looking and discrimination) should be used to more accurately capture early biases and capacities.

Future directions

The goal of this dissertation was to understand infants' early experiences, attention, discrimination, and electrical brain response to faces. To this end, we collected a rich corpus of video data. These data provided an infant's-eye-view of the world, including audio, which can be used to inform many other potential research questions. Using these data to answer other research questions is both practically and ethically ideal, because it maximizes the contributions made by the families and infants who participated in the current dissertation. Although these are not the central question addressed in this dissertation, we suggest additional ways in which this data can be utilized to better understand the early infant environment.

How are faces experienced? The rich corpus of video data collected for this dissertation can be coded at a finer grain to appreciate how infants experience faces. For example, how near are the faces? It has been suggested that proximity determines how faces are processed in adulthood (Yang, Shafai, & Oruc, 2014). Similarly, infants' visual systems are still developing and their visual acuity is poor (Dobson & Teller, 1978). Consequently, they may have difficulty resolving and therefore processing faces beyond a certain boundary. Near faces may also be problematic, in that they are presented so near to the infant that only one or two features of the face are visible at any given moment. Infants' ability to use the features of a face and to integrate the features of the face into a single holistic gestalt changes over development (Mondloch, Le Grand, & Maurer, 2002). The development of early holistic processing at around 6 months of age may relate to a proximity and whole face visibility at around this time. Further, infants' focus on the mouth that appears at around 6 months of age may be related to the increased visibility of the mouth at around this time, which subsequently may relate to their use of this feature to facilitate communicative development (Lewkowicz & Hansen-Tift, 2012). As a second example, we are coding for social interactivity in the visual (i.e., infant-directed gaze and emotion) and auditory (i.e., infant-directed speech) domains. If social theories of attention or early learning are correct, only the faces that are most socially interactive should be learned, further refining our model of infant attention and discrimination. These questions all lie outside of the purview of the main research question in this dissertation. We identify them, however, because we believe that they highlight the multiple and diverse research questions that the data we have collected can be used, as well as the advantage of using a method that provides a rich documentation of infants' natural experiences.

How does face experience change? The current dissertation aimed to understand how early experience (i.e., experience at 3 months) related to attention and ability across the first year of life. Since infants were re-recruited at 6 and 9 months to complete the looking tasks, they also recorded infant-perspective video data at these ages. Although considering later exposure is beyond the scope of the research question for this dissertation, this later documentation of experience allows us to examine how experience changes across the first year of life. It also allows us to examine how changing patterns of exposure might relate to changing patterns of performance.

The influence of other factors? The current dissertation did not consider differences in infants' gender, race, family make-up (e.g., number of siblings), or other individual or family-level factors because these fell outside of the immediate goal which was to explore the relationship between exposure, attention, and ability. There are, however, infant-specific factors that have been found to influence face processing. For example, there are likely gender differences in infants' early face processing exposure, attention, discrimination, and potentially brain response. This has been argued in several review articles (Herlitz & Lovén, 2013; Ramsey, Langlois, & Marti, 2005). Although this is also outside of the immediate scope of this dissertation, we would anticipate that this would be present at all levels of analysis. Newborn infant girls are found to attend more to faces whereas newborn boys attend more to a mobile (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000) and by 3.5 months girls engage in more eye contact with a social partner than do boys (Leeb & Rejskind, 2004), however, this difference was not found in newborns (Hittelman & Dickes, 1979). We imagine that gender differences may become evident in infants' behaviour in the looking tasks, experience, and potentially their electrical brain response to faces. Similarly, infant race, culture, and dozens of other infant- or family-level factors could be explored within this rich dataset to answer more nuanced questions about how infant- or family-level differences impact the relationship we have documented in this dissertation.

How does this experience predict later visual attention and development? Lastly, as identified within the limitations section, we are following-up with these infants at 12 and 18 months of age. Although this is also outside of the scope of the research question of this dissertation, it highlights the advantage of the methods we chose for this dissertation and how they can be applied to a diversity of other, unrelated, research questions. The goals of these follow-up studies are to understand longer-time-scale outcomes of early visual and face experience. We are measuring infants' self-regulation, social referencing, self-identification, communicative development, achievement of developmental milestones, and motor capacities. This follow-up includes head-mounted eye-tracking to measure how infants deploy their attention to the faces in their environment in a quasi-natural lab-based-task. While not the same as an at-home, natural recording and not answering the central questions of the current dissertation which are restricted to early experience, it is anticipated that early experiences will predict infants' later social, communicative, and developmental capacities.

Importance of face discrimination. Early ability to discriminate between faces likely has some important applications (e.g., infants apply their ability to discriminate between individuals to recognize familiar faces, like mom and dad), however the author could find no studies documenting down-stream effects of early discrimination on later outcomes (e.g., are infants who show superior discrimination also better at face discrimination, facial expression understanding, or lip-reading in adulthood?). This suggests an area for renewed investigation. If this is an important skill, it is likely one on which infants build and that shows improvement with development. If, however, it is a transient skill or a skill that undergoes substantial later reorganization (e.g., with the development of other capacities; Cashon, Ha, Allen, & Barna, 2013), then the relation between discrimination in infancy and later abilities is unclear.

Conclusion

The early environment is deceptively simple. It presents clear, multiply redundant information to a newborn system to chaperone the development of a foundational skill: attention. This seemingly simple process has substantial and fundamental effects that shape the path of learning. Early experience simplifies the input infants receive to teach them about a highly complex visual stimulus, faces. It does this through caregivers providing large quantities of consistent, contextually-independent, and regular inputs to their own faces (Chapter 2). Consequently, once the infant begins to be able to deploy their attention within their environment, attention can constrain their experience to only the level of complexity with which they are currently grappling (e.g., familiar faces followed by familiar face types; Chapter 3), further simplifying their visual input to their cognitive or perceptual level. It is this titration, first by the environment and then by the infant themselves, that allows them to make the great leaps in capacity seen throughout infancy, developing their ability to discriminate and brain maturation in response to faces (Chapters 4 and 5). Experience and attention are highly predictive of their later discrimination ability

(Chapter 6), pointing to experience-level and individual-level factors in shaping early capacity. Through this path, the dynamic, reciprocal relationship between experience and attention shape learning.

Appendices

Appendix A: 3-month-old consent form

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS

Ryerson University Consent Agreement for 3-month-old participation in the study: How daily experiences influence infant development.

You and your infant are being asked to participate in a research study. Before you give your consent to be a volunteer, it is important that you read the following information and ask as many questions as necessary to be sure you understand what you will be asked to do.

Investigators: Nicole Sugden, PhD Student, department of Psychology, Ryerson University and Dr. Margaret Moulson, PhD, department of Psychology, Ryerson University. (See page 5 for contact information.)

Purpose of the Study: Two hundred and ten infants between 3 and 9 months of age are being recruited to participate in this study. Ninety infants will participate one time at either 3, 6, or 9 months of age. Ninety infants will participate twice, at 3 and 6, 3 and 9, or 6 and 9 months of age. Thirty infants will participate three times, at 3, 6, and 9 months of age. Since your infant is 3 months old, you may choose to participate up to three times (at 3, 6, and 9 months of age).

This study is designed to look at what infants see in their daily lives and how this relates to their early perceptual development. We are particularly interested in examining how infants are exposed to faces and how this exposure shapes their preference for faces, their ability to recognize faces, and how their brain responds to faces.

Description of the Study: To participate, you and your infant will be asked to do the following:

Attend Ryerson University or have an investigator visit your home for thirty minutes to:

- complete a five-minute questionnaire about your infant, the people your infant sees, the activities of a normal day, and the hours your infant spends awake,
- receive training on privacy issues around recording using the head-mounted camera and the operation of a small smiley-face video-camera on a headband, and
- receive training on how to use a daily experiences diary that you will be completing over the course of a week.

After the visit, you will be asked to record the world from your infant's perspective over the course of one week. During this week, you will be asked to:

- complete a daily experiences diary (which should take no more than 5 minutes per day) describing the experiences your child received during the day,
- place the camera on your infant’s head when they are awake and alert and you feel it is an appropriate time to record,
  - The camera’s dimensions are 4.8x1.6cm (diameter X depth) and weighs 20 grams.
- please remove the camera when your infant falls asleep and/or you feel that it is no longer an appropriate time to record,
  - While we would like you to attempt to record as much as is possible, we understand that your infant may not always want to record.
  - Since you know your infant best, please use your judgment when deciding when and how long to record.
  - Please only record when you feel it is appropriate for your infant.
- watch your infant to ensure that the headband is not uncomfortable for your infant and, if it is uncomfortable, take steps to make it less uncomfortable and/or remove the camera,
- re-charge the video-cameras' battery overnight, and
- receive short (approximately 1-2 minute) follow-up telephone calls about your study experience.

After your week with the camera, you and your infant will be asked to come to Ryerson University for a two hour visit to:

- complete a 5-minute questionnaire about your experience using the video-camera, your experiences over the past week, and your comfort with camera,
- return the video-camera and it's accessories,
- have your infant complete three computer-based face tasks where we show your infant many faces and record how they respond to these faces.
  - During these tasks, your infant will remain on your lap, but you will be blindfolded, so that you do not influence your infant's reactions to the faces. (You may view the faces your child was shown after the task.)
  - Your infant's eyes will be video-recorded during all of these tasks, so that we can review, more precisely, how much time your infant spent looking at each face. This will help us determine if your infant can tell the difference between the

faces, which faces your infant prefers, and how your infant's brain is responding to faces.

– The tasks are:

1) A face preference task. This task is approximately 3 minutes long. In this task your infant will be shown pairs of faces (e.g., male and female faces). We can determine which face your infant prefers based on the faces your infant looked at the most. During this task, we will be video recording where your infant looks.
2) A face recognition task. This task is approximately 5 to 7 minutes long. In this task your infant will be shown a single face (e.g., an adult's face) over and over until they become bored with it. Once they are bored and no longer looking at the face, we will show them a new face (e.g., a child's face). If your infant shows renewed interest in looking at the face, we can conclude that your infant recognized that this was a new face. During this task, we will be video recording where your infant looks. We will also be recording your infant's heart rate during this task. Recording your infant's heart rate requires us to place a small sticker on your infant. The sticker is hypo-allergenic and the least 'sticky', most infant appropriate heart rate monitoring sticker available.
3) A task during which we record the electrical activity of your infant's brain. This task is approximately 15 minutes long. During this task we will show your infant many faces of different types (e.g., upright and inverted faces). During this task, we will be video recording where your infant looks. We will also be recording the electrical activity of your infant's brain using electroencephalogram (EEG).

   EEG is a safe, infant-friendly, non-invasive way of recording electrical brain activity. To record EEG, we will apply the cap, which requires us to:

   - measure your infant's head,
   - draw a very small 'x' in grease pencil on the top of your infant's head,
   - place a towel around your infant's shoulders to catch drips from the EEG cap,
   - place an EEG cap on your infant's head (the cap will be moistened with salt-

     water and tear-free baby shampoo),
   - receive a small towel to use to blot any drips away from your infant's head,
   - massage your infant's head so that the little sponges on the cap are touching

     your infant's scalp,

- add salt-water and baby shampoo solution to the little sponges in the cap,

  We will then record your infant's brain's electrical response to photographs of faces. Afterwards, we will remove the cap from your infant's head, use a small towel and tear-free baby shampoo to wash the 'x' from your infant's head, and provide you with a towel to dry any damp spots on your infant's head or hair.

- take breaks between tasks, and
- receive a copy of the videos recorded from your infant's perspective, a copy of a video of how the electrical activity of your infant's brain responds to faces, a $25 honorarium, and a small thank-you gift for your infant.

If the camera malfunctions or you experience any difficulties with it, you may be asked to have an investigator visit your home (or meet you in a location that is convenient to you) for approximately ten minutes to repair or exchange the camera.

Future participation: Since your infant is 3 months old, they are eligible to participate in the study up to three times (i.e., this time and two more times). We would like permission to contact you again to see if you would like to participate when your infant is 6 and/or 9 months old.

We would also like permission to contact you again by telephone to follow-up on your infant's development once every 3 months, until they are 18 months of age. During these follow-ups, we would be asking you questions about things like your infant's sleep, motor development, and communicative development. This would be done over the phone and would take no more than 30 minutes.

If you consent to us contacting you in the future, this does not require you to participate again. You may choose, at the later time, to participate or not participate a second or third time in this study. Your choice to participate or not participate again will not impact your current participation in this study.

What is Experimental in this Study: None of the procedures or questionnaires used in this study are experimental in nature. The only experimental aspect of this study is the gathering of information for the purpose of analysis.

Risks or Discomforts: There is no risk to your infant from the act of video-taping. The headband they will be asked to wear is designed to be comfortable and fuzzy. If your infant does not enjoy wearing the headband, you may clip the video-camera to a different headband or other headwear. If your infant does not enjoy wearing the camera, you may stop recording, take a break, or discontinue your child's participation in the study.

Since your child is video-taping, there is a risk that you may be uncomfortable with the act of video-taping during the course of a normal day. If, for any reason, you feel uncomfortable video-recording, stop recording. The people who you are video-recording may object to your recording or request that they not be recorded. If at any time you are requested not to record, you must stop recording. If you begin to feel uncomfortable, you may discontinue participation in the study either temporarily or permanently.

With the computer-based task in which your child will participate at the end of the study, your child may become fussy. If your child becomes fussy and you believe that they need a break, please take a break. During the break, we will ask you to determine whether your infant wishes to continue

Your infant may find the EEG cap uncomfortable. The cap will be moist when it is placed on your infant's head. It will also be snug, like a swim-cap. We will provide you with a towel with which to blot excess moisture. We will also adjust the cap to try to ensure your infant is comfortable. Finally, we will be engaging your infant with toys to distract them while we are placing the cap on their head and adjusting the cap. If they experience significant discomfort, we can adjust or remove the cap.

Your infant may find the small sensor sticker uncomfortable. We have selected the smallest, least sticky, hypo-allergenic sensor sticker possible to minimize discomfort. If your infant experiences significant discomfort, we can move or remove the sticker.

If your infant experiences significant discomfort during any task, your infant can take a break, you can choose to skip any particular task, and/or you can choose to discontinue participation in the study.

It is very important to us that you and your infant have a good experience. We are relying on you to help us know if your infant needs a break or wants to end their participation. Please let us know if, at any point, you are or your infant is uncomfortable and wish to take a break or end the task. Participation is voluntary. You may discontinue at any time without penalty. Thank you!

Benefits of the Study: Although it is expected that this study will add to the body of knowledge of face perception and expertise, development, and learning, it is not expected that you will receive any benefits from participating in this study. We currently have no measurement how natural, daily, exposure influences the development of infants' behaviour and the infant brain. This study is designed to provide an estimation of how the amount of time people spend looking at faces influences both behaviour and the brain.

Confidentiality: Any information obtained in connection with this study will remain confidential. All participants in this study will have their information protected using a participant ID number. Any written notes (including questionnaires, check-lists, and surveys) and video recordings will be identified only by this participant ID number, will be stored separately from the participant consent forms, and will be accessed only by those individuals directly involved in the study. Hard copies of the data will be stored in locked filing cabinets in the BEE Lab; electronic video and data files will be stored on password-protected media in the BEE Lab. The BEE Lab is locked and only accessible to members of the lab. All data will be pooled and published in aggregate form only. Since most journals require data to be stored for five years post-publication, this data will be stored for this period of time prior to being destroyed. No video from your participation in this study will be released to anyone outside of the BEE Lab.

Incentives to Participate: As a thank-you, you will be given a small gift for your infant, a copy of the video your infant recorded from their perspective, a copy of the video of your infant's electrical brain activity, and $25 honorarium. If your infant does not complete the task where we measure the electrical activity of their brain, we will not be able to provide you with a video of your infant's brain. If you decide that you do not wish to participate at any time and/or withdraw your infant's data, you will still receive a gift for your infant, a copy of the video recorded up to that time, and the $25 honorarium.

If you choose to participate in this study more than once, each time you participate you will receive the videos, gift, and honorarium.

Anecdotally, we have found that parents appreciate seeing the world from their infant's perspective. Past participants have also been very excited to be able to see the electrical activity of their brain in real time. We hope that you too find this interesting and informative.

Costs and/or Compensation for Participation: There are no anticipated costs associated with your participation in this research. Your infant will receive a small gift for their participation. You will also receive a copy of the video-recordings from your infant's perspective and a video depicting how the electrical activity of your infant's brain changes in response to faces. You will also be provided with a $25 honorarium.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not influence your or your infant's future relations with Ryerson University. If you decide to participate, you are free to withdraw your and your infant's consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. At any particular point in the study, you may refuse to answer any particular question and/or you or your infant may stop participation altogether.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact.

Principal Investigator: Nicole Sugden
Telephone Number: (416) 979 5000 ext. 2189
E-mail Address: nsugden@ryerson.ca

Research Supervisor: Margaret Moulson, PhD
Telephone Number: (416) 979 5000 ext. 2661
E-mail Address: mmoulson@psych.ryerson.ca

If you have questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board for information.

Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Ryerson University

350 Victoria Street
Toronto, ON M5B 2K3
416-979-5042
REBChair@ryerson.ca

Agreement: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement.

You have been told that by signing this consent agreement you are not giving up any of your legal rights.

____
Name of Infant Participant (please print)

____
Name of Parent Participant (please print)

______________________________________ ___________________
Signature of Parent Date

______________________________________ ___________________
Signature of Investigator Date

Appendix B: 6-month-old consent form

RYERSON UNIVERSITY

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS

Ryerson University Consent Agreement for 6-month-old participation in the study: How daily experiences influence infant development.

You and your infant are being asked to participate in a research study. Before you give your consent to be a volunteer, it is important that you read the following information and ask as many questions as necessary to be sure you understand what you will be asked to do.

Investigators: Nicole Sugden, PhD Student, department of Psychology, Ryerson University, Amy Mackenzie, undergraduate honours thesis student, department of Psychology, Ryerson University, and Dr. Margaret Moulson, PhD, department of Psychology, Ryerson University. (See page 5 for contact information.)

Purpose of the Study: Two hundred and ten infants between 3 and 9 months of age are being recruited to participate in this study. Ninety infants will participate one time at either 3, 6, or 9 months of age. Ninety infants will participate twice, at 3 and 6, 3 and 9, or 6 and 9 months of age. Thirty infants will participate three times, at 3, 6, and 9 months of age. Since your infant is 6 months old, you may choose to participate up to two times (at 6 and 9 months of age).

This study is designed to look at what infants see in their daily lives and how this relates to their early perceptual development. We are particularly interested in examining how infants are exposed to faces and how this exposure shapes their preference for faces, their ability to recognize faces, and how their brain responds to faces.

Description of the Study: To participate, you and your infant will be asked to do the following:

Attend Ryerson University or have an investigator visit your home for thirty minutes to:

- complete a five-minute questionnaire about your infant, the people your infant sees, the activities of a normal day, and the hours your infant spends awake,
- receive training on privacy issues around recording using the head-mounted camera and the operation of a small smiley-face video-camera on a headband, and
- receive training on how to use a daily experiences diary that you will be completing over the course of a week.

After the visit, you will be asked to record the world from your infant's perspective over the course of one week. During this week, you will be asked to:

- complete a daily experiences diary (which should take no more than 5 minutes per day) describing the experiences your child received during the day,
- place the camera on your infant's head when they are awake and alert and you feel it is an appropriate time to record,

    - The camera’s dimensions are 4.8x1.6cm (diameter X depth) and weighs 20 grams.
- please remove the camera when your infant falls asleep and/or you feel that it is no longer an appropriate time to record,
    - While we would like you to attempt to record as much as is possible, we understand that your infant may not always want to record.
    - Since you know your infant best, please use your judgment when deciding when and how long to record.
    - Please only record when you feel it is appropriate for your infant.
- watch your infant to ensure that the headband is not uncomfortable for your infant and, if it is uncomfortable, take steps to make it less uncomfortable and/or remove the camera,
- re-charge the video-cameras' battery overnight, and
- receive short (approximately 1-2 minute) follow-up telephone calls about your study experience.

After your week with the camera, you and your infant will be asked to come to Ryerson University for a two hour visit to:

- complete a 5-minute questionnaire about your experience using the video-camera, your experiences over the past week, and your comfort with camera,
- return the video-camera and it's accessories,
- have your infant complete three computer-based face tasks where we show your infant many faces and record how they respond to these faces.
    - During these tasks, your infant will remain on your lap, but you will be blindfolded, so that you do not influence your infant's reactions to the faces. (You may view the faces your child was shown after the task.)
    - Your infant's eyes will be video-recorded during all of these tasks, so that we can review, more precisely, how much time your infant spent looking at each face. This will help us determine if your infant can tell the difference between the faces, which faces your infant prefers, and how your infant’s brain is responding to faces.
    - The tasks are:
        1) A face preference task. This task is approximately 3 minutes long. In this task your infant will be shown pairs of faces (e.g., male and female faces). We can determine which face your infant prefers based on the faces your infant looked at the most. During this task, we will be video recording where your infant looks.
        2) A face recognition task. This task is approximately 5 to 7 minutes long. In this task your infant will be shown a single face (e.g., an adult’s face) over and over until they become bored with it. Once they are bored and no longer looking at the face, we will show them a new face (e.g., a child’s face). If your infant shows renewed interest in looking at the face, we can conclude that your infant recognized that this was a new face. During this task, we will be video recording where your infant looks. We will also be recording your infant’s heart rate during this task. Recording your infant’s heart rate requires us to place a small sticker on your infant. The sticker is hypo-allergenic and the least ‘sticky’, most infant appropriate heart rate monitoring sticker available.

3) A task during which we record the electrical activity of your infant’s brain. This task is approximately 15 minutes long. During this task we will show your infant many faces of different types (e.g., upright and inverted faces). During this task, we will be video recording where your infant looks. We will also be recording the electrical activity of your infant’s brain using electroencephalogram (EEG).

EEG is a safe, infant-friendly, non-invasive way of recording electrical brain activity. To record EEG, we will apply the cap, which requires us to:

- measure your infant’s head,
- draw a very small ‘x’ in grease pencil on the top of your infant’s head,
- place a towel around your infant’s shoulders to catch drips from the EEG cap,
- place an EEG cap on your infant’s head (the cap will be moistened with salt-
  water and tear-free baby shampoo),
- receive a small towel to use to blot any drips away from your infant’s head,
- massage your infant’s head so that the little sponges on the cap are touching
  your infant’s scalp,
- add salt-water and baby shampoo solution to the little sponges in the cap,

We will then record your infant’s brain’s electrical response to photographs of faces. Afterwards, we will remove the cap from your infant’s head, use a small towel and tear-free baby shampoo to wash the ‘x’ from your infant’s head, and provide you with a towel to dry any damp spots on your infant’s head or hair.

– take breaks between tasks, and
– receive a copy of the videos recorded from your infant’s perspective, a copy of a video of how the electrical activity of your infant’s brain responds to faces, a $25 honorarium, and a small thank-you gift for your infant.

If the camera malfunctions or you experience any difficulties with it, you may be asked to have an investigator visit your home (or meet you in a location that is convenient to you) for approximately ten minutes to repair or exchange the camera.

Future participation: Since your infant is 6 months old, they are eligible to participate in the study up to two times (i.e., this time and one more time). We would like permission to contact you again to see if you would like to participate when your infant is 9 months old.

We would also like permission to contact you again by telephone to follow-up on your infant’s development once every 3 months, until they are 18 months of age. During these follow-ups, we would be asking you questions about things like your infant’s sleep, motor development, and communicative development. This would be done over the phone and would take no more than 30 minutes.

If you consent to us contacting you in the future, this does not require you to participate again. You may choose, at the later time, to participate or not participate. Your choice to participate or not participate again will not impact your current participation in this study.

What is Experimental in this Study: None of the procedures or questionnaires used in this study are experimental in nature. The only experimental aspect of this study is the gathering of information for the purpose of analysis.

Risks or Discomforts: There is no risk to your infant from the act of video-taping. The headband they will be asked to wear is designed to be comfortable and fuzzy. If your infant does not enjoy wearing the headband, you may clip the video-camera to a different headband or other headwear. If your infant does not enjoy wearing the camera, you may stop recording, take a break, or discontinue your child's participation in the study.

Since your child is video-taping, there is a risk that you may be uncomfortable with the act of video-taping during the course of a normal day. If, for any reason, you feel uncomfortable video-recording, stop recording. The people who you are video-recording may object to your recording or request that they not be recorded. If at any time you are requested not to record, you must stop recording. If you begin to feel uncomfortable, you may discontinue participation in the study either temporarily or permanently.

With the computer-based task in which your child will participate at the end of the study, your child may become fussy. If your child becomes fussy and you believe that they need a break, please take a break. During the break, we will ask you to determine whether your infant wishes to continue

Your infant may find the EEG cap uncomfortable. The cap will be moist when it is placed on your infant's head. It will also be snug, like a swim-cap. We will provide you with a towel with which to blot excess moisture. We will also adjust the cap to try to ensure your infant is comfortable. Finally, we will be engaging your infant with toys to distract them while we are placing the cap on their head and adjusting the cap. If they experience significant discomfort, we can adjust or remove the cap.

Your infant may find the small sensor sticker uncomfortable. We have selected the smallest, least sticky, hypo-allergenic sensor sticker possible to minimize discomfort. If your infant experiences significant discomfort, we can move or remove the sticker.

If your infant experiences significant discomfort during any task, your infant can take a break, you can choose to skip any particular task, and/or you can choose to discontinue participation in the study.

It is very important to us that you and your infant have a good experience. We are relying on you to help us know if your infant needs a break or wants to end their participation. Please let us know if, at any point, you are or your infant is uncomfortable and wish to take a break or end the task. Participation is voluntary. You may discontinue at any time without penalty. Thank you!

Benefits of the Study: Although it is expected that this study will add to the body of knowledge of face perception and expertise, development, and learning, it is not expected that you will receive any benefits from participating in this study. We currently have no measurement how natural, daily, exposure influences the development of infants' behaviour and the infant brain. This study is designed to provide an estimation of how the amount of time people spend looking at faces influences both behaviour and the brain.

Confidentiality: Any information obtained in connection with this study will remain confidential. All participants in this study will have their information protected using a participant ID number. Any written notes (including questionnaires, check-lists, and surveys) and video recordings will be identified only by this participant ID number, will be stored separately from the participant consent forms, and will be accessed only by those individuals directly involved in the study. Hard copies of the data will be stored in locked filing cabinets in the BEE Lab; electronic video and data files will be stored on password-protected media in the BEE Lab. The BEE Lab is locked and only accessible to members of the lab. All data will be pooled and published in aggregate form only. Since most journals require data to be stored for five years post-publication, this data will be stored for this period of time prior to being destroyed. No video from your participation in this study will be released to anyone outside of the BEE Lab.

Incentives to Participate: As a thank-you, you will be given a small gift for your infant, a copy of the video your infant recorded from their perspective, a copy of the video of your infant's electrical brain activity, and $25 honorarium. If your infant does not complete the task where we measure the electrical activity of their brain, we will not be able to provide you with a video of your infant's brain. If you decide that you do not wish to participate at any time and/or withdraw your infant's data, you will still receive a gift for your infant, a copy of the video recorded up to that time, and the $25 honorarium.

If you choose to participate in this study more than once, each time you participate you will receive the videos, gift, and honorarium.

Anecdotally, we have found that parents appreciate seeing the world from their infant's perspective. Past participants have also been very excited to be able to see the electrical activity of their brain in real time. We hope that you too find this interesting and informative.

Costs and/or Compensation for Participation: There are no anticipated costs associated with your participation in this research. Your infant will receive a small gift for their participation. You will also receive a copy of the video-recordings from your infant's perspective and a video depicting how the electrical activity of your infant's brain changes in response to faces. You will also be provided with a $25 honorarium.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not influence your or your infant's future relations with Ryerson University. If you decide to participate, you are free to withdraw your and your infant's consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. At any particular point in the study, you may refuse to answer any particular question and/or you or your infant may stop participation altogether.

<u>Questions about the Study</u>: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact.

Principal Investigator:	Nicole Sugden
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Telephone Number:	(416) 979 5000 ext. 2189
E-mail Address:	amy.mackenzie@ryerson.ca
Research Supervisor:	Margaret Moulson, PhD
Telephone Number:	(416) 979 5000 ext. 2661
E-mail Address:	mmoulson@psych.ryerson.ca

If you have questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board for information.

Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Ryerson University
350 Victoria Street
Toronto, ON M5B 2K3
416-979-5042
REBChair@ryerson.ca

<u>Agreement</u>: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement.

You have been told that by signing this consent agreement you are not giving up any of your legal rights.

____
Name of Infant Participant (please print)

____
Name of Parent Participant (please print)

____________________________________ __________________
Signature of Parent Date

____________________________________ __________________
Signature of Investigator Date

Appendix C: 9-month-old consent form

RYERSON UNIVERSITY

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS

Ryerson University Consent Agreement for 9-month-old participation in the study: How daily experiences influence infant development.

You and your infant are being asked to participate in a research study. Before you give your consent to be a volunteer, it is important that you read the following information and ask as many questions as necessary to be sure you understand what you will be asked to do.

Investigators: Nicole Sugden, PhD Student, department of Psychology, Ryerson University, Amy Mackenzie, undergraduate honours thesis student, department of Psychology, Ryerson University, and Dr. Margaret Moulson, PhD, department of Psychology, Ryerson University. (See page 5 for contact information.)

Purpose of the Study: Two hundred and ten infants between 3 and 9 months of age are being recruited to participate in this study. Ninety infants will participate one time at either 3, 6, or 9 months of age. Ninety infants will participate twice, at 3 and 6, 3 and 9, or 6 and 9 months of age. Thirty infants will participate three times, at 3, 6, and 9 months of age. Since your infant is 9 months old, you will be asked to participate one time in this study.

This study is designed to look at what infants see in their daily lives and how this relates to their early perceptual development. We are particularly interested in examining how infants are exposed to faces and how this exposure shapes their preference for faces, their ability to recognize faces, and how their brain responds to faces.

Description of the Study: To participate, you and your infant will be asked to do the following:

Attend Ryerson University or have an investigator visit your home for thirty minutes to:

- complete a five-minute questionnaire about your infant, the people your infant sees, the activities of a normal day, and the hours your infant spends awake,
- receive training on privacy issues around recording using the head-mounted camera and the operation of a small smiley-face video-camera on a headband, and
- receive training on how to use a daily experiences diary that you will be completing over the course of a week.

After the visit, you will be asked to record the world from your infant's perspective over the course of one week. During this week, you will be asked to:

- complete a daily experiences diary (which should take no more than 5 minutes per day) describing the experiences your child received during the day,
- place the camera on your infant's head when they are awake and alert and you feel it is an appropriate time to record,

    - The camera's dimensions are 4.8x1.6cm (diameter X depth) and weighs 20 grams.
- please remove the camera when your infant falls asleep and/or you feel that it is no longer an appropriate time to record,
    - While we would like you to attempt to record as much as is possible, we understand that your infant may not always want to record.
    - Since you know your infant best, please use your judgment when deciding when and how long to record.
    - Please only record when you feel it is appropriate for your infant.
- watch your infant to ensure that the headband is not uncomfortable for your infant and, if it is uncomfortable, take steps to make it less uncomfortable and/or remove the camera,
- re-charge the video-cameras' battery overnight, and
- receive short (approximately 1-2 minute) follow-up telephone calls about your study experience.

After your week with the camera, you and your infant will be asked to come to Ryerson University for a two hour visit to:
- complete a 5-minute questionnaire about your experience using the video-camera, your experiences over the past week, and your comfort with camera,
- return the video-camera and it's accessories,
- have your infant complete three computer-based face tasks where we show your infant many faces and record how they respond to these faces.
    - During these tasks, your infant will remain on your lap, but you will be blindfolded, so that you do not influence your infant's reactions to the faces. (You may view the faces your child was shown after the task.)
    - Your infant's eyes will be video-recorded during all of these tasks, so that we can review, more precisely, how much time your infant spent looking at each face. This will help us determine if your infant can tell the difference between the faces, which faces your infant prefers, and how your infant's brain is responding to faces.
    - The tasks are:
        1) A face preference task. This task is approximately 3 minutes long. In this task your infant will be shown pairs of faces (e.g., male and female faces). We can determine which face your infant prefers based on the faces your infant looked at the most. During this task, we will be video recording where your infant looks.
        2) A face recognition task. This task is approximately 5 to 7 minutes long. In this task your infant will be shown a single face (e.g., an adult's face) over and over until they become bored with it. Once they are bored and no longer looking at the face, we will show them a new face (e.g., a child's face). If your infant shows renewed interest in looking at the face, we can conclude that your infant recognized that this was a new face. During this task, we will be video recording where your infant looks. We will also be recording your infant's heart rate during this task. Recording your infant's heart rate requires us to place a small sticker on your infant. The sticker is hypo-allergenic and the least 'sticky', most infant appropriate heart rate monitoring sticker available.

3) A task during which we record the electrical activity of your infant's brain. This task is approximately 15 minutes long. During this task we will show your infant many faces of different types (e.g., upright and inverted faces). During this task, we will be video recording where your infant looks. We will also be recording the electrical activity of your infant's brain using electroencephalogram (EEG).

   EEG is a safe, infant-friendly, non-invasive way of recording electrical brain activity. To record EEG, we will apply the cap, which requires us to:
   - measure your infant's head,
   - draw a very small 'x' in grease pencil on the top of your infant's head,
   - place a towel around your infant's shoulders to catch drips from the EEG cap,
   - place an EEG cap on your infant's head (the cap will be moistened with salt-
     water and tear-free baby shampoo),
   - receive a small towel to use to blot any drips away from your infant's head,
   - massage your infant's head so that the little sponges on the cap are touching
     your infant's scalp,
   - add salt-water and baby shampoo solution to the little sponges in the cap,

   We will then record your infant's brain's electrical response to photographs of faces. Afterwards, we will remove the cap from your infant's head, use a small towel and tear-free baby shampoo to wash the 'x' from your infant's head, and provide you with a towel to dry any damp spots on your infant's head or hair.

– take breaks between tasks, and
– receive a copy of the videos recorded from your infant's perspective, a copy of a video of how the electrical activity of your infant's brain responds to faces, a $25 honorarium, and a small thank-you gift for your infant.

If the camera malfunctions or you experience any difficulties with it, you may be asked to have an investigator visit your home (or meet you in a location that is convenient to you) for approximately ten minutes to repair or exchange the camera.

Future participation: We would also like permission to contact you again by telephone to follow-up on your infant's development once every 3 months, until they are 18 months of age. During these follow-ups, we would be asking you questions about things like your infant's sleep, motor development, and communicative development. This would be done over the phone and would take no more than 30 minutes.

If you consent to us contacting you in the future, this does not require you to participate again. You may choose, at the later time, to participate or not participate. Your choice to participate or not participate again will not impact your current participation in this study.

What is Experimental in this Study: None of the procedures or questionnaires used in this study are experimental in nature. The only experimental aspect of this study is the gathering of information for the purpose of analysis.

Risks or Discomforts: There is no risk to your infant from the act of video-taping. The headband they will be asked to wear is designed to be comfortable and fuzzy. If your infant does not enjoy wearing the headband, you may clip the video-camera to a different headband or other headwear. If your infant does not enjoy wearing the camera, you may stop recording, take a break, or discontinue your child's participation in the study.

Since your child is video-taping, there is a risk that you may be uncomfortable with the act of video-taping during the course of a normal day. If, for any reason, you feel uncomfortable video-recording, stop recording. The people who you are video-recording may object to your recording or request that they not be recorded. If at any time you are requested not to record, you must stop recording. If you begin to feel uncomfortable, you may discontinue participation in the study either temporarily or permanently.

With the computer-based task in which your child will participate at the end of the study, your child may become fussy. If your child becomes fussy and you believe that they need a break, please take a break. During the break, we will ask you to determine whether your infant wishes to continue

Your infant may find the EEG cap uncomfortable. The cap will be moist when it is placed on your infant's head. It will also be snug, like a swim-cap. We will provide you with a towel with which to blot excess moisture. We will also adjust the cap to try to ensure your infant is comfortable. Finally, we will be engaging your infant with toys to distract them while we are placing the cap on their head and adjusting the cap. If they experience significant discomfort, we can adjust or remove the cap.

Your infant may find the small sensor sticker uncomfortable. We have selected the smallest, least sticky, hypo-allergenic sensor sticker possible to minimize discomfort. If your infant experiences significant discomfort, we can move or remove the sticker.

If your infant experiences significant discomfort during any task, your infant can take a break, you can choose to skip any particular task, and/or you can choose to discontinue participation in the study.

It is very important to us that you and your infant have a good experience. We are relying on you to help us know if your infant needs a break or wants to end their participation. Please let us know if, at any point, you are or your infant is uncomfortable and wish to take a break or end the task. Participation is voluntary. You may discontinue at any time without penalty. Thank you!

Benefits of the Study: Although it is expected that this study will add to the body of knowledge of face perception and expertise, development, and learning, it is not expected that you will receive any benefits from participating in this study. We currently have no measurement how natural, daily, exposure influences the development of infants' behaviour and the infant brain.

This study is designed to provide an estimation of how the amount of time people spend looking at faces influences both behaviour and the brain.

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<u>Incentives to Participate</u>: As a thank-you, you will be given a small gift for your infant, a copy of the video your infant recorded from their perspective, a copy of the video of your infant's electrical brain activity, and $25 honorarium. If your infant does not complete the task where we measure the electrical activity of their brain, we will not be able to provide you with a video of your infant's brain. If you decide that you do not wish to participate at any time and/or withdraw your infant's data, you will still receive a gift for your infant, a copy of the video recorded up to that time, and the $25 honorarium.

Anecdotally, we have found that parents appreciate seeing the world from their infant's perspective. Past participants have also been very excited to be able to see the electrical activity of their brain in real time. We hope that you too find this interesting and informative.

<u>Costs and/or Compensation for Participation</u>: There are no anticipated costs associated with your participation in this research. Your infant will receive a small gift for their participation. You will also receive a copy of the video-recordings from your infant's perspective and a video depicting how the electrical activity of your infant's brain changes in response to faces. You will also be provided with a $25 honorarium.

<u>Voluntary Nature of Participation:</u> Participation in this study is voluntary. Your choice of whether or not to participate will not influence your or your infant's future relations with Ryerson University. If you decide to participate, you are free to withdraw your and your infant's consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. At any particular point in the study, you may refuse to answer any particular question and/or you or your infant may stop participation altogether.

<u>Questions about the Study</u>: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact.

Principal Investigator:	Nicole Sugden
Telephone Number:	(416) 979 5000 ext. 2189
E-mail Address:	nsugden@ryerson.ca

Undergraduate honours thesis student:	Amy Mackenzie
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E-mail Address:	amy.mackenzie@ryerson.ca
Research Supervisor:	Margaret Moulson, PhD
Telephone Number:	(416) 979 5000 ext. 2661
E-mail Address:	mmoulson@psych.ryerson.ca

If you have questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board for information.

Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Ryerson University
350 Victoria Street
Toronto, ON M5B 2K3
416-979-5042
REBChair@ryerson.ca

<u>Agreement</u>: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement.

You have been told that by signing this consent agreement you are not giving up any of your legal rights.

____
Name of Infant Participant (please print)

____
Name of Parent Participant (please print)

____________________________________ __________________
Signature of Parent Date

____________________________________ __________________
Signature of Investigator Date

Appendix D: Home visit questionnaire

Date: ____________________ RA: ____________ Participant Number: _______________ Visit #: _
DOB: ___________________ Due date: ________________________ Age in days: ______________________
Age:_____________________ Gender:__________ Ethnic group(s):___________________________
On average, how many hours do you spend awake?_______________ And asleep? _____________________________
With how many people do you live? ___________Who are they?____(E.g., mom) ______________________________
Is mom or dad on maternity/paternity leave? Mom / Dad / Both / Neither For how long? _________
With whom do you spend most of your time? (Relationship, not name) ______________________________________
What gender are they?______________How old are they? _________What's their ethnicity? _____________
With whom do you spend most of the rest of your time? ____
What gender are they?______________How old are they? _________What's their ethnicity? _____________
To what ethnic group(s) do your parents belong? ________________How old are your parents? __________
Who else do you spend time with regularly?

Relationship to person	Gender of person	Ethnicity of person	Age of person	How often do you see them? (per day/week/mo?)

How many and what type of pets do you live with? Do you interact with them? How often?
Pet: ____________________________ Interaction type: __________________ Times per day: ___________
Pet: ____________________________ Interaction type: __________________ Times per day: ___________
Pet: ____________________________ Interaction type: __________________ Times per day: ___________
How many hours do you spend watching a screen (e.g., tv/pc/media)?________________ per day/week/month
What do you watch? ____ Times per day / week: _____________
What is your temperament? Easy / Difficult / Shy at first / Very Calm / No consistent temperament
What language(s) are spoken in your home? ____
Where do you spend most of your time? ____
On how many days did you go outside of the house last week? _____________ out of 7 days.
Where did you go? Location: ________________________________ Number of times: _________
Went with (people): ____
Why did you go? __________________________ Hours spent: _____________________
Where did you go? Location: ________________________________ Number of times: _________
Went with (people): ____
Why did you go? __________________________ Hours spent: _____________________
Where did you go? Location: ________________________________ Number of times: _________
Went with (people): ____
Why did you go? __________________________ Hours spent: _____________________
Where did you go? Location: ________________________________ Number of times: _________
Went with (people): ____
Why did you go? __________________________ Hours spent: _____________________
Where did you go? Location: ________________________________ Number of times: _________
Went with (people): ____
Why did you go? __________________________ Hours spent: _____________________
Where did you go? Location: ________________________________ Number of times: _________
Went with (people): ____
Why did you go? __________________________ Hours spent: _____________________

Will you go to any of the places above-described this week? ________________________(today is M/T/W/J/F/St/Sn)
Yes, these ones: ____

____

And outside of what you've already mentioned, will you go anywhere else this week?

Where did you go? Location: ________________________ Number of times: _________
Went with (people): ____
Why did you go? ________________________ Hours spent: ________________
Where did you go? Location: ________________________ Number of times: _________
Went with (people): ____
Why did you go? ________________________ Hours spent: ________________
Where did you go? Location: ________________________ Number of times: _________
Went with (people): ____
Why did you go? ________________________ Hours spent: ________________

Is there anywhere else that you typically go not already mentioned?

Where do you go? Location: ________________________ Number of times: _________
Typically went with (people): ____
Why did you go? ________________________ Hours spent: ________________
Where do you go? Location: ________________________ Number of times: _________
Typically went with (people): ____
Why did you go? ________________________ Hours spent: ________________
Where do you go? Location: ________________________ Number of times: _________
Typically went with (people): ____
Why did you go? ________________________ Hours spent: ________________

Please describe your typical day: ____

Appendix E: Video recording privacy agreement

Discussion About How to Ensure Privacy is Respected While Video-Recording

This is not just a form. This is meant to be a discussion about privacy issues related to video-recording. If you have any questions at any time, please ask!

While video-recording, there are privacy concerns of which you must be aware at all times. You must be vigilant to ensure that you are not violating the privacy of the people you record. What this means is that you cannot record when the person you are recording has a reasonable expectation of privacy. In other words, if the person being recorded is in a situation where they reasonably should expect not to be recorded, you cannot record. In some public places, like in the street or a transit station, for example, there is no reasonable expectation of privacy. In others, however, like in a change-room, rest-room, medical office, or dental office, recording is forbidden since people in these places have a reasonable expectation of privacy.

There is a third, less clear situation, in which you are entering a private area (for example, a private office or someone's home) or will be interacting face-to-face with people in close proximity (for example, going out to dinner with a group of friends). In these situations, we ask that you provide the people with whom you will be interacting or whose home or office you will be visiting with an 'inquiry card' and ask them if they are comfortable with you recording while you are there. If they say 'yes', you may continue recording. If they say 'no', you must not record. If they have questions, answer the questions or direct them to the BEE Lab, whose contact information is on the back of the interest card.

Understandably, there may be some situations in which you may not be sure whether or not recording is appropriate. In these situations, please do not record. If you record in a situation and then, afterwards, are unsure as to whether recording was appropriate, please advise the BEE Lab by telephone or email and we will happily discuss the situation with you. Any inappropriate recordings will be deleted without anyone ever watching the video.

1) In a typical week, where do you go with your infant? (E.g., home, park, friends')

2) And, this week, where do you intend to go with your infant?

3) Given what we have just discussed, do you believe that it is or is not appropriate to film in these locations?

    a. If there are locations of concern (e.g., a doctor's office), please do not record in these locations. The researcher will explain why this is the case (i.e., reasonable expectation of privacy).

4) Do you expect to go anywhere with your infant where you're not really sure whether it is okay to film?

    a. The researcher will help the parent work through what to do in these situations.

5) What might you do if you encounter a location we haven't discussed, in which you aren't sure whether it is okay to record?

    a. If possible, ask the people in attendance whether it is okay to record and offer them interest cards (e.g., if at a private home).

    b. If you're not sure, aren't comfortable at any point while recording, and/or don't feel comfortable asking whether people mind if you record, please do not record.

c. If you have questions or concerns, please feel free to call or email the BEE Lab at any time. We will be more than happy to help!

6) What questions do you have about privacy, recording, or anything else we’ve discussed?

a. The researcher will answer your questions fully.

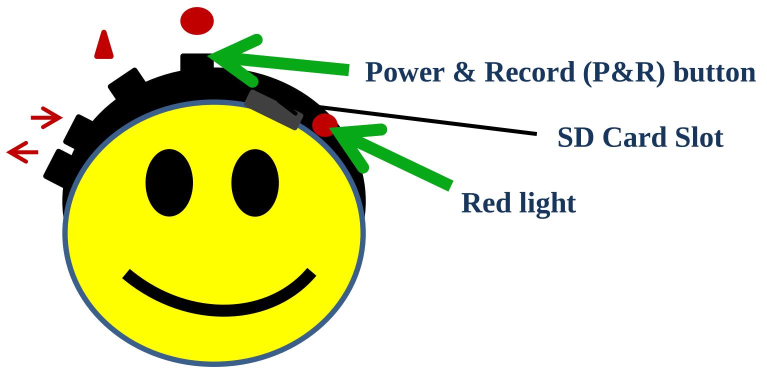
Privacy Agreement

I understand where I can film and I cannot film. I agree only to film in areas in which I believe filming is appropriate. I will discontinue filming when I feel uncomfortable and will only film when I am comfortable filming.
in the case where filming falls within the third category of uncertain social circumstances, I will not film without first informing others around me and seeking their permission after providing them with an inquiry card.
I will call the BEE Lab if I have any questions or concerns.

____ ________________________
Signature of Participant’s Parent/Legal Guardian Date

____ ________________________
Signature of Researcher Date

Appendix F: Directions on how to operate the camera



To turn camera on press P&R button
- **Red light will flash 1x then remain on**
- **Please wait for flash before recording**

To start recording press the P&R
- **Red light will blink 3x quickly**
- **Red light will blink on and off slowly while recording**
  - **If red light stops blinking, the battery's dead**
  - **If red light blinks quickly it's not recording**
  - **If red light on & not blinking, it's not recording**

To stop recording press P&R button
- **Red light will remain on (not blinking)**

To turn off press & hold P&R button for 6 seconds, until the red light blinks 1x, then release P&R
- **Upon release of the P&R button, the red light will turn off (if the light is off, the camera is off)**

Please charge after each recording, if possible

Appendix G: Daily diary to be completed by parents while spending the week recording

Date: _______________ Today I recorded ____________ times

How was your day today? (Please circle one.) Excellent / Good / Average / Not-so-good / Bad

How typical were your activities today? (Please circle one.) Typical / Not typical

How many hours did you spend awake? _________________________________hours

How many hours did you sleep? ____hours

Who did you spend time with today?
Person/Relationship: ________________ Gender: Male / Female Age: _________ Ethnicity:
How much time did you spend with this person? _____________ Hours ________Mins.
How often do you see this person? (Circle 1.) Daily/Weekly/Monthly/Rarely/First Time
Person/Relationship: ________________ Gender: Male / Female Age: _________ Ethnicity:
How much time did you spend with this person? _____________ Hours ________Mins.
How often do you see this person? (Circle 1.) Daily/Weekly/Monthly/Rarely/First Time
Person/Relationship: ________________ Gender: Male / Female Age: _________ Ethnicity:
How much time did you spend with this person? _____________ Hours ________Mins.
How often do you see this person? (Circle 1.) Daily/Weekly/Monthly/Rarely/First Time
Person/Relationship: ________________ Gender: Male / Female Age: _________ Ethnicity:
How much time did you spend with this person? _____________ Hours ________Mins.
How often do you see this person? (Circle 1.) Daily/Weekly/Monthly/Rarely/First Time
Person/Relationship: ________________ Gender: Male / Female Age: _________ Ethnicity:
How much time did you spend with this person? _____________ Hours ________Mins.
How often do you see this person? (Circle 1.) Daily/Weekly/Monthly/Rarely/First Time
Person/Relationship: ________________ Gender: Male / Female Age: _________ Ethnicity:
How much time did you spend with this person? _____________ Hours ________Mins.
How often do you see this person? (Circle 1.) Daily/Weekly/Monthly/Rarely/First Time

Did you see anyone who did not interact with you? (Please circle one.)
Yes, more than 10 people. Yes, 5-10 people.
Yes, 1-5 people No, everyone I saw interacted with me..

How many did you spend watching tv/pc/media?____________________
What do you watch? _______________________ Hours: _______ Minutes: _____
What do you watch? _______________________ Hours: _______Minutes: ______
What do you watch? _______________________ Hours: _______Minutes: ______

How many times did you go outside of the house? ____________
Where did you go? Location: ______________________ Number of times: ___________
Went with (people): ____
Why did you go? __________________________ Hours spent: _______________
Do you usually go here? (Circle one) Yes, daily. Yes, weekly. Yes, monthly. No.
Where did you go? Location: ______________________ Number of times: ___________
Went with (people): ____
Why did you go? __________________________ Hours spent: _______________
Do you usually go here? (Circle one) Yes, daily. Yes, weekly. Yes, monthly. No.
Where did you go? Location: ______________________ Number of times: ___________

Went with (people): ____
Why did you go? _________________________ Hours spent: _______________
Do you usually go here? (Circle one) Yes, daily. Yes, weekly. Yes, monthly. No.

Please describe what you did today: ____

____

____

____

____

____

____

____

____

____

Privacy Reminders:

In all locations in which I video-recorded, I believe I was allowed to video-record	Yes	No
I believe that in the locations in which I recorded there was no expectation of privacy by the people there.	Yes	No
I stopped recording if I felt that continuing to record would violate privacy.	Yes	No
I stopped recording if someone asked me to stop recording and/or leave.	Yes	No
I stopped recording if I entered any area in which recording is not allowed.	Yes	No
I stopped recording if I felt uncomfortable recording.	Yes	No
If you have answered 'no' to any of the above questions, please use this space to let us know your concern so that we can delete the video(s) about which you are concerned. Thank you!		

Appendix H: Lab visit questionnaire

Date: _________ Time: ________ RA: _________________

How many hours have your infant been awake as of right now? _ Hours of sleep last night?

Who is the baby here with? Mom / Dad / ____________________ When did the baby last eat?

What is the baby's temperament today?

Would you say that today your baby is: **(read all options to parent!)**
easy / a little fussy / shy/ calm / doesn't seem to have a consistent temperament today

How many times did you go outside of the house today, before coming to Ryerson?
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________

And this week, on how many days did you go outside this week? ____days out of 7 Days
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________
Where did you go? Location: ________________ Number of times: ____________
Went with (people): _________________Hours spent: _________
If unclear, ask: why did you go? ___________________________

Please describe your day: Please describe your baby's typical day:
(include: time woke up, time to bed, # of times up per night, what baby does, who they saw/interact with, approximate times per interaction)________________________

____

____

____

____

For your infant, was this week: **(read all options to parent!)**

Typical / Mostly typical / Not very typical / Not at all typical

How would you describe your activities this week? **(read all options to parent!)**

No new things / A few new things / Lots of new things

What new activities did you engage in this week? ________________________

What old activities did you engage in this week?_________________________

Of the activities, what did your infant enjoy? ____________________________

Where did you record this week? ____

Where did you not record this week? ____

When did you find it was easiest or best to record? ______________________________

Why? ____

How well do you think the recordings represent your infant's typical day?

(read all options to parent!) Very well / Mostly / Somewhat / Not really / Not at all

How well do you think the recordings represent your infant's typical experiences?

(read all options to parent!) Very well / Mostly / Somewhat / Not really / Not at all

If parent did not say 'very well' to both above questions, ask:

You said that the videos don't exactly represent your baby's typical daily experiences, why not? What are we missing?

____

____

How did your infant respond to the camera?

(read all options to parent!) Liked / Indifferent / Inconsistent / Disliked

Please describe: ____

Were there any challenges, difficulties, or issues with the camera? No / Yes

If yes, please describe: ____

Would you mind if we called you next month to see how things are going? Yes / Maybe / No

Would you be willing to participate in this study again in three months? Yes / Maybe / No

Sleep and Feeding

How many hours does your infant spend awake in an average day?______

& sleep per night, in an average night? _____

Where does your infant sleep on an average night?

(In what type of bed and where is this located?)

How is your baby fed? (e.g., breast, bottle, both?)

Has there been a change to your infant's feeding?

(Ex: started taking a bottle, started solid foods)

Do you remember when this changed occurred? If you were to try to pick a specific day, what day would you say this change occurred?

What is the height of your child? (height as of [date])

What is your child's weight? (weight as of [date])

Changes in General Environment

Has there been a change to the location where you live?

(e.g., moved to a different home/neighborhood) If so, what?

Have there been any changes with the family?

(Ex: A sibling in attending school full day, parent return to work) If so,

what is this change? If you were to try to pick a specific day,

what day would you say this change occurred?

Is your infant attending any new activities or classes? (Ex: Swimming classes, Library visits)

<u>Activity Type:</u>
Location (e.g., library, early years centre):
Times per week:
Hours spent per visit:
Went with (people):

<u>Activity Type:</u>
Location:
Times per week:
Hours spent per visit:
Went with (people):

Activity Type:
Location:
Times per week:
Hours spent per visit:
Went with (people):

Are there any new people who interact with your infant on a regular basis?

(For example, a new babysitter.)

Relationship:
When did your child meet this person?
What gender is this person?
Approximately how old is this person? (Ex: 20's. 30's, 40's)
To what ethnic group(s) does this person belong?
How often does your child interact with this person?

Relationship:
When did your child meet this person?
What gender is this person?
Approximately how old is this person? (Ex: 20's. 30's, 40's)
To what ethnic group(s) does this person belong?
How often does your child interact with this person?

Relationship:
When did your child meet this person?
What gender is this person?
Approximately how old is this person? (Ex: 20's. 30's, 40's)
To what ethnic group(s) does this person belong?
How often does your child interact with this person?

Developmental Milestone Questions

"Now I'm going to ask you some questions about developmental milestones. Just so you know, these milestones cover from birth to 12 months, so a lot of them won't apply to your baby."

When did your child begin holding his or her head up independently?

Can your child push up to their elbows or hands when lying on their tummy

(prone position)? Y / N When did this start? (Provide exact date, not a range.)

How much time a day, on average, does your infant spend in "tummy time" (the prone position)?

Can your child roll from back to tummy (from supine to prone)? Y / N

When did this start? (Provide exact date, not a range.)

Can your child roll from tummy to back (from prone to supine)? Y / N

When did this start? (Provide exact date, not a range.)

Can your child hold a toy independently? Y/ N

When did this start? (Provide exact date, not a range.)

Is your child reaching for objects independently? Y/N

When did this start? (Provide exact date, not a range.)

Does your child reach for or attempt to get things that are out of reach? Y/N

When did this start? (Provide exact date, not a range.)

What types of objects or toys do they reach for?

	Toy 1:	Toy 2:	Toy 3:	Toy 4:	Toy 5:
Colour (if many, what colour is it mostly?)					
Shape (exactly or like what?)					
Size (e.g., 'as big as… what?)					
Texture and material (e.g., spikey plastic)					
Other Features (sound, movement, etc.)					

What is your child's favourite toy, if they have one? Yes favorite toy / No favorite toy

Colour:
Shape:
Size:
Texture:
Other Features (sound, movement, etc):

How much support does your child require to sit? **(read all options to parent!)**

Full/Moderate/Minimal/None but uses hands (tripod sit)/ None

From sitting position, can your child get into a prone position, lying on tummy, pushing up with hands? Y/N

When did this start? (Provide exact date, not a range.)

From prone position, can your child get into a sitting position independently? Y / N

When did this start? (Provide exact date, not a range.)

In prone position, does your child make any other movements, such as rocking back and forth on their hands, pivoting around in a circle, or pulling themselves backwards or forwards? Y / N **(if yes then circle 1 or describe how they move)**

When did this start? (Provide exact date, not a range.)

Can your child crawl? Y/ N

When did this start? (Provide exact date, not a range.)

Can they move forward more than three crawling "steps"? Y/N

What kind of crawling does your child do or, to put it another way, how do they crawl? (Ex: Belly crawling-army crawl, hands and knees, hands and feet –aka bear crawl)

Can your child pull themselves up to a standing position? Y/ N

When did this start? (Provide exact date, not a range.)

How much support does your child require when standing? **(read all options to parent!)** Full/Moderate/Minimal/None

Can your child stand up independently? Y / N

When did this start? (Provide exact date, not a range.)

Can your child walk while holding onto your hands? Y/N

When did this start? (Provide exact date, not a range.)

Can your child cruise, by which we mean walking by holding onto furniture? Y/N

When did this start? (Provide exact date, not a range.)

Can your child take a few steps independently? Y/N

When did this start? (Provide exact date, not a range.)

Language Questions

Is your child pointing? Y/ N

How do they point? With their whole hand / with their index finger / other: _____

When did this start? (Provide exact date, not a range.)

Can they point with just their index finger? Y/N

When did this start? (Provide exact date, not a range.)

What do they point at?

Does your baby know any baby sign language signs? Y/N

What signs do they know? (Provide words – not signs!)

When did they begin signing? (Provide approximate date for each sign.)

Who taught your baby to sign?

Does anyone else sign at your baby?

Does your baby know or understand any words or names? Y/N

What words or names does your baby know/understand?

When do you think they began to recognize or understand these words or names?

How do you think your baby learned the word(s)/names? (e.g., were the parents actively trying to teach the baby the word?)

Have you tried to teach your infant any words or names? Y/N

What words or names have you tried to teach your infant?

When did this begin? (Provide exact date, not a range.)

How do you go about teaching your infant words/names?

Can your baby speak? Y/N

What words does your baby say?

When did this begin? (Provide approximate date, not a range, for each word)

How do you think your baby learned the word(s)/names? (e.g., were the parents actively trying to teach the baby the word? Provide learning technique for each word.)

I know your baby is still quite young, so again this may not apply, but have you begun reading to your baby? Yes / No

If yes, how often do you read to your baby? __ times per day/week/month **(circle one)**

Did you read to your baby yesterday? Yes / No

If yes, what book(s) did you read to your baby yesterday?

What book(s) do you typically read to your baby?

How does your baby respond to your reading? **(What behaviors?)**

Social / Emotion Questions

How is your baby around strangers? **(What behaviors do they display?)**

Do you show your baby expressions of surprise, for example, during peek-a-boo? Y / N

How often would you do this? __ times per day/week/month **(circle one)**

When did this begin? (Provide exact date, not a range.)

How does your baby respond? **(What behaviors do they display?)**

Do you show your baby expressions of disgust, for example, playfully showing your baby when things are 'stinky'? Y / N

How often would you do this? ____ times per day/week/month **(circle one)**

When did this begin? (Provide exact date, not a range.)

How does your baby respond? **(What behaviors do they display?)**

Do you show your baby any other expressions of emotion, like anger, fear, or sad, for example while reading and acting out the stories or while playing? Y/N

How often would you do this? __ times per day/week/month **(circle one)**

When would you do this (i.e., in what context? Which emotions)?

When did this begin? (Provide exact date, not a range.)

How does your baby respond? **(What behaviors do they display?)**

How often do you think your baby sees happy, smiling faces? (E.g., per day?)

How does your baby typically respond to smiles?
(What behaviors do they display?)

If someone doesn't smile at your baby, how does your baby typically respond?
(What behaviors?)

When did your baby first smile at you? (Approximate date – not a range)

How often does your baby smile? **(read all options to parent!)**

All of the time / Often / Sometimes / Not often / Rarely

When or in what situation are they most likely to smile?

If you smile at them, are they likely to smile back? Would you say:
(read all options to parent!) Very likely/Somewhat likely/50-50/Rarely/Unlikely

If a stranger smiles at them, are they likely to return the smile? Would you say:
(read all options to parent!) Very likely/Somewhat likely/50-50/Rarely/Unlikely

Who are they most likely to smile at? (Which one person?
If 2+, of these people, who would they be most likely to be smile at?)

Does your baby see any faces that are upside down? (e.g., when playing?)

When might they see these faces? (In what context? What are they doing?)

How often do they see upside-down faces? __ times per day/week/month **(circle one)**

How does your baby respond to upside-down faces?
(What behaviors do they display?)

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