Neural Correlates of Face Processing: Perceptual Narrowing and Categorization

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ABSTRACT

Perceptual narrowing is a developmental process that occurs between 6 and 9 months of age, during which infants transition from having more general perceptual abilities to more specific abilities. An example of this would be the other-species effect, in which infants experience a decline in the ability to individuate other species' faces. It has been suggested that an infant's growing ability to categorize could lead to a decline in their ability to discern individuals within other-species groups (Scott & Monesson, 2009), and that this difference is related to processing styles. In this study, 9-month-old infants were tested on their subordinate-level categorization ability with different species of monkey faces. Subordinate-level categorization is categorization on the species level. ERP data was recorded while the infants were shown presentations of the novel face/familiar species category and the novel face/novel species category after being familiarized to either a single face or a group of exemplars. It was predicted that the 9-month-olds in the categorization group would have a greater amplitude ERP response, namely the P400 component, to the Novel Other face category versus the Novel Same and Familiar face categories. This would provide evidence that infants at this age are not processing individual faces from other-species but are categorizing other species faces. It was also predicted that there would be differences in the Nc component between groups based on condition type. It was found that the categorization group showed an ability to categorize the monkey faces by species, as shown by a larger amplitude Nc and P400 for the Novel Other face category, whereas the individuation group did not. These findings add support to the idea that subordinate-level categorization could be a mechanism behind the effects seen from perceptual narrowing of other-species faces.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

Face perception is an important ability for interacting with the environment and understanding the intentions of others (Park et al., 2009; Souza, Feitosa, Eifuku, Tamura, & Ono, 2008). Development of face perception begins in infancy (Halit, De Haan, Johnson, 2003; Le Grand, Mondloch, Maurer, & Brent, 2003), and continues throughout childhood (Taylor, Batty, & Itier, 2004). This developmental change in face processing and perception is vital for typical development (Farroni, Csibra, Simion, & Johnson, 2002). Deficits in various face processing abilities have been associated with autism (Harms, Martin, & Wallace, 2010), bipolar disorder (Brotman et al., 2008; Deveney et al., 2014), and schizophrenia (Morris, Weickert, & Loughland, 2009). Understanding the mechanisms driving normal development of face processing in infancy might help to better understand how some of these deficits develop.

Human infants prefer looking at faces to looking at almost any other type of image (Mondloch et al., 1999). Infants as young as 9 minutes of age have been found to track unscrambled faces further than scrambled or blank faces (Johnson, Dziurawiec, Ellis, & Morton, 1991). Across the first year of life, infants demonstrate a preference for attractive faces (Langlois et al, 1987), faces that are perceived to be of the same gender as their caregiver (Quinn, Yahr, Kuhn, Slater, & Pascalils, 2002), and for faces that are of their own racial group (Kelly et al., 2007). Six-month-old infants can also discriminate between familiar and unfamiliar faces (de Haan & Nelson, 1999), human and nonhuman faces (Pascalis et al., 2005), and racially similar and dissimilar faces (Nelson 2001). There is also evidence to suggest a differential processing

strategy for happy versus fearful faces (Martinos & de Haan, 2012; Nelson & de Haan, 1996). Alongside these preferences and capacities, infants' abilities to process and discriminate faces become more sophisticated as they age (Carey, De Schonen, & Ellis, 1992).

One of the developmental changes seen in face perception during infancy is perceptual narrowing. The infant brain is teeming with an overabundance of neurons, which then systematically die off, or are "pruned", as a function of experience (Greenough, 1987). It has been suggested that one of the results of this pruning in normal development is the phenomenon known as perceptual narrowing (Lewkowicz & Ghazanfar, 2006; Scott, Pascalis, Nelson, 2007), in which infants transition from having perceptual abilities that are more broadly tuned to having abilities later in life that appear more specialized. There is a large body of research on perceptual narrowing, possibly because of its occurrence in several domains across perception, including language (Pons, Lewkowicz, Soto-Faraco, & Sebastián-Gallés, 2009), music (Hannon & Trehub, 2005), and face recognition (Cashon & DeNicola, 2011).

In one of the classic studies on perceptual narrowing, researchers tested English-speaking adults, Hindi-speaking adults, and 6- to 8-month-old infants being raised in English-speaking environments on their ability to differentiate Hindi vocal contrasts (Werker, Gilbert, Humphrey, & Tees, 1981). Eight examples of two different Hindi phonemes recorded by a native speaker served as the stimuli. Infants' head turns to changes in stimuli were recorded and correct turns were reinforced, while the adult participants pressed a button to indicate that they heard a change in the phonemes presented. It was found that the Hindi adults and the infants had the most success with discriminating the contrast when compared to the English-speaking adults. The authors attributed the differences in performance to infants' natural ability to distinguish contrasts in nonnative languages. A series of follow-up studies by Werker and Tees (1984)

sought to replicate and expand on their results from their earlier study. Experiment 1 tested English-speaking adults, Thompson (a Native Indian language) -speaking adults, and 7-month-old infants being raised in English-speaking homes on their discrimination of phonemes using the same head turn procedure as the previous study (Werker, Gilbert, Humphrey, & Tees, 1981). Thompson glottal contrasts not found in the English language were used as the test stimuli. The results were similar to the previous study, with the Thompson-speaking adults and the 7-month-old infants being able to distinguish between the contrasts, whereas the English-speaking adults could not. Experiment 2 sought to ascertain the time frame in which the decline in this ability to discriminate took place. It was found that the majority of 6- to 8-month-old English infants could discriminate between two non-English contrasts, whereas the 10- to 12-month-old performed as poorly as native English-speaking adults on the task. However, the infants being raised to speak the Thompson language could still discriminate the contrasts by 10-12 months of age (Werker & Tees, 1984). These findings provide evidence that even without direct experience with a language, infants can discriminate phonemes of non-native languages, but that past the age of 6-8 months, without continued experience with a language, the ability to discriminate declines. Other studies also provide evidence that without continued experience with a certain language, the ability to discriminate sounds from that language declines by 12 months (1984; Kuhl et al., 1992; Kuhl et al., 2007).

Research on infants' perceptual abilities has shown parallels between the decline in language perception and the decline in face perception. The two perceptual narrowing effects related to face processing and perception are the other-race effect and the other-species effect. The other-race effect occurs between 6 and 9 months of age, and is a decline in the ability to discriminate between other-race faces (De Heering, De Liedekerke, Deboni, & Rossion, 2010;

Ge et al., 2009; Meissner & Brigham, 2001; Nelson, 2001). The decline, between 6 and 9 months of age, in the ability to discriminate non-human faces has been termed the other-species effect. Pascalis, de Haan, and Nelson (2000) used a visual paired-comparison (VPC) task to determine if infant participants could, at 6 and 9 months of age, discriminate between a pair of human faces or a pair of monkey faces. In the VPC task, the infants were first familiarized with a single monkey or human face. They were then shown two pictures side by side of either a pair of monkey faces or a pair of human faces. The pairings consisted of the face to which the infant had been familiarized, and a novel face of the same species as the familiar face. In preferential looking procedures such as this, recognition of the familiar face is assumed to have occurred if the infant fixates longer on the novel face. The 6-month-olds showed this novelty preference when shown monkey faces, but the 9-month -olds did not (Pascalis, de Haan, & Nelson, 2000). Both age groups showed novelty preference with human faces. These results suggest that with 20 s of exposure, 6-month-olds can differentiate between a novel and familiar monkey face whereas 9-month-olds cannot. A similar study was performed with non-primate stimuli. Simpson and colleagues (2011) presented 4- to 6-month-old infants and 9- to 11-month-old infants with novel and familiar sheep faces in a VPC task after they were familiarized to an individual sheep's face. The 4- to 6-month old infants showed a preference for looking at the novel sheep faces, suggesting again an ability to discriminate individual sheep. The 9- and 11-month-olds did not display looking preferences, suggesting an inability to discriminate between the sheep faces. (Simpson, Varga, Frick, & Fragaszy, 2011). The body of research on this effect seems to suggest that there is maintenance of discrimination for own-species faces (human) and a decrease for in discrimination of other-species faces (Pascalis, de Haan, & Nelson, 2002, Pascalis, Scott, & Kelly, 2005).

As in the domain of language perception, the development of face perception and face processing abilities have been shown to be malleable. There are several studies that provide evidence that the other-species effect and the other-race effect can be modified by experience, and that the ability to distinguish between other-species and other-race faces can be maintained through individuation training (Heron-Delaney et al., 2011; Scott & Monesson, 2009; Sugita, 2007). Scott and Monesson (2009) gave the parents of three groups of 6-month-olds three different books of six monkey faces and asked that the books be "read" to the infants periodically over a three month period. The faces in each book were the same, but the labels accompanying the pictures differed. One book had the monkeys labeled at the individual level (e.g., Boris, Fiona), another had the monkeys labeled at the basic level (ex: monkey), and the third had no labels at all. The 6-month-olds who were given the individually labeled book were found to have retained the ability to discriminate between individual monkey faces at 9 months; however, the other two groups (categorical labels and no labels) did not retain this ability. The 9-month-olds who did not receive the individualized training experienced perceptual narrowing for non-human faces. Most of the current research suggests that behaviorally, without specific training, perceptual narrowing for non-human faces occurs by 9 months of age in the typically developing infant (Kelly et al., 2007; Pascalis et al., 2002; Pascalis et al., 2005; Scott, Pascalis, & Nelson, 2007; Scott and Monesson, 2009; Simpson et al., 2011).

Event-related potentials (ERPs) have been used to study perceptual narrowing as it relates to face processing in infancy (Scott, Pascalis, Nelson, 2007). ERPs are positive or negative voltage oscillations measured on the scalp using EEG (electroencephalogram), which are time-locked to an event of interest (de Haan, 2013). The ERP components that are identified with infant face processing in general are the N290 and the P400, both of which are thought to be

precursors to the adult N170 (Hoehl & Peykarjou, 2012; Halit, de Haan, Johnson, 2003; de Haan et al., 2002). The N290 is larger to inverted human faces but not inverted monkey faces at 12 months of age which is not seen at earlier ages (Halit et al., 2003), and is thought to be related to the process of encoding physical information about faces rather than the process of recognition of individual faces (de Haan, Johnson, & Halit, 2003). This component is also particularly sensitive to eyes and gaze direction. The P400 is an infant component for face processing which peaks faster to faces than objects in 6-month-olds (de Haan & Nelson, 1999), and becomes more sensitive to human faces in an upright orientation as the infant ages (de Haan, Johnson, & Halit, 2003).

Another component utilized to study face processing is the Negative central (Nc) component. Nc is sensitive to stimulus probability (Courchesne, Ganz, & Norcia, 1981). It also represents attention allocation (a greater Nc can mean a larger allocation of attention is being directed to that particular stimulus), and is typically larger to the novel, or most salient stimuli (de Haan, Johnson, & Halit, 2003; Reynolds, Courage, & Richards, 2010). The latest latency component involved in infant face perception is the late slow wave (LSW). The LSW is thought to represent recognition memory (de Haan & Nelson, 1997; Reynolds, Guy, & Zhang, 2011). For example, 12-month-olds have similar LSW responses to toys and upright faces, but not to inverted faces, suggesting recognition of the familiar items (de Haan, Johnson, & Halit, 2003).

One study used ERPs to examine how infants process other-species faces after perceptual narrowing is thought to occur (Scott, Shannon, & Nelson, 2006). The authors tested two groups of 9-month-old infants in two conditions. In the first condition, infants were familiarized with a human face in a frontal orientation and then tested for recognition of the familiar face in a different orientation while differentiating it from a novel face in similar (frontal) and dissimilar

(profile) orientations. The second condition was identical except that monkey faces were used instead of human. Researchers expected the ERP findings to fall in line with the behavioral results from previous face perception studies on 9-month-olds. Rather than demonstrating differential electrophysiological responding for each of the four faces (familiar-frontal, familiar-profile, novel-frontal, and novel-profile), the 9-month-olds showed discrimination between different monkeys by producing similar ERP responses (on the P400 component) for the same monkey in both orientations (Scott, Shannon, & Nelson, 2006). This suggests that the infants recognized the individual monkey despite changes in face orientation, and were able to discriminate between the different individuals. Based on these results, the authors suggested that there might be some kind of face recognition happening for the individual monkeys. The authors posit that perhaps methodological inconsistencies might be at the heart of this unexpected finding, or that "although past findings suggest that 9-month- olds do not behaviorally discriminate monkey faces, part of the ventral visual stream may be processing this information" (Scott, Shannon, & Nelson, 2006). This is one of the few studies that used ERPs to examine other-species face processing in infancy after perceptual narrowing has occurred.

As mentioned above, there is a large body of research on the effects of perceptual narrowing across domains. One of the questions that remains is how face processing changes during development to create these effects. Two processing strategies are important to consider when assessing the development of this phenomena: categorization and individuation. Categorization is the process by which exemplars are classified into groups using shared characteristics (ex: classifying an animal as a cat), whereas individuation is the process of "discrimination among exemplars of a category" (ex: discriminating individuals within a group of cats) (Hugenberg, Young, Bernstein, & Sacco, 2010).

The development of categorization moves from general to specific in the first year of life, from the superordinate to the subordinate. Superordinate (or global) categorization is the broadest level and has been seen in 2 month-olds when forming a category for animate objects that excludes inanimate objects (mammals vs. furniture) (Quinn & Johnson, 2000). The next level, basic, is seen at 3-4 months of age, but not in younger infants. Three- to four-month-olds are able to form categories for different types of animals; for example, a category that includes cats but excludes horses (Eimas & Quinn, 1994). Subordinate representations are formed around 6-7 months of age (Eimas & Quinn, 1994). For example, 6- to 7-month-olds were found to have categorical representations for Saint Bernards that excluded Beagles, which is a subordinate level distinction (Quinn & Tanaka, 2007). Attention style and previous experience can also affect an infant's ability to develop categories. Four-month-old infants' development of an exclusive category for cats that did not include dogs was facilitated if they had cats at home and exhibited high switching looking behavior during testing, whereas infants had a harder time if they did not have cats at home and exhibited low switching (Kovack-Lesh, Oakes, & McMurray, 2012).

ERPs have also been used to look at categorization in infants. In a recent paper, 6- to 7-month-old infants' subordinate categorization was investigated. ERP data was recorded while 10 infants were familiarized with 36 St. Bernard images in various poses and orientations. These infants were being raised in homes without dogs. Each image was presented for 500 ms by itself, centered on a computer screen in front of the infant. The next stage consisted of 20 novel St. Bernard images interspersed with 20 novel Beagle images. Two five-second, paired-comparison trials were also run after the ERP phase of testing in order to analyze looking behavior. A novel St. Bernard image was presented paired with a novel Beagle image. It was found that the late slow wave was associated with subordinate level (species level) categorical processing and the

Nc was associated with novel category preference at the basic level. Novel category preference at the subordinate level was also associated with the Nc, with an addition of a P400 component. This suggests that the mechanisms involved in subordinate-level categorization are supplementary to the mechanisms involved in basic-level categorization, and that it is the P400 component that is related to subordinate-level categorization (Quinn et al., 2010).

Learning at the individual level may serve to either maintain or foster an infant's ability to continue to discriminate among other-race or other-species faces; for example, training on a group of monkeys named at the individual level can lead to a maintenance of the ability to individuate monkeys (Scott & Monesson, 2009). The ability to individuate and process human faces then may develop from everyday interaction with and viewing of this type of face (for the average infant developing in a typical environment). One theory is that this difference in experience creates two distinct processing methods- configural and featural coding (Rhodes, Brake, Taylor, & Tan, 1989; Tanaka, Kiefer, & Bukach, 2004; Michel, Rossion, Han, Chung, & Caldara, 2006). In featural processing, an object/face is coded in its individual parts. In configural processing, an infant analyzes the relationship between the individual parts of the face and processes it as a whole (Hugenberg, Young, Bernstein, & Sacco, 2010). There is also neural evidence to suggest that individuation is accomplished through configural/holistic processing. In a recent study, infants were trained to recognize images of strollers either by category ("stroller") or by a name exclusive to a single stroller. The infants that were in the individual level training group showed, in occipital areas, amplified holistic processing where the category group did not (Scott, 2011).

The decline that is seen in discrimination of other-species faces may in fact be caused by a change in processing strategy. Nine-month-old infants may categorize other-race and other-

species faces instead of individuating them (Mauer & Werker, 2014). The proposed study will examine, using ERPs, the neural correlates of other-species category processing by 9-month-old infants. Many questions still remain about processing mechanisms of other-species faces after perceptual narrowing has occurred. Understanding more about neural correlates of infant categorization (especially of an other-species face) may help to identify the mechanisms involved in the development of perceptual narrowing. Also, it might help to understand more about the development of categorization in infancy. Based on the work by Quinn and colleagues (2010), it was predicted that 9 months olds should be able to categorize monkey faces at the subordinate level when familiarized to an exemplar group of the same species of monkey.

Infants were divided into two groups: a categorization group and an individuation group. The participants in the categorization group were familiarized to a group of capuchin faces, whereas the participants in the individuation group were familiarized with a single capuchin face, presented multiple times. Both groups were then presented with faces from either the Novel Same category of faces (same species, novel faces), the Novel Other category of faces (different species, novel faces), or the Familiar category (or face). ERPs were recorded during this phase, as well as during the familiarization phase. Based on previous work suggesting that the P400 is related to subordinate categorization, it was predicted that the mean P400 amplitude would be the greatest for the novel other condition when compared to the novel same and familiar conditions in the categorization group, suggesting that the familiarization with a group of exemplars allowed infants in this group to be able to differentiate between the two species of monkey. It was predicted that the individuation group would not show a difference in mean P400 amplitude across stimulus type, which would provide evidence that it is categorization of faces, and not individuation that is taking place. Evidence of subordinate categorization in the

categorization group would suggest that this level of categorization might be the processing strategy used for other-species faces after perceptual narrowing has occurred. These results would support the possibility that 9-month-olds engage in subordinate level categorization as opposed to individuation. I also expected Nc mean amplitude differences between the two groups, but that there would not be a difference for the N290 component. The Nc represents attention allocation (de Haan, Johnson, & Halit, 2003; Reynolds, Courage, & Richards, 2010), which was expected to be greater for the novel other condition as compared to the novel same and familiarization conditions in the categorization group, based on the prediction that these infants would be able to discriminate between the monkey species. For the individuation group, no differences in Nc between conditions were predicted. The N290 has been shown to be an infant face detection component (de Haan, Johnson, & Halit, 2003), so no difference within or between the two groups would suggest that all of the participants perceived the stimuli as faces.

CHAPTER 2

METHOD

Participants

A sample of 21, 9-month-old infants participated in this experiment. Only infants with uncomplicated deliveries who were born full-term with a healthy, normal birth weight were recruited. Seven infants' data was not usable due to fussiness (n=1), having less than 10 good trials per condition (n=2), premature birth (n=1), or experimenter error (n=3). Fourteen infants were included in the final data set. Half of these infants were male (n=7), and half were female (n=7). The ethnic/racial division of participants used in the final data set was: 12 Caucasian (non-Hispanic), 1 African-American, and 1 Asian.

Apparatus

Participants were seated in their parent's lap in a sound-attenuated room, 55 cm away from a 27" color LCD monitor (Dell 2707 WFP). A digital camcorder (Sony DCR-HC28) was placed on a stand just above the monitor, and the video from it was used to judge infant looking behavior. This behavior was judged using video feed to a computer in the experiment control room next to the testing room. Netstation software (produced by Electrical Geodesic Incorporated- EGI) was also used for video recording, as well as being used to record and synchronize EEG data with the video (see further details below).

Visual Stimuli

Capuchin faces: Digital color, oval-shaped photographs of adult capuchins faces were presented sequentially on the monitor, see Figure 1. The pictures were bitmapped files. **Macaque**

faces: Digital color, oval-shaped photographs of macaques were presented sequentially as well. All faces were 22.5 cm tall and 14.5 cm wide when presented on the monitor. They were presented in the center of the monitor against a white background. **Attractor:** During the familiarization phase, an orange star was used as an attractor to insure that the infant was focused on the screen. The orange star was approximately 8 cm x 8 cm, and was presented in the middle of the screen against a white background. **Sesame Street clips:** Video clips of Sesame Street characters were used to redirect infants' interest and attention on the monitor after becoming distracted. The video covered a 15" square area centered on the monitor.

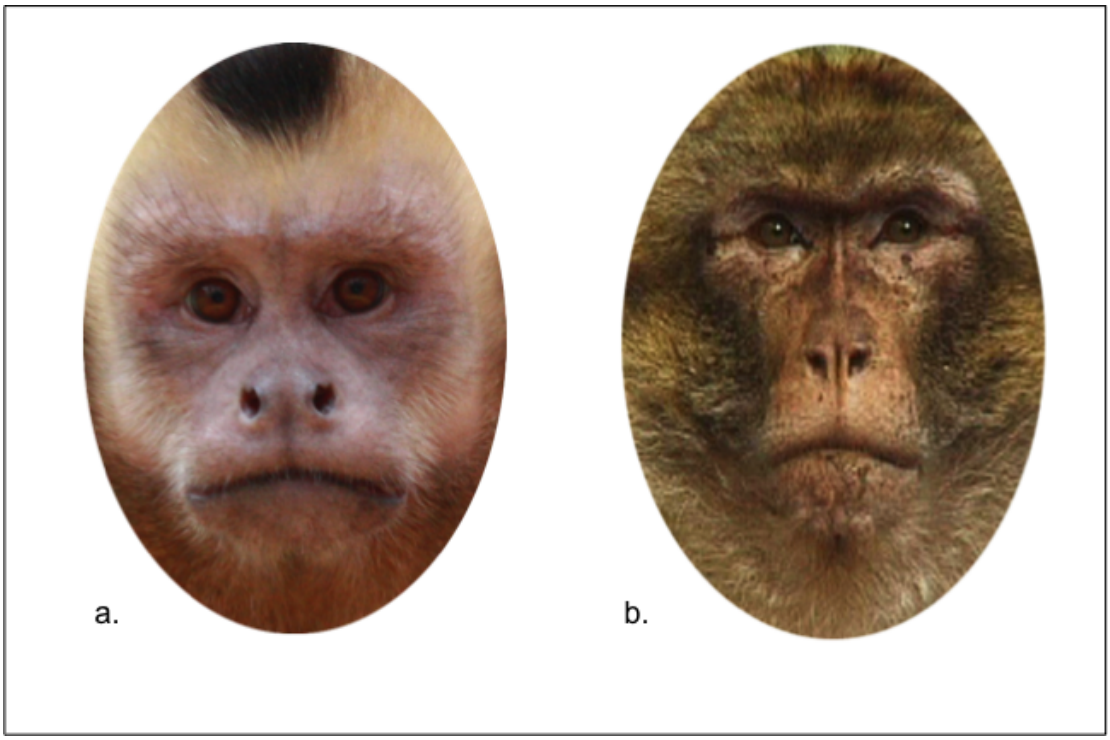


Figure 1. Examples of capuchin (a.) and macaque (b.) stimuli

Procedure

After informed consent was obtained, infants were seated on a parent's lap in the testing room about 55 cm away from the computer monitor. An appropriately sized EGI sensor net was then selected and placed on the infant. Placement took about 5-10 minutes, during which an experimenter tried to distract the infant during the process, so that the infant would not become distressed. An experimenter then measured impedances. The experiment had two stages. The first stage ("Learn" trials) consisted of sequential presentations of capuchin faces. The individuation group was only familiarized with one individual's face, which was presented twenty times. Each image was presented by itself for 500 ms following the attractor. The categorization group was familiarized with 10 different capuchin faces, each presented twice. Again, each presentation lasted for 500 ms, which each face presentation being preceded by the attractor. The second stage consisted of experimental ERP trials made up of 500 ms presentations of novel capuchin faces (novel individual, same species- "Novel Same"), novel macaque faces (novel individual, other species- "Novel Other"), and capuchin faces from the familiarization phase ("Familiar"), The presentation of these faces was shown in pseudo-random order, with equal probability for each participant. Looking behavior was analyzed offline. If an infant became distracted, Sesame Street clips were played to regain the infant's attention. The familiarization stimulus was changed between participants in the individuation group. Five different capuchin faces were used; with 2 participants being familiarized to C1, 2 participants being familiarized to C2, and 1 participant each being familiarized to C11, C10, and C21.

EEG Recording

The Electrical Geodesics Incorporated (EGI) Geodesic EEG System 300 (GES 300) 128 channel EEG recording system was used. It consisted of the HydroCel Geodesic Sensor net, the NetAmps hardware, and the Netstation recording program. The recording net is a web of elastic, consisting of a geodesic configuration of pedestals on which 128 channels are mounted behind electrolytic sponges. 124 channels were used for infant recording. The net was submerged in a saline solution before use. The elasticity of the net maintains the spacing between electrodes once it is placed, using the mastoid, nasion, and vertex locations to find the correct position on the participant. The average interelectrode distance of the electrodes on the scalp was 21 mm.

When the net is placed properly, the electrode impedances range from 10 to 50 kΩ. If during placement the impedance of an electrode was deemed as high (>100 kΩ), the electrode was repositioned. The EGI system contains 128 channels that use high-impedance amplifiers, which are connected to a computer A/D card in a PowerPC-based computer system. The EGI system's Mac program performed the A/D sampling, stored the data and the calibrations for each channel, and measured the impedances. A Dell Workstation was used to control the protocol and communicated with the Netstation program on the Mac computer. This communication was synchronized based on the information sent. Band-pass filters will were set from 0.1 to 100 Hz with 20k amplification, with a sampling rate of about 250 Hz.

The EEG recordings were edited with the Netstation review system in regard to artifact, noise, and poor recording. Movement and eye-blinks can create artifact. Artifact was defined as changes that are greater than 300-microvolt changes within a single ERP segment. EEG channels were excluded from the overall analyses if artifact was found. Each participant needed at least 10

artifact-free trials per stimulus type to be included in the data analysis. ERP grand waveform averages were used to make waveform plots, and also were used for the analyses of experimental effects. ERP averages were calculated from 100 ms before the stimulus onset to 1.5 seconds after the onset. These averages were then used for statistical analysis and waveform plots. Nc mean amplitude was analyzed from 350 to 650 ms following stimulus onset. The Nc component was analyzed at midline central electrodes (Cz, 7, 106, 13, 6, 112, 5, and 12- "CentralZ"). P400 mean amplitude was analyzed from 300 to 500 ms following stimulus onset. The P400 component was analyzed at midline occipital electrodes (81, 74, 82, 75, 69, and 89- "OccipitalZ"). The LSW mean amplitude was analyzed from 1 to 2 seconds following stimulus onset. It was analyzed at two locations: right posterior temporal (97, 96, 95, 90, 91- "TemporalR"), and left posterior temporal (51, 58, 59, 64, 65- "TemporalL"). The N290 mean amplitude was analyzed from 150-350 ms following stimulus onset. It was analyzed at three locations: midline occipital (75, 70, 71, 76, 83- "OccipitalZ"), parietal left (53, 52, 60- "ParietalL), and parietal right electrodes (86, 92, 85- "ParietalR").

Design for Statistical Analysis

The design for this study included the between-subjects factor of group (two: individuation, categorization), and the within-subjects factor of condition (three: Familiar, Novel Other, Novel Same) and electrode cluster (number of levels dependent on the component of interest). Repeated-measures analyses of variance (ANOVAs) were used and the Greenhouse-Geisser correction was used if necessary. For significant effects, follow up tests were run using either one-way or two-way ANOVAs along with paired samples t-tests, with the data for each group (categorization or individuation) being run separately with only three conditions (Familiar,

Novel Other, Novel Same), with a separate ANOVA conducted for differences between the Learn and Familiar conditions. All significant effects are shown at $p < .05$.

CHAPTER III

RESULTS

N290 and LSW

For the analysis of mean amplitude of the LSW component, a repeated measures ANOVA was used with a between-subjects factor of group (2: categorization, individuation), a within-subjects factor of condition (3: Familiar, Novel Other, Novel Same), and a within-subjects factor of electrode cluster (2: Temporal Left, Temporal Right). No effects were found in the analysis of the LSW component (F (2,24)<.00, p=.99, η_p^2 <.00). For the analysis for mean amplitude of the N290 component, a repeated measures ANOVA was used with a between subjects factor of group (2: categorization, individuation), a within-subjects factor of condition (3: Familiar, Novel Other, Novel Same), and a within-subjects factor of electrode cluster (3: OccipitalZ, Parietal Left, Parietal Right). As expected, no effects were found in the analysis of the N290 component (F (2,24)=1.36, p=.26, η_p^2= .10). The remainder of the analyses focused on Nc and P400 components. The grand average waveforms for these two components are presented in Figure 2.

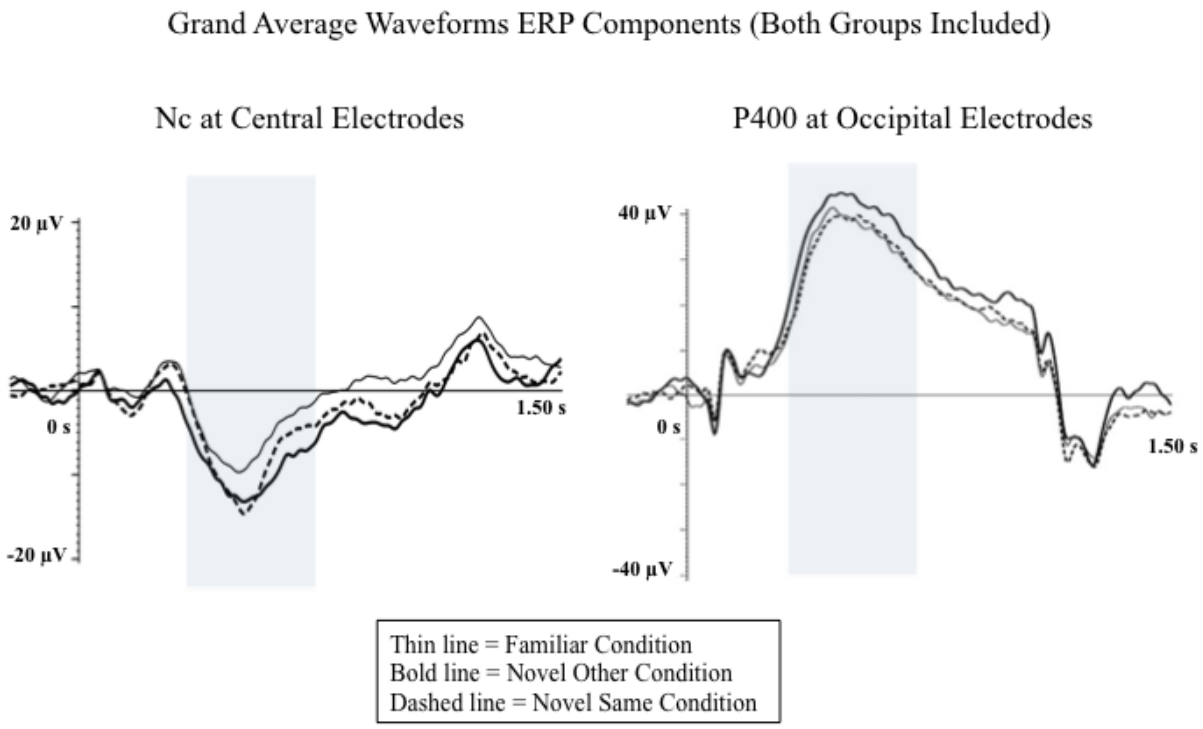


Figure 2. The grand average waveforms for both groups for the Nc and P400 components. Time following stimulus onset is indicated on the x-axis, and change in amplitude from baseline is indicated on the y-axis.

The Nc component

For the analysis of mean amplitude of the Nc component, there was a significant main effect of condition, F (2,24)=4.77, p= .02, η_p^2=.28. Across both groups, the Novel Other condition (M= -11.14 µV, SD=1.83 µV) had a significantly larger mean Nc amplitude than the Familiar condition (M= -6.53 µV, SD=1.88 µV). There was a significant interaction of condition by group, F (2,24)=4.13, p= .03, η_p^2=.26. There was also a significant between-subjects main effect of group F (1,12)=44.48, p<.00, η_p^2=.79, with the categorization group having an overall

greater mean Nc (*M*=-12.04 μV, *SD*=1.92 μV) when compared to the individuation group (*M*=-6.05 μV, *SD*=1.92 μV).

In the post hoc analysis of the interaction of condition by group, no significant results were found on the one-way ANOVA for the individuation group, F (2,12)=2.76, p=.10, η_p^2=.32. In the categorization group, there was an effect of condition, F (2,12)=4.885, p=.03, η_p^2=.45. As expected for this group, the Novel Other condition (*M*= -16.64 μV, *SD*=2.79 μV) had a significantly larger mean Nc amplitude than the Familiar condition (*M*= -8.38 μV, *SD*=2.91 μV), t(6)= 3.04, p=.02. A two-tailed t-test indicated that mean amplitude for Nc was marginally larger for the Novel Other condition than for the Novel Same condition (*M*= -11.09 μV, *SD*=1.27 μV) in the categorization group, t(6)= -2.06, p=.09. This difference became significant when using one-tailed tests (t(6)=-2.06, p=.04). For the individuation group, the Novel Same condition had a marginally greater mean amplitude Nc than the Familiar condition, (t(6)=2.03, p=.09) that became significant when using a one-tailed test, t(6)=2.03, p=.05. Figure 3 shows the mean average amplitudes for Nc for each group. Nc is identified by a negative deflection, occurring between 350-650 ms after stimulus onset.

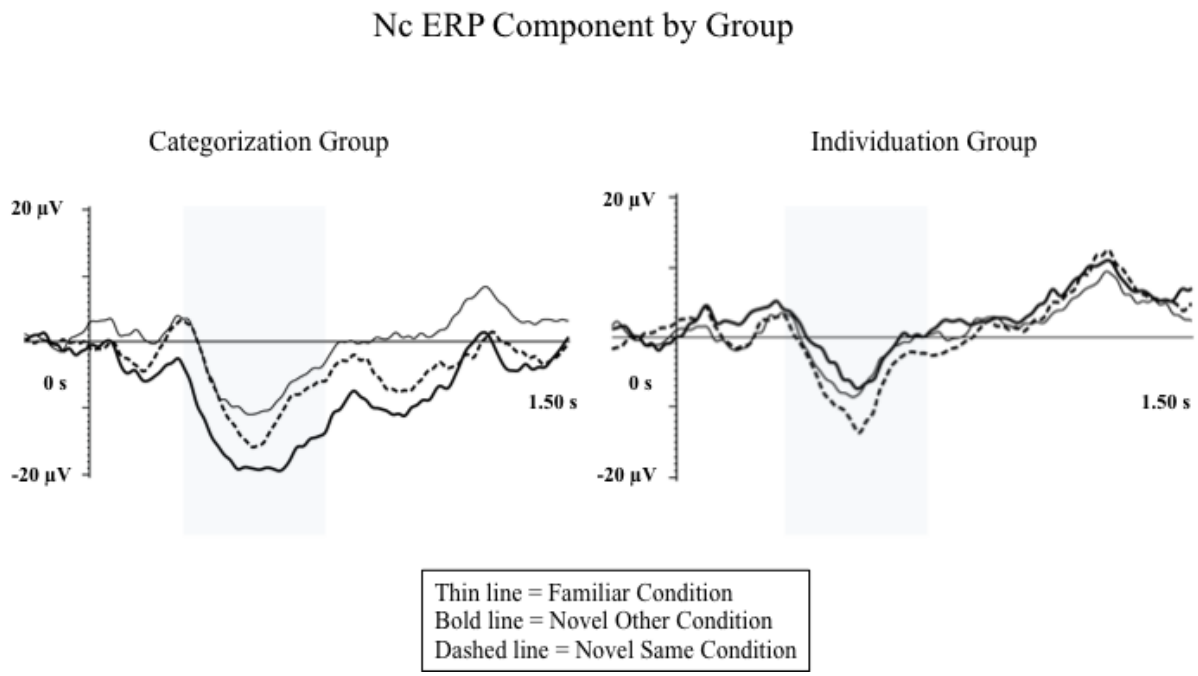


Figure 3. The mean amplitudes for Nc for the categorization and individuation groups. Time following stimulus onset is indicated on the x-axis, and change in amplitude from baseline is indicated on the y-axis.

The P400 component

For analysis of the mean amplitude of the P400 component, there was a marginal main effect of condition, F (2,24)=3.223, p=.06, η_p^2=.21. Across both groups, the Novel Other condition (M= 34.46 μV, SD=3.76 μV) had a marginally significant larger mean Nc amplitude than the Familiar condition (M= 27.91 μV, SD=3.04 μV). There was also a significant between-subjects main effect of group, F (1,12)=118.21, p<.00, η_p^2=.91, with the categorization group having a larger overall P400 amplitude (M= 35.41 μV, SD=3.97 μV) when compared to the

individuation group (*M*= 25.62 μV, *SD*=3.97 μV). Figure 2 shows the grand average waveforms for each component, with both groups combined.

For the purpose of hypothesis testing, a priori comparisons were conducted by running one-way ANOVAs and t-tests separately for each group. No significant results were found on the one-way ANOVA for the individuation group, F (2,12)=.19, p=.83, η_p^2=.03, as was expected. The categorization group revealed a marginally significant effect of condition F (2,12)=3.719, p=.06, η_p^2=.38. As predicted, a t-test on the categorization group showed that mean amplitude for the P400 was marginally larger for the Novel Other (*M*= 42.25, *SD*=15.29) condition than for the Familiar condition (*M*= 31.19 μV, *SD*=10.34 μV) in the categorization group, t(6)= -2.16, p=.07, which became significant when using a one-tailed test (p=.04). Figure 4 illustrates the mean amplitudes on each condition for each group. The P400 is identified by a positive peak, which occurs between 300-500 ms after stimulus onset.

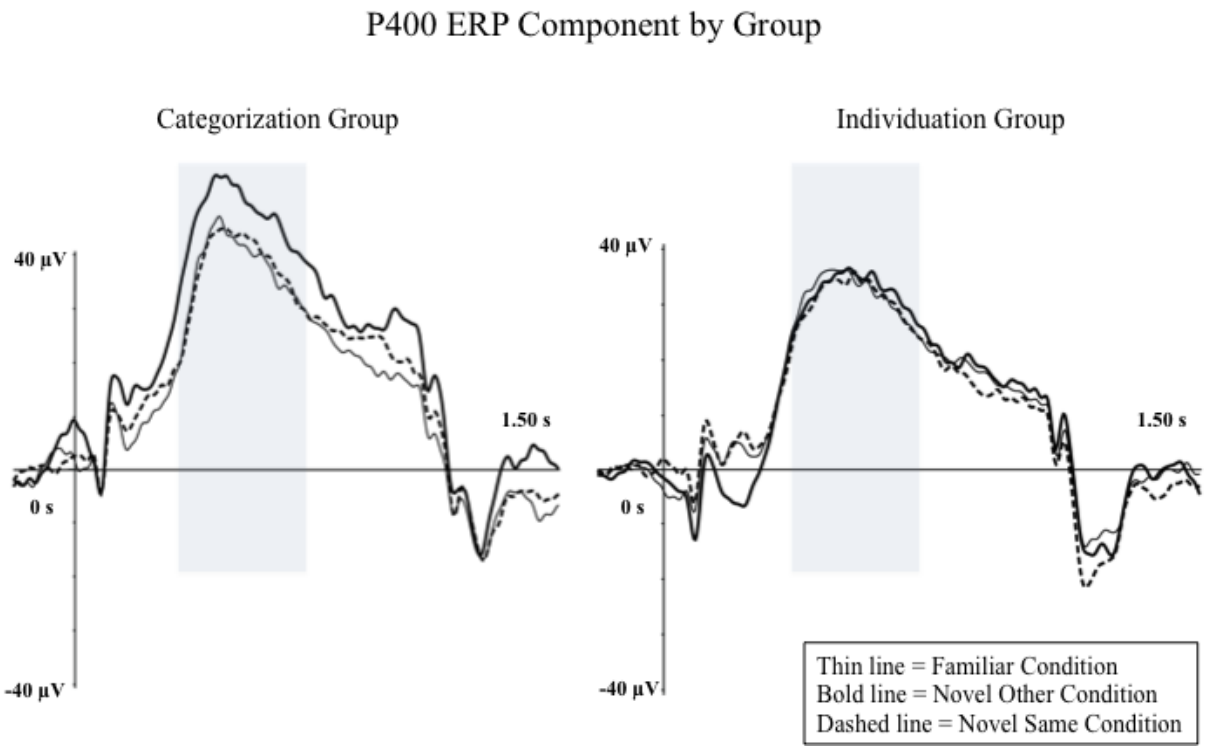


Figure 4. The mean amplitudes for the P400 for the categorization and individuation groups. Time following stimulus onset is indicated on the x-axis, and change in amplitude from baseline is indicated on the y-axis.

CHAPTER IV

Conclusions

The current study examined 9-month-old infants' abilities to categorize monkey faces at the species level. The purpose of this study was to examine categorization as a potential mechanism behind perceptual narrowing as it related to other-species' faces. The study was focused on four different ERP components, but the main focus was on the Nc, an indicator of attention allocation in infants (de Haan, Johnson, & Halit, 2003; Reynolds, Courage, & Richards, 2010), and the P400, which is thought to be a component related to subordinate-level categorization (Quinn et al., 2010). It was predicted that mean amplitude for the P400 would be the greatest for the Novel Other condition in the categorization group, and that there would not be significant differences in amplitude in the individuation group. It was also predicted that Nc would be greater in amplitude for the Novel Other condition in the categorization group, and that there would not be any differences in the N290 between groups across conditions. The results partially supported these predictions.

By the age of 9 months, typically developing infants show a decline in the ability to discriminate between individuals of other species (Kelly et al., 2007; Pascalis et al., 2002; Pascalis et al., 2005; Scott, Pascalis, & Nelson, 2007; Scott and Monesson, 2009; Simpson et al., 2011). This decline might be caused by a change in processing strategy, namely using categorization instead of individuation as a processing strategy (Maurer & Werker, 2014). It was predicted that 9 months olds should be able to categorize monkey faces at the subordinate level when familiarized to an exemplar group of the same species of monkey, but that when exposed to an individual face, neither categorization nor individuation would take place.

The P400 results supported the prediction that the categorization group would show differences in mean amplitudes, whereas the individuation group would not. Quinn and colleagues (2010) posited the idea that the P400 component was related to subordinate-level (species-level) categorization. The categorization group in the current study demonstrated a larger P400 to the macaque faces (novel face and novel species), showing an ability to discriminate between the two species, which suggests that this group was able to form a category for capuchin faces that did not include macaque faces. The individuation group did not show evidence of category discrimination. It is possible that other-species faces are processed at the basic level once perceptual narrowing has occurred, and only through being familiarized with an exemplar group are infants in this age group able to categorize at the subordinate level. This would explain the lack of differences across conditions in the P400 component in the individuation group.

For the categorization group, it was found that the Novel Other condition had a larger mean amplitude Nc than the means for both the Novel Same condition and the Familiar condition. Because Nc was larger on the Novel Other condition, it can be inferred that the infants in this group viewed the macaque faces as novel compared to the familiar capuchin face and the novel capuchin faces. This suggests that the infants in this group were able to discriminate between the species, and recognized the Novel Same and Familiar faces as belonging to the same category of monkey. It could also be indicative of a failure to individuate within the species, which would be consistent with the results from previous behavioral studies with 9-month-olds on other-species face discrimination tasks (Pascalis, de Haan, & Nelson, 2000). For the individuation group, the Novel Same condition was found to have a larger amplitude Nc than the Familiar condition, which suggested that the effects seen in the categorization were not because

macaque are easily discriminated from capuchins. Nine-month-old infants, as evidenced by behavioral studies, should not be able to individuate monkey faces due to the effects of perceptual narrowing (Pascalis, de Haan, & Nelson, 2000), yet these results indicate that the individuation group was able to individuate within the familiar species group. A possible explanation for this result may be that while infants do not show behavioral discrimination of other-species faces at 9 months, there may be some processing of these faces occurring in the ventral visual stream (Scott, Shannon, & Nelson, 2006). Another explanation for this finding may be related to the nature of the familiarization presentations. Fair, Flom, Jones, & Martin (2012) found that altering the amount of familiarization time for 12-month-old infants on a monkey face discrimination task could affect their ability to discriminate. 12-month-olds who received 40 seconds of familiarization were able to discriminate, whereas the infants who received 20 seconds were not. In the current study, instead of a single presentation of a face for 20 seconds, infants were given 20 presentations with each presentation lasting for 500 ms. It is possible that this type of familiarization led to more efficient processing.

Future studies might serve to elucidate the Nc results. Different lengths and types of familiarization might facilitate discrimination of other-species faces in 9-month-old infants. Another question that remains is how infants process faces that they categorize, and how they process faces that they individuate. One theory is that a difference in experience creates two distinct processing methods- configural and featural coding which leads to either categorization of faces or individuation (Rhodes, Brake, Taylor, & Tan, 1989; Tanaka, Kiefer, & Bukach, 2004; Michel, Rossion, Han, Chung, & Caldara, 2006). Eye-tracking could be a viable method in establishing how infants scan other-species faces after perceptual narrowing when they create species-level face categories.

Overall the results supported the theory that subordinate categorization may be the processing strategy used for other-species faces after perceptual narrowing for other-species faces has occurred. Infants were able to categorize at the subordinate level, given a sufficient group of exemplars, and they were not able to individuate when familiarized to a single face. A limitation of the current study; however, is the small sample size. The power was low, and many of the important effects were marginal when using two-tailed comparisons and only became significant when a one-tailed test was used. Another is that only the capuchin stimuli were used as the familiar stimuli. It is possible that capuchin faces might be easier to process and recognize when compared to macaque faces. Ongoing research will counterbalance the familiar condition between capuchin and macaque faces, and will also include more participants in the data set. This was one of the first studies to examine the neural correlates of other-species face processing after perceptual narrowing is thought to have occurred for this type of stimuli; however, more research is needed to replicate and expand on these findings.

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