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Introduction

Infant categorization is a process by which infants learn to recognize and differentiate between objects and events. This process is thought to be a fundamental part of cognitive development and is believed to be a precursor to more complex cognitive processes (Rakison & Yermolayeva, 2010). Infant categorization can help infants to develop problem-solving skills, as it allows them to recognize patterns and solutions to certain problems (Bjorkland, 1990). Research has suggested that infants can individuate and categorize faces from a young age (Ramsey et al., 2005). This ability is believed to result from the variability found in faces, which allows infants to create categories to differentiate between the many types of faces they come across.

How we start to construct notions that go beyond the information our senses give us is one of the enduring mysteries of the mind. The big question is how concepts are created in the first place; once a conceptual framework is established, it is not difficult to see how it affects how we experience the world. For instance, when and how do young children first begin to understand what a dog or an animal is, and what do these conceptions initially entail? Children as young as 3 months of age classify images of dogs as distinct from cats and horses as distinct from zebras (Quinn, Eimas, & Rosenkrantz, 1993; Eimas & Quinn, 1994). Quinn and Eimas (1996) discovered that rather than overall appearance, the early classification of dogs and cats is based mostly on distinctions in their facial features. This study, along with those of Mareschal, French, and Quinn (1998), demonstrated that there are some asymmetries in the learning of these two categories, which may be related to the fact that dogs' facial features vary more than humans do. Additional studies have revealed that between the ages of 4 and 10 months, infants gradually develop sensitivity to the linked attribute structure that describes the look of both faces and animals (Younger & Cohen, 1986). This highlights the importance of variability in the categorization of faces by infants and demonstrates the early development of facial recognition in infants.

Hugenberg, Young, Bernstein, and Sacco's (2010) Categorization-Individuation Model (CIM) proposes that young infants are primarily driven to process objects at the individual level and that attention to category-level attributes emerges later in development. This model has been supported by studies showing that infants can distinguish between object categories based on characteristics such as texture and pattern (Mandler, 2000). According to their research, infants between the ages of 6 and 9 months can differentiate between objects based on form and function and can also differentiate between themselves and other people or objects. This research suggests that categorization is essential for the development of object concepts and differentiation between self and other. Both the variability theory and CIM suggest that categorization plays an important role in infants' cognitive development and that individual-level features are important in driving infants to categorize objects.

Infant cognitive development is a highly complex and multi-faceted process, and categorization appears to be a key component of this development. Despite its importance, the cognitive mechanisms underlying categorization are still not completely understood. To shed light on this process, Rakison and Yermolayeva (2010) conducted a study to compare categorization strategies in infants and adults. They sought to understand if the same cognitive processes were used by both age groups, or if infant categorization strategies were different from those used by adults. To test this, they designed a laboratory experiment using a preferential-looking paradigm. This study found that by 3 and 4 months of age, infants could categorize objects based on shape, color, or texture. Furthermore, they found that infants used a holistic approach to categorization, meaning they would categorize objects based on the overall similarity of the objects, rather than analyzing individual components.

The CIM proposed by Hugenberg et al. (2010) is an integrative account of the Other-Race Recognition Deficit (ORRD). The CIM proposes that the ORRD is caused by a combination of two processes: categorization and individuation. The Other-Race Effect (ORE) is an established phenomenon in psychology that suggests individuals show an advantage in recognizing and differentiating own-race faces over other-race faces (Hugenberg et al., 2010). Categorization is the process of perceiving and encoding a face as a member of a group or category, while individuation is the process of perceiving and encoding a face as an individual. The CIM suggests that the ORRD is caused by relatively poor individuation of other-race faces, which leads to difficulty in recognizing them at the individual level. Hugenberg et al. (2010) analyzed the results of many studies that examined the ties between categorization, motivation, and experience. Viewing faces as belonging to a category causes perceivers to focus their memories on the prototype and decreases recognition (Young et al., 2009). They found that the motivation to individuate faces can be increased by placing them in an ingroup as opposed to an outgroup (Hugenberg et al., 2010). By examining results from a series of studies, Hugenberg et al. (2010) concluded that people with little to no experience processing the faces of individuals from outgroups have significant difficulties identifying exemplars from that group at an individual level. This was supported by multiple studies indicating the importance of early infant exposure to a diverse group of people.

Kelly et al., (2009) sought to explore the development of the ORE during infancy in a study of Caucasian and Chinese infant participants. Their research (2009) focused on the early infancy period when the human brain is still developing and forming facial recognition abilities. The authors hypothesized that infants would show greater facial recognition of their race as compared to an unfamiliar race. The results of the study demonstrated that 4-month-old infants did indeed recognize their race more accurately than an unfamiliar race and that this recognition was further enhanced when the unfamiliar race was presented in a visually distinct manner. Furthermore, the results indicated that the ORE was not present in 2-month-old infants. However, they did find that infants as young as six months of age could already discriminate individual faces from different races, though their results suggested that infants of this age were more likely to recognize members of their race. The results showed that infants from homogenous racial backgrounds showed an own-race advantage as they got older, but those from heterogenous did not. These findings suggest that the ORE may develop during the first few months of life and that the lack of experience with other-race faces may play a role in the development of this effect. This suggests that even before the age of two when the ORE is usually observed, the human brain may already be predisposed to differentiate between races. This also suggests that perceptual narrowing, a process of becoming more attuned to stimuli regularly encountered in everyday life, begins in infancy.

A study by Ellis et al. (2017) examined the scanning of own- versus other-race faces in 6- and 8-month-old infants from racially diverse and homogenous communities. The results showed that infants from racially diverse communities spent more time looking at other-race faces than infants from homogenous communities. Furthermore, the results indicated that the amount of time spent looking at other-race faces was related to the amount of exposure to other-race faces in the infants' environment. These findings suggest that early exposure to other-race faces may be important for developing the ability to recognize and process faces of different races.

Kelly et al. (2009) and Ellis et al. (2017) have shed light on the developmental origins of the other-race effect and the importance of exposure to heterogenous communities. By studying the recognition of faces of different races in infants across diverse and homogenous communities, both studies demonstrated that the own-race bias is developed as early as 6 months into one's life and persists even when infants are exposed to people of multiple different races. These findings demonstrate how powerful and wide-reaching the other-race effect is and underscore the importance of recognizing and taking action to diminish its effects.

Sex Differences in Facial Scanning

In a 2000 Psychological Bulletin publication, McClure described a meta-analytic review of the previous studies that had examined the differences between male and female infants in facial scanning. He found that sex differences in patterns of lateralization have been reported early in development for other face-processing tasks. De Schonen and Mathivet (1990), for example, found that female infants between the ages of 4 and 10 months had a weaker right hemisphere advantage for discriminating between faces compared to their male peers. Research suggesting that female infants' habituation skills increase in sophistication more quickly than male infants' was also taken into account given that effect sizes obtained using habituation tasks were significantly larger than those obtained using visual preference or social referencing (Creighton, 1984). McClure also found that female infants displayed an earlier and more frequent preference for scanning faces than male infants.

Girls and boys may receive different types of information and assistance from adults and peers, according to findings from studies specifically focused on emotional socialization, even though one meta-findings analysis (Lytton & Romney, 1991) found little evidence that parents socialize their sons and daughters differently. Yet, relying solely on parental expression is probably insufficient to support gender differences in infant face processing in infancy. Additionally, mothers appear to be both more expressive generally and more positively expressive toward their infant daughters than toward their infant sons, even though mother-son interactions during infancy may typically be characterized by more emotional contingency than mother-daughter interactions (Fogel, Toda, & Kawai, 1988; Malatesta, Culver, Tesman, & Shepard, 1989). According to Ablon (1993), such sex disparities in mother-infant emotional interactions may reflect early differences in the processing of expressivities. So, mothers may tend to downplay their own emotions or to keep conditioned reactions to their son's actions. In contrast, moms may exhibit their emotions more openly while engaging with their less expressive infant daughters, exposing girls to emotional displays that may not necessarily be related to their own emotional experiences. Furthermore, this study provides evidence that early experiences with faces may influence the development of social cognition. By establishing a clear link between early infant facial scanning and later social development, this study could have significant implications for parents. McClure's meta-analysis provides important insight into the development of early social cognitive processes and how gender differences can influence them.

In recent years, there has been a growing interest in understanding differences in behavior and development between male and female infants. Males appear to process information more holistically than females, based on their decreased reliance on the left hemisphere of the brain, by integrating the internal facial features and the internal and external facial features as a whole rather than as individual parts (Rennel and Cummings, 2013). Rennel and Cummings' (2013) studied 3- to 4-month-old infants and 9- to 10-month-old infants by having them view individual faces while collecting eye-tracking data. The individual faces were familiar and unfamiliar faces to analyze processing differences across various types of faces for male and female infants. This study found that the scanning behavior of females seemed to be favorable for differentiating between emotional expressions during infancy. Male scanning tendencies from infancy seem helpful for facial recognition due to the finding that male infants spent more time looking at faces with an averted gaze than female infants (Rennel & Cummings, 2013).

During the first year of life, there have been reports of sex differences in basic and sensory functions, social behavior, and cognition. Alexander and Wilcox (2012) reviewed these reports and discussed the current state of knowledge regarding the causes of these differences and the degree to which they influence later behavior. Some of the major points that Alexander and Wilcox (2012) identified were infant females develop visual acuity, stereopsis, and evoked responses to changes in the visual pattern earlier than males do throughout the first 4-6 months of postnatal life (Held, Shimojo, & Gwiazda, 1984; Makrides, Neumann, & Gibson, 2001). Compared to males, female infants exhibit more sensitivity to environmental changes, greater fearfulness, and lower activity levels, according to a meta-analysis of gender variations in temperament (ElseQuest, Hyde, Goldsmith, & Van Hulle, 2006). Moreover, female infants may respond more quickly to social cues like the touch, tone, or face of their mothers. Infant's affective processing and response disparities between genders have also been documented. Like adult women, female infants distinguish emotional expressions more accurately than males do

(McClure, 2000). Female infants screamed longer than male infants in response to recordings of a female infant's cry in investigations of infectious crying in neonates (Hoffman, 1973).

According to a new eye-tracking study evaluating infants' scanning of the first event and final display, boys may be more likely than girls to recognize the trajectories of moving occluded objects and, thus, may be more likely to extract the simple structure (Alexander and Wilcox, 2012). It should be noted that eye-tracking technology, which provides a more sensitive assessment of performance than look duration approaches, has indicated sex differences favoring boys at a younger age. When items were entirely obscured at 9.5 months, boys searched both sides of an occluding screen, adjusting their focus when the objects moved from left to right (or right to left) behind the screen (they did this even though the objects were out of their field of view). Yet, as the occlusion interval increased, girls rarely turned their attention to the side of the screen behind which an object had most recently vanished (they failed to follow occluded trajectories). In addition, when the occluder was lowered, boys were more likely than girls to notice a discrepancy between the ball-box event and the one-ball display because they looked for the missing box at the platform's center. The ability to recognize occluded trajectories may facilitate the extraction of the event's basic structure and subsequent mapping. This is supported by the observation that infants (mostly boys) who followed the trajectory of the objects as they moved behind the screen during the occlusion sequence were more likely to scan the center of the platform for the missing box when the screen was lowered. At 4 months, no gender differences were seen; both sexes displayed behavior consistent with 9.5-month-old girls who were unable to map the ball-box event onto the one-ball display.

Alexander and Wilcox (2012) and Rennels and Cummings (2013) revealed consistent findings. For example, both studies found that there were gender differences in the development of infants’ visual scanning, with male infants displaying faster scanning rates than female infants (Alexander and Wilcox, 2012; Rennels and Cummings, 2013). Additionally, both studies concluded that the age of the infant and the type of facial stimulus used could influence the gender differences observed. Overall, these studies indicate that early sex differences in visual scanning and face processing exist in infancy. Alexander and Wilcox (2012) analyzed the video and audio recordings of babies, finding that male infants tended to display more gross motor activity, vocalizations, and smooth movement transitions. Similarly, Rennels and Cummings (2013) examined photographs of infants and concluded that female infants display significantly more facial scanning than male infants. These findings suggest that sex differences in early development are present from as early as 9 months of age.

Roth & Reynolds (2022) explored how infants categorize faces at a subordinate level and whether this categorization varies between own- and other-race faces. This study looked at 10-month-old infants and their ability to differentiate between their own- and other-race faces. Infants were randomly assigned to an own-race single exemplar, other-race single exemplar, own-race multiple exemplars, or other-race multiple exemplars familiarization condition and their neural responsiveness to faces was analyzed using EEG. The multiple exemplar condition did not display significant results. But there were significant findings in the Nc, P400, and LSW components for the single-exemplar condition. Roth and Reynolds (2022) found that infants differentiated the novel race from the familiar race by significant differences in the late slow wave (LSW) amplitude that is associated with recognition memory at the left frontal electrodes. The LSW often occurs at the temporal and anterior electrode sites, lasting between 750 to 2000 milliseconds (de Haan, 2007, 2013; Guy et al., 2013; Roth and Reynolds, 2022). It has repeatedly been demonstrated that the LSW has varied amplitude in response to stimulus novelty or repetition; as a result, variations in the amplitude of the LSW are thought to represent early perceptual processing and recognition memory (de Haan & Nelson, 1999; Guy et al., 2013; Guy et al., 2017; Nelson & Collins, 1991, 1992; Reynolds et al., 2011; Roth and Reynolds, 2022, Snyder et al., 2002; Snyder et al., 2010; Webb et al., 2005; Wiebe et al., 2006). Infants did not individuate the familiar face, as evidenced by the infants not exhibiting any differences in LSW amplitude between faces that were familiar and novel faces from the same race. However, White infants who saw either a single White face or a single Black face during familiarization did show significant differences in the LSW component between familiar faces and novel faces from a different race suggesting that they are categorizing by race. Based on the study's findings, it appears that 10-month-old infants process other racial faces similar to their own racial faces. It should be noted that the sample from the Roth & Reynolds (2022) study was primarily limited to White infants due to recruitment limitations. It should also be noted that due to the brief 1000 ms familiarization stage, the results from the Roth & Reynolds (2022) study from the single exemplar conditions might only reflect a partial encoding of the familiar face, which might be enough for categorization by race but may be insufficient for individuation within racial categories. Infants may become skilled at processing faces of their own race as a result of the perceptual narrowing, but it is unlikely that they will entirely lose sensitivity to faces of other races. Instead, their inexperience with the faces of people of different races may lead to less effective encoding; however, this issue can be resolved with training and exposure to people of different races (Roth & Reynolds, 2022). These findings suggest that early exposure to a diverse range of faces may play a crucial role in developing own- and other- race face categorization in infancy.

According to research from the body of literature, infants that grow up in a racially homogenous environment experience perceptual narrowing within the first year of life, which causes own-race bias (Kelly et al., 2009). These infants seem to place other races into a subordinate level category rather than individuating each face (Ellis et al. 2009; Hugenberg et al., 2010). The proposed study examined the influence of sex on infants' ability to individuate and/or categorize faces of their own and other races at the age of 10 months. This was examined by exposing 10-month-old infants to a single exemplar of either own-race or other-race faces during familiarization. This study is a supplemental analysis utilizing the existing data set from the study by Roth and Reynolds (2022). Because only infants in the single exemplar groups showed effects in the Roth and Reynolds study (2022), this study focused exclusively on males and females from the single exemplar groups. Building upon that study's findings, the proposed research study aimed to further the literature on sex differences by examining potential sex differences among the infant participants in the single exemplar groups on their responses to facial processing when observing same-race and other-race faces. Based on previous literature on categorization and literature on sex differences in infant processing, I predicted that 10-month-old White male infants will be more likely to categorize other-race faces at a subordinate-level category due to the increased speed of their face processing.

Methods

This study was conducted utilizing the existing data sets from the study by Roth and Reynolds (2022).

Participants

The University of Tennessee, Knoxville Institutional Review Board gave their approval to the research protocol for all of the procedures in this study. Forty-six 10-month-old infants were included in the final sample. The sample size was determined based on earlier studies with comparable methods and designs (Dixon et al., 2019; Guy et al., 2013; Guy et al., 2017; Pickron et al., 2018; Quinn et al., 2010; Scott& Monesson, 2010).

Within three weeks of their 10-month birthdate, all infants were recruited for participation in the study. The average age at testing was 308.61 days (SD: 5.93; range: 298-320). Infants who were born full-term (no less than 37 weeks gestation) without any significant complications during pregnancy or delivery, and who had no known vision impairments or other developmental complications, were considered eligible. Participants were chosen without regard to their race, ethnicity, or gender. However, given the demographics of the area, the majority of infants tested were White. The breakdown of the final dataset was 42 non-Hispanic White infants and 4 Hispanic White infants were participants (23 females, 23 males).

Apparatus

The testing was performed in a silent, dark space. Participants sat roughly 55 cm from a color monitor (27-inch Dell Gaming Monitor S2716DG) in their caregiver's lap. To guarantee that the baby was focused on the monitor and that outside distractions were kept to a minimum, black cloth drapes were drawn around the testing area. A digital video recorder placed right above the monitor recorded the child's attention on the screen (AXIS P3364-LV Network Camera). A video feed to the experiment control room was used to judge an infant's attention to the screen while being tested. The video was captured and synchronized with the EEG data using the software NetStation 5.4.1.2 (Electrical Geodesics Incorporated, EGI; Eugene, Oregon). The experimental stimuli were displayed using E-Prime 2.0 software (Psychology Software Tools, Inc., Sharpsburg, PA), and experimental events were sent to NetStation through NTP (Network Time Protocol), which synchronized these events with the EEG and video data.

Visual stimuli

The Chicago Face Database, a computerized archive of high-resolution full-color images of human faces of different races, genders, and ages exhibiting various emotions, provided the visual stimuli for this experiment (Ma et al., 2015).To further verify that visual perception properties were taken into account, the database's stimuli underwent extensive standardization and brightness testing. Based on previous research, options were limited to women actors to prevent any gender interaction effects on racial categorization due to the fact that infants typically show a preference for female faces over male faces (Tham et al., 2015; Tham et al., 2018). To prevent any interaction effects with faces showing a very salient emotion, neutral expressions were used in the images of Caucasian, Black, and Asian faces (Quinn et al., 2020). Age-based photo selection was done inside each race to weed out faces that were either very young or very old to prevent any potential age-related influences on race classification as well (Damon et al., 2016). Eventually, a total of sixty (60) faces were chosen to be included in the final dataset, with twenty (20) White, twenty (20) Black, and twenty (20) Asian faces chosen based on the percentage of independent raters who agreed the face's race matched the actor's self-identified race. The selection of the study's stimuli was based on the substantial norming data that was given in the data set. The rating proportion was calculated by dividing the total number of participants who indicated the chosen race by the total number of participants who assessed the face. A rating of 1.0 means that all raters concurred on the actor's race. The 20 White and Black faces all scored a perfect 1.0, and the twenty (20) Asian faces all scored an average of 0.95 (SD = 0.04, range = 0.88-1.0). Depending on the measure, the 1087 independent raters of the Chicago Face Database had a high range of reliability, ranging from 0.89 to 0.99. (Ma et al., 2015).

After the faces were chosen, a unique MATLAB script was used to crop the photos to an oval form (MATLAB, 2018). Ovalizing the faces decreased the use of extra peripheral indicators like hair color and style. The resulting full-color ovals were displayed in the monitor's center against a white background. Stimuli were given in full color to maintain ecological validity based on previous research that had indicated that infants do not distinguish between races based on color (Bar-Haim et al., 2006).

Procedure

A demographic survey was completed by the baby's caretaker after receiving informed consent. This survey requested demographic and family history data and was solely connected to the participant's experimental ID number. Questions inquired about the caregivers' occupation, degree of education, and home income to determine socioeconomic status. Further inquiries focused on the race of the infant, the race of the caregivers, and the race, age, gender, and relationship to the infant of any additional people residing with or frequently interacting with the infant. The survey also asked how frequently the baby went to daycare or another communal environment. This was done to gather information on the possibility that the baby was frequently exposed to faces of other races that weren't their caregiver’s race(s). Yet, during this study, the infant participants were either from mixed-race families or had almost exclusively been exposed to people of their own race. As a result, infants were initially omitted based on the race of their immediate family's self-reported members, and none of the remaining infants were disqualified based on their responses to the question about the group setting.

The baby was placed on the caregiver's lap around 55 cm from the monitor. As a second experimenter diverted the baby with toys and infant-directed conversation to lessen the likelihood of fussiness, a suitably sized EGI sensor net was installed. The Dixon et al. (2019) paradigm served as the basis for the experimental process. Pictures of White actors were used as the familiar stimuli in the experiment's "own-race" familiarization condition, while photographs of Black actors were used in the experiment's "other-race" familiarization condition. According to previous research, Black faces lose their sensitivity to White infants' perceptions of other-race faces earlier than Asian ones (Kelly et al., 2007; Kelly et al., 2009). Roth & Reynolds (2022) chose to consistently use Black faces as the familiar race for the other-race familiarization condition. Asian faces were presented as the novel-other stimuli in both the own-race and other-race familiarization conditions for the test trials. The experiment was divided into two phases: test trials and familiarization trials. Each of the 2 familiarization conditions—own-race, single exemplar (N = 10) and other-race, single exemplar (N = 13)—were randomly assigned to participants. The familiarization condition (single exemplar) was produced to counterbalance the example faces between subjects. As a result, for the single exemplar condition, one of two potential faces was utilized for familiarization, and each face was evenly distributed among participants. For the single exemplar familiarization conditions, the first phase included 20 repeated 1000 ms presentations of a single face. This produced a total familiarization duration of 20 seconds for each of the four familiarization scenarios, which is sufficient, according to earlier research, for infants to exhibit a novelty preference at this stage (e.g., Courage & Howe, 2001; Richards, 1997; Rose, 1983; Rose et al., 1982). The attention-grabbing stimulus was interspersed between each face during familiarization to ensure the infants' attention to the screen. Once the experimenter considered the infant to be centrally fixated, a button was pressed that centrally displayed a face image for 1000 ms. Each image was preceded by a 200 ms white blank screen that served as a pre-stimulus ERP baseline. Each stimulus display was also followed by a blank white screen, whose length fluctuated at random between 1000 and 1500 milliseconds. A dynamic non-social attention-getter was used between each face presentation during familiarization. An audio track of wind chimes playing in the background as a little, colorful circle radiated out from its center was used to ensure the infants were centered during the familiarization trials. If infants grew distracted or bored during the test sessions, Sesame Street audiovisual recordings without human faces were used to refocus their attention.

The test trials started right away after the 20 familiarization trials were finished. There were three stimulus types shown during testing: familiar trials, novel-same trials, and novel-other trials. We used the face or faces used during the familiarization phase (familiar trials), novel faces from the same race as the face or faces shown during familiarization (novel-same trials), and novel Asian faces which were not used during any familiarization condition (novel-other trials). The presentation of the three stimulus categories (familiar, novel same, and novel-other) was provided in a pseudo-random order with an equal frequency of presentation across a block of trials. Thirty (30) stimulus presentations of images were presented in blocks. Presentation of the stimuli persisted as long as the baby didn't get sleepy or cranky. The dataset's infant participants finished an average of 108 test trials with stimulus presentations.

EEG recording and analysis

EEG data were collected using the EGI GeodesicEEG System 400 (GES 400) 128-channel device. This system comprises NetAmps hardware, HydroCel Geodesic Sensor nets, and the NetStation software recording tool. The nets feature 124 electrodes set in a geodesic arrangement of pedestals that are held in place with elastic connections. Before capping the infant, the entire net is submerged for five minutes in an electrolytic solution based on saline and contains electrolytic sponges. To position the sensor net on the baby's head for anatomical landmarks, pedestals corresponding to the vertex, mastoids, and nasion sites were marked and employed during capping. The flexibility of the net connections preserves the right position of the pedestals corresponding to the other 120 electrodes. The scalp electrodes have an average interelectrode spacing of 21 mm.

The electrode impedance of the net, when properly positioned, ranged from 10 to 50 k. The electrodes were relocated if the impedance during net deployment was greater than 100 k to achieve the desired impedance. The iMac computer's A/D card is connected to high-impedance amplifiers as part of the EGI system. The A/D sampling, calibrations for each channel, and impedance data were all carried out using the NetStation program of the EGI system. Based on the experimental data being sent from the experimental Dell PC to the NetStation program on the Mac utilizing the E-Prime NTP, communication between the two machines was time synced. Using 20 k amplification and a sampling rate of 1000 Hz, bandpass filters were configured to range from 0.10 to 30.00 Hz.

Once EEG data were acquired, the recordings were reviewed for artifacts (e.g., blinks, movement, saccades, drift, distraction) and poor recordings using the NetStation Review system. Artifacts were defined as $\Delta > 250$ µV/250 milliseconds within a single ERP segment and NetStation's Artifact Detection tool was used to mark trials as poor if artifacts were identified. Segments in which >10 % of the channels were marked bad were excluded from the analysis. Bad channels were substituted for those with less than 10% of the channels rated as bad using a spherical spline interpolation (Perrin et al., 1989; Srinivasan et al., 1998). Following EEG editing, only subjects who provided 7 or more ERP trials per trial type for stable ERP averages were included for analysis (Carver & Vaccaro, 2007; de Haan & Nelson, 1997; Hoehl & Wahl, 2012; Reynolds & Richards, 2019). Across familiarization conditions and trial types, the number of trials included in the ERP averages did not change substantially (F(6,84) 0.746, p =.615).

As is standard practice in the field (DeBoer et al., 2007), electrode locations used for each ERP component were based on visual inspection of the grand average waveforms and previous studies (i.e., LSW component: de Haan & Nelson, 1999; Guy et al., 2013; Reynolds & Richards, 2019; Snyder et al., 2002; Webb et al., 2005; Wiebe et al., 2006). The EEG was divided from 200 ms before the stimulus start to 1500 ms after onset. From 800 to 1500 milliseconds after stimulus onset, the LSW mean amplitude was examined at frontal-central electrode locations ("Fz", 5, 6, 12, 13, and 112). The stimuli and data from this investigation are publically available at:

https://doi.org/10.17605/OSF.IO/ZN8YD. The data was then separated by condition and sex to be further analyzed.

Results

ERP averages for the LSW component associated with infant recognition memory were analyzed separately for experimental effects using 3 × 2 × 2 multivariate analysis of variance (MANOVA) with race (2: Black, White) and sex of participant (2: female, male) as between-subjects factors, and stimulus type (4: familiar, novel-other, novel-same) as a within-subjects factor. Two-sided paired-sample t-tests were used to conduct follow-up analyses and planned comparisons. For all tests, the significance level was set at $p<.05$. Effect sizes (η_p^2) are reported for significant findings. The current analysis and reported effects were limited to the main effects and interaction effects relating to the participant's sex because this study involved supplemental analyses of data from a prior study (Roth & Reynolds, 2022). Refer to Figure 1 for averaged ERP waveforms presented by participant sex and stimulus type.

A significant interaction between stimulus type and sex was found in the MANOVA on the LSW component associated with infant recognition memory ($F(2, 18)$ 3.78; p=.04; *Wilks Δ* = .704; η_p^2 = .296). Follow-up analyses revealed that male participants demonstrated significantly lower LSW amplitude (t(10) -3.15; p=.01) to familiar faces (M = 1.24, SE = 2.44) in comparison to novel-other race faces (M = 9.68, SE = 3.36). In contrast, the LSW amplitude was greater for female participants when they saw familiar faces (*M* = 4.70, *SE* = 3.08) as opposed to novel-other race faces (M = -1.64, SE = 2.33). However, for female participants, this difference only approached significance (*t*(11)1.90; *p* = .08). See Figure 1.

Planned comparisons were carried out examining potential differences in how female and male participants processed faces based on race. These comparisons revealed that the LSW effects reported above for male participants were primarily driven by males tested with other-race faces. The LSW amplitude in response to familiar faces (*M*= 0.95, *SE* = 3.32) compared to novel-other race (Asian) faces (*M*= 12.28, *SE* = 4.03) was significantly different in males familiarized with other-race (Black) faces (*t*(7) -4.37, *p* = .003). Males familiar with their own race (White) faces, in contrast, did not exhibit any differences in LSW amplitude based on familiarity or race (all ps > .20). However, given the very small sample size for this group (n=3), this null result must be interpreted with considerable caution.

In contrast to male participants, female participants tested with their own race (White) faces primarily drove the marginal differences between familiar and novel-other race faces reported above. The LSW amplitude between familiar (White) faces (*M*= 8.68, *SE* = 4.72) and novel-other race (Asian) faces (*M*= -2.59, *SE* = 3.67) was significantly different for females tested with own-race faces (*t*(6) 2.54, *p* = .04). When tested with other-race faces, females showed no racial or familiarity-related differences in LSW amplitude (all ps > .45).

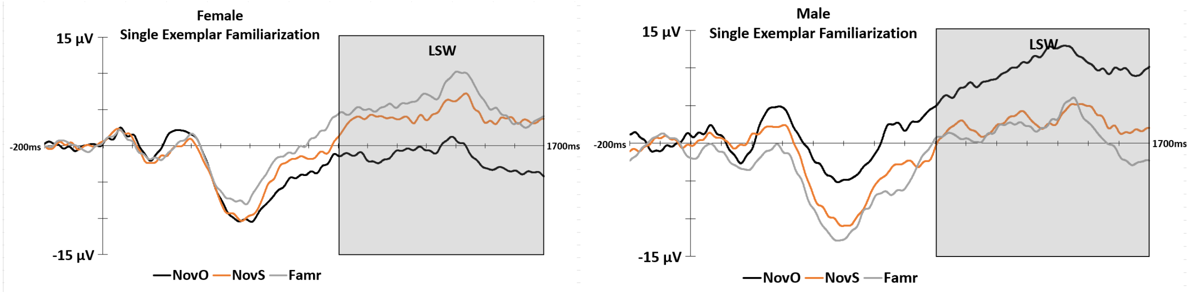

Figure 1: LSW components by stimulus type are present at frontal-central electrodes for the single exemplar familiarization condition. The left panel displays the female infants in the single exemplar familiarization condition, whereas the right panel displays the male infants in the single exemplar familiarization condition. Familiar trials are represented with a gray line. Novel-same trials are represented with an orange line. Novel-other trials are represented with a black line. The time is shown on the x-axis as 100 ms segments, while the amplitude is shown on the y-axis as microvolts. The intersection of the x and y axes represents the stimulus onset. The time window for the analysis of the LSW component (800-1500ms) is shown by the shaded box.

Discussion

This study's design was influenced by the results of the Roth and Reynolds (2022) study and the categorization-individuation model. Based on previous literature on categorization and literature on sex differences in infant processing, I predicted that 10-month-old White male infants would be more likely to categorize other-race faces at a subordinate-level category due to the increased speed of their face processing. The findings were somewhat consistent with my predictions based on the cautionary interpretations from the limited sample size. This study primarily focused on the LSW, it can be seen that the male infants have a significantly lower LSW amplitude to familiar faces in comparison to novel-race faces. This effect was strongest for male infants tested with other-race faces, and indicates that the male infants are most likely actively encoding the novel race faces due to their decreased response to the familiar faces. This could potentially be an indicator of subordinate-level categorization. In contrast, the female infants seem to have a greater amplitude of the LSW for the familiar faces. It seems that the females were still processing, and thus showing greater amplitude LSW to, the familiar faces. These findings for the female infants approached significance but did not produce significant results. However, in contrast to male infants, female infants tested with own-race faces showed significantly greater amplitude to the familiar (own-race) face in comparison to novel-other race faces. Although speculative, it may be the case that the female infants were still engaged in the process of individuating the familiar faces from the novel race faces, and thus they continued to demonstrate high amplitude LSW to the familiar own-race face indicative of active stimulus encoding (de Haan & Nelson, 1997, 1999). The finding from the full factorial analysis of the full dataset indicated that male infants showed significant differences in LSW amplitude between familiar and novel-other race faces. While female infants did not remain consistent with my prediction that 10-month-old White male infants would be more likely to categorize other-race faces, it did remain consistent with the possibility male infants have faster processing speed for faces.

Limitations

One of the major limitations of this study was the small sample size of infants that were used. Due to the small sample size, the results of the planned comparisons examining sex differences in infant face processing based on race must be interpreted with caution. However, the analysis yielded interesting findings which warrant replicating this study replicated with a larger sample size to allow for greater statistical power and more reliable findings.

Additionally, including a variety of age groups would add important developmental insight into this study. Particularly, a longitudinal design testing participants at various ages throughout early childhood and infancy would yield useful information that could present a developmental trajectory and shed light on whether and when infants start to show less effective individuation of other-race faces compared to own-race faces. According to the categorization-individuation model, longitudinal data may potentially show a transition from individuation to categorization (Hugenberg et al., 2010).

Conclusions

The current findings in conjunction with the Roth and Reynolds (2022) study seem to indicate that 10-month-old White infants process other-race faces similar to own-race faces, with an increased facial processing speed of male infants. Further research should examine the possibility of male infants being more likely to categorize other-race faces as the current findings suggest. Male and female infants may become skilled at processing faces of their own race as a result of perceptual narrowing, but it is unlikely that they will entirely lose sensitivity to faces of other races. Future research should replicate this study with a larger sample size and should look at the factors that male and female infants, children, and adults use to categorize or individuate the faces of people of different races. This will help to continue to shed light on how face processing develops as well as highlight differences in male and female development and how social biases and racial prejudices emerge in childhood development.

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