Neural Correlates of Individuation and Subordinate-Level Categorization of Other-Race Faces in Infancy

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Kelly C. Roth

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DEDICATION

For my Grandma Bev.

Although she is unable to see this final milestone in person, she completely supported me in all of my endeavors. As mama bear, she taught me unconditional love and was a major influence on my fondness for cats and cows.

This is for you. I love you.

Beverly D. Jackson
February 12, 1953 – April 22, 2020

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ABSTRACT

Perceptual narrowing is a domain-general process in which infants move from a broad sensitivity to a wide range of stimuli to developing expertise within often experienced native stimuli (Maurer & Werker, 2014). One outcome of this is the own-race bias, characterized by an increasing difficulty in discriminating other-race faces with age and experience for those raised in a racially homogenous environment (Anzures, Quinn, Pascalis, Slater, Tanaka, & Lee, 2013). Recent theorists have proposed that this is due to a categorization-individuation process, wherein infants begin to categorize non-native stimuli, such as other-species' faces, but individuate native stimuli, such as often-experienced human faces (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Reynolds & Roth, 2018). Previous work has shown that exposure to multiple exemplars during initial learning facilitates categorization of other-species faces while exposure to a single exemplar does not (Dixon, Reynolds, Romano, Roth, Stumpe, Guy, & Mosteller, 2019). The goal of this study was to investigate the effects of initial learning conditions on infants' ability to individuate and categorize own- and other-race faces. Ten-month-old infants were familiarized with either a single exemplar or multiple exemplars of either own- or other-race faces. Event-related potentials (ERP) were recorded while infants were presented with the familiar face(s) they were exposed to during familiarization, a novel face from the same race used during familiarization, and a novel face from a race other than the one used in familiarization. Infants familiarized with a single face, either own-race or other-race, were able to discriminate between faces at the categorical level of race, but not at an individual level. Infants familiarized with multiple exemplars failed to discriminate at the categorical or individual level, regardless of race. Results suggest that in contrast to other-species faces, infants at this age may be focused on individuating own-species faces, regardless of race. The implications of the current findings are discussed in relation to the impact of initial learning conditions on infants' ability to individuate and categorize own- and other-species faces, the developmental timeline of own-species face processing, and social implications of infants' and older children's processing of other-race faces.

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CHAPTER I INTRODUCTION

Famous American psychologist William James once described a newborn's perception of the world as a "blooming, buzzing confusion". James was suggesting that the plethora of perceptual information in one's environment is overwhelming to a young infant's underdeveloped sensory systems. As perceptual development in infancy has been studied extensively over the last century, theorists now recognize that infants use sophisticated classification strategies to make sense of the world around them (e.g., Rakison & Oakes, 2003). Born with broad sensitivity to perceptual differences in their environment, newborns are able to discriminate subtle variability in stimuli that adults may have trouble with, such as discriminating between two individual monkey faces. However, with time, infants begin to develop greater sensitivity to stimuli they are repeatedly exposed to in their native environment, such as becoming better at processing own-species (i.e., human) faces at the expense of a reduced ability to differentiate other-species (e.g., monkey) faces (e.g., Pascalis, de Haan, & Nelson, 2002). Young infants show a greater sensitivity to non-native stimuli, e.g., stimuli not experienced in their native environments, compared to older infants, who show a reduction in this sensitivity. However, older infants show greater expertise in processing native stimuli compared to younger infants (Lewkowicz, 2014).

Perceptual narrowing is a term used to describe the developmental process of an infant's initial broad sensitivity to a wide range of stimuli narrowing in sensitivity to stimuli routinely encountered in their native environment. One of the current theories on perceptual narrowing is defined by an attunement theory wherein repeated exposure to a class of stimuli helps infants maintain early levels of sensitivity and facilitate

developing expertise; meanwhile sensitivity is "lost" or reduced to irrelevant stimuli over time (Aslin & Pisoni, 1980; Maurer & Werker, 2014; Narayan, Werker, & Beddor, 2010). Other theorists suggest perceptual narrowing should not be defined as a loss of ability but rather as a reorganization of a perceptual processing hierarchy as native stimuli become the focus for refinement (Sorcinelli & Vouloumanos, 2018). Perceptual narrowing is thought to be a domain-general developmental process (Maurer & Werker, 2014; Scott, Pascalis, & Nelson, 2007), as evidence of it can be seen across multiple forms of perceptual processing in human infants, including: facial recognition (Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018), language perception (Werker, Gilbert, Humphrey, & Tees, 1981), non-human primate face and voice intersensory perception (Lewkowicz & Ghazanfar, 2006), non-human primate face perception (Scott & Monesson, 2009), non-primate (sheep) face perception (Simpson, Varga, Frick, & Fragaszy, 2011), and even musical rhythms (Hannon & Trehub, 2005; Tichko & Large, 2019).

Perceptual narrowing continues within native categories throughout infancy, such as more narrowed sensitivity to specific types of human faces, which may be tied to developing expertise in face processing (Nelson, 2001). One example of this is the own-race bias, also called the other-race effect, which refers to cases in which younger infants have been found to be better at differentiating other-race faces in comparison to older infants and adults (Anzures, Quinn, Pascalis, Slater, Tanaka, & Lee, 2013; Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007). As infants gain more experience with own-race faces, they maintain and improve the ability to individuate faces within their own-race but fail to show this ability to individuate other-race faces from about 9 months of

age and on (Kelly et al., 2009; Kelly et al., 2007; Sugden & Marquis, 2017). One explanation of this is the categorization-individuation model, which is based on decades of research but formally proposed by Hugenberg and colleagues (2010). According to this model, with increasing age, infants shift to processing other-race faces at a categorical level but maintain the ability to individuate own-race faces as they continue to develop expertise in processing own-race individuals (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018). As infants' own-race face processing improves, they begin to fail to individuate other-race faces, meaning they do not recognize individuals that belong to another race. The Perceptual-Social Linkage Hypothesis (Lee, Quinn, & Heyman, 2017; Lee, Quinn, & Pascalis, 2017) states that due to perceptual narrowing and own-race bias, older infants begin to view members of other-races as a homogenous “out-group” that is exclusive of their own-race, ignoring perceptual differences between individuals from other-races in order to better focus on own-race members. This is theorized to be due to the asymmetrical experience infants have with own- and other-race individuals. Often own-race individuals are the caretakers, setting the infants up to form dichotomous categories between those who they experience often in a positive way (own-race caretakers) and strangers (i.e., an other-race individual would not be associated with being a caretaker).

1.1 Perceptual Narrowing and Face Processing

There are many other factors associated with perceptual narrowing of face processing in infancy in addition to race, such as gender and age (see meta-analytic review, Marquis & Sugden, 2019). Perceptual narrowing is a component of a much

broader process of developing increasingly refined face processing skills across the infancy period. Newborn infants show an attentional bias towards faces and face-like patterns (e.g., Johnson & Morton, 1991; Morton & Johnson, 1991; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995; Valenza, Simion, Cassia, & Umiltà, 1996). Within geometric patterns, newborns prefer face-like top-heavy patterns and face-like inverse triangles that mirror the two eyes and mouth schematic of human faces (Simion, Valenza, Macchi, Cassia, Turati, & Umiltà, 2002; Valenza et. al, 1996). A recent study by Reid and colleagues (2017) has even shown this preference for face-like schematics may exist in utero, although these findings are highly controversial and awaiting further replication (Reid, Dunn, Young, Amu, Donovan, & Reissland, 2017). Infants' initial preference for face-like shapes helps to bootstrap attentional engagement with caregivers' faces, improving face processing with experience (Reynolds & Roth, 2018). By three months of age, the preference for face-like geometric patterns no longer exists, but a preference for human faces strengthens with the infant's repeated exposure to faces (Chien, 2011). Preferences for specific types of faces are seen early in life, such as infants' preference for their mother's face over a similar looking female stranger's face (Pascalis et al., 1995), adult-judged attractive faces over less attractive faces (Slater, Quinn, Hayes, & Brown, 2000), and female over male faces when the primary caregiver is female (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). Overall, young infants prefer the race and gender of their primary caregiver, showing attentional biases to familiar over unfamiliar traits in the first few months of life (Marquis & Sugden, 2019)

While young infants' biases for faces have been clearly documented, debate over factors that may account for these biases is ongoing in the literature (for in-depth reviews of the different theories, see Pascalis & Kelly, 2009; Reynolds & Roth, 2018). Some theorize there is an innate system that specializes in face processing (e.g., Buiatti et al., 2018; Johnson & Morton, 1991; Pyykkö, Ashorn, Ashorn, Niehaus, & Leppänen, 2019). Others theorize that perceptual constraints tied to an immature visual system result in a bias for faces that is initially based on the perceptual properties of face-like stimuli, as opposed to faces per se (e.g., Kleiner & Banks, 1987; Markant & Scott, 2018; Turati, 2004; Turati, Simion, Milani, & Umiltà, 2002; Wilkinson, Paikan, Gredebäck, Rea, & Metta, 2014). Although there is considerable debate regarding the origins of young infants' attentional biases for faces, research clearly indicates that asymmetrical levels of exposure lead to a maintenance of perceptual sensitivity to human faces and a loss of perceptual sensitivity to other-species faces (for a review, see Maurer & Werker, 2014).

1.1.1 The Own-Race Bias

One specific example of perceptual narrowing in own-species human face processing is the own-race bias. While newborn infants do not show a preference for own-race over other-race faces, 3-month-old infants do prefer faces of the same race as their caregivers, indicating perceptual narrowing to race begins as early as 3 months (Kelly et. al., 2005). The own-race bias refers to the tendency for infants raised in racially homogenous environments to lose sensitivity to other-race faces over development, eventually being unable to discriminate individual other-race faces by 9 to 10 months of age (see meta-analysis by Sugden & Marquis, 2017). Studies provide

support for the possibility that the own-race bias occurs universally across races. For example, Kelly and colleagues (2007) habituated 3-, 6-, and 9-month-old White infants and tested their ability to discriminate the habituated (familiar) face from a novel face using a visual-paired comparison task. The habituation phase used infant-controlled looking at a single Chinese, Middle Eastern, Black, or White face; habituation was reached when infants showed a 50% reduction in looking to the face. Infants were then presented with the familiar face and a novel face of the same race and gender shown side by side. If they had processed the habituated face, it was predicted they would look more at the novel face as infants generally prefer to look at novel over familiar stimuli (Fantz, 1964). If the infants were able to successfully individuate the face during habituation, they would show a visual recovery (i.e., look more) to novel faces. This implies they are able to discriminate the novel from the familiar face during test trials. White 3-month-old infants were able to discriminate between individual Black, Middle Eastern, and Chinese faces in addition to their own-race White faces; however, 6-month-old infants were no longer able to discriminate Black or Middle Eastern faces, and 9-month-old infants could only discriminate own-race White faces (Kelly et al., 2007). Kelly and colleagues (2009) replicated this study using Chinese infants and Black, White, and Chinese faces to test if this may be a universal phenomenon. Chinese infants showed the same trajectory of losing sensitivity to Black and White faces across 3, 6, and 9 months of age, but still showed the ability to discriminate novel and familiar own-race Chinese faces at all three ages. Similarly, eye-tracking studies have supported these results, showing that infants scan all faces similarly before 6-months-of-age, but begin to scan own- and other-race faces differently as the own-race

bias develops (Ellis, Xiao, Lee, & Oakes, 2017; Fassbender & Lohaus, 2019; Krasotkina, Götz, Höhle, & Schwarzer, 2020; Singarajah et al., 2017; Wheeler, Anzures, Quinn, Pascalis, Omrin, & Lee, 2011).

In addition to the behavioral research described above, researchers have also used neural measures such as functional near-infrared spectroscopy (fNIRS), magnetic resonance imaging (MRI), electroencephalogram (EEG), and event-related potential (ERP) data to investigate the own-race bias in infancy (e.g., Balas, Westerlund, Hung, & Nelson, 2011; Kelsey, Krol, Kret, & Grossman, 2019; Telzer, Flannery, Shapiro, Humphreys, Goff, Gabard-Durman, Gee, & Tottenham, 2013; Timeo, Brigadoi, & Farroni, 2017; Vogel, Monesson, & Scott, 2012). This dissertation utilized EEG, which is a measure of ongoing electrical activity on the scalp, and ERP components are time-locked voltage oscillations in the EEG that are produced by the summation of postsynaptic potentials produced in response to experimental events. The ERP is utilized as an electrophysiological measure of perceptual and cognitive processes and can shed light on different components of face processing (de Haan, 2013). ERPs are often utilized to study neural processes because of their excellent temporal resolution, on the order of milliseconds, and the ease of recording across multiple scalp locations (Otten & Rugg, 2005). ERPs can demonstrate exogenous potentials that result from "bottom-up" responses to physical characteristics of external stimuli, or endogenous potentials that result from "top-down" cognitive processes associated with processing the stimulus event (de Haan, 2013; Picton, Bentin, Berg, Donchin, Hillyard, Johnson, …, & Taylor 2000).

Scott, Shannon, and Nelson (2006) conducted one of the first ERP studies on infant face processing of both human and monkey faces. Their analysis focused on the P400 component. The P400 is an infant ERP component associated with face processing, as it has a shorter latency to faces over non-faces in young infants and becomes more sensitive to upright human faces with age (Halit, de Haan, & Johnson, 2003). It is manifested as a positively-polarized change in ERP amplitude that occurs approximately 400 milliseconds post stimulus onset at posterior lateral locations on the scalp (de Haan, Johnson, & Halit, 2003; Dixon et al., 2019). Scott and colleagues (2006) found that infants showed greater P400 amplitude to unfamiliar monkey faces compared to familiar monkey faces, but no differences were found based on orientation of monkey faces, indicating a less in-depth processing of the other-species faces. In contrast, the P400 was sensitive to both familiarity and orientation of human faces, which indicates more thorough processing of human faces compared to other-species faces (Scott, Shannon, & Nelson, 2006). This sensitivity to the orientation of human but not monkey faces provides further evidence of perceptual narrowing toward human faces in infancy (de Haan, 2007, 2013; de Haan, Johnson, & Halit, 2003; de Haan & Nelson, 1997; de Haan, Pascalis, & Johnson, 2002; Dixon et al., 2019; Halit, de Haan, & Johnson, 2003; Quinn, Doran, Reiss, & Hoffman, 2010; Xie, McCormick, Westerlund, Bowman, & Nelson, 2018).

Another relevant component is the Nc or negative central, a negatively-polarized ERP component that peaks around 400 to 800 milliseconds after stimulus onset over frontal and midline locations on the scalp. Originally associated with novelty detection (Courchesne, 1977, 1978; Courchesne, Ganz, & Norcia, 1981; de Haan & Nelson,

1999; Karrer & Ackles, 1987; Nikkel & Karrer, 1994), more recent literature has found the component to be specifically associated with attentional engagement (Conte, Richards, Guy, Xie, & Roberts, 2020; Guy, Zieber, & Richards, 2016; de Haan, 2013; de Haan, Johnson, & Halit, 2003; Quinn, Westerlund, & Nelson, 2006; Reynolds & Richards, 2019; Webb, Long, & Nelson, 2005; Xie, McCormick, Westerlund, Bowman, & Nelson, 2018). Nc amplitude has been correlated with heart rate defined periods of attention and inattention, with a greater Nc amplitude associated with greater attentional engagement (Guy, Zieber, & Richards, 2016; Reynolds, Courage, & Richards, 2010; Reynolds & Richards, 2005, 2009; Richards, 2003).

In a study on the own-race bias in infancy, Vogel, Monesson, and Scott (2012) recorded infant EEG data while showing 5- and 9-month-old infants a sensory matching task. Infants heard either a crying or laughing sound followed by a static grayscale image of either a Black or White woman's face displaying either a sad or happy emotion. Trials could be congruent, meaning a crying sound was followed by a sad face or a laughing sound was followed by a smiling face, or incongruent, meaning the crying was followed by a smiling face or the laughing was followed by a sad face. Infants saw both Black and White actors, and the final dataset consisted of all White infants. Two of the ERP components the researchers looked at were the Nc and the P400 to measure infant attention to the stimuli. Five-month-old infants showed no differential Nc response by race when viewing the sequential sound and image test trials of women crying or laughing. The 5-month-old infants were able to differentiate the congruent trials (laughing sound/smiling face; crying sound/sad face) from the incongruent trials (laughing sound/sad face; crying sound/smiling face) regardless of the race of the actor.

However, 9-month-old infants' P400 response was dependent on race, as their waveforms showed an interaction effect of congruency and race. White 9-month-old infants only differentiated the congruent from the incongruent trials if the actor was White, but they did not show differences between congruent and incongruent trials if the actor was Black. If perceptual narrowing and the own-race bias did not interfere with emotional processing development, it would be expected that no differences would be found between the two age groups. However, evidence from this study suggests that, with age, perceptual narrowing is related to a reduced sensitivity in emotional processing of other-race faces (Vogel, Monesson, & Scott, 2012).

It is generally accepted that the own-race bias is due to consistent experience with own-race faces and little to no experience with other-race faces (for a review of infant own-race bias, see Anzures, Quinn, Pascalis, Slater, Tanaka, & Lee, 2013). Studies investigating conditions where the own-race bias does not develop or can be "trained away" have shown that experience plays a large role. Black African infants raised in a primarily White environment do not show an own-race bias, instead maintaining their ability to differentiate both Black African and White faces at the individual level (Bar-Haim, Ziv, Lamy, & Hodes, 2006). On the other hand, children who have had complete other-race face deprivation due to being raised exclusively in a racially homogenous orphanage show strong racial biases (Telzer et al., 2013). Children either from an Eastern European or an East Asian orphanage who were subsequently adopted by White American families were tested with own- and other-race faces displaying emotion. Functional MRI data showed deprivation to other-race faces in infancy led to differential emotional processing and heightened amygdala response to

other-race faces. A later adoption age was associated with greater reactivity to race, indicating that exposure to other-race faces does influence own- and other-race face emotional processing (Telzer et al., 2013). Preliminary eye-tracking results also suggest 10-month-old White infants scan White faces differently depending on what emotion they are expressing, but do not scan Black faces differently based on emotional expression (Roth et al., 2019). In a study comparing facial scan patterns of infants raised in either racially diverse or homogenous communities, researchers found differences between the groups at 8-months-old but not 6-months-old. This suggests that even early community experience has an influence on other-race face processing, not just the infant's immediate homelife (Ellis, Xiao, Lee, & Oakes, 2017).

There is also evidence that "training" or consistent other-race face exposure that helps maintain early perceptual sensitivity can prevent the onset of the own-race bias. White infants who were exposed to multiple Chinese face exemplars over a three week period (Heron-Delaney, Anzures, Herbert, Quinn, Slater, Tanaka, …, & Pascalis, 2011) or who were provided brief daily exposure to videos of Asian women from 6 to 9 months of age (Anzures, Wheeler, Quinn, Pascalis, Slater, Heron-Delaney, …, & Lee, 2012) maintained their ability to discriminate other-race Asian faces at 9 months of age. Similarity, White infants who had exposure to pictures of Black African faces in a longitudinal study at 3- and 6-months-old subsequently did not show the own-race bias at 9 months of age (Spangler, Schwarzer, Freitag, Vierhaus, Teubert, Fassbender, …, & Knopf, 2013). Additionally, 9-month-old infants given a cue to expect a face in a certain location were able to discriminate cued faces from other faces regardless of race experience or training (Markant, Oakes, & Amso, 2016). Infants shown other-race faces

depicting either angry or happy expressions were able to differentiate novel individuals from familiar ones at 9-months-old, suggesting highly salient emotional expressions may help reduce the own-race bias (Quinn, Lee, & Pascalis, 2020b). Another study showed that 10- to 12-month-old infants were able to discriminate other-race dynamic faces if the faces produced speech sounds, but not if the faces produced a non-speech sound or were silent; however, infants were able to discriminate own-race dynamic faces in all three conditions (Minar & Lewkowicz, 2018).

In general, language experience has an influence on the development of own-race bias, such as 18- to 24-month-old monolingual infants showing attentional biases based on race, but bilingual infants not showing differences between own- and other-race faces (Singh, Quinn, Xiao, & Lee, 2019; Singh, Tan, Lee, & Quinn, 2020). Similarly, 9-month-old infants display correlated dishabituation scores, a measure of discrimination, when both viewing other-race faces and listening to non-native speech, supporting perceptual narrowing as a domain-general process (Krasotkina, Götz, Höhle, Schwarzer, 2018). Thus, the own-race bias is related to experience with and attention to, or lack of, other-race faces. Consistent experience with other-race faces, either through training, attentional cues, or natural exposure within the infant's environment, modulates the own-race bias. Additionally, experience with other-race faces depicting highly salient emotions or dynamic speech, or being raised in a bilingual environment, influences infants' responsiveness to other-race faces.

1.2 Perceptual Narrowing and Categorization

Studies indicate that perceptual narrowing may be associated with the development of categorization in infancy (Dixon et al., 2019; Hugenberg, Young,

Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Quinn, 2002; 2019; Reynolds & Roth, 2018). The own-race bias may provide an example of early perceptually-based categories evolving into conceptually-based categories later in development (Quinn, Lee, & Pascalis, 2019, 2020a). Categorical perception of other-race faces, and individuation of own-race faces, is currently one of the leading explanations for the early onset of the own-race bias in infancy (Balas, 2013; Hugenberg, Young, Bernstein, & Sacco, 2010; Lee, Quinn, & Heyman, 2017; Lee, Quinn, & Pascalis, 2017; Reynolds & Roth, 2018). Categorization of own- and other-race faces is a vital step in the development of face perception in infancy, as this allows infants to begin individuating own-race faces at a higher-level while allowing less common other-race faces to be merged into a category of "not own race" (Balas, 2013; Quinn, Lee, & Pascalis, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016).

While 6-month-old White infants do not categorize Asian and White faces separately, at 9 months of age they categorize Asian faces as separate from White faces and show further individuation of White own-race faces (Anzures, Quinn, Pascalis, Slater, & Lee, 2010). Within other-race faces, White infants respond to the perceptual differences between Black and Asian faces at 6 months of age, representing them as distinct categories. However, at 9 months of age, White infants do not discriminate between Black and Asian faces at the level of race despite their obvious perceptual differences (e.g., color), implying social experience has led to the formation of a conceptual, broad other-race category that is exclusive of own-race White faces (Quinn, Lee, Pascalis, & Tanaka, 2016). In support of this, a computational simulation was fed examples of White, Black, and Asian faces at a ratio of 8:1:1 to replicate the

asymmetrical exposure to own-race faces infants experience. As time went on, the simulation began to merge Black and Asian faces together, identifying them as more similar to each other, despite visual differences such as color (Balas & Quinn, 2015).

Perceptual narrowing and categorization of faces occur based on gender as well as race. For example, young infants show a visual preference for (i.e., look longer at) female over male faces, which is theorized to be due to infants' experience with primarily female caregivers (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). Evidence of this is seen in infants who are raised primarily by male caregivers who instead show a preference for male over female faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). Within the more common preference for female faces, 3- to 4-month-old infants are only able to discriminate female own- and other-race faces; however, at 8- to 9-months-old, infants are able to discriminate both female and male own-race faces, but neither female nor male other-race faces (Tham, Bremner, & Hay, 2015). A study by Tham, Woo, and Bremner (2018) compared results of British White infants raised in homogenous racial environments of all White faces with results of Chinese infants raised in multiracial environments that included Chinese as well as Malay faces. At 3 to 4 months of age, the Chinese infants were able to recognize female own-race faces. At 8 to 9 months of age, Chinese infants were able to recognize female own-race faces as well as the heavily experienced other-race Malay female faces. However, neither age group of Chinese infants were able to discriminate male Chinese or male Malay faces. In contrast, 8 to 9-month-old British White infants were able to discriminate both male and female own-race White faces (Tham, Bremner, & Hay, 2015; Tham, Woo, & Bremner, 2018). Thus, gender and race interact when infants are developing their face

processing skills, and whether or not older infants are able to individuate male own-race faces depends on their experience with both race and gender (see meta-analytic review by Marquis & Sugden, 2019).

This line of thinking has been explored with the own-species bias, which is analogous to the own-race bias. Pascalis, de Haan, and Nelson (2002) studied 6-month-old infants', 9-month-old infants', and adults' processing of human and monkey face stimuli. Their findings showed that all three age groups displayed a novelty preference when shown a familiar and novel human face, indicating they individuated the familiar face and were able to distinguish it from the unfamiliar one. However, only the 6-month-old infants also showed a novelty preference when viewing familiar and novel monkey faces, indicating they recognized the familiar face and were able to individuate the other-species. The older infants' and the adults' lack of novelty preference when shown monkey faces implies they were unable to differentiate the two non-native other-species monkey faces (Pascalis, de Haan, & Nelson, 2002).

Other studies have investigated if sensitivity to non-native stimuli can be maintained with training (Pascalis et al., 2005; Scott & Monesson, 2009). Scott and Monesson (2009) gave parents of 6-month-old infants one of three books to be read or shown to the infant over a three-month period. Infants received a picture book with monkey faces that were one of three types: each monkey labeled individually with a unique name (e.g., "Boris"), all monkeys labeled categorically as "monkey", or no labels. At 9 months of age, only the infants who had been trained with individually named monkey faces were able to discriminate familiar from novel faces when tested with faces not included in their picture books. Infants who had the categorically labeled or

unlabeled picture book were unable to discriminate the familiar from the novel monkey faces at 9 months of age despite 3 months of experience with the books (Scott & Monesson, 2009). The literature suggests that there is a developmental trajectory wherein infants begin to categorize non-native stimuli while continuing to individuate native stimuli (Dixon et al., 2019; Nelson, 2001; Hugenberg, Young, Bernstein, & Sacco, 2010; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018). This shift from individuation to categorization likely contributes to perceptual narrowing in face processing, resulting in own-race and own-species biases.

Parallel with perceptual narrowing, the ability to categorize develops across the first year of life. Literature on categorization focuses on formation of three types of categories: superordinate-level, which are very broad or general categories (e.g., animate, inanimate); basic-level, which are generic categories based on perceptual characteristics nested within superordinate-level categories (e.g., cats, dogs); and subordinate-level, which are more inclusive and specific categories nested within basic-level categories (e.g., black-and-white cow cat, tortishell cat). Two-month-old infants can categorize at very broad, superordinate-levels, such as discriminating animate from inanimate stimuli by differentiating mammals from furniture (Quinn & Johnson, 2000). At three to four months of age, infants begin to categorize at a basic-level, such as differentiating cats from dogs (Eimas & Quinn, 1994; Eimas, Quinn, & Cowan, 1994; Oakes & Ribar, 2005). From six to seven months of age, infants begin forming subordinate-level categories, such as differentiating Siamese cats from tabby cats (Quinn & Tanaka, 2007). At 12 months of age, infants are able to form discrete human age categories; they are able to differentiate adult from infant faces as well as

differentiate infant from child faces (Damon, Quinn, Heron-Delaney, Lee, & Pascalis, 2016).

The neural correlates of categorization in infancy have been explored using EEG and ERP data, and findings indicate that category learning is robust (for a review of category learning in infancy using EEG and ERP measurements, see Hoehl, 2016). In a study conducted by Quinn, Westerlund, and Nelson (2006), 6-month-old infants viewed images of cats during a familiarization phase and were subsequently presented with images of novel cats randomly mixed with images of novel dogs for ERP testing. In addition to the Nc (attentional engagement) component, the late slow wave (LSW) was also analyzed. The LSW is characterized by a late onset-latency and long duration, occurring from approximately 1000 to 2000 milliseconds after stimulus onset and most often located at temporal and anterior electrode sites (de Haan, 2007, 2013; Dixon et al., 2019). The LSW is associated with perceptual processing and recognition memory, as a change in LSW amplitude is seen with repeated exposure to a stimulus (de Haan & Nelson, 1999; Grossman, Gliga, Johnson, & Mareschal, 2009; Guy, Reynolds, Mosteller, & Dixon, 2017; Guy, Reynolds, & Zhang, 2013; Nelson & Collins, 1991, 1992; Reynolds, Guy, & Zhang, 2011; Reynolds & Richards, 2019; Snyder, Garza, Zolot, & Kresse, 2010; Snyder, Webb, & Nelson, 2002; Webb, Long, & Nelson, 2005; Wiebe, Cheatham, Lukowski, Haight, Muehleck, & Bauer, 2006).

Quinn, Westerlund, and Nelson (2006) recorded ERP data as they familiarized 6-month-old infants with images of cats, then showed the familiarized cats, novel cats, and novel dogs during test trials. Infants displayed a greater negative amplitude LSW to the first half of the familiarized cats and to the novel dogs in comparison to the second

half of the familiarized cats and the novel cats. Infants' reduced LSW amplitude to both the second half of familiarized cats and to novel cats indicates that in addition to processing the second half of the familiarized cats as familiar, the infants also processed the novel cats presented in the second phase of testing as familiar, despite their novelty. The authors proposed this indicates categorization (as opposed to individuation) of cats, as the infants perceived the novel individual cats as a part of the familiarized category. Additionally, the researchers found that there was greater Nc amplitude to the novel dogs in comparison to both familiarized cats and novel cats. Because the Nc is associated with attentional engagement (de Haan, 2013; de Haan, Johnson, & Halit, 2003; Guy, Zieber, & Richards, 2016; Reynolds, Courage, & Richards, 2010; Reynolds & Richards, 2005, 2009, 2019; Richards, 2003; Webb, Long, & Nelson, 2005), the researchers interpreted this effect as novel-category detection, i.e., recognizing the dogs did not belong to the familiarized category of cats (Quinn, Westerlund, & Nelson, 2006). Thus, the infants showed evidence of recognizing the novel cats as belonging to the familiarized cat category; they also showed evidence of perceiving the novel dogs as from a novel category separate from the familiarized cat category (Quinn, Westerlund, & Nelson, 2006).

Grossman, Gliga, Johnson, and Mareschal (2009) also conducted an ERP investigation on categorization with 6-month-old infants. Infants were familiarized with 4 repeated images of either fish or birds, two basic-level categories within the superordinate-level category of animals, then tested with the same images used for category exemplars in the familiarization phase, novel images from the familiarized category, and novel images from a novel category (either fish or birds, whichever the

infant was not familiarized to). Similar to Quinn, Westerlund, and Nelson's (2006) study, Grossman and colleagues were interested in how infants form perceptual categories and differentiate between exemplars that belong to different groups. Infants showed greater Nc amplitude to images from the new category compared to images from the familiarized category. However, there was no difference in Nc amplitude between new and familiar images of the familiarized category. This implies that enhanced attention as indexed by the Nc can be used as a marker for infant novel category detection, adding to Quinn, Westerlund, and Nelson's (2006) conclusions about the Nc and categorization. In Grossman and colleagues' (2009) second study, 6-month-old infants were tested with birds and cars, two basic-level categories. Results showed larger Nc amplitude to images from the novel category in comparison to images from the familiar category. Despite the differences in superordinate-level or global properties of stimuli between the two studies (animals versus objects), infants showed similar processing of perceptual categories. Infants reliably show greater Nc amplitude to novel categories compared to familiar categories, which is evidence of their recognition of exemplars from the familiarized category as well as their detection of exemplars from a novel category (Grossman, Gliga, & Mareschal, 2009).

While Quinn et al. (2006) and Grossman et al. (2009) looked at ERP components associated with 6-month-old infants' basic-level categorization, Quinn, Doran, Reiss, and Hoffman (2010) investigated 6- to 7-month-old infants' ability to form subordinate-level categories. Infants were familiarized with pictures of Saint Bernards, then shown novel Saint Bernards and Beagles, two breeds of dog, during testing. Similar to Quinn et al.'s (2006) study with cats, LSW amplitude was greater for the first half of the

familiarized Saint Bernards and the novel Beagles compared to the second half of the familiarized Saint Bernards and the novel Saint Bernards. This indicates the infants showed greater LSW amplitude when first experiencing category exemplars compared to when they were processing the learned Saint Bernard category. More simply, the infants showed evidence of learning a category of Saint Bernards that included both familiar and novel Saint Bernards but excluded novel Beagles. Again, similar to Quinn et al. (2006) and Grossman et al. (2009), infants displayed greater Nc amplitude to the novel Beagles in comparison to familiarized Saint Bernards and novel Saint Bernards, showing evidence of the infants recognizing the Beagles as belonging to a novel category that excludes Saint Bernards. Additionally, the researchers analyzed the P400 ERP component at occipital-parietal electrode sites. As discussed earlier, the P400 component has been proposed to be a marker of face processing in infancy (de Haan, 2007; de Haan, Johnson, & Halit, 2003; de Haan & Nelson, 1997; de Haan, Pascalis, & Johnson, 2002; Halit, de Haan, & Johnson, 2003; Xie, McCormick, Westerlund, Bowman, & Nelson, 2018). However, recent literature has begun to utilize the P400 as an index of subordinate-level processing in infancy (Scott, Monesson, & Buchinski, 2008; Quinn, Doran, Reiss, & Hoffman, 2010). Infants showed a greater positive P400 amplitude in response to novel Beagles compared to familiar Saint Bernards and novel Saint Bernards (Quinn, Doran, Reiss, & Hoffman, 2010).

While the increased Nc amplitude may indicate general novel category detection, the addition of the increased P400 amplitude may specify novel subordinate-level category detection. In Vogel et al.'s (2012) study on 9-month-olds' ability to detect emotional congruency of face-voice pairings, White infants showed significantly greater

P400 amplitude to White faces compared to Black faces, two subordinate-level categories within the basic-level own-species faces (Vogel, Monesson, & Scott, 2012). Similarly, the P400 results in Quinn et al.'s (2010) study indicate infants recognized a novel subordinate-level category of breed (Beagles) within the salient basic-level category (dogs) (Quinn et al., 2010). Thus, repeated exposure to a subordinate-level category (Saint Bernards) allowed infants to develop a sensitivity that facilitated their ability to differentiate between Saint Bernards and Beagles during test trials (Quinn et al., 2010). This parallels the perceptual narrowing developmental trajectory, as infants are able to maintain and improve their perceptual processing of often experienced categories of stimuli. In contrast, infants fail to differentiate between less experienced categories of stimuli if they are not consistently exposed to them (e.g., loss of other-species sensitivity in Pascalis, de Haan, & Nelson, 2002; Scott & Monesson, 2009). Similar to perceptual narrowing and maintaining sensitivity to non-native stimuli during the first year of life, category formation requires repeated exposure to certain types of stimuli in order to form perceptual categories at the superordinate-, basic-, and subordinate-level (Grossman, Gliga, & Mareschal, 2009; Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Quinn, Westerlund, & Nelson, 2006).

1.2.1 Learning Conditions

Several studies have shown that experiencing multiple exemplars during initial exposure enhances learning in infancy. For example, infants at 3.5, 4.5, and 6.5 months of age are more likely to show evidence of recognition of an object if it is presented paired with another object during familiarization than if the object is presented by itself during familiarization (Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). Furthermore,

4-month-old infants demonstrate basic-level categorization of cats and dogs when given paired presentations of two exemplars during learning, but they do not demonstrate this level of learning when exposed to single presentations of exemplars (Oakes & Ribar, 2005). In general, exposure to multiple exemplars appears to enhance infant processing and recognition of stimuli over single exemplars (e.g., Casasola & Park, 2013; Oakes, Kovack-Lesh, & Horst, 2009; Vukatana, 2017; Vukatana, Graham, Curtin, & Zepeda, 2015).

Dixon and colleagues (2019) investigated the potential effects of initial learning conditions on subordinate-level categorization of other-species in infancy. While previous studies had examined infants' categorization of animals at 6 months of age (Quinn et al., 2006), this was the first study to examine older infants' subordinate-level categorization of non-human primate faces after the onset of perceptual narrowing. Nine-month-old infants were shown repeated presentations of either a single exemplar or multiple exemplars of a monkey species (either capuchin or macaque) during familiarization (learning trials). During test trials, infants then viewed the familiar exemplar(s) (familiar trials), novel exemplars from the *same* species as the familiarized category (novel-*same* trials), and novel exemplars from a novel category of *other*-species of monkey (novel-*other* trials). For example, if infants were familiarized to multiple exemplars of capuchin monkeys during learning trials, the familiar trials would be those same faces used during learning trials, the novel-same trials would be novel capuchin faces, and the novel-other trials would be novel macaque faces (the species not used during familiarization).

The results revealed several interesting findings. Infants who were familiarized with multiple exemplars showed greater Nc amplitude to novel-other (novel category exemplars) compared to learning, familiar, and novel-same trials. Infants also showed a greater P400 amplitude to novel-other trials in comparison to learning, familiar, and novel-same trials. Taken together, these Nc and P400 results for the multiple exemplar group show the infants processed the monkey faces at the subordinate-level based on species, as opposed to based simply on novelty and familiarity. More simply, if infants were familiarized with capuchin faces, they were able to differentiate between novel capuchin and novel macaque faces at the species level and they categorized the familiar capuchin and the novel capuchin together. In contrast to the multiple exemplar group, infants who only viewed a single exemplar of a subordinate-level monkey category had non-significant ERP component results. Infants in the single exemplar group showed no difference in Nc, P400, or LSW (recognition component) amplitude between any of the four trial conditions (learn, familiar, novel-same, novel-other). Thus, when familiarized to multiple exemplars of other-species faces, 9-month-old infants demonstrated subordinate-level categorization of two monkey species, discriminating between macaque and capuchin monkeys. But, if given a single category exemplar for the same number of learning trials, infants were unable to demonstrate evidence of either subordinate-level categorization or individuation (Dixon et al., 2019).

1.3 Focus of the Current Study

Findings from the extant literature indicate that perceptual narrowing during the first year of postnatal life results in an own-race bias for infants who experience a racially homogenous environment (Anzures et al., 2013). This own-race bias leads to a

reduced ability to discriminate novel from familiar other-race faces with increased age in infancy (Kelly et al., 2007; Kelly et al., 2009; Mauer & Werker, 2014; Quinn, Lee, & Pascalis, 2018). Eventually, infants may begin to combine other-race faces into a single category and stop differentiating between subordinate-level categories of other-race faces if they lack training in individuation of other-race members or if they are not cued to individuate during testing (Anzures et al., 2012; Balas, 2013; Heron-Delaney, Wirth, & Pascalis, 2011; Markant, Oakes, & Amso, 2016; Quinn, Lee, & Pascalis, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016; Spangler et al., 2013).

Similar to the own-race bias, infants show an own-species bias around 9 months of age, such as being unable to differentiate novel from familiar monkey faces (Heron-Delaney, Wirth, & Pascalis, 2011; Pascalis, de Haan, & Nelson, 2002; Scott & Fava, 2013; Slater et al., 2010). However, 9-month-old infants can form subordinate-level categories of other-species when given multiple exemplars during familiarization, allowing for differentiation between two other-species groups; conversely, familiarization with a single exemplar of an other-species face does not allow for differentiation between two other-species categories (Dixon et al., 2019). Behavioral literature on whether older infants are able to form these subordinate-level categories in human face processing has shown that infants differentiate between own-race and other-race categories, but not between two subordinate-level other-race categories, such as White infants not spontaneously differentiating between Black and Asian faces (Lee, Quinn, & Pascalis, 2017; Quinn, Lee, Pascalis, & Tanaka, 2016) unless specifically cued to individuate a face (Markant, Oakes, & Amso, 2016). Presumably, as the own-race bias and the own-species bias are both related to perceptual narrowing and categorization, it

is likely that similar cognitive processes are involved in infants' categorization of human faces based on race as those involved in infants' categorization of other-species' faces, such as differentiating capuchin and macaque species (Dixon et al., 2019).

Using ERP components, the current study investigated whether initial learning conditions affect 10-month-old infants' ability to individuate and categorize own- and other-race faces at the subordinate-level through four experiments. Similar to the procedure used by Dixon et al. (2019), this possibility was tested by exposing 10-month-old White infants to different learning conditions during familiarization with faces. Experiment 1 showed infants a single exemplar of an own-race (White) face to facilitate individuation of the own-race individual, Experiment 2 showed infants multiple exemplars of own-race (White) faces to facilitate categorization between own- and other-race, Experiment 3 showed infants a single exemplar of an other-race (Black) face to facilitate individuation of an other-race individual, and Experiment 4 showed infants multiple exemplars of other-race (Black) faces during learning trials to facilitate categorization between two other-races at test trials. Infant EEG data was then analyzed for attention, face processing, and recognition memory ERP components (Nc, P400, and LSW respectively) while test trials included the face(s) shown during familiarization (familiar), novel faces from the same race used during familiarization (novel-same), and novel faces from a race not used during familiarization (novel-other, Asian faces). Ideally, recruitment would have yielded test groups of infants of many different races, but due to demographic limitations we were unable to recruit enough non-White participants. Data from these experiments shed light on how initial learning conditions and previous experience with faces influences infant individuation and

subordinate-level categorization of own- and other-race faces within the basic-level category of own-species faces.

CHAPTER II GENERAL METHODS

2.1 Participants

The final dataset included 48 10-month-old infants recruited from the Child Development Research Group participant database at the University of Tennessee, Knoxville. Participants were randomly assigned to one of the four experiments: Experiment 1, single exemplar, own-race (*N* = 11); Experiment 2, multiple exemplars, own-race (*N* =12); Experiment 3, single exemplar, other-race (*N* =13); and Experiment 4, multiple exemplars, other-race (*N* =12). Counter-balancing of the exemplar faces used during familiarization resulted in two versions of each experimental paradigm (A and B), and infants were equally split into A or B.

Infants had a mean age of 308.42 days (*SD* = 5.89, *range* = 298 - 320) at time of testing and included 44 Non-Hispanic White infants and 4 Hispanic White infants (24 females, 24 males). All infants recruited for this study were tested within three weeks of their 10-month (44 weeks, 304 days) birth date. Eligible infants included those who were born full-term (no less than 37 weeks gestation) without any major complications during pregnancy or birth, and who had no known visual difficulties or other developmental issues. Participants were recruited without regard to race, ethnicity, or gender, but it was expected that the majority of infants would be White due to the demographics of the local population. Therefore, the “own-race” group refers to using pictures of White actors as the familiar stimuli, and the “other-race” group uses pictures of Black actors as the stimuli. An additional 41 infants were tested but excluded due to fussiness (*N* = 10), not enough artifact free ERP trials (*N* = 25), or technical difficulties (*N* = 6). Additionally, 14 infants were excluded from this dataset due to identifying as a race other than Non-

Hispanic White or Hispanic White but are included in an ongoing dataset exploring how minority race infants process majority and minority race faces.

2.2 Apparatus

Testing took place in a sound-attenuated darkened room. Participants were positioned in their caregiver's lap approximately 55 centimeters away from a color monitor (27-inch Dell Gaming Monitor S2716DG). Black cloth curtains were drawn to surround the infant and caregiver to ensure attention was paid to the monitor and distractions were minimized. Infant attention to the screen was logged via a digital video recorder positioned directly above the monitor (AXIS P3364-LV Network Camera). During coding, infant looking to the screen was judged online using a video feed to the experiment control room during the study. The camera footage was recorded and synchronized with EEG data through NetStation 5.4.1.2 software (Electrical Geodesics Incorporated, EGI; Eugene, Oregon). E-Prime 2.0 software (Psychology Software Tools, Inc., Sharpsburg, PA) was used to display the experimental stimuli onscreen and to send experimental events to NetStation, which utilizes a NTP (Network Time Protocol) process to synchronize these stimulus events with the EEG and video data.

2.3 Visual Stimuli

Stimuli for this experiment were sourced from The Chicago Face Database, which is a digital collection of high-resolution full-color photographs of human faces of various races, genders, and ages expressing different emotions (Ma, Correll, & Wittenbrink, 2015). Stimuli for this study were chosen based on extensive norming data included with the database. Options were constrained to all women actors to avoid possible gender interaction effects on categorization of race (Tham, Bremner, & Hay,

2015; Tham, Woo, & Bremner, 2018). Neutral expressions were chosen to avoid any interaction effects with faces displaying a highly salient emotion (Quinn, Lee, & Pascalis, 2020b). Women displaying a neutral expression were selected by their rating of Suitability or how representative they are of their race/gender; however, this score is only available for select Black and White faces. Within each race, photos were narrowed down based on age to exclude very young or very old faces to avoid possible age interaction effects on categorization of race (Damon, Quinn, Heron-Delaney, Lee, & Pascalis, 2016). Finally, faces were chosen to be included in the final dataset based on what proportion of independent raters agreed the race of the face matched the self-identified race of the actor.

Once 60 faces were chosen (20 Asian, 20 Black, and 20 White faces), the images were run through a custom MATLAB script that cropped them to an oval shape (MATLAB R2018a version 9.4.0.813654. Natick, Massachusetts: The MathWorks Inc., 2018). Having the faces displayed as an oval reduces additional peripheral cues such as hairstyle and hair color. The resulting full-color ovals were presented against a white background in the center of the monitor (see Figure 1 for an example of both stimuli and procedure for each experiment). Although many studies on own-race bias have used grayscale images to reduce perceptual differences between faces, it has been found that infants do not discriminate races by color (Bar-Haim, Ziv, Lamy, & Hodes, 2006) and that grayscale versus full-color has no effect on whether the own-race bias manifests in adults (Ito & Urland, 2003). Therefore, to maintain ecological validity, stimuli were presented in full-color.

A dynamic non-social attention-getter was used between each face presentation during familiarization. A small colorful circle radiated centrally as a wind chime audio track played in the background. This attention-getter was used to ensure infants were centrally fixated during learning trials. During testing, Sesame Street audiovisual clips that do not feature human faces were used to redirect infants' attention if they became distracted or bored during the test trials.

2.4 Procedure

Procedure was the same for all four experiments. After informed consent was obtained, the infant's caregiver filled out a demographic survey. This survey was linked only with the participant's experimental ID number and asked family background and demographic information. Questions included asking the caregivers' occupation, level of education, and household income to determine socioeconomic status. There were also questions about the caregivers' self-reported race, the race of the infant, and race, age, gender, and relationship to the infant of any other people living with or interacting often with the infant. There was also a question about whether the infant attended a daycare or other group setting often. This was to collect data on the likelihood that the infant was often exposed to other-race faces that differed from their caregivers' race(s). However, for this study, the infant participants had experienced either nearly exclusive exposure to own-race individuals or were from an interracial family. Therefore, infants were first excluded based on self-reported race of immediate family, and none of the remaining infants were excluded based on answers to the group setting question (see Figures 11 and 12 in Appendix for survey questions).

After informed consent and the background survey, the infant was seated on their caregiver's lap approximately 55 centimeters away from the monitor. An appropriately sized EGI sensor net was fitted as a second experimenter distracted the infant with toys and infant-directed speech to reduce the chance of fussiness. The experimental procedure was modeled after the Dixon et al. (2019) paradigm. There were two phases of the experiment: familiarization (learning) trials and test trials. The first phase consisted of 20 repeated 1000 millisecond presentations of a single face for the single exemplar experiments, or 10 faces repeated twice each for a total of 20 presentations for the multiple exemplar experiments ("learning" trials). This resulted in 20 seconds total of familiarization time for all four conditions, which is based on previous studies showing this is adequate for infants to show a novelty preference (e.g., Courage & Howe, 2001; Richards, 1997; Rose, 1983; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). During familiarization, the attention-getter stimulus played between each face to ensure central fixation of the infant. Once the experimenter judged the infant to be centrally fixated, a button was pressed that centrally displayed a face image for 1000 milliseconds. A 200 millisecond blank white screen preceded each image to be used as a pre-stimulus ERP baseline. A blank white screen also followed each stimulus presentation and varied randomly in duration from 1000 to 1500 milliseconds.

Immediately after the 20 learning trials were complete, the test trials began. There were three stimulus types: depending on if it was a single or multiple exemplar experiment, the face or faces used during the familiarization phase (familiar), novel faces from the same race used during familiarization (novel-same), and novel Asian faces which were not used during any familiarization condition (novel-other). The

presentation of the three stimulus types (familiar, novel-same, and novel-other) were presented in pseudo-random order with equal probability of presentation across a block of trials. Images were presented in blocks of 30 stimulus presentations. Stimulus presentation continued as long as the infant did not become tired or fussy. Infants included in the dataset completed an average of 93 test trials of stimulus presentations.

2.5 EEG Recording and Analysis

EEG data was collected using the EGI Geodesic EEG System 400 (GES 400) 128-channel system. This system includes HydroCel Geodesic Sensor nets, NetAmps hardware, and NetStation software recording program. The nets include 124 electrodes mounted in a geodesic configuration of pedestals that are held in place with elastic connections. Electrolytic sponges are located within the pedestals and the entire net is soaked in a saline-based electrolytic solution for five minutes prior to capping the infant. The additional 4 channels included in the 128-channel system are available for EOG (electrooculogram) and/or ECG (electrocardiogram) recording, which were not used in this study. During capping, pedestals corresponding to the vertex, mastoids, and nasion locations were marked and used to position the sensor net on the infant's head in relation to the anatomical landmarks. The elasticity of the net connections maintains the correct position of the pedestals corresponding to the remaining 120 electrodes. The average interelectrode distance of the scalp electrodes is 21 millimeters.

When placed properly, electrode impedance of the net ranged from 10 to 50 kΩ. If impedance exceeded 100 kΩ during net placement, the electrodes were repositioned until an appropriate impedance was obtained. The EGI system uses high-impedance amplifiers connected to a computer A/D card in an iMac computer. The EGI system's

NetStation program performs the A/D sampling, stores calibrations for each channel, and stores impedance data. Communication between the two computers was temporally synchronized based on the sending of experimental information (e.g., trial type, trial onsets) from the experimental Dell computer to the NetStation program on the Mac using the E-Prime NTP. Bandpass filters were set from 0.10 to 30.00 Hz with 20k amplification and a sampling rate of 1000 Hz.

Once EEG data was collected, the recordings were inspected for artifacts (e.g. blinks, movement, saccades, drift, distraction) and poor recordings using the NetStation Review system. Artifacts were defined as Δ>250 μV/250 milliseconds within a single ERP segment and NetStation's Artifact Detection tool was used to mark trials bad if artifacts were found. Segments in which more than 10% of the channels were marked bad were excluded from analysis. For those that had less than 10% of the channels marked bad, bad channels were replaced using a spherical spline interpolation (Perrin, Pernier, Bertrand, & Echallier, 1989; Srinivasan, Tucker, & Murias, 1998). Following EEG editing, only participants who contributed 7 or more ERP trials per condition for stable ERP averages were included for analysis (Carver & Vaccaro, 2007; de Haan & Nelson, 1997; Hoehl & Wahl, 2012; Reynolds & Richards, 2019).

For the ERP analysis, grand average waveforms were used to make waveform plots and for analyses of experimental effects. Electrode location for each ERP component was based on previous findings (i.e., Nc component: Guy, Zieber, & Richards, 2016; Reynolds, Courage, & Richards, 2010; Reynolds & Richards, 2005, 2009; Richards, 2003; P400 component: de Haan, 2007, 2013; de Haan & Nelson, 1997; de Haan, Pascalis, & Johnson, 2002; Quinn, Doran, Reiss, & Hoffman, 2010; Xie,

McCormick, Westerlund, Bowman, & Nelson, 2018; LSW component: de Haan & Nelson, 1999; Guy, Reynolds, & Zhang, 2013; Nelson & Collins, 1991, 1992; Reynolds & Richards, 2019; Snyder, Garza, Zolot, & Kresse, 2010; Snyder, Webb, & Nelson, 2002; Webb, Long, & Nelson, 2005; Wiebe, Cheatham, Lukowski, Haight, Muehleck, & Bauer, 2006). Additionally, a visual inspection of each of the four experiment's grand average waveforms was used to determine at which specific electrode locations the component was most prominent (DeBoer, Scott, & Nelson, 2007). ERP averages were segmented from 200 milliseconds before stimulus onset to 1500 milliseconds after onset. Nc mean amplitude was analyzed from 345 to 600 milliseconds following stimulus onset. The Nc component was analyzed at frontal-central electrode locations ("Frontal Z" or "Fz", 5, 6, 12, 13, and 112). P400 mean amplitude was analyzed from 350 to 750 milliseconds following stimulus onset. The P400 component was analyzed at midline occipital electrodes ("Oz", 70, 74, 75, 82, and 83). The LSW mean amplitude was analyzed from 800 to 1500 milliseconds following stimulus onset. The LSW was also analyzed at frontal-central electrode locations ("Fz", 5, 6, 12, 13, and 112).

2.6 Design for Statistical Analysis

For each experiment, planned comparisons were carried out for hypothesis testing on each of the ERP components of interest (Nc, P400, LSW) using paired-samples t-tests (two-tailed) between stimulus types (familiar, novel-same, novel-other). If no significant differences were found between familiar and novel-same amplitudes, those trial averages were collapsed together for an average of the familiarized race category, which was then compared to the novel race category (novel-other) in a paired samples t-test. All significant tests are reported based on an alpha level of $p < .05$.

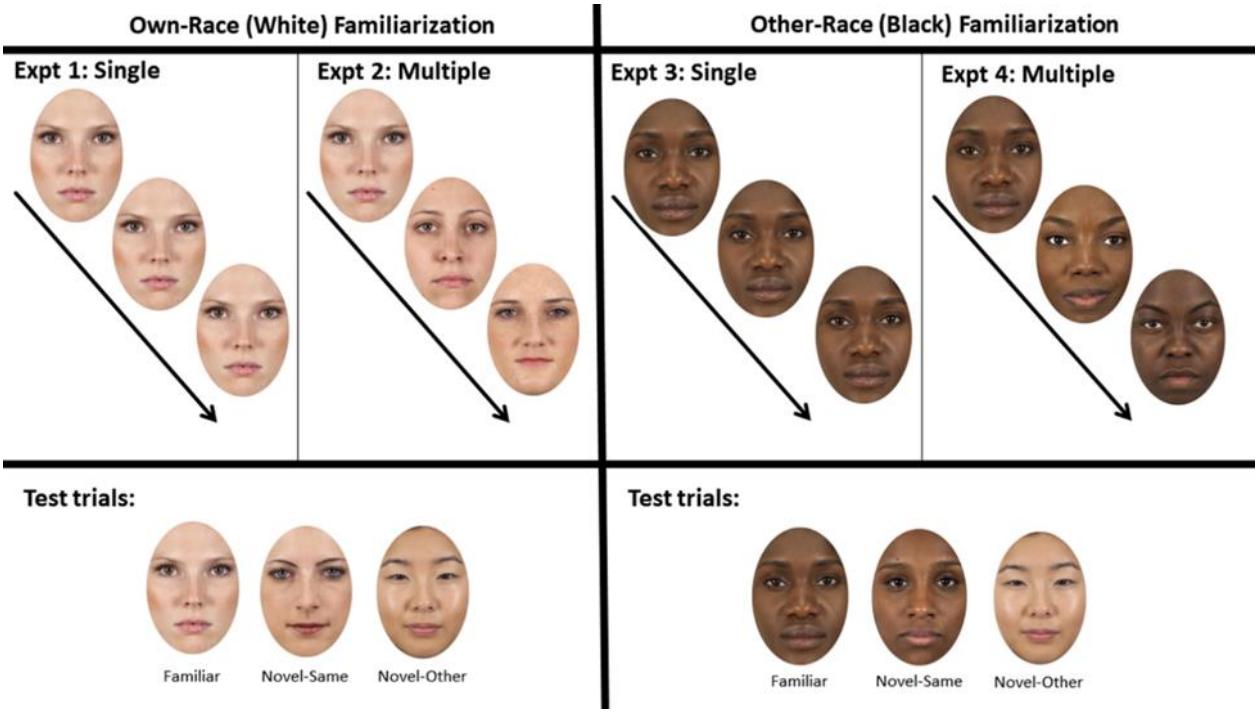

Figure 1. Sample stimuli and procedure for each experiment.

CHAPTER III EXPERIMENTS

3.1 Experiment 1 – Single Exemplar Own-Race Familiarization

The first experiment sought to test infants' ability to categorize by race if they were exposed to a procedure intended to facilitate individuation. The familiarization trials were simply a repeated singular own-race face shown 20 times. By 10 months, infants raised in racially homogenous homes have had extensive own-race experience. This enables them to form dichotomous own-race and other-race categories, allowing them to discriminate own-race faces from other-race faces and identify own-race individuals (Kelly et al., 2007; Kelly et al., 2009; Markant, Oakes, & Amso, 2016; Quinn, Lee, Pascalis, & Tanaka, 2016). In Dixon et al. (2019), infants in the same individuation procedure, shown a singular other-species face 20 times, failed to discriminate at either the individual or the species level during test trials. This may be related to perceptual narrowing and infants' focus on individuating own-species faces but categorizing other-species faces at this age (Dixon et al., 2019). As infants have had heavy exposure to and presumably begun to develop expertise in processing faces of their own-race, it was predicted infants would individuate the familiar face and differentiate between the familiarized and novel race during test trials. If infants individuated the singular own-race face used during familiarization, it was predicted they would recognize the familiar (singular White) face as distinct from both the novel-same (novel White) and novel-other (Asian) faces during test trials, and would discriminate between the two races at a categorical level: differentiating between novel-other (Asian) faces and the familiarized race faces (familiar and novel-same).

See Table 1 for a summary of ERP predictions. At the level of ERP components, if infants individuated the familiar face, it was predicted they would show a greater Nc amplitude (i.e., greater attention) to novel-same (White) faces as they are more novel compared to the familiar trials (singular White face). It was also predicted that infants would show greater Nc amplitude to novel-other (Asian) faces in comparison to the familiar and novel-same (White) faces as they recognized the novelty of an unfamiliar race. For the P400 associated with face processing and subordinate-level category detection, it was predicted infants would show differential P400 amplitude to novel-other (Asian) faces in comparison to novel-same (White) faces and the familiar (White) face, indicating they recognized a novel race category. Similarly for the LSW component associated with recognition memory, it was predicted infants would show significant differences in amplitude LSW amplitude to novel-other (Asian) faces compared to familiar and novel-same (White) faces, which would indicate infants recognized the novel own-race exemplars during test trials as belonging to the familiarized category of own-race faces. It was predicted infants would also show differential LSW amplitude to the familiar face compared to the novel-same (novel White faces), suggesting the infants did individuate the singular White face used during familiarization due to their greater expertise in processing own-race faces (de Haan & Nelson, 1999; Guy, Reynolds, Mosteller, & Dixon, 2017; Guy, Reynolds, & Zhang, 2013; Nelson & Collins, 1991, 1992; Quinn, Doran, Reiss, & Hoffman, 2010; Reynolds, Guy, & Zhang, 2011; Snyder, Garza, Zolot, & Kresse, 2010; Snyder, Webb, & Nelson, 2002; Webb, Long, & Nelson, 2005; Wiebe, Cheatham, Lukowski, Haight, Muehleck, & Bauer, 2006).

3.1.1 Method

A total of 11 infants were included for analysis in this experiment (10 Non-Hispanic White, 1 Hispanic White). Counter-balancing of the exemplar faces used during familiarization resulted in two versions of each experimental paradigm (A and B), with 6 infants viewing version A and 5 infants viewing version B. Infants in this experiment were familiarized with a single own-race (White) face that was shown a total of 20 trials. Test trials consisted of repeated presentations of the same face used during familiarization (familiar), novel White faces (novel-same), and novel Asian faces (novel-other). See Figure 1 for a schematic of the procedure.

3.1.2 Results

See Figure 2 for the Nc waveform and Table 2 for a summary of ERP results. For the Nc component, infants showed greater Nc amplitude when viewing novel-other trials (M = -8.125, SE = 2.261) in comparison to familiar trials (M = -4.256, SE = 2.261) that approached significance, $t(10) = 2.136$, $p = .058$. Significantly greater Nc amplitude was found for novel-other trials in comparison to novel-same trials (M = -2.818, SE = 2.376), $t(10) = -2.498$, $p = .032$. Familiar trials and novel-same trials were not significantly different in amplitude, $t(10) = -0.490$, $p = .635$. Since results showed familiar and novel-same trials were not significantly different, these two familiar race conditions (i.e., familiar, novel-same) were collapsed together to allow for a comparison by race. Results showed significantly greater Nc amplitude, $t(10) = 3.475$, $p = .006$, in response to the novel race category (M = -8.125, SE = 2.261) compared to the familiar race category (M = -3.537, SE = 2.016).

See Figure 3 for the P400 waveform. For the P400 component, no differences were found between familiar trials (M = 14.608, SE = 3.947) in comparison to novel-same trials (M = 11.233, SE = 5.067), $t(10) = 0.681$, p = .511, or novel-other trials (M = 20.477, SE = 4.824), $t(10) = -1.156$, p = .274. Novel-same trials and novel-other trials were not significantly different from each other, $t(10) = 1.277$, p = .230. As familiar and novel-same trials were not significantly different, they were collapsed together to allow for a comparison by race. Results showed no P400 amplitude differences, $t(10) = -1.317$, p = .217, between the response to the novel race category (M = 20.477, SE = 4.824) compared to the familiar race category (M = 12.920, SE = 3.805).

See Figure 2 for the LSW waveform. For the LSW component, no differences were found between familiar trials (M = 5.235, SE = 3.485) and novel-same trials (M = 8.899, SE = 2.797), $t(10) = -0.802$, p = .441, or familiar trials and novel-other trials (M = -0.816, SE = 2.718), $t(10) = 1.665$, p = .127. There was a significant difference in amplitude between novel-same trials and novel-other trials, $t(10) = -2.360$, p = .040. Since results showed familiar and novel-same trials were not significantly different, the average amplitude for both familiar race conditions were collapsed together and compared to novel-other to compare infants' responses to the familiar race category to the novel race category. Results showed the familiar race category had significantly greater LSW amplitude (M = 7.067, SE = 2.182) compared to the novel race category (M = -0.816, SE = 2.718), $t(10) = 2.512$, p = .031.

3.1.3 Discussion

In line with predictions, significant comparisons for the Nc and LSW components, which are used as markers for attentional engagement and recognition memory

respectively, indicate that the infants familiarized to a single own-race (White) face were able to differentiate between the familiarized race (White) and the novel race (Asian) faces during test trials. The familiar (single White face) and novel-same (White) faces were not significantly different in both the Nc and LSW component, suggesting the infants processed the faces at a categorical, not individual, level and did not individuate the singular Familiar face. Infants did not show a LSW amplitude difference between familiar (single White face) and novel-other (Asian) trials, but infants did show a significant difference in amplitude at the category of race, after the familiarized race was collapsed across trial types and compared to the novel race trials. A LSW amplitude difference was predicted to occur if they were processing at a categorical level, as the familiar White face would have a different level of familiarity compared to the novel-other Asian faces. The Nc and LSW results point to the infants categorizing by race, but not individuating the familiar single face. Interestingly, there were no significant effects found for the P400 component, which was used as a novel subordinate-level category marker. While it was predicted that the P400 amplitude would not differ between familiar and novel-same (White) faces because both trial types belong to the same subordinate-level category of race, there was also not a P400 difference between novel-other (Asian) faces and the familiarized race (White: familiar and novel-same) trials.

Overall, these findings indicate that infants familiarized with a single own-race face were able to differentiate at the subordinate-level category of race between novel own-race and novel other-race faces but did not individuate the singular face used during familiarization. Since infants at this age should be able to individuate an own-race face if shown 20 times, it is possible they were focused on individuating but were

unable to finish encoding. The largest Nc amplitude to novel-other faces indicates greatest attention to the novel race, but the second largest Nc amplitude to the familiar face and the marginally significant differences between the familiar face and the novel-other faces, as well as the lack of LSW differences between familiar and novel-other trials, all provide evidence for partial encoding of the singular familiar face (de Haan & Nelson, 1999; Nelson & Collins, 1991). This potential partial recognition resulted in the infants differentiating between the familiar and novel *race* during test trials, but not recognizing the familiar *individual.*

It is possible that during familiarization, infants began to individuate the repeated face. However, due to the brief exposure common to ERP paradigms, the 20 trials may not have been sufficient for the infants to complete individuation of the familiar face. Other studies on the other-race effect either let the infants scan the faces until they lose interest, or use 20 to 30 second long continuous presentations of the faces (e.g., Anzures et al., 2010; Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007; Krasotkina, Götz, Höhle, Schwarzer, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016). Therefore, it is possible that when infants were viewing the 1 second test trials, they were able to recognize the familiar *race* after 20 trials, but not necessarily the familiar *individual*, as they were still encoding the face. This would potentially explain why infants had the greatest Nc amplitude to the novel-other faces but trending significant Nc differences between familiar and novel-other. Infants who are attempting to process a stimulus, but who are interrupted during habituation before encoding is complete, will continue to show a visual preference for the familiar stimulus over novel stimuli (Hunter, Ames, & Koopman, 1983; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982).

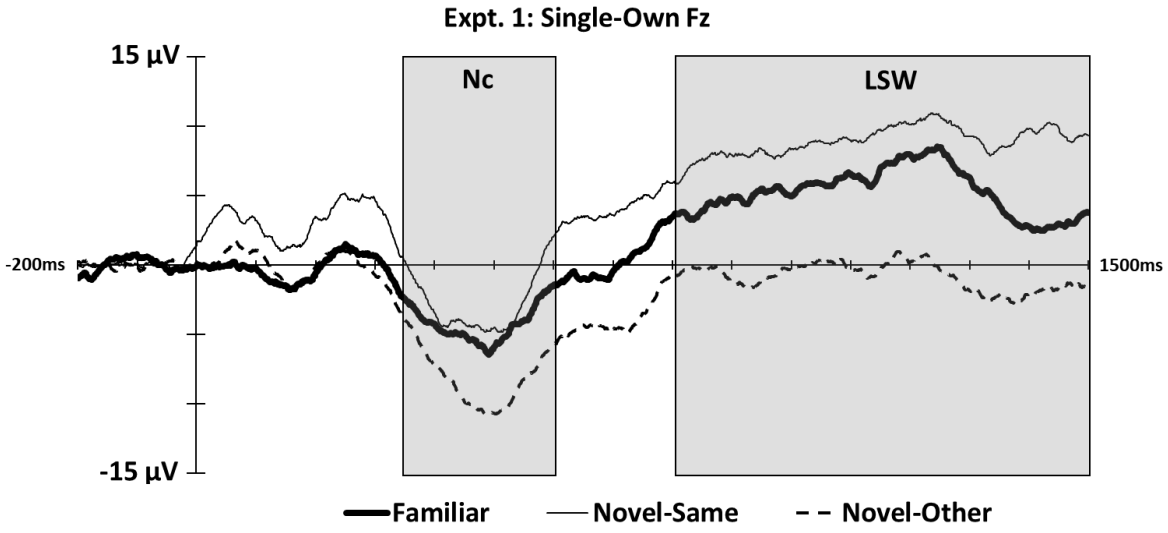

Figure 2. Expt. 1: Single-Own Nc and LSW components by stimulus type at frontal-central electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

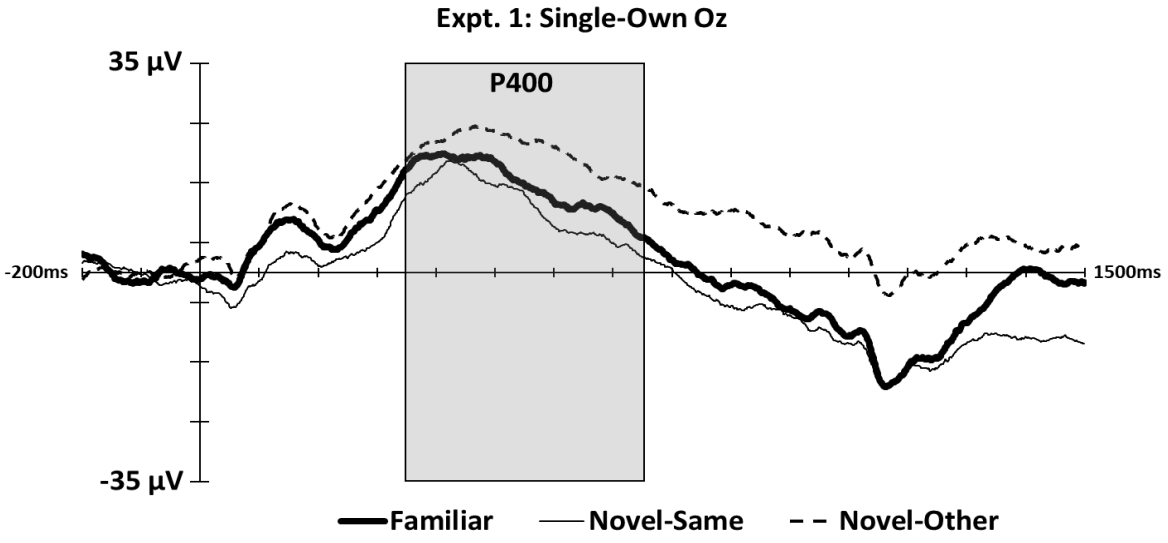

Figure 3. Expt. 1: Single-Own P400 component by stimulus type at midline occipital electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

3.2 Experiment 2 – Multiple Exemplar Own-Race Familiarization

Given previous findings on the use of multiple exemplars to facilitate categorization, this experiment's learning condition used multiple exemplars of own-race faces to promote infants' ability to differentiate by race (Casasola & Park, 2013; Dixon et al., 2019; Oakes, Kovack-Lesh, & Horst, 2009; Oakes & Ribar, 2005; Vukatana, 2017; Vukatana, Graham, Curtin, & Zepeda, 2015). Similar to Experiment 1, it was predicted infants would recognize, at a categorical level, the familiar own-race (White) faces used in familiarization and the novel-same faces (novel White faces) shown during test trials as both belonging to the familiarized race. Infants would also recognize the difference between own-race faces (both familiar and novel-same) and the novel-other (Asian) faces at a categorical level due to their expertise with own-race faces (Kelly et al., 2007; Kelly et al., 2009; Markant, Oakes, & Amso, 2016; Quinn, Lee, Pascalis, & Tanaka, 2016). It was also predicted infants would not show individuation of any of the faces from the familiar condition as the familiarization phase involved exposure to 10 faces shown twice each, which would not provide enough exposure to fully process any of the ten faces at the individual-level (Anzures et al., 2010; Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007; Krasotkina, Götz, Höhle, Schwarzer, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016).

See Table 1 for a summary of ERP predictions. At the level of ERP components, it was predicted that infants would recognize the novel race category and show greater Nc amplitude (i.e., greater attention) to novel-other (Asian) faces in comparison to the familiar and novel-same (White) faces. It was also predicted infants would show differential P400 amplitude, associated with face processing and subordinate-level

category detection, to novel-other (Asian) faces in comparison to novel-same (White) faces and familiar (White) faces, signaling they identified a novel race category. It was further predicted that infants would show differential LSW amplitude, associated with recognition memory, to novel-other (Asian) faces in comparison to novel-same and familiar faces (White), suggesting they were familiarized to the own-race (White faces) category and recognized the novel-other (Asian) faces as separate from the familiar category (de Haan & Nelson, 1999; Guy, Reynolds, Mosteller, & Dixon, 2017; Guy, Reynolds, & Zhang, 2013; Nelson & Collins, 1991, 1992; Quinn, Doran, Reiss, & Hoffman, 2010; Reynolds, Guy, & Zhang, 2011; Snyder, Garza, Zolot, & Kresse, 2010; Snyder, Webb, & Nelson, 2002; Webb, Long, & Nelson, 2005; Wiebe, Cheatham, Lukowski, Haight, Muehleck, & Bauer, 2006).

3.2.1 Method

A total of 12 infants were included for analysis in this experiment (9 Non-Hispanic White, 3 Hispanic White). Counter-balancing of the exemplar faces used during familiarization resulted in two versions of each experimental paradigm (A and B), with 6 infants viewing version A and 6 infants viewing version B. Infants in this experiment were familiarized with 10 own-race (White) faces that were repeated twice for a total of 20 trials. Test trials consisted of the same 10 faces used during familiarization (familiar), novel White faces (novel-same), and novel Asian faces (novel-other). See Figure 1 for an example.

3.2.2 Results

See Figure 4 for the Nc waveform and Table 2 for a summary of ERP results. For the Nc component, there were no differences between familiar trials (*M* = -3.943, *SE* =

2.375) and novel-same trials (*M* = -7.355, *SE* = 2.794), *t*(11) = 1.474, *p* = .168, or familiar trials and novel-other trials (*M* = -2.917, *SE* = 1.565), *t*(11) = -0.409, *p* = .691. There was trending significance for amplitude differences between novel-same trials and novel-other trials, *t*(11) = -2.011, *p* = .070. Since results showed familiar and novel-same trials were not significantly different, these two familiar race conditions (i.e., familiar, novel-same) were collapsed together to allow for a comparison by race. Results showed no differences in Nc amplitude, *t*(11) = -1.326, *p* = .212, in response to the novel race category (*M* = -2.917, *SE* = 1.565) compared to the familiar race category (*M* = -5.649, *SE* = 2.321).

See Figure 5 for the P400 waveform. For the P400 component, there were no significant amplitude differences. Familiar trials (*M* = 18.133, *SE* = 4.082) were not significantly different than novel-same trials (*M* = 22.274, *SE* = 2.787), *t*(11) = -1.021, *p* = .329, or novel-other trials (*M* = 16.680, *SE* = 4.874), *t*(11) = 0.347, *p* = .735. Novel-same trials and novel-other trials were not significantly different from each other, *t*(11) = -1.287, *p* = .225. As familiar and novel-same trials were not significantly different, they were collapsed together to allow for a comparison by race. Results showed no P400 amplitude differences, *t*(11) = 0.938, *p* = .368, between the response to the novel race category (*M* = 16.680, *SE* = 4.874) compared to the familiar race category (*M* = 20.204, *SE* = 2.846).

See Figure 4 for the LSW waveform. For the LSW component, there were no significant amplitude differences. Familiar trials (*M* = 5.426, *SE* = 3.763) were not significantly different than novel-same trials (*M* = 2.489, *SE* = 4.131), *t*(11) = 0.751, *p* = .469, or novel-other trials (*M* = 5.533, *SE* = 3.047), *t*(11) = -0.021, *p* = .984. Novel-same

trials and novel-other trials were not significantly different from each other, $t(11) = 0.720$, $p = .487$. Since results showed familiar and novel-same trials were not significantly different, these two familiar race conditions (i.e., familiar, novel-same) were collapsed together to allow for a comparison by race. Results showed no differences in LSW amplitude, $t(11) = -0.367$, $p = .721$, in response to the novel race category ($M = 5.533$, $SE = 3.047$) compared to the familiar race category ($M = 3.958$, $SE = 3.434$).

3.2.3 Discussion

Against predictions, the waveform data does not support the hypothesis that infants would be able to categorize at the subordinate-level between own-race (White) and other-race (Asian) faces if shown multiple exemplars of own-race faces during familiarization. These findings are in stark contrast to Dixon et al. (2019), in which exposure to multiple exemplars facilitated infants' categorization of two different monkey species. Using the same procedure with human faces did not facilitate categorization based on race. It is possible that these contrasting findings are due to differences in processing strategy for own- and other-species. Regardless of race, 10-month-old infants may be focused on processing own-species faces at the individual, not categorical, level. Infants in the current experiment may not have shown evidence of subordinate-level categorization because the multiple exemplars familiarization procedure, designed to induce categorization, was at odds with their tendency to individuate human faces. This could also explain why the same multiple exemplar procedure led to subordinate-level categorization of other-species monkey faces (Dixon et al., 2019), as infants are primed to categorize non-native faces at this age.

Eleven-month-old infants visually attend to other-species, other-race, and own-race faces differently, which may imply they are using different processing strategies (Keenan & Markant, 2020). The categorization-individuation model proposes that infants begin to categorize non-native stimuli as perceptual narrowing develops, with a focus on individuating native stimuli to help further develop expertise (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018). Interpreting these data within the categorization-individuation model, infants in this study may still be individuating own-species faces but have begun utilizing different processing strategies for other-species (Scott & Fava, 2013). It is likely that if the infants in the current experiment were focused on individuating own-species faces, they were unable to fully individuate any single face due to the rapid presentation of multiple faces. This failure to individuate may explain the null results. In contrast, infants in the Dixon et al. (2019) study may have been focused on categorizing the other-species faces and benefited from multiple exemplars during familiarization.

In summary, showing multiple exemplars of own-race (White) faces during familiarization did not facilitate infants subordinate-level categorization based on race, and infants did not show evidence of individuating. This is intriguing as a previous study has shown the same paradigm facilitated subordinate-level categorization by species for infants in the same age range (Dixon et al., 2019). The lack of significant findings in the current experiment may have been due to infants attempting to individuate the own-species faces shown during familiarization. However, they were unable to fully process at the individual level due to the rapid presentation of multiple faces and minimal exposure to each individual during familiarization (Peykarjou, Pauen, & Hoehl, 2014).

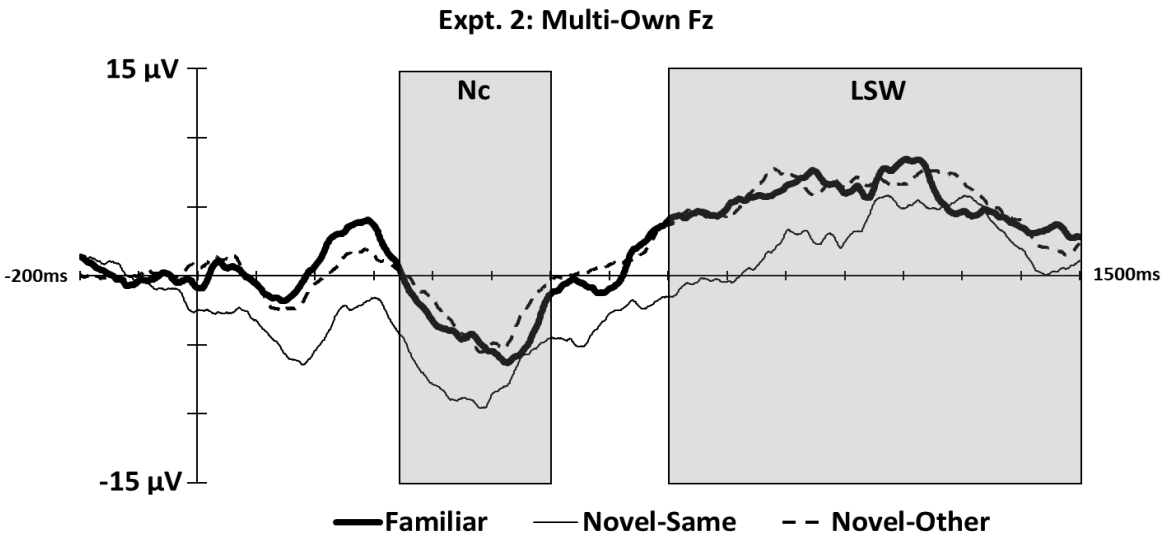

Figure 4. Expt. 2: Multi-Own Nc and LSW components by stimulus type at frontal-central electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

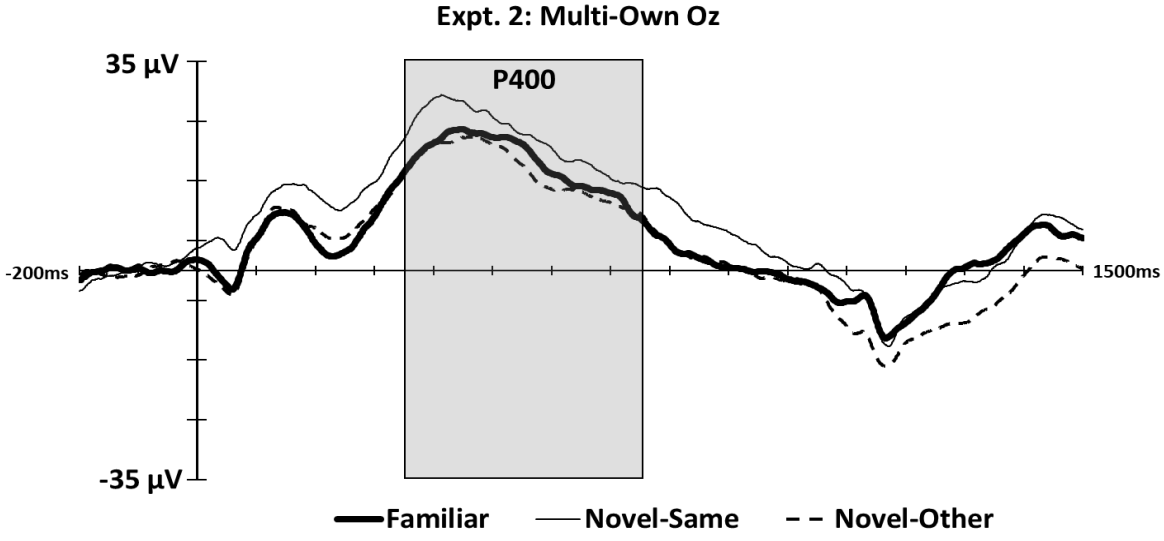

Figure 5. Expt. 2: Multi-Own P400 component by stimulus type at midline occipital electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

3.3 Experiment 3 – Single Exemplar Other-Race Familiarization

While Experiments 1 and 2 explored the effects of different learning conditions on 10-month-olds infants' individuation and subordinate-level categorization using own-race exemplars, Experiments 3 and 4 used other-race exemplars in the same learning conditions. Because previous findings indicate 9-month-old infants process other-species faces at the subordinate-level when shown multiple exemplars during initial exposure, but they fail to do so if only shown a single exemplar during initial exposure (Dixon et al., 2019), it was predicted infants in the other-race familiarization conditions would show differential results depending on if they were familiarized to a single exemplar or multiple exemplars. In Experiment 3, infants were familiarized with a single other-race face, designed to induce individuation, to investigate if infants could differentiate between two other-race categories during test trials. Literature suggests infants at this age are unable to individuate an other-race face without training or cueing, and infants no longer differentiate between two other-races (Kelly et al., 2007; Kelly et al., 2009; Quinn, Lee, Pascalis, & Tanaka, 2016; Sugden & Marquis, 2017). It was predicted infants who were familiarized to a single exemplar would fail to show subordinate-level categorization based on race during test trials, meaning they would not differentiate familiar and novel-same race (Black) faces from novel-other race (Asian) faces. It was also predicted infants would not individuate the single Familiar other-race face and would fail to recognize the individual during test trials, as past findings indicate that by 9 months of age infants no longer individuate other-race faces (e.g., Kelly et al., 2007; Kelly et al., 2009).

See Table 1 for a summary of ERP predictions. At the level of ERP components, for infants familiarized with a single other-race exemplar, it was predicted there would be no significant differences in Nc, P400, or LSW amplitude across all stimulus categories, indicating a failure to either individuate or categorize other-race faces at the subordinate-level.

3.3.1 Method

A total of 13 infants were included for analysis in this experiment. Counter-balancing of the exemplar faces used during familiarization resulted in two versions of each experimental paradigm (A and B), with 7 infants viewing version A and 6 infants viewing version B. Infants in this experiment were familiarized with a single other-race (Black) face that was shown a total of 20 trials. Test trials consisted of the same face used during familiarization (familiar), novel Black faces (novel-same), and novel Asian faces (novel-other). See Figure 1 for an example.

3.3.2 Results

See Figure 6 for the Nc waveform and Table 2 for a summary of ERP results. For the Nc component, infants showed significantly greater amplitude to familiar trials (M = -10.805, SE = 2.424) compared to novel-other trials (M = -2.813, SE = 2.484), $t(12) = -4.395$, $p = .001$. Infants also showed significant amplitude differences when viewing novel-other trials compared to novel-same trials (M = -10.100, SE = 2.276), $t(12) = 2.470$, $p = .030$. Familiar and novel-same trials were not significantly different in amplitude, $t(12) = -0.292$, $p = .775$. Since results showed familiar and novel-same trials were not significantly different, an average of the amplitude for both trial types was compared to novel-other to compare the familiar race category to the novel race

category. Results showed the familiar race category had significantly greater Nc amplitude (*M* = -10.452, *SE* = 2.017) compared to the novel race category (*M* = -2.813, *SE* = 2.484), *t*(12) = -3.583, *p* = .004.

See Figure 7 for the P400 waveform. For the P400 component, familiar trials (*M* = 25.833, *SE* = 3.21) were not significantly different than novel-same trials (*M* = 23.862, *SE* = 3.027), *t*(12) = 0.498, *p* = .627. There was trending significance for amplitude differences between familiar trials and novel-other trials (*M* = 18.368, *SE* = 4.233), *t*(12) = 1.919, *p* = .079. Novel-same trials and novel-other trials were not significantly different from each other, *t*(12) = -1.224, *p* = .245. As familiar and novel-same trials were not significantly different, they were collapsed together to allow for a comparison by race. Results showed no P400 amplitude differences, *t*(12) = 1.748, *p* = .106, between the response to the novel race category (*M* = 18.368, SE = 4.233) compared to the familiar race category (*M* = 24.848, SE = 2.416).

See Figure 6 for the LSW waveform. For the LSW component, there was a significant difference between familiar trials (*M* = 0.241, *SE* = 2.074) and novel-other trials (*M* = 7.437, *SE* = 3.135), *t*(12) = -2.903, *p* = .013. There was no significant difference between familiar trials and novel-same trials (*M* = 0.191, *SE* = 1.500), *t*(12) = 0.019, *p* = .985. There was a significant difference between novel-same trials and novel-other trials, *t*(12) = 2.254, *p* = .044. Since results showed familiar and novel-same trials were not significantly different, an average of the amplitude for both trial types was compared to novel-other to compare the familiar race category to the novel race category. Results showed the familiar race category had significantly lower LSW

amplitude (*M* = 0.216, *SE* = 1.226) compared to the novel race category (*M* = 7.437, *SE* = 3.135), *t*(12) = -2.839, *p* = .015.

3.3.3 Discussion

Surprisingly, waveform data for the Nc and LSW components support the notion that infants familiarized with a single other-race (Black) face were able to categorize at the subordinate-level between two other-race faces (Black and Asian). Additionally, infants seemed to process both the familiar (Black) face and the novel-same (Black) face as belonging to the same category, a category that excludes the novel-other (Asian) faces. Similar to Experiment 1, the P400 results, which were used as a marker of novel subordinate-level category detection, did not show statistical significance but do show visual differences in amplitude between the novel-other (Asian faces) trials and the two other trial types (Black faces). As the statistical comparison showed marginal differences between familiar and novel-other, it is possible that with a larger dataset and increased power significant differences may have emerged.

Following familiarization with a single other-race (Black) face, infants showed evidence of subordinate-level categorization of other-race faces (Black and Asian). These findings are inconsistent with previous literature suggesting 10-month-old infants combine other-race faces into a single category due to the own-race bias (Quinn, Lee, Pascalis, & Tanaka, 2016). What the current findings may instead reflect is an own-species processing strategy. While infants in Dixon et al. (2019) failed to demonstrate either individuation or categorization when shown a single exemplar of a monkey species, this may be because infants at this age have shifted their processing strategy from individuation to categorization for other-species faces (Dixon et al., 2019; Scott &

Fava, 2013). This would be in line with the categorization-individuation model, which suggests infants continue to individuate native stimuli but switch to categorizing non-native stimuli with age (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018). Thus, exposure to a single exemplar of a monkey species did not facilitate the other-species categorization processing strategy in Dixon and colleagues' study (Dixon et al., 2019). In contrast, this study used own-species faces. Because infants may be focused on individuation of own-species, the single exemplar condition facilitated encoding the familiar face, resulting in infants differentiating between the two other-races during test trials.

However, infants may not have had sufficient exposure to finish individuating. This incomplete individuation may have allowed infants to recognize the familiar *race* component, but not the familiar *individual*, meaning infants were able to discriminate faces during test trials at the categorical, but not the individual, level. Evidence of this partial encoding can be seen in the greater Nc amplitude to the familiarized race trials (familiar, novel-same) in comparison to the novel race trials (novel-other). Infants show a preference for familiarity over novelty if they have not had sufficient time to process a stimulus, presumedly to finish encoding (Colombo, Mitchell, & Horowitz, 1988; Fagan, 1974; Freeseman, Colombo, & Coldren, 1993; Hunter & Ames, 1988; Reynolds, 2015; Richards, 1997; Rose et al., 1982; Simpson, Jakobsen, Fragaszy, Okada, & Frick, 2014). The greater Nc amplitude, a marker of attentional engagement, to familiar and novel-same trials compared to novel-other trials may imply the infants are showing a *familiarity* preference for the partially encoded Black faces during test trials, instead of a *novelty* preference for the completely novel Asian faces.

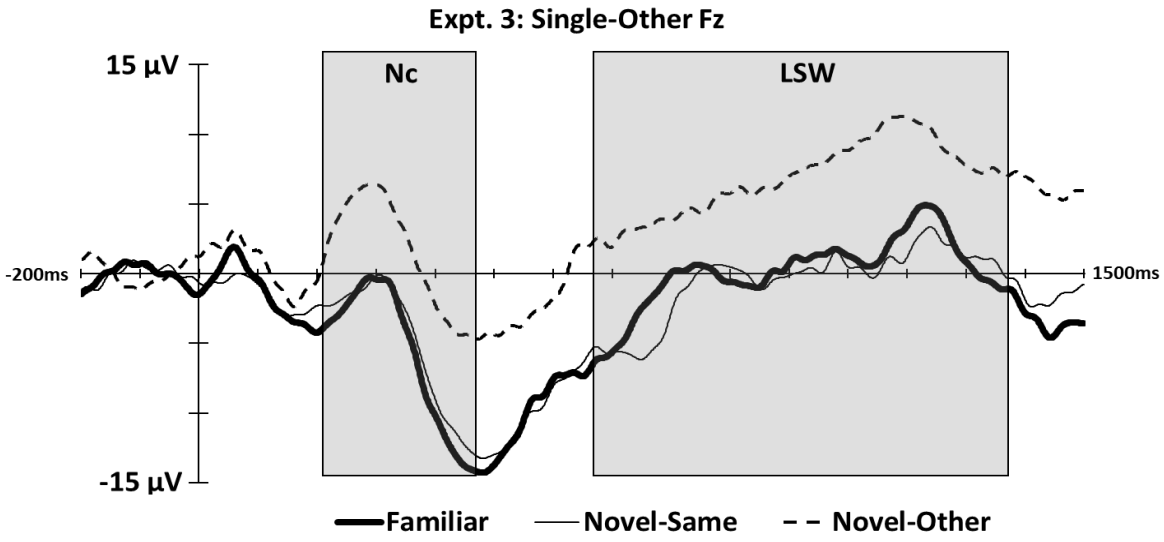

Figure 6. Expt. 3: Single-Other Nc and LSW components by stimulus type at frontal-central electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

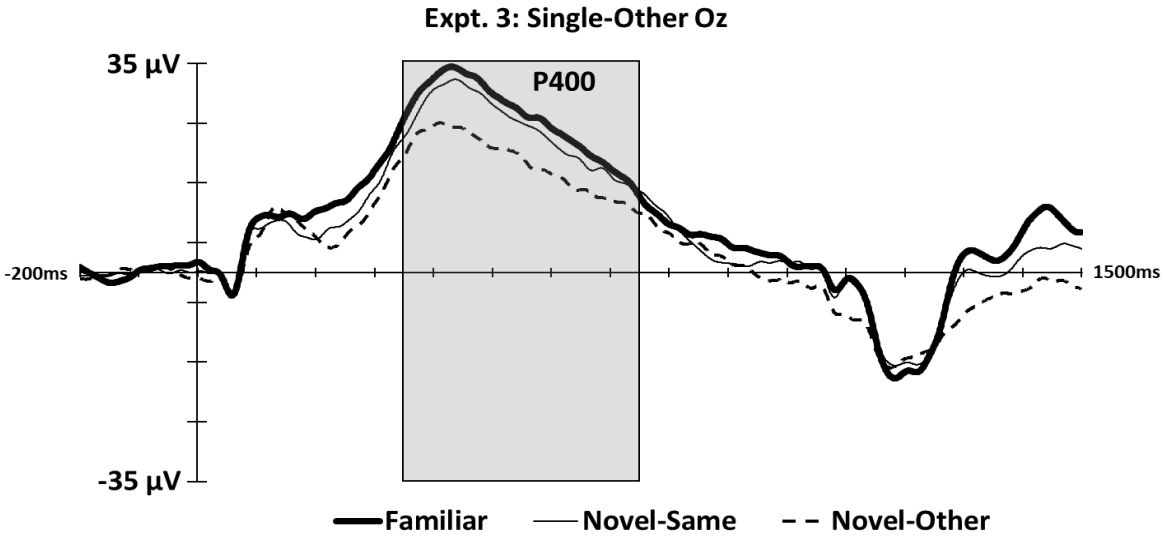

Figure 7. Expt. 3: Single-Other P400 component by stimulus type at midline occipital electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

3.4 Experiment 4 – Multiple Exemplar Other-Race Familiarization

This experiment was designed to test if multiple exemplars of other-race faces would facilitate infants' ability to differentiate between two-other races. Behavioral evidence suggests infants at this age combine all other-race individuals into a category that excludes own-race (Quinn, Lee, Pascalis, & Tanaka, 2016). Previous findings show exposure to multiple exemplars during learning facilitates subordinate-level categorization of other-species (Dixon et al., 2019; Quinn, Doran, Reiss, & Hoffman, 2010; Vukatana, 2017). The same learning conditions may support infants' ability to form subordinate-level categories within own-species faces. It was predicted familiarization with multiple exemplars would facilitate subordinate-level categorization of other-race faces for 10-month-old infants. While infants this age do not discriminate other-race individuals, some experimental conditions can overcome the own-race bias (Markant, Oakes, & Amso, 2016; Minar & Lewkowicz, 2018; Quinn, Lee, & Pascalis, 2020b). Exposure to multiple exemplars of Black individuals may facilitate White infants' ability to differentiate between Black and Asian faces at the subordinate-level of race.

See Table 1 for a summary of ERP predictions. It was predicted infants would show greater Nc amplitude to novel-other (Asian) faces compared to familiar and novel-same (Black) faces, indicating greater levels of attention toward the completely novel race (de Haan, 2013; de Haan, Johnson, & Halit, 2003; Grossmann, Gliga, Johnson, & Mareschal, 2009; Quinn, Doran, Reiss, & Hoffman, 2010; Quinn, Westerlund, & Nelson, 2006; Reynolds, Courage, & Richards, 2010; Reynolds & Richards, 2005, 2009, 2019; Richards, 2003; Webb, Long, & Nelson, 2005). Likewise, it was predicted infants would show differential P400 amplitude to the novel-other (Asian) faces compared to the

familiar and novel-same (Black) faces, indicating infants categorized Black and Asian faces separately (de Haan, Johnson, & Halit, 2003; Dixon et al, 2019; Quinn, Doran, Reiss, & Hoffman, 2010; Vogel, Monesson, & Scott, 2012). It was predicted infants would show differential LSW amplitude to novel-other (Asian) faces compared to familiar and novel-same (Black) faces. This would indicate infants were responding to novel-other (Asian) faces as a novel subordinate-level race category. Additionally, it was predicted no LSW amplitude differences between novel-same (Black) faces and familiar (Black) faces would indicate infants combined novel and familiar Black faces into the same subordinate-level category (de Haan & Nelson, 1999; Nelson & Collins, 1991, 1992; Quinn, Doran, Reiss, & Hoffman, 2010; Reynolds, Guy, & Zhang, 2011; Snyder, Garza, Zolot, & Kresse, 2010; Snyder, Webb, & Nelson, 2002; Webb, Long, & Nelson, 2005; Wiebe, Cheatham, Lukowski, Haight, Muehleck, & Bauer, 2006).

3.4.1 Method

A total of 12 infants were included for analysis in this experiment. Counter-balancing of the exemplar faces used during familiarization resulted in two versions of each experimental paradigm (A and B), with 6 infants viewing version A and 6 infants viewing version B. Infants in this experiment were familiarized with 10 other-race (Black) faces that were repeated twice for a total of 20 trials. Test trials consisted of the same 10 faces used during familiarization (familiar), novel Black faces (novel-same), and novel Asian faces (novel-other). See Figure 1 for an example.

3.4.2 Results

See Figure 8 for the Nc waveform and Table 2 for a summary of ERP results. For the Nc component, there were no significant amplitude differences. Familiar trials (*M* = -

3.863, *SE* = 1.581) were not significantly different than novel-same trials (*M* = -5.351, *SE* = 2.075), *t*(11) = 0.616, *p* = .551, or novel-other trials (*M* = -4.702, *SE* = 1.496), *t*(11) = 0.417, *p* = .685. Novel-same trials and novel-other trials were not significantly different from each other, *t*(11) = 0.309, *p* = .763. Since results showed familiar and novel-same trials were not significantly different, these two familiar race conditions (i.e., familiar, novel-same) were collapsed together to allow for a comparison by race. Results showed no differences in Nc amplitude, *t*(11) = -0.057, *p* = .955, in response to the novel race category (*M* = -4.702, *SE* = 1.496) compared to the familiar race category (*M* = -4.607, *SE* = 1.393).

See Figure 9 for the P400 waveform. For the P400 component, there were no significant amplitude differences. Familiar trials (*M* = 15.159, *SE* = 3.209) were not significantly different than novel-same trials (*M* = 16.023, *SE* = 4.101), *t*(11) = -0.279, *p* = .785, or novel-other trials (*M* = 16.625, *SE* = 4.400), *t*(11) = -0.317, *p* = .757. Novel-same trials and novel-other trials were not significantly different from each other, *t*(11) = 0.167, *p* = .871. As familiar and novel-same trials were not significantly different, they were collapsed together to allow for a comparison by race. Results showed no P400 amplitude differences, *t*(11) = -0.269, *p* = .793, between the response to the novel race category (*M* = 16.626, *SE* = 4.400) compared to the familiar race category (*M* = 15.591, SE = 3.340).

See Figure 8 for the LSW waveform. For the LSW component, there were no significant amplitude differences. Familiar trials (*M* = 2.364, *SE* = 1.264) were not significantly different than novel-same trials (*M* = 4.721, *SE* = 2.562), *t*(11) = -0.830, *p* = .424, or novel-other trials (*M* = 2.798, *SE* = 1.809), *t*(11) = -0.199, *p* = .846. Novel-same

trials and novel-other trials were not significantly different from each other, $t(11) = -0.624$, $p = .546$. Since results showed familiar and novel-same trials were not significantly different, these two familiar race conditions (i.e., familiar, novel-same) were collapsed together to allow for a comparison by race. Results showed no differences in LSW amplitude, $t(11) = -0.329$, $p = .748$, in response to the novel race category ($M = 2.798$, $SE = 1.809$) compared to the familiar race category ($M = 3.542$, $SE = 1.437$).

3.4.3 Discussion

The ERP data did not support the hypothesis that infants would be able to differentiate between two categories of other-race (Black and Asian) faces if shown multiple exemplars of Black faces during familiarization. There were no significant ERP amplitude differences found between the three trial types: familiar Black faces, novel Black faces, or novel Asian faces. Although Dixon and colleagues (2019) showed that exposure to multiple exemplars of other-species can facilitate infants' categorization of two different monkey species at the subordinate-level, the contrasting findings from the current study indicate infants of this age may process other-species and own-species differently (Dixon et al., 2019; Keenan & Markant, 2020; Scott & Fava, 2013). This implies infants employ different processing strategies when viewing native and non-native faces, and this may indicate that perceptual narrowing impacts infants' processing of other-race and other-species faces to varying extents. This interpretation aligns with the categorization-individuation model, which theorizes infants begin to categorize non-native stimuli and continue to individuate native stimuli as they develop (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018).

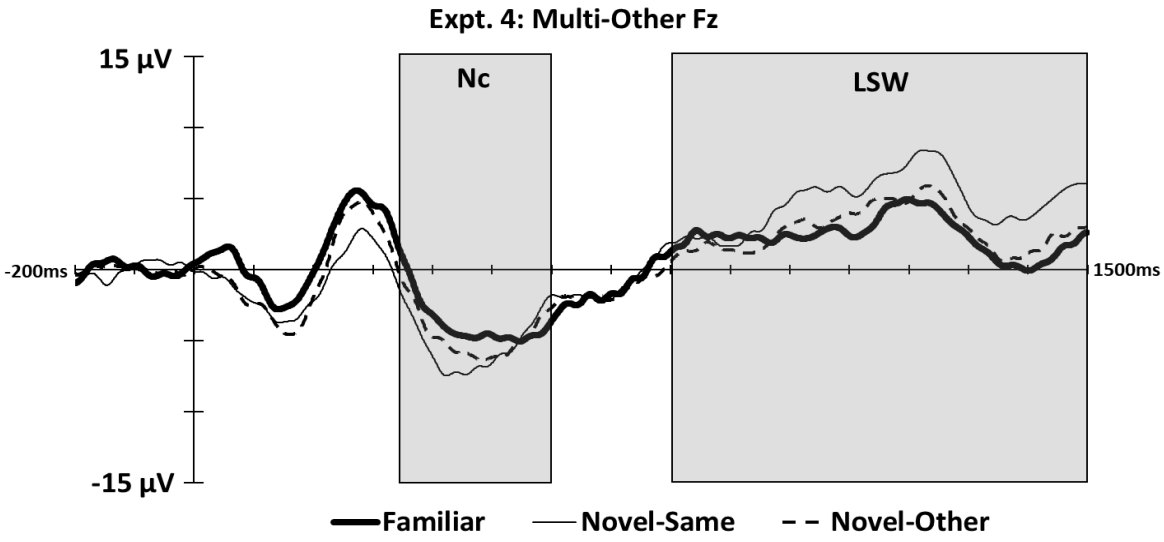

Figure 8. Expt. 4: Multi-Other Nc and LSW components by stimulus type at frontal-central electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

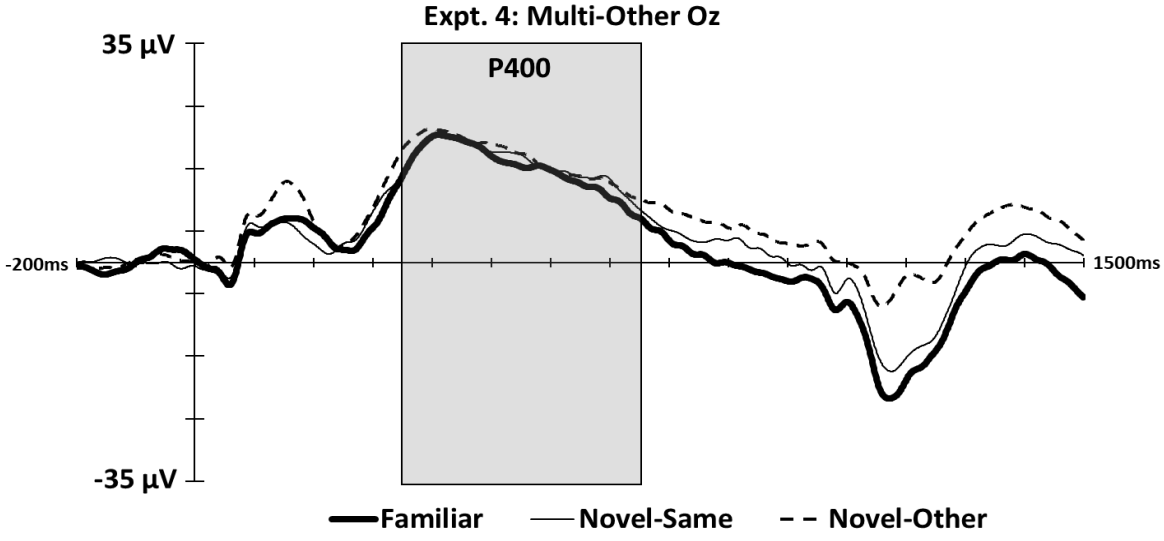

Figure 9. Expt. 4: Multi-Other P400 component by stimulus type at midline occipital electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

3.5 Summary and Discussion of Findings Across Experiments

Results suggest that, regardless of race, the use of multiple exemplars during familiarization did not facilitate categorization or individuation of the familiar faces in Experiments 2 and 4. However, the use of a single exemplar repeated 20 times during familiarization facilitated infants processing at the subordinate-level category of race, regardless if 10-month-old infants were familiarized to an own-race (White) face or an other-race (Black) face. Both single exemplar groups, Experiments 1 and 3, showed evidence of categorizing at the subordinate-level of race. Meanwhile both multiple exemplar groups, Experiments 2 and 4, did not show evidence of either categorizing or individuation of familiar faces. A possible explanation for this is the categorization-individuation model, wherein infants continue to individuate native stimuli but begin to categorize non-native stimuli with age and experience (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018). Infants may have been attempting to individuate the single face shown 20 times during familiarization but may not have received enough exposure to fully encode the face at the individual level and differentiate the familiar face from novel same-race faces during testing. However, the level of exposure during familiarization may have been sufficient for infants to differentiate between the familiar race and novel race during test trials.

In contrast to the current procedure, which used 20 brief 1000 millisecond presentations of a face for familiarization (i.e., initial learning), the majority of the previous research on infant recognition of other-race faces has used infant-controlled habituation, in which infants are able to scan faces until they lose interest, or experience

continuous exposure to a face for 20 to 30 seconds (e.g., Anzures et al., 2010; Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007; Krasotkina, Götz, Höhle, Schwarzer, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016). The rapid presentation familiarization procedure used in the current study and in Dixon et al. (2019) was designed to allow for the collection of ERP data during learning trials and to reduce attrition due to boredom (Fisch, 1999; Luck, 2014; Picton et al., 2000). However, given the null results from the multiple exemplar experiments designed to facilitate subordinate-level categorization (Experiments 2 and 4) and the significant differences found only at the categorical level in the single exemplar experiments designed to facilitate individuation (Experiments 1 and 3), it may be the case that this rapid presentation familiarization procedure was suboptimal for individuation of own-species faces.

Table 1. ERP Component Amplitude Predictions.

	ERP Components		
Familiarization Face(s)	**Nc: Novelty**	**P400: Category**	**LSW: Recognition**
Expt 1: Single Own-Race (White)	Greatest to Novel-Other (Asian) compared to Familiar & Novel-Same (White) Greater to Novel-Same (White) compared to Familiar (Individual White)	Differential between Novel-Other (Asian) compared to Familiar & Novel-Same (White)	Differential between Novel-Other (Asian) compared to Familiar & Novel-Same (White) Differential between Familiar (Individual White) compared to Novel-Same (White)
Expt 2: Multi Own-Race (White)	Greatest to Novel-Other (Asian) compared to Familiar & Novel-Same (White)	Differential between Novel-Other (Asian) compared to Familiar & Novel-Same (White)	Differential between Novel-Other (Asian) compared to Familiar & Novel-Same (White)
Expt 3: Single Other-Race (Black)	No differences	No differences	No differences
Expt 4: Multi Other-Race (Black)	Greatest to Novel-Other (Asian) compared to Familiar & Novel-Same (Black)	Differential between Novel-Other (Asian) compared to Familiar & Novel-Same (Black)	Differential between Novel-Other (Asian) compared to Familiar & Novel-Same (Black)

Table 2. ERP Component Amplitude Results.

	ERP Components		
Familiarization Face(s)	**Nc: Novelty**	**P400: Category**	**LSW: Recognition**
Expt 1: Single Own-Race (White)	Greatest to Novel-Other (Asian) compared to Familiar & Novel-Same (White) No difference between Familiar (Individual White) & Novel-Same (White)	No differences	Significant differences between Novel-Same (White) & Novel-Other (Asian) No difference between Familiar (Individual White) & Novel-Same (White) or Familiar (White) & Novel-Other (Asian)
Expt 2: Multi Own-Race (White)	Trending significance between Novel-Other (Asian) & Novel-Same (White) No difference between Familiar (White) & Novel-Same (White) or Familiar (White) & Novel-Other (Asian)	No differences	No differences
Expt 3: Single Other-Race (Black)	Greater to Familiar & Novel-Same (Black) compared to Novel-Other (Asian) No difference between Familiar (Black) & Novel-Same (Black)	Trending significance between Familiar (Black) & Novel-Other (Asian) No difference between Familiar (Black) & Novel-Same (Black) or Novel-Same (Black) & Novel-Other (Asian)	Greatest to Novel-Other (Asian) compared to Familiar & Novel-Same (Black) No difference between Familiar (Black) & Novel-Same (Black)
Expt 4: Multi Other-Race (Black)	No differences	No differences	No differences

CHAPTER IV GENERAL DISCUSSION

This study is the first of its kind to directly measure 10-month-old infant ERP data while viewing own-and other-race faces under learning conditions designed to induce either individuation or categorization. While infants do not spontaneously differentiate between two other-race categorizes at this age, the main purpose of the current study was to investigate if certain learning conditions would facilitate categorization by race (Lee, Quinn, & Pascalis, 2017; Quinn, Lee, Pascalis, & Tanaka, 2016). As infants develop, a process known as perceptual narrowing allows for a greater sensitivity to native stimuli while leading to a reduced sensitivity to non-native stimuli. By around 9 months of age, infants who have been raised in racially homogenous homes show an enhanced ability to process own-race faces but a decreased ability to process other-race faces. There is behavioral evidence to suggest infants at this age no longer differentiate between two other-race faces, but instead focus on developing expertise for own-race face processing (Quinn, Lee, Pascalis, & Tanaka, 2016). However, previous research has shown that exposure to multiple exemplars of non-native stimuli may facilitate subordinate-level categorization (considered a marker of perceptual expertise, Quinn & Tanaka, 2007), such as categorizing monkey faces by species at 9 months of age (Dixon et al., 2019). Based on these findings, it was hypothesized that infants who should already have an own-race bias based on perceptual narrowing may be able to categorize other-race faces at the subordinate-level if exposed to multiple exemplars during familiarization.

The categorization-individuation model was a major influence on the design and reasoning behind this study, as it is theorized to be related to perceptual narrowing and

is a possible explanation for the own-race bias seen in 9- to 10-month-old infants (Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Reynolds & Roth, 2018). According to this model, infants process all types of stimuli at the individual level in early development. With age and experience, they begin to develop expertise and continue to individuate native stimuli commonly encountered in their environment. However, due to perceptual narrowing, they begin to fail to individuate and instead begin to categorize non-native stimuli (Maurer & Werker, 2014). The current study predicted infants at this age would categorize other-race faces as non-native stimuli and would thus benefit from exposure to multiple exemplars during familiarization. In contrast, it was predicted exposure to a single exemplar during familiarization would possibly facilitate individuation of an own-race face but would not promote individuation of a single other-race face due to the own-race bias (Sugden & Marquis, 2017).

For this dissertation, four different experiments were designed to test the effects of familiarizing infants with either a single face intended to facilitate individuation or multiple faces intended to facilitate categorization. The different learning conditions included a single exemplar of an own-race face, multiple exemplars of own-race faces, a single exemplar of an other-race face, and multiple exemplars of other-race faces. Results showed 10-month-old infants were able to discriminate faces at the subordinate-level category of race if familiarized with a single face, the individuation condition, regardless of race. Those who saw either a single White face or a single Black face during familiarization subsequently showed significant differences in both the Nc component (associated with visual attention) and the LSW (associated with

recognition memory) between White and Asian faces or Black and Asian faces at the subordinate-level category of race. However, they did not show differences in Nc or LSW amplitude between the familiar face and novel faces from the same race, indicating that for one reason or another the infants did not individuate the familiar face from other faces of the same race.

One reason for the lack of individuation in the current study could be that the infants were simply processing the familiar face at the categorical level based on race. However, and also regardless of race, infants who were shown multiple faces during familiarization did not demonstrate significant differences in either Nc or LSW amplitude between White and Asian faces or Black and Asian faces at the subordinate-level category of race or at the individual level. Importantly, the single exemplar results indicate 10-month-old infants *are indeed* capable of differentiating between two other-race categories, if certain initial learning conditions are used. Yet, questions remain as to why exposure to only a single face during familiarization led to what appears to be subordinate-level categorization based on race, and why infants failed to show evidence of individuating a familiar human face from novel faces of their own race when behavioral evidence indicates they should be fully capable of doing this (Pascalis, de Haan, & Nelson, 2002).

Given the behavioral literature on own-race bias, it was hypothesized that this study would reveal differential effects of initial learning conditions on categorization and P400 amplitude when 10-month-old infants viewed own- and other-race faces. In face processing literature, the P400 is often associated with familiarity and orientation of human faces (de Haan, Pascalis, & Johnson, 2002; Halit, de Haan, & Johnson, 2003;

Scott, Shannon, & Nelson, 2006). The P400 has also been identified as a subordinate-level category marker (Dixon et al., 2019; Quinn et al., 2010; Scott, Monesson, & Buchinski, 2008; Xie et al., 2010). Studies utilizing source analysis have shown that the posterior cingulate cortex is a potential cortical source of the P400 (Conte, Richards, Guy, Xie, & Roberts, 2020; Guy, Zieber, & Richards, 2016; Xie, McCormick, Westerlund, Bowman, & Nelson, 2018). For all four current experiments, there were no significant differences between test trials in P400 amplitude. It may be the case that these null effects reflect all face types being categorized as human faces, as opposed to being categorized by race. It must be noted that this possibility is speculative as null effects should be interpreted with caution.

However, the combined findings of the current study and the Dixon et al. (2019) study using other-species faces may be consistent overall with the categorization-individuation model in that infants tested with human faces in the current study only differentiated faces at the subordinate-level when familiarized with a single face exemplar (an individuation procedure), and this differential responding based on race was found for ERP components related to attention (Nc) and recognition memory (LSW) but not for the ERP component related to subordinate-level categorization (P400). In contrast, infants tested with monkey faces (Dixon et al., 2019) only differentiated faces at the subordinate-level when familiarized with multiple face exemplars (a categorization procedure), and this differential responding based on monkey-species was found for ERP components related to attention (Nc), recognition memory (LSW), and subordinate-level categorization (P400). Taken together, these findings may indicate 9-

to 10-month-old infants are still focused on individuating own-species faces (regardless of race) but have shifted to categorizing other-species faces.

4.1 Individuation and Own-Species Bias

The categorization-individuation model may explain the development of both own-race and own-species biases (Heron-Delaney, Wirth, & Pascalis, 2011; Pascalis, de Haan, & Nelson, 2002; Scott & Fava, 2013; Slater et al., 2010). Research suggests infants individuate other-species (monkey) faces around 6 months of age but fail to individuate after 9 months of age (e.g., Dixon et al., 2019; Nelson, 2001; Pascalis, de Haan, & Nelson, 2002; Scott & Fava, 2013; Scott & Monesson, 2009). This loss of individuation for other-species is theorized to relate to category formation (Grossman, Gliga, & Mareschal, 2009; Hugenberg, Young, Bernstein, & Sacco, 2010; Nelson, 2001; Quinn, Westerlund, & Nelson, 2006). When older infants view non-native stimuli, they may focus on processing the perceptual properties at a categorical level, not an individual level. It is theorized that a similar process occurs in development of the own-race bias. While infants are initially skilled at individuating human faces of all races, studies have shown that around 9 months of age infants maintain the ability to individuate own-race (or the most experienced race) faces but fail to individuate other-race faces, possibly categorizing them instead (Balas, 2013; Quinn, Lee, & Pascalis, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016).

While the infants in the single exemplar familiarization experiments did not show evidence of fully individuating the familiar face, the single exemplar presentation did facilitate infant face processing in comparison to the multiple exemplar presentations, allowing infants to pick up on the perceptual distinction between the familiar and novel

races shown during test trials. Likewise, the infants in the multiple exemplar familiarization experiments may have been focused on individuating the own-species faces being shown, even if they were other-race faces, but the multiple exemplar presentation was likely suboptimal for completely processing a face at the individual level. This could explain why infants who viewed multiple exemplars during familiarization failed to differentiate between the familiar and novel race during test trials, and across all testing conditions, none of the groups showed evidence of subordinate-level categorization through differential P400 amplitude based on race. This failure to categorize by race after multiple exemplars occurred even in the case of differentiating between own-race and other-race (Experiment 2), which the literature suggests infants should be capable of (e.g., Anzures, Quinn, Pascalis, Slater, & Lee, 2010; Krasotkina, Götz, Höhle, Schwarzer, 2018; Quinn, Lee, Pascalis, & Tanaka, 2016; Vogel, Monesson, & Scott, 2012; Xiao, Quinn, Liu, Ge, Pascalis, & Lee, 2018; Xiao, Wu, Quinn, Liu, Tummeltshammer, Kirkham, …, & Lee, 2018).

Evidence in support of the possibility that the current findings may reflect partial familiarization is also seen in the opposite direction of the Nc component results for the single-exemplar conditions, Experiments 1 and 3 (see Figure 10). The Nc component is located at frontal and central sites and associated with activation in the orbitofrontal gyrus and ventral anterior cingulate (Conte et al., 2020; Guy, Zieber, & Richards, 2016; Reynolds & Richards, 2005, 2009). The amplitude of the Nc relates directly to visual preferences and the magnitude of attentional engagement, with higher Nc amplitude representing greater levels of attention (Richards, 2003). Infants show greater amplitude Nc for stimuli they demonstrate visual preferences for behaviorally, regardless of

novelty or familiarity (Reynolds, Courage, & Richards, 2005). Behaviorally, infants show a novelty preference if they are able to fully encode a stimulus, but they show a familiarity preference if they are still engaged in processing the familiar stimulus. This sequence of visual preferences can be thought of as a spectrum, with one end being infants strongly preferring a partially encoded familiar stimulus over a novel one, presumably because they are motivated to finish encoding the partially encoded stimulus, and the other end being infants strongly preferring novel stimuli after fully encoding familiar stimuli (Colombo, Mitchell, & Horowitz, 1988; Fagan, 1974; Freeseman, Colombo, & Coldren, 1993; Hunter & Ames, 1988; Reynolds, 2015; Reynolds, Courage, & Richards, 2010; Richards, 1997; Rose et al., 1982; Simpson, Jakobsen, Fragaszy, Okada, & Frick, 2014).

Infants in Experiment 1 who viewed an own-race single exemplar showed greater Nc amplitude to the novel-other race faces during test trials, indicating they may have encoded, at least somewhat, the familiar White race category and were more attentionally engaged with the novel Asian faces. In contrast, infants in Experiment 3 who viewed an other-race single exemplar showed greater Nc amplitude to familiar and novel-same faces (Black faces, the familiarized race) compared to Asian faces (the novel race). This may imply infants in Experiment 3 were slower to process the other-race face during familiarization and their Nc results reflect a *familiarity* preference for the partially encoded Black face during test trials.

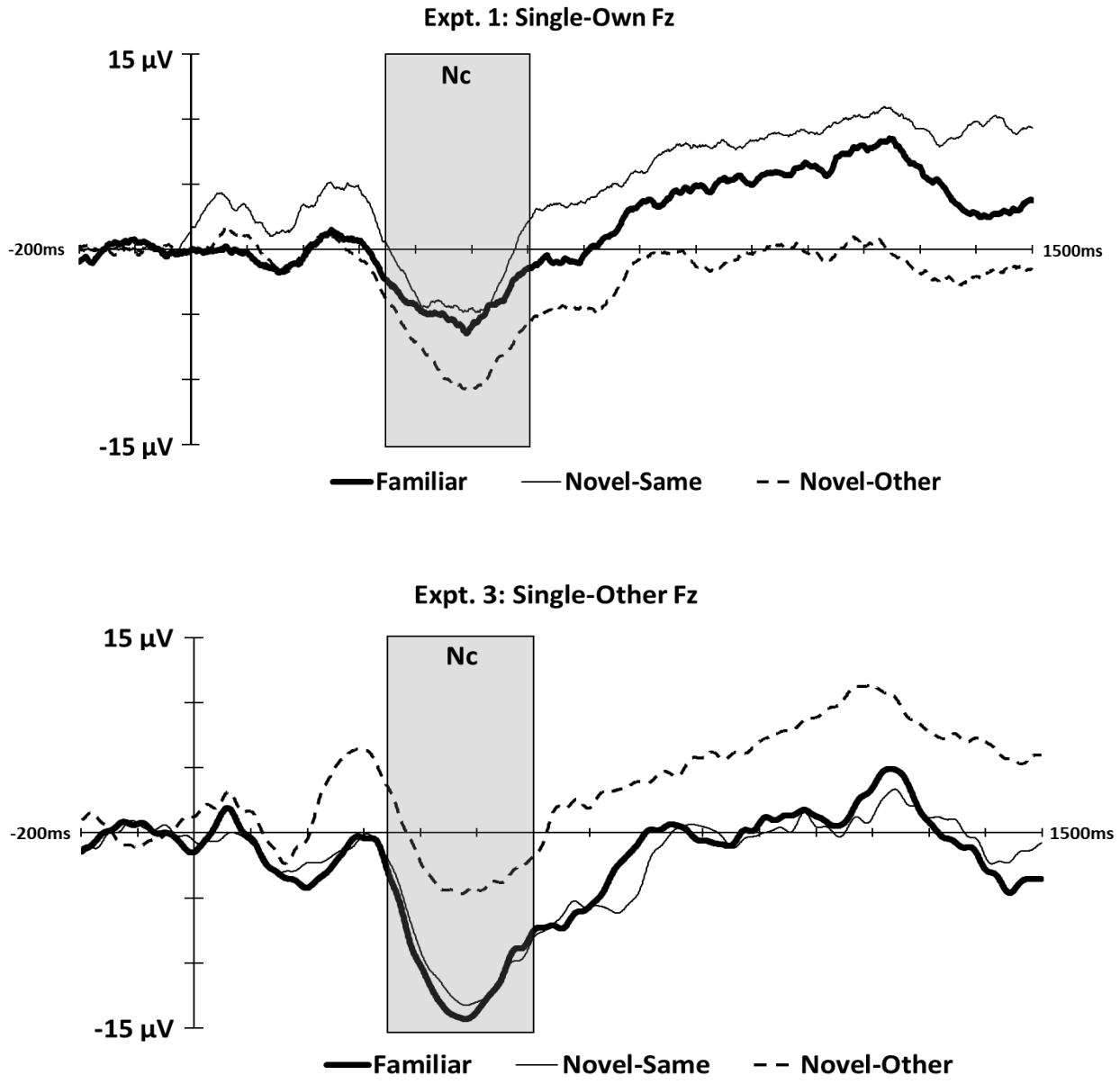

Figure 10. Comparison of Nc Amplitude in Expt. 1 and Expt. 3 by stimulus type. The Single-Own experiment waveform is on the top panel and the Single-Other experiment waveform is on the bottom panel. The waveforms are located at frontal-central electrodes. The y-axis represents amplitude in microvolts and the x-axis represents time in 100ms segments. Stimulus onset is at the x-axis and y-axis intersection.

These flipped Nc amplitude results may show evidence of the own-race bias, as infants may have been more efficient at processing the own-race face and less efficient at processing the other-race face (Reynolds, Courage, & Richards, 2010; Reynolds & Richards, 2019). In support of this line of reasoning, a study by Fair and colleagues (2012) found that 12-month-old infants did not show evidence of discriminating monkey faces if given 20 seconds of familiarization time but were able to differentiate novel from familiar monkeys at the individual level if given 40 seconds of familiarization (Fair, Flom, Jones, & Martin, 2012). Therefore, it is possible that infants in the current study were less efficient at processing the other-race face compared to the own-race face (Experiments 1 and 3) and would have benefited from additional exposure for individuation.

These findings open the door for future studies aimed at further investigating how infants can be primed to differentiate at the subordinate-level category of race and what factors influence whether infants individuate both own-race and other-race faces. This study also brings up the question of whether infants in previous behavioral studies on own-race bias were in fact engaged in the process of individuating other-race faces, albeit at a slower pace than individuating own-race faces. Many studies that have concluded infants are categorizing other-race faces at this age may be manipulated in future experiments to better test if infants are truly categorizing or if they are simply failing to encode individual faces during familiarization phases at a sufficient level for subsequent individuation. At a broad level, the contrasting findings between this study and Dixon et al. (2019) indicate prior experience plays a significant role in how infants

process faces, as the effects of initial learning conditions varied greatly depending on whether infants were tested with human or monkey faces.

4.2 Social Implications of Own-Race Bias

Studying how early attentional biases associated with face processing can later develop into social biases has implications for infant development as well as our understanding of child and adult social prejudices. As perceptual categorization has been shown to be a precursor to later conceptual categorization, it is important to understand when and how this shift occurs. Infants at 6 months of age will discriminate between different other-race faces, but at 9 months behavioral data suggests infants may combine two other-race faces into a broad category of “not own-race” (Quinn et al., 2016). Despite obvious perceptual differences between the two other-race faces, infants still include them in a category that excludes own-race faces, suggesting infants begin to categorize based on socialized conceptual information instead of basic perceptual information (Quinn, 2019). One theory about this move from perceptual to conceptual categorization of other-race faces is linked to social and language development (Timeo, Farroni, & Maass, 2017). While infants are able to form prelinguistic perceptual categories of colors, it has been shown that adults form conceptual categories of colors based on language (Franklin, Drivonikou, Bevis, Davies, Kay, & Regier, 2008). Adult categories do not build on the prelinguistic categories infants form based on perceptual information, but rather are created within language constraints at a socialized conceptual level (Franklin et al., 2008).

Beyond color perception, effects of language labels on face perception have also been studied. As demonstrated in Scott & Monesson (2009), 6-month-old infants who

were trained with individual monkey names differentiated novel and familiar monkey faces at 9 months of age, but those who were trained with a category name ("monkey") or had an unlabeled picture book did not (Scott & Monesson, 2009). Similarly, White adults who were shown individually labeled Black and Hispanic faces differentiated novel and familiar other-race faces but did not when the faces were categorically labeled by race (Tanaka & Pierce, 2009). Timeo and colleagues (2019) recently used EEG to investigate how children and adults respond to racial categories of faces and found a stronger ERP effect (N400, associated with semantic face encoding) when viewing two faces of different racial categories compared to comparing two faces within the same racial category. This effect was correlated with learning racial labels in children, not the children's age, implying it is vocabulary acquisition and not standard brain maturation that plays a role in how individuals of different races and individuals of the same race are perceived. Further analysis revealed activation in areas of the brain associated with language, the left superior temporal gyrus and inferior frontal gyrus, lending support to the hypothesis that language plays a large part in how conceptual understanding of perceptual processing occurs (Timeo, Mento, Fronza, & Farroni, 2019).

Connected to language development, social development is related to own-race bias as well. Lee and colleagues (Lee, Quinn, & Heyman, 2017; Lee, Quinn, & Pascalis, 2017; Quinn, 2019) have proposed a Perceptual-Social Linkage Hypothesis, which states that due to asymmetrical exposure to own- and other-race faces, infants typically form positive associations with own-race individuals (most likely the infant's immediate family and caregivers), and by default other-race individuals are thus more likely to be

associated with negative traits. With repeated positive experiences with own-race individuals, own-race becomes conceptualized as trustworthy and friendly, but by contrast this leads to other-race individuals being seen as less trustworthy or friendly (Lee, Quinn, & Heyman, 2017; Lee, Quinn, & Pascalis, 2017; Linville, Fischer, & Salovey, 1989; Xiao, Quinn, Lee, & Pascalis, 2017). In line with this possibility, 7-month-old Chinese infants are more likely to rely on gaze cues from own-race faces than other-race faces if the cues are not 100% accurate or 100% inaccurate. This means in situations of uncertainty, infants are more likely to rely on own-race than other-race individuals (Xiao, Wu, Quinn, Liu, Tummeltshammer, Kirkham, …, & Lee, 2018). Nine-month-old Chinese infants associate own-race Chinese faces with happy music and other-race Black faces with sad music, but 6-month-olds do not show this association (Xiao, Quinn, Liu, Ge, Pascalis, & Lee, 2018). Other consequences beyond a simple visual preference for own-race faces include more in-depth facial scanning, attributing more positive emotions with own-race faces, trusting own-race faces more, and other positive social biases for own-race faces (Xiao, Quinn, Lee, & Pascalis, 2017).

And while infants and young children are beginning to switch from forming perceptual categories, based on basic perceptual characteristics and familiarity, to forming conceptual categories, where higher-level socialization begins to play a role, it is not an immediate transition (Pauker, Williams, & Steele, 2017). Ten-month-old infants and 2.5-year-old children do not show a racial bias when accepting or giving toys to an own- or other-race actor, but 5 to 6 year old children do show an explicit own-race bias for giving toys to actors (Kinzler & Spelke, 2011). Toddlers do not show racial preferences for playmates at 24 months of age but both White and Black 30-month-olds

prefer own-race playmates (Katz & Kofkin, 1997). At 3 years of age, White children still prefer own-race playmates but Black children now prefer White over Black playmates, and this effect is still present at 5 years of age (Katz & Kofkin, 1997). Children ages 3 to 14 years old belonging to a majority racial group show stronger own-race positive biases, and children who belong to minority racial groups are less likely to show a positive bias for their own-race (Dunham, Chen, & Banaji, 2013; Setoh, Lee, Zhang, Qian, Quinn, Heyman, & Lee, 2018). Additionally, 3- to 7-year-old children's ability to sort faces by race predicts their implicit association test (IAT) results on racial biases, with better categorizing by race associated with more negative other-race biases. IAT is a measure of association between concepts, such as race and positive/negative words, to explore subconscious prejudices (Dunham, Baron, & Banaji, 2008; Setoh et al., 2018). Thus, social development can clearly have an effect on children's racial prejudices.

Considering it is hypothesized that this move from perceptual to conceptual categorization is a result of children experiencing positive associations with own-race individuals, and therefore concluding negative associations with other-race individuals, explicitly talking about race and prejudice can improve school age children's biases fairly quickly (Skinner & Meltzoff, 2019; Vittrup & Holden, 2011). Unfortunately, many parents, especially White parents, rely on "colorblind" or non-explicit ways of discussing prejudice, such as asserting "everyone is equal" without talking about race. This leads to children picking up race-related stereotypes from other sources (Pahlke, Bigler, & Suizzo, 2012; Sullivan, Wilton, & Apfelbaum, 2020; Vittrup, 2018; Vittrup & Holden, 2011; Zucker & Patterson, 2018). Parents tend to underestimate their children's

understanding of race, which leads to them delaying important conversations; however, children are noticing perceptual variances and forming conceptual beliefs about racial differences with or without adult intervention (Loyd & Gaither, 2018; Sullivan, Wilton, & Apfelbaum, 2020). Both White children and racial minority children are negatively affected by this societal norm of not discussing race explicitly (Pauker, Apfelbaum, & Spitzer, 2015).

In addition to explicit conversations about race, other studies have explored the effects of individualization of other-race members on children's prejudices (e.g., Xiao, Fu, Quinn, Qin, Tanaka, Pascalis, & Lee, 2015). Individuation training of other-race faces can reduce Chinese children's anti-other-race, pro-own-race racial biases (Qian, Quinn, Heyman, Pascalis, Fu, & Le, 2017a). Importantly, training to reduce implicit racial biases must involve individuating other-race faces and not merely exposure to other-race faces at the categorical level (Qian, Quinn, Heyman, Pascalis, Fu, & Lee, 2017b). Training is also not temporary in preschool-aged children, as Chinese children who were trained with Black faces maintained a reduction in anti-Black bias one week and 70 days later; however, those trained with White or own-race Asian faces did not show a reduction in anti-Black bias at any time point (Qian, Quinn, Heyman, Pascalis, Fu, & Le, 2017a).

Thus, this early categorization of other-race faces as separate from own-race faces has social consequences in later years. Investigating how these face processing biases develop is crucial for understanding later racial biases seen in children and adults. Explicitly discussing race can help guide conceptual categorization as children grow by adding social context to the perceptual differences they are already noticing

between people (Loyd, & Gaither, 2018; Skinner & Meltzoff, 2011; Sullivan, Wilton, & Apfelbaum, 2020; Vittrup 2018; Vittrup & Holden, 2011; Zucker & Patterson, 2018). Other-race biases are still malleable, even in adulthood: being exposed to more diverse communities and having more diverse acquaintances (Mousavi & Oruc, 2020; Pauker, Carpinella, Meyers, Young, & Sanchez, 2018) or undergoing implicit conditioning (Olson & Fazio, 2006) can reduce White individuals' negative stereotypes of Black people. While it is encouraging that training, individuation, explicit discussion, and exposure can moderate racial biases, it is important to know when this shift from perceptual to conceptual categorizing may be taking place. Future research should focus on what mediating factors may prevent these categorical perceptions from forming into negative conceptual biases against other-race individuals and groups (Lee, Quinn, & Heyman, 2017; Lee, Quinn, & Pascalis, 2017; Loyd & Gaither, 2018; Pauker, Williams, & Steele, 2017; Sullivan, Wilton, & Apfelbaum, 2020; Quinn, 2019; Xiao et al., 2015; Zucker & Patterson, 2018).

4.3 Limitations and Future Directions

A global pandemic (COVID-19) was a limiting factor in participant recruitment, resulting in data collection concluding earlier than anticipated in order to progress within the PhD program (Freedman, Headley, Serwas, Ruhland, Castellanos, Combes, & Krummel, 2020). Including more participants in each of the experimental groups would have increased statistical power for analyses. Including infant participants who did not belong to the majority White group also would have added important comparative data for the main four experiments; however, this was not a viable option for the current study due to recruitment limitations.

This study utilized full-color images for its stimuli. This was done because other research has shown infants do not discriminate races by color (Bar-Haim, Ziv, Lamy, & Hodes, 2006) and adults do not show own-race bias differences between grayscale and full-color stimuli (Ito & Urland, 2003). However, there is undeniable perceptual contrast between the Black and Asian faces during the other-race experiment test trials (Experiments 3 and 4). Additionally, the brief presentations associated with ERP paradigms may have led infants to rely more heavily on the obvious perceptual differences seen between Black and Asian faces during the singular exemplar condition, although results were null for the multiple exemplar condition. A possible follow-up may include grayscale images to rule out any obvious color differences driving an effect.

Given the possibility that infants in the current study may have been focused on individuating own-species faces, a follow up study using additional single exemplar trials or using familiarization trials of a longer duration would be beneficial. Infants could be given additional familiarization trials in order to fully encode the face, perhaps 30 or 40 trials instead of 20, or continuous presentations of 10 or 15 seconds to allow for more extensive facial scanning. It would be interesting to see if infants would recognize the individual face during test trials and if this would be different between infants familiarized with an own-race or other-race individual.

Including a range of different age groups, either with the same infants tested longitudinally at different ages or with a cross-sectional design, would likewise add valuable information to this study. The current experiments tested 10-month-olds as infants would be expected to have already developed an own-race bias by this age. However, although beyond the scope of this project, a longitudinal design testing infants

at several ages throughout infancy and early childhood would provide valuable data that could present a developmental trajectory and shed light on if and when infants begin to show less efficient individuation of other-race faces compared to own-race faces. Longitudinal data could also possibly reveal a shift from individuation to categorization consistent with the categorization-individuation model (Hugenberg et al., 2010). Alternatively, it may be the case that children continue to individuate other-race faces but become less efficient compared to own-race faces with increasing age, a possibility that would be more consistent with an attunement conceptualization of perceptual narrowing (Aslin & Pisoni, 1980; Maurer & Werker, 2014; Narayan, Werker, & Beddor, 2010).

4.4 Conclusions

Data from this study suggest the exciting possibility that infants continue to individuate other-race faces beyond 9 months of age, but they may simply be less efficient at individuating other-race faces compared to own-race faces. This is in contrast to previous literature implying infants begin to categorize by race at this age, which contributes to later development of negative social biases. Comparing this study's results to those of Dixon and colleagues (2019), infants in the 9- to 10- months age range are able to quickly categorize other-species faces, but they may not be processing own-species, other-race faces at a categorical level. Instead, their lack of familiarity with other-race faces may result in less efficient individuation compared to when processing own-race faces.

Consistent with this possibility, infants who are given additional time to encode monkey faces show evidence of individuation of other-species faces (Fair, Flom, Jones,

& Martin, 2012). Similarly, Sorcinelli and Vouloumanos (2018) replicated Pascalis and colleagues' (2002) seminal work on perceptual narrowing in other-species face processing with a larger sample size of adult participants and found that adults *were* able to successfully individuate monkey faces. It may be the case that, while humans are primed to categorize non-native stimuli as perceptual narrowing develops, individuation can still be achieved, even for other-species faces, if given the proper experimental conditions and longer familiarization time. Instead of a dichotomous choice between individuation or categorization of stimuli, it is possible that more familiar, native stimuli are individuated more efficiently than non-native stimuli, which would be more consistent with a soft version of an attunement framework for interpreting the effects of experience on non-native face processing (Aslin & Pisoni, 1980; Maurer & Werker, 2014; Narayan, Werker, & Beddor, 2010). It may be the case that infants begin with a sensitivity to both own-race and other-race individuals as well as other-species faces, but over time they experience a loss of sensitivity to stimuli they do not often encounter, such as other-species faces. As this non-native sensitivity loss progresses, infants maintain sensitivity to native stimuli, such as own-species faces, and also experience an increase in expertise with heavy exposure to specific types of faces , such as own-race faces (Aslin & Pisoni, 1980).

The current findings are encouraging and bode well for the flexibility of racial biases that may arise later on in development, as it seems 10-month-old infants still process other-race faces similar to own-race faces more commonly encountered in their native environment. Perceptual narrowing may lead to infants gaining expertise in processing own-race faces, but it is not likely that they completely lose the ability to

individuate other-race individuals. Instead, their lack of experience with other-race faces may result in less efficient encoding – something that can be mitigated with training and exposure to other-race individuals. Future studies should look into what conditions lead to older infants, children, and adults individuating other-race individuals, and if there is a shift to defaulting to categorizing other-race faces as seen with other-species faces. Understanding how other-race faces are processed in different contexts, especially compared to own-race faces, will provide valuable information on the development of basic perception as well as the development of social biases and racial prejudices seen in childhood and adulthood.

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APPENDIX

LAB USE ONLY
*Study:*_____
*ID:*_____
*Date:*_____

Family Background Questionnaire

*The following information is used to maintain accurate records of our subject population.
We report demographic information in our publications as well as to our funding agencies as requested.
All questions are voluntary, and your responses will be kept confidential.

1. Your child's sex/gender: _____ 2. Your child's date of birth: _____

3. Your child's due date: _____ 4. Total weeks gestation: _____

5. What is your child's race or ethnicity? Please check one or more boxes:
   ___ White
   ___ Black
   ___ Hispanic, Latino, or Spanish origin
   ___ Native American, First Nations, or Inuit
   ___ Asian
   ___ Native Hawaiian or Other Pacific Islander
   ___ Not listed (please specify: _____)

6. Does your child frequently interact with people who are a different race(s) than their own?
   ___ Yes ___ No

7. Does your child have a known hearing or vision problem? Yes / No
   If so, please explain: _____

8. Do you have any concerns about your child's development? Yes / No
   If so, please explain: _____

9. What is your total annual household income?
   ___ Less than $25,000
   ___ $25,000 to $34,999
   ___ $35,000 to $49,999
   ___ $50,000 to $74,999
   ___ $75,000 to $99,999
   ___ $100,000 to $149,999
   ___ $150,000 to $199,999
   ___ $200,000 or more

10. Parent A's highest degree earned:
    ___ Eighth grade completion
    ___ High School Diploma
    ___ Some college
    ___ 2 year degree at a college/trade school
    ___ 4 year degree from a college/university
    ___ Master's Degree
    ___ Doctoral Degree (Ph.D., M.D., etc.)

11. Parent B's highest degree earned:
    ___ Eighth grade completion
    ___ High School Diploma
    ___ Some college
    ___ 2 year degree at a college/trade school
    ___ 4 year degree from a college/university
    ___ Master's Degree
    ___ Doctoral Degree (Ph.D., M.D., etc.)

Figure 11. Demographic background survey, front.

Parent A

12. Parent A's sex/gender: _____

13. Parent A's occupation: _____

14. Parent A's native language(s): _____

15. Parent A's race or ethnicity; please check one or more boxes:
    ___ White
    ___ Black
    ___ Hispanic, Latino, or Spanish origin
    ___ Native American, First Nations, or Inuit
    ___ Asian
    ___ Native Hawaiian or Other Pacific Islander
    ___ Not listed (please specify: _____)

Parent B

16. Parent B's sex/gender: _____

17. Parent B's occupation: _____

18. Parent B's native language(s): _____

19. Parent B's race or ethnicity; please check one or more boxes:
    ___ White
    ___ Black
    ___ Hispanic, Latino, or Spanish origin
    ___ Native American, First Nations, or Inuit
    ___ Asian
    ___ Native Hawaiian or Other Pacific Islander
    ___ Not listed (please specify: _____)

Siblings, other children, or adults who live with you or often interact with your child

Relation examples: Sibling, grandmother, nanny, cousin, etc

Relation: _____ Age: _____ Sex/gender: _____ Race/ethnicity: _____
Relation: _____ Age: _____ Sex/gender: _____ Race/ethnicity: _____
Relation: _____ Age: _____ Sex/gender: _____ Race/ethnicity: _____
Relation: _____ Age: _____ Sex/gender: _____ Race/ethnicity: _____
Relation: _____ Age: _____ Sex/gender: _____ Race/ethnicity: _____
Relation: _____ Age: _____ Sex/gender: _____ Race/ethnicity: _____

Additional Comments: _____
_____
_____

Figure 12. Demographic background survey, back.

VITA

Kelly Roth graduated from Clinton High School in May 2012. She then attended the University of Tennessee Knoxville (UTK) as a first-generation college student, where she received her bachelor's degree in Psychology Honors. She graduated cum laude in the Chancellor's Honors program in May 2015. She continued her education at UTK by earning her master's degree in Experimental Psychology with a minor in Statistics. After successfully defending her thesis in November 2017, she entered UTK's Experimental Psychology doctoral program, concentrating in Cognitive and Developmental Science.