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# The Role of Intersensory Redundancy in Face Recognition in 5- and 12-Month-Old Infants

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# THE ROLE OF INTERSENSORY REDUNDANCY IN FACE RECOGNITION IN 5- AND 12-MONTH-OLD INFANTS

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ABSTRACT

The goal of this study was to examine the role of audiovisual synchrony in 5- and 12-month-old infants' attention to and processing of face stimuli. Infants were tested using an online platform called Lookit. In the first phase of the experiment, infants were familiarized with two videos presented simultaneously and side-by-side. Each video displayed a woman speaking in an infant-directed manner. A soundtrack was played that matched one of the videos (experimental condition) or neither of the videos (control condition). It was hypothesized that synchronous audiovisual presentation would attract infants' attention and promote processing, especially among 12-month-olds. Visual-paired comparison (VPC) trials were completed to measure looking preferences for faces in the videos presented synchronously and asynchronously during familiarization and novel faces. The results showed that 12-month-olds spent a longer time fixated on the videos during the familiarization period, compared to 5-month-olds. However, results of the VPC trials indicated that both 5- and 12-month-olds failed to recognize the faces presented during familiarization. Taken together, the results from this study indicate that 12-month-olds may have been more engaged during familiarization than 5-month-olds, but that their exposure was not sufficient for face processing. It is possible that the stimuli were too complex to be processed during the familiarization period or that the multimodal stimulus presentation attracted infants' attention to other stimulus properties.

# CHAPTER ONE

# INTRODUCTION

As humans, we see and interact with faces as a part of our everyday lives. Faces are salient stimuli and even newborn infants prefer looking at faces over non-face-like stimuli. The way we encounter faces is usually dynamic and multimodal, which means that even though faces alone are visual stimuli, multiple senses may play a role in our exposure to faces, like audition and vision. When a person speaks, their speech is in synchrony with the movements of their face and mouth, providing visual and auditory stimulation that is coupled together. This multimodal exposure is characterized by intersensory redundancy, the synchrony between presentations of different sensory modalities (e.g., vision and audition). It is still not well understood how intersensory redundancy impacts face processing in our daily lives. Even though everyday experience with faces typically occurs in a multimodal context, most of the past research investigating infants' face processing and recognition has been done with static, unimodal stimuli. Studying face processing with dynamic stimuli will help us to understand the role of intersensory redundancy on face processing and to improve the ecological validity of this line of research. In this study, 5- and 12-month-old infants were presented with videos of women speaking, and the effect of synchronous and asynchronous multimodal stimulation on face processing was examined.

## Literature Review

### Face Processing

Previous research has shown that infants prefer to attend and orient to faces, and that face preferences are even evident at birth (Goren et al., 1975; Johnson et al., 1991; Turati et al., 2002; Valenza et al., 1996). Additionally, newborn infants are able to recognize their mothers' faces only a few hours after birth (Bushnell et al., 1989; Field et al., 1984), indicating an early ability to recognize faces. Morton and Johnson (1991) proposed that a subcortical mechanism present at birth, known as CONSPEC, includes perceptual mechanisms which contribute to face detection and face preferences in newborns. According to Morton and Johnson (1991), the cortical processing of faces begins to develop around 2-3 months of age. In summary, the innate CONSPEC mechanism drives infants to attend to faces, which then contributes to the development of later cortical specialization for faces.

As infants mature and gain more experience with faces, they show greater neural specialization during face processing. Several studies have examined the progression of neural responses to faces in the first year of life. Event-related potentials (ERPs) have been commonly used in the examination of early neural responses during face processing (e.g., Conte et al., 2020; Guy et al., 2016; Leppänen et al., 2007; Proverbio & De Gabriele, 2019). ERPs measure the brain's electrical activity on the scalp through the electrodes. They also provide great temporal resolution, as well as being an infant-friendly method, as they are non-invasive, can be collected across a variety of ages, and do not require any behavioral or verbal response from the participant (de Haan, 2013). Conte et al. (2020) utilized ERPs to study neural responses to static face and object stimuli in 3- to 12-month-old infants. The N290 ERP component, associated with the development of face specialization, was among the ERP components examined. The N290 is characterized by a negative peak occurring approximately 290 ms after stimulus onset and that is often greater in amplitude to faces than non-face stimuli (e.g., Guy et al., 2016; Halit et al., 2003). They found that the N290 amplitude was larger for faces than objects only at 9 and 12 months of age. These findings indicate that the N290 may be tied to cortical specialization for face processing and that face processing responses become more specialized across the first year of life.

**Intersensory Redundancy and the Intersensory Redundancy Hypothesis**

Intersensory redundancy (IR) is the temporally synchronous presentation of information across different sense modalities. Although some sensory information is unique to an individual sensory modality (e.g., the color of a person's eyes is experienced only through the visual modality), other properties are perceived redundantly across more than one sensory modality (e.g., the rate at which a person is speaking can be experienced across visual and auditory modalities). These properties, such as tempo and rhythm, are known as amodal properties. The intersensory redundancy hypothesis (IRH) was proposed by Bahrick and Lickliter (2000), who predicted that early in infancy, temporally synchronous information recruits more attention than information presented unimodally. The IRH has three components: (1) the presence of IR will recruit infant attention, (2) enhanced attention to multimodal, synchronous stimulation will lead to earlier perception and processing of amodal properties, and (3) these biases will aid infants' unitary perception of multimodal events that possess IR. Bahrick and colleagues (2004) also predicted that as infants grow older, they will become more experienced perceivers of the outside world, allowing them to recognize and distinguish both amodal or modality-specific properties in multimodal or unimodal contexts.

Habituation is a commonly used method in studies of infant cognition (e.g., Bettoni et al., 2021; Colombo et al., 2010; Krasotkina et al., 2021; Singh et al., 2015). During habituation, infants are continuously presented with a stimulus of interest as their looking time is recorded. It is expected that infants' looking time will decrease as they process and become habituated to the stimulus through repeated presentations (Oakes, 2010). In their foundational study, Bahrick and Lickliter (2000) assessed the IRH across three experiments by habituating 5-month-old infants to multimodal synchronous, multimodal asynchronous, auditory unimodal, and visual unimodal events of a red hammer tapping to create a rhythm. To assess the identification of changes in the rhythm, they assessed infants' visual recovery in response to seeing a novel rhythm. If infants noticed the change of stimulus, they were expected to show an increase in looking time to the novel rhythm. Bahrick and Lickliter (2000) found that infants could not detect the changes in rhythm when they were habituated to the hammer tapping in multimodal asynchronous or unimodal conditions. In contrast, habituation to the multimodal synchronous presentation led to discrimination of novel and familiar tapping patterns. These findings indicated that the presence of IR is salient and emphasizes amodal properties, such as rhythm, guiding the attention of 5-month-old infants. In another study, Bahrick et al. (2002) tested the IRH with 3-month-olds by habituating them to three different presentations of a hammer tapping on a surface (i.e., synchronous audiovisual, unimodal visual, unimodal auditory). Infants were then tested for their ability to discriminate a change in the temporal information of the hammer. Replicating the results of Bahrick and Lickliter (2000), they found that infants who were habituated to synchronous, multimodal presentations were able to detect a novel tempo, whereas those who were habituated to unimodal presentations could not discriminate between the two tempos. These findings indicate that the effects of IR on discriminating amodal properties are present in infants as young as 3-months of age.

The IRH further predicts that IR draws infant attention to amodal stimulus properties at the expense of modality-specific properties and that processing of modality-specific properties is facilitated by unimodal stimulus presentation (Bahrick et al., 2006; Bahrick et al., 2013). In one study, Bahrick et al. (2006) tested the sensitivity of 3-, 5- and 8-month-old infants to a modality-specific property, the direction of a tapping toy hammer, which was only observed visually. Infants were habituated to multimodal (i.e., audiovisual) synchronous or unimodal visual presentations, while the hammer was tapping in an upward or downward direction. Although 3- and 5-month-olds could discriminate between the old and new directions with unimodal stimulation, they did not detect the change with multimodal stimulation. Eight-month-olds were able to detect the changes under both unimodal and multimodal presentations. Additionally, 3-month-olds could detect the changes in the direction of the hammer after multimodal nonredundant exposure. These results show that modality-specific properties are more salient in unimodal and asynchronous conditions, where attention is not directed to amodal properties as much. The results also support the prediction of IRH that infants become more skilled processors of both amodal and modality-specific properties, under unimodal and multimodal presentations, as they mature.

In another study, Bahrick and Lickliter (2004) tested their prediction that older infants will be more flexible when directing their attention to amodal properties of events in multimodal or unimodal contexts, so that they will be able to direct their attention to and perceive amodal properties even under unimodal stimulation (without IR). They first habituated 5-month-old infants with a tempo that was tapped by a toy hammer, then tested the infants' ability to discriminate between familiar and novel tempos. The results showed that 5-month-olds could detect a novel tempo following multimodal or unimodal presentations, whereas a previous study showed that 3-month-olds could only detect a novel tempo following multimodal habituation to the familiar tempo (Bahrick et al., 2002). In the second part of Bahrick and Lickliter's (2004) experiment, 8-month-old infants were tested on a rhythm discrimination task. They chose an older group of infants for this experiment, as past research has indicated that detection of tempo develops earlier than the detection of rhythm (Pickens & Bahrick, 1997), and they believed that it would be more difficult than the tempo discrimination task. The procedure was identical to the first experiment's, except that the presentation of the rhythm changed instead of the tempo. Eight-month-olds could discriminate familiar and novel rhythms under both synchronous audiovisual and unimodal visual conditions, as opposed to the findings from a previous study, where 5-month-olds could discriminate rhythm only if they were habituated to a multimodal presentation (Bahrick & Lickliter, 2000). Findings from both experiments supported the IRH's prediction that attention to amodal properties becomes more flexible such that detection of amodal properties extends from multimodal contexts to unimodal contexts, as infants get older and gain more perceptual experience.

Bahrick et al. (2010) proposed that increasing task difficulty would affect infants' ability to process amodal and unimodal information, such that older infants would show a pattern similar to that of younger infants, despite being more experienced and skilled processors of information. Five-month-old infants were recruited and randomly assigned to one of the two conditions during habituation (i.e., synchronous audiovisual or unimodal visual), where they viewed a toy hammer tapping. Within these conditions, they were assigned to one of the two rhythms and one of the two tempos. During the test trials, infants viewed the hammer tapping the same rhythm, with a novel tempo in moderate (110 bpm during familiarization vs. 138 bpm during the test trials) or high difficulty (110 bpm during familiarization vs. 129 bpm during the test trials). The results showed that under the conditions with moderate difficulty, 5-month-olds could discriminate the novel presentations of tempo with both synchronous audiovisual and unimodal visual presentations. When the task difficulty was high, infants could discriminate the changes in tempo only with synchronous audiovisual presentations, similar to 3-month-olds (Bahrick et al., 2002), indicating intersensory facilitation.

Overall, these results support Bahrick and Lickliter's (2000) IRH, indicating that intersensory redundancy guides and attracts infant attention and makes amodal properties of events more salient. This in turn leads synchronous multimodal stimuli to be perceived and learned more easily than other stimuli, especially amodal stimulus properties. The synchronous stimulation from multiple sense modalities is more likely to be viewed unitarily than multimodal sense information that is asynchronous. IR can also provide increased facilitation of more complex stimuli, such as faces.

**Faces and IR**

Faces can provide highly complex multimodal stimulation and IR has been shown to play a role in the processing and recognition of faces. The influence of IR on attention to faces is evident at the time of birth (Sai, 2005). Sai (2005) tested the effect of hearing the mother's voice on recognizing the mother's face in neonates. The results showed that infants were able to discriminate between their mother's face and a stranger's face only a few hours after birth. However, when infants had no experience of hearing their mother's voice prior to testing, they were not able to recognize the face of their mother. These findings indicate that in neonates, multimodal face and voice exposure may contribute to and even be necessary for face recognition.

Additional research has shown that IR continues to play a role in attention to faces throughout the first year of life. For example, Curtindale et al. (2019) investigated the visual attention of 4- and 8-month-old infants to social (i.e., a woman speaking) and non-social stimuli (i.e., a tapping hammer) under multimodal synchronous or asynchronous conditions. They assessed average look duration, peak look duration, and heart-rate measures. They found that social stimuli produced a longer look duration and longer sustained attention in both age groups than non-social stimuli. Additionally, heart rate measures showed that synchronous, compared to asynchronous stimuli produce longer durations of sustained attention. Their results support past research showing that stimuli with IR are salient and extend this work to social stimuli presented in dynamic, multimodal contexts.

Additionally, developmental change in sensitivity to amodal information conveyed during face processing has been reported. In one study, Flom and Bahrick (2007) tested 3-, 4-, 5-, and 7-month-old infants in their ability to discriminate between faces displaying different affects (i.e., happy, angry, or sad). Infants were habituated to synchronous audiovisual presentations of people speaking in an infant-directed manner, displaying one of the three affective expressions. When habituated to the multimodal synchronous presentations, they could discriminate between the expressions, starting at 4-months of age. When the presentations were unimodal (i.e., auditory or visual), 3- and 4-month-olds could not discriminate between the different affective expressions, 5-month-olds could do so with the auditory-only presentation, and 7-month-olds in both unimodal presentations. Moreover, when the habituation to affective expressions was asynchronous, 4-month-olds showed no evidence of affect detection. Five-month-olds, who had already shown auditory discrimination of affect, were able to detect affect under this condition. These results show that for younger infants to discriminate between different affective facial expressions, face and voice synchrony is needed.

Furthermore, there is some evidence that synchronous and multimodal presentation of face stimuli may inhibit face recognition. Hillairet de Boisferon and colleagues (2021) recently explored how language familiarity influences face recognition among 9- and 12-month-old infants. Infants were familiarized with videos of women speaking in their native language (i.e., French) or a foreign language (i.e., German). During the test trials, they were presented with the familiar face beside a novel face, and the researchers hypothesized that participants would be more likely to discriminate a French-speaking face from a novel face, than a German-speaking face from a novel face. The results showed that when familiarization included dynamic audiovisual videos of the actors speaking, infants did not show an advantage for recognizing the native speaker's face. When the familiarization included a still face paired with the auditory information, infants later recognized the actor with which they were familiarized in the native condition. The authors proposed that language familiarity influenced the face recognition skills of own-language faces. These results also indicate that multimodal audiovisual stimulus presentation may have shifted attention away from unimodal stimulus properties relevant to face processing.

Amodal information presented synchronously can guide infants' attention differently across different ages. For example, Lewkowicz and Hansen-Tift (2012) found that between 4- and 8-months of age, infants shift their visual attention to the mouth of a dynamic, speaking face when hearing a native or nonnative speaker. In contrast, they found that 12-month-old infants focus more on the eyes when hearing their native language, but not for nonnative speech. These results show it is possible that infants who are younger and less experienced with perceiving and recognizing faces may allocate their attention more to the dynamic properties of a speaking face, making it less likely to encode other properties of the face, which indicate that amodal stimulus properties may strongly impact attention, especially in younger infants.

## Present Study

In the present study, I examined whether the presence of intersensory redundancy affects infants' face processing at 5 and 12 months of age. To date, most research on infant face recognition has used static, unimodal stimuli (e.g., Bar-Haim et al., 2006; Conte et al., 2020; de Haan et al., 2002; Halit et al., 2004; Leppänen et al., 2007; Pascalis et al., 2002).

Audiovisual face stimuli were utilized in the current study to increase understanding of how multimodal exposure influences face processing, by providing infants with ecologically valid stimulation that resembles the way they interact with faces in real life. The multimodal face stimuli also help to understand how the presence of IR may attract attention, and in turn can lead to the processing of one face over the other. Multimodal stimulation can help to explore if the bias towards amodal information processing discourages unimodal stimulus processing and if this changes with age.

Specifically, I investigated whether faces possessing IR (i.e., presented with multimodal synchronous speech) would recruit greater attention compared to the faces presented without IR (i.e., presented with multimodal asynchronous speech) and whether greater attention to a face possessing IR influences the possessing and recognition of the faces. It was predicted that, because IR is very salient, the face presented with IR would recruit more attention, leading to enhanced discrimination of that face, compared to the face presented without IR.

Five- and 12-month-olds were recruited for the study to examine changes in the influence of IR on face processing over time. Based on previous research, 5 months is a time point when the effects of IR on infants' attention recruitment are seen (e.g., Bahrick & Lickliter, 2004; Reynolds et al., 2014). I also included 12-month-olds, as evidence of specialized face processing is seen at this age (e.g., Chen et al., 2021; Conte et al., 2020; Halit et al., 2003). Past studies also show that 5-month-olds are less skilled processors than older infants (e.g., Bahrick & Lickliter, 2004; Bahrick et al., 2006; Flom & Bahrick, 2007). Even though IR is expected to be very salient for 5-month-olds, they may not be able to process the face features as well as 12-month-olds, because they have less experience with faces and are more immature in information processing. Additionally, 5-month-olds may have a more difficult time moving past the amodal information, whereas the 12-month-olds may be able to process amodal and unimodal information. This study asked the following research questions: Does IR facilitate unimodal face processing and recognition? Do the developmental changes occurring between 5 and 12 months of age impact attention to and recognition of faces presented with and without IR?

Infants participated in the study online, from their homes. A webcam recorded their look direction and duration. During the study, infants were first familiarized with two videos that were presented side-by-side, simultaneously. Half of the infants viewed two videos of women speaking, in which the soundtrack was synchronous with one of the videos (i.e., experimental group), whereas the other half viewed two videos of women speaking, in which the soundtrack was not synchronous with either video (i.e., control group). After familiarization, infants viewed three pairs of faces: 1) the two familiar faces, 2) one of the familiar faces paired with a novel face, and 3) the other familiar face paired with the same novel face.

A visual paired-comparison (VPC) procedure was used to assess infants' face recognition. The VPC is an established, commonly used method in infancy research to measure looking preference both in humans (e.g., Pascalis et al., 1998, 2002; Quinn et al., 2020) and non-human primates (e.g., Gothard et al., 2004, 2009; Nemanic et al., 2004; Sliwa et al., 2011). VPC uses observation of eye movements and selective visual attention in order to study cognitive development in infants, including recognition memory (Fagan, 1990). During a typical VPC procedure, the infant is seated in front of a screen, as they view pairs of pictures for a set duration of time. A camera may be placed to view the looking behavior and understand the look direction. This procedure is appropriate for use with young infants, as it does not require a specific motor or language response. Studies that include stimulus familiarization often test for a novelty response using VPC trials. Infants are naturally attracted to novel stimuli and novelty preferences are present days after birth (Pascalis & de Schonen, 1994).

Based on these, it was hypothesized that:

1. Twelve-month-olds would display more skilled processing compared to 5-month-olds, as they are more experienced in processing and recognizing faces, and thus more efficiently process the amodal and unimodal information presented.
2. For the 12-month-olds in the experimental group, the faces with IR would recruit more attention and be more easily recognized, and that this will be indicated by a novelty preference for the novel face during VPCs. For the 5-month-olds in the experimental group, the presence of auditory information may lead to dividing their attention and impede face recognition for the IR-face.
3. In the control group, there would be no difference in the processing of the two non-IR faces and the equal weighting of them would result in incomplete processing of both faces and no novelty preferences during the VPC trials.
4. There would be a relationship between participants' looking pattern during familiarization and VPC trials, such that longer looking time to a face during familiarization will be negatively correlated with looking time to the same face during the VPC trials, indicating recognition of that face.

# CHAPTER TWO

# METHODS

## Participants

Thirty-one 5-month-olds (age *M* = 157.61 days, *SD* = 15.26 days, 14 females) and 58 12-month-olds (age *M* = 359.05 days, *SD* = 15.06 days, 26 females, 1 non-binary) participated in this study. Additional participants were recruited but their data were removed due to incomplete recordings (*N* = 6), the parent facing the screen during testing (*N* = 2), the eyes of the infant not being visible in the video (*N* = 2), or technical issues (*N* = 10). To be eligible for participation, infants had to be born full-term and have previous exposure to English at home, school, or through a caregiver. In addition to English, 33 participants were exposed to at least one other language. The majority of participants identified only as Caucasian or White (*N* = 60), however, 10 participants identified as Asian, one as Black or African American, one as American Indian/Alaskan Native, and 15 as two or more races (13 identified as Asian and White, one as Black and White, and one as Native Hawaiian/other Pacific Islander and White). Additionally, seven participants identified as Hispanic or Latino.

Participants were recruited through Lookit, an online data collection platform for developmental researchers. Through Lookit, researchers can create experiments and collect and download experiment data. Eligible studies are published on the Lookit homepage for parents to find and participate in with their children. Families registered to the Lookit database received email notifications when their child was of eligible age to take part in this study. Families in the Loyola University Center for Research in Child Development (CRCD) database were invited via email to take part in the study if their child was in the appropriate age range. Additionally, posts and advertisements on social media directed parents of infants to the Lookit site to complete the study. Prior to participating in the study, parents provided video recorded verbal consent for their child's participation in the study in accordance with study approval by the IRB at Loyola University Chicago. Parents of participants were compensated for their time with $5 Amazon e-gift cards.

## Stimuli and Apparatus

### Familiarization stimuli

During familiarization, participants viewed two separate videos presented simultaneously on the screen, side-by-side. Two Caucasian women (one in each video) recited a children's story in an infant-directed manner. Videos were presented with or without their matching soundtrack. Each actor wore a black shirt. They had no jewelry, glasses, or makeup on and wore their hair tied back. They were filmed against a white background, with only the faces and shoulders visible. The familiarization phase in which infants viewed these two videos simultaneously lasted for 30 s.

### Visual-paired comparison (VPC) stimuli

During the paired comparisons, pairs of static pictures of women were presented side-by-side on the screen. These included the two faces viewed during the familiarization and one novel Caucasian female face. The faces had a neutral expression and were presented against a white background. The actors wore black shirts, with no jewelry, glasses, or makeup on, and tied their hair. Each paired comparison lasted for 7.5 s.

### Apparatus

Any parent or legal guardian could participate in studies posted to the Lookit platform using internet access and the Google Chrome and Firefox web browsers. Participants had to use a desktop or laptop computer to participate in studies on Lookit. They also had to have a working webcam, microphone, and speaker.

## Procedure

Prior to data collection, the parent or legal guardian provided verbal consent and filled out a demographic form. They were then given the option to watch a 10 s preview of the familiarization video. After that, they were asked to position themselves so that their back would be facing the computer screen, and their child would be viewing the screen over their shoulder. A calibration video was presented as the participants got into position, and the familiarization phase began. Participants participated in either an experimental or a control condition of the study. Each participant viewed two videos during familiarization. In the experimental condition, a soundtrack played that was synchronous with one of the two videos presented (IR condition). In the control condition, a soundtrack played that was asynchronous with both of the videos presented (non-IR condition). In both conditions, the familiarization phase lasted for 30 seconds.

Once the familiarization phase ended, the VPC procedure started. During this procedure, infants viewed a total of three pairs of pictures: 1) face A which infant saw during familiarization, paired with face B which infant saw during familiarization, 2) face A, paired with the novel face C, and 3) face B, paired with the novel face C. Each pairing appeared on the screen for 7.5 seconds.

At the end of the experiment, parents were taken to a page where they were asked the types of uses of their video that they are okay with and selected privacy settings. At this point, they were also given the option to withdraw their videos.

## Behavioral Coding

The data were coded using the Datavyu software (Datavyu Team, 2014). This software is used to code and analyze behavioral observations from video sources. Four videos were coded for each participant: 1 for familiarization and 3 for VPC trials. Each video was coded for infants' direction of looking to the screen: (L) indicated gaze to the left, (R) indicated gaze to the right, and (0) indicated looking off-screen. To be included in the analyses, infants had to have their eyes visible, spend at least 20 s looking at the screen during the 30 s familiarization, spend at least 5 s looking at the screen during 7.5 s VPC trials, and the parents had to be facing the opposite direction of the screen.

### Statistical Analyses

Analyses were conducted using IBM SPSS. For the test trials, looking time was calculated as the ratio of looking time towards the novel stimulus to the accumulated looking time to novel and familiar stimuli. Multiple analytical strategies were employed to examine differences in looking behavior within and across groups, including 1) one-sample t-tests to test for novelty preferences by determining if look durations to the novel stimulus were above the chance value of 50% (e.g., Wagner et al., 2020; Yamashita et al., 2011), 2) correlations to examine individual differences, specifically examining whether individual participants' looking times during familiarization were associated with their looking times during the VPCs, 3) between-subjects analysis of variance (ANOVAs) to examine the differences in stimulus processing between age groups and conditions (e.g., Kelly et al., 2007), and 4) paired-comparison t-tests to measure the differences in looking times to familiar and novel faces within age groups (e.g., Pascalis et al., 2002).

# CHAPTER THREE

# RESULTS

In the experimental group, there were five 5-month-olds and 31 12-month-olds. In the control group, there were 26 5-month-olds and 27 12-month-olds. Table 1 shows the mean looking times and standard deviations during familiarization and VPC trials for each group of participants.

## Analysis 1: Looking Time During Familiarization

Looking time to each of the stimuli presented during familiarization were measured for the experimental and control conditions and one-sample t-tests were computed to test if the percentage of look duration to either face was above the chance value of 50%.

### Experimental Group

In the experimental condition, 5-month-olds looked at the screen an average of 26.3 s during familiarization. This included an average of 11.63 s to the face displaying synchronous speech and 14.69 s to the face displaying asynchronous speech.  They spent on average 53.41% of their time looking at the asynchronous face, $t(4) = .314$, $p = .769$, $d = 0.14$. Twelve-month-olds in the experimental condition demonstrated a mean looking time of 28.95 s. They spent 14.48 s on average looking at the synchronous face, and 14.39 s on average looking at the asynchronous face. On average, they spent 50.03% of their time looking at the synchronous face, $t(28) = 0.1$, $p = .992$, $d = .001$.

### Control Group

Five-month-olds looked for an average of 28.16 s during familiarization, with a mean of

13.87 s towards the asynchronous face displayed on the left side of the screen and 14.28 s towards the asynchronous face displayed on the right side of the screen. They spent on average 50.51% of their time looking at the asynchronous face on the right, $t(24) = 0.148$, $p = .883$, $d = .02$. For the 12-month-old control group, the mean total looking time was 29.44 s, including 14.11 s of looking to the asynchronous face displayed on the left side of the screen and 15.26 s to the face displayed on the right side of the screen. On average, they spent 52.12% of their time looking at the right asynchronous face, $t(25) = .843$, $p = .407$, $d = .16$.

Paired-comparison t-tests were computed to examine whether 5- or 12-month-old participants looked longer to one stimulus over another during familiarization based on the experimental condition. Results showed that infants demonstrated no significant preferences towards one face over another during the familiarization, across 5- and 12-months of age and experimental and control conditions.

Independent samples t-test analysis was conducted to look at group differences between 5- and 12-month-olds. The results showed that the difference in looking times of 5- and 12-month-old infants during familiarization was significant. On average, 12-month-olds looked longer to the stimuli on the screen ($M = 29.19$ s) compared to 5-month-olds ($M = 27.85$ s), $t(83) = -2.331$, $p = .037$, $d = .51$.

## Analysis 2: Looking Time During VPCs

Data collected during the VPCs was used to test for novelty preferences, indicative of stimulus processing. One-sample t-tests were run for each age group and condition to test for novelty preference against a chance value of 50%. Paired sample t-tests were computed to analyze differences in looking time across the stimuli included in the VPC trials. In the experimental condition, this included VPC 1 (synchronous-familiar vs. asynchronous-familiar face), VPC 2 (novel vs. asynchronous-familiar face), and VPC 3 (novel vs. familiar-synchronous face). In the control condition, this included VPC 1 (right vs. left familiar-asynchronous face), VPC 2 (novel vs. left familiar-asynchronous face), and VPC 3 (novel vs. right familiar-asynchronous face).

**Experimental Group**

The total looking time for 5-month-olds during VPC 1 was 6.44 s, during VPC 2 it was 6.49 s, and during VPC 3 it was 7.05 s. Five-month-olds looked longer at the synchronous-familiar face ($M$ = 4.17 s) than the asynchronous-familiar face ($M$ = 2.27 s) in VPC 1, the novel face ($M$ = 3.27 s) than the asynchronous-familiar face ($M$ = 3.22 s) in VPC 2, and the novel face ($M$ = 4.1 s) than the synchronous-familiar face ($M$ = 2.94 s) in VPC 3. One-sample t-test analysis was conducted to test for a novelty preference above the chance value of 50%. The results showed that they spent on average 64.74% of their time looking at the synchronous face (versus the asynchronous face) during VPC 1, $t(3) = 2.047$, $p = .133$, $d =$ 1.02, 51.85% of their time looking at the novel face (versus the asynchronous face) during VPC 2, $t(4) = .144$, $p = .892$, $d = .06$, and 55.82% of their time looking at the novel face (versus the synchronous face) during VPC 3, $t(3) = .449$, $p = .684$, $d = .22$. Thus, 5-month-olds in the experimental group did not show any significant novelty preferences during the VPC trials.

Independent samples t-test analysis was conducted to see age differences within the participants in the experimental group. The results showed that in the experimental group, during VPC 1, 12-month-olds looked longer at the asynchronous-familiar face ($M$ = 3.93 s) than 5-month-olds ($M$ = 2.27 s), $t(29) = -2.326$, $p = .027$, $d = 1.41$. No other significant results were found.

**Control Group**

Five-month-olds' total mean looking time was 6.48 s for VPC 1, 7.09 s for VPC 2, and 7.12 s for VPC 3. Five-month-olds looked longer towards the left asynchronous-familiar face (*M* = 3.31 s) than the right asynchronous-familiar face (*M* = 3.16 s) in VPC 1, the novel face (*M* = 3.63 s) than the left asynchronous-familiar face (*M* = 3.46 s) in VPC 2, and the right asynchronous-familiar face (*M* = 3.78 s) than the novel face (*M* = 3.34 s) in VPC 3. One sample t-test analysis revealed that they spent on average 52.47% of their time looking at the left asynchronous-familiar face (versus right asynchronous-familiar face) during VPC 1, $t(18)=0.591$, $p = .562$, $d = .13$, 52.42% of their time looking at the novel face (versus the left asynchronous-familiar face) in VPC 2, $t(22) = 0.405$, $p = .689$, $d = .08$, and 52.67% of their time looking at the right asynchronous-familiar face (versus the novel face) on VPC 3, $t(20) = 0.569$, $p = .576$, $d = .12$. No novelty preferences were found for this group.

Twelve-month-olds showed no significant differences in their looking times toward either face during the VPC trials. The total mean looking time for VPC 1 was 7.21 s, for VPC 2 was 7.14 s, and for VPC 3 was 7.04 s. They looked longer at the right asynchronous-familiar (*M* = 3.76 s) compared to the left asynchronous-familiar face (*M* = 3.42 s) in VPC 1, the novel (*M* = 3.88 s) compared to the left asynchronous-familiar face (*M* = 3.2 s) in VPC 2, and the right asynchronous-familiar (*M* = 3.66 s) compared to the novel face (*M* = 3.44 s) in VPC 3. One sample t-test showed that they spent on average 52.20% of their time looking at the right asynchronous face (versus the left asynchronous-familiar face) during VPC 1, $t(24) = .585$, $p = .564$, $d = .12$, 54.42% of their time looking at the novel face (versus the left asynchronous-familiar face) in VPC 2, $t(24) = 1.178$, $p = .25$, $d = .23$, and 52.34% of their time looking at the right asynchronous face (versus the novel face) on VPC 3, $t(21) = .788$, $p = .44$, $d = .16$, showing no novelty preference during the VPC trials. In addition, results from

Table 1. Total looking times during familiarization and VPC trials (s).

| | Experimental group | | | | Control group | | | |
|---|---|---|---|---|---|---|---|---|
| | 5-month-olds | | 12-month-olds | | 5-month-olds | | 12-month-olds | |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Familiarization | 26.32 | 4.21 | 28.95 | 1.97 | 28.16 | 2.66 | 29.44 | 2.53 |
| VPC 1 | 6.44 | 1.42 | 7.03 | 0.58 | 6.48 | 9.21 | 7.21 | 0.59 |
| VPC 2 | 6.49 | 1.02 | 6.94 | 0.73 | 7.09 | 0.81 | 7.14 | 0.64 |
| VPC 3 | 7.05 | 1.08 | 7.23 | 0.52 | 7.12 | 0.64 | 7.04 | 0.79 |

independent samples t-test analysis showed that there was a significant difference between the total look times of 5- and 12-month-olds in the control group for VPC 1. Twelve-month-olds looked significantly longer in total ($M$ = 7.21 s) compared to 5-month-olds ($M$ = 6.48 s), $t(42) = -3.207$, $p = .003$, $d = .94$. The paired samples t-tests revealed no other significant effects.

## Analysis 3: Correlations Between Looking Patterns During Familiarization and Visual Paired Comparison

Pearson product-moment correlations were run for each age group and experimental condition to understand the relationship between looking time during familiarization and looking preferences during VPC trials. Tables 2-5 show the correlations between looking times to each stimulus, for both age groups and experimental conditions. Highlighted correlations between the time looking at faces during familiarization and VPC trials are displayed on scatter plots in Figures 1-6.

### Experimental Group

In the experimental group, 5-month-olds' looking time to the synchronous face (vs. asynchronous face) during familiarization was significantly and positively correlated with the looking time to the novel face (versus asynchronous face) during VPC 2 ($r = .978$, $N = 5$, $p = .004$), as displayed in Figure 4. Looking time to the asynchronous face (versus synchronous face) during familiarization was significantly and negatively correlated with the looking time to the novel face (versus asynchronous face) during VPC 2 ($r = -.945$, $N = 5$, $p = .015$). All other correlations are reported in Table 2, however those not discussed here were non-significant and/or weak correlations.

The correlations between patterns of looking during familiarization and the VPC trials for 12-month-olds in the experimental group were below moderate, as shown in Figures 1, 4, and 6, and Table 3.

Figure 1. Scatterplot of looking times for IR face during familiarization and IR face during VPC 1 (experimental group).

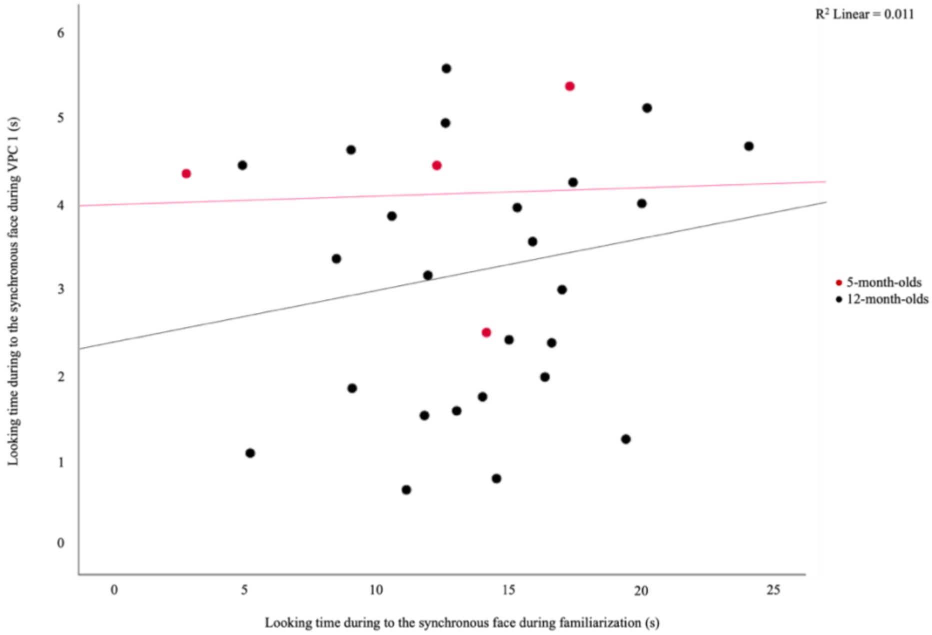



Figure 2. Scatterplot of looking times for right face during familiarization and right face during VPC 1 (control group).

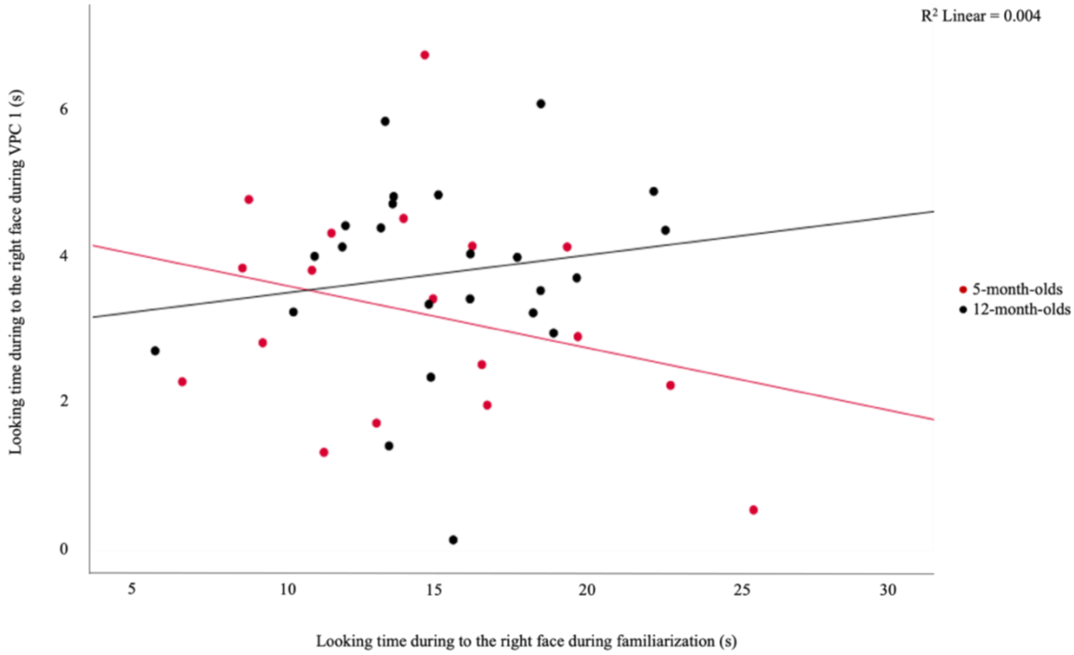


Figure 3. Scatterplot of looking times for right face during familiarization and novel face during VPC 2 (control group).

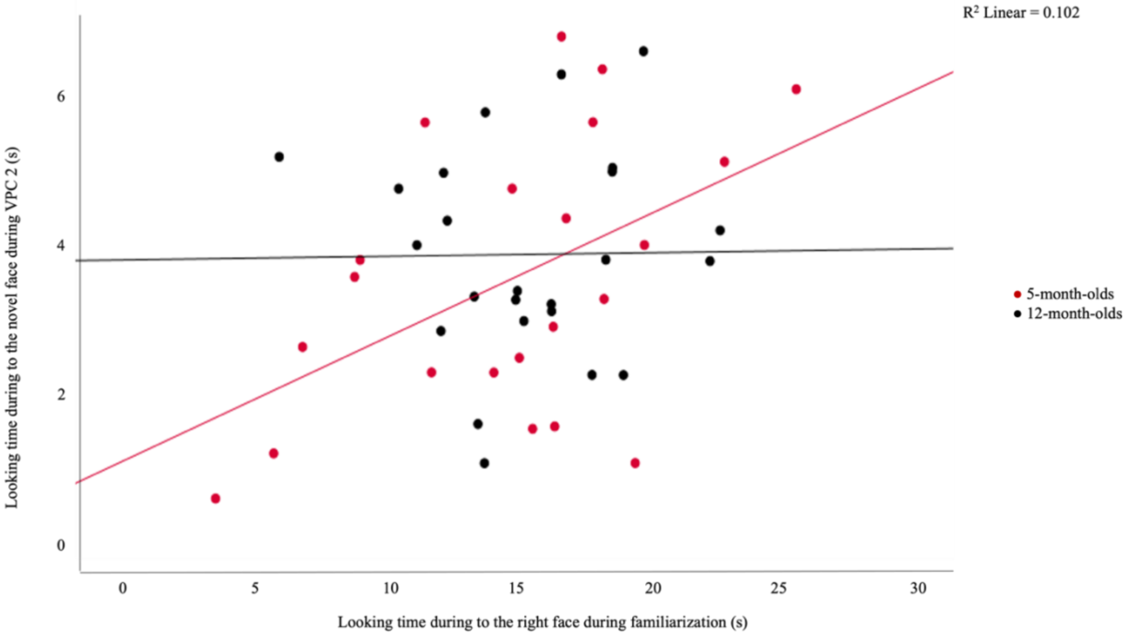



Figure 4. Scatterplot of looking times for IR face during familiarization and novel face during VPC 2 (experimental group).

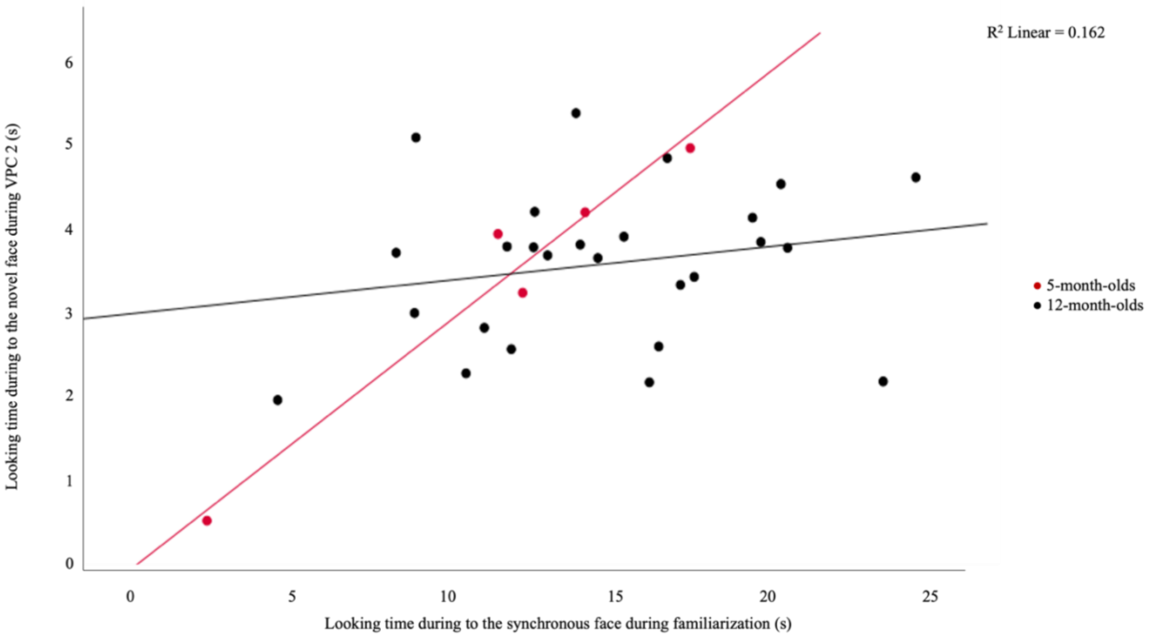


Figure 5. Scatterplot of looking times for right face during familiarization and novel face during VPC 3 (control group).

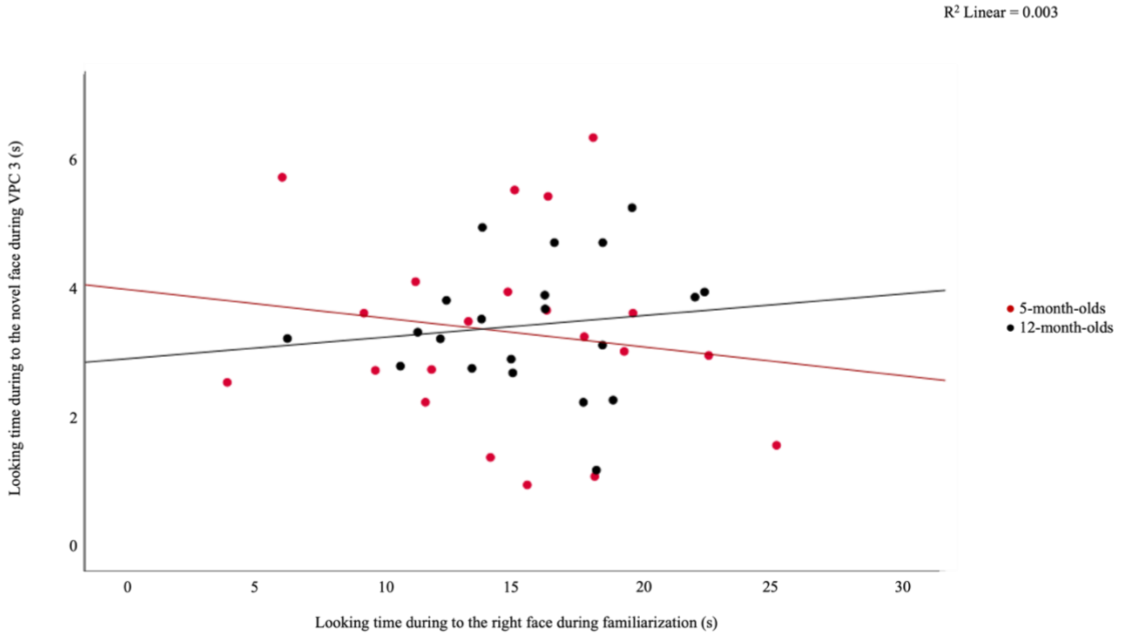
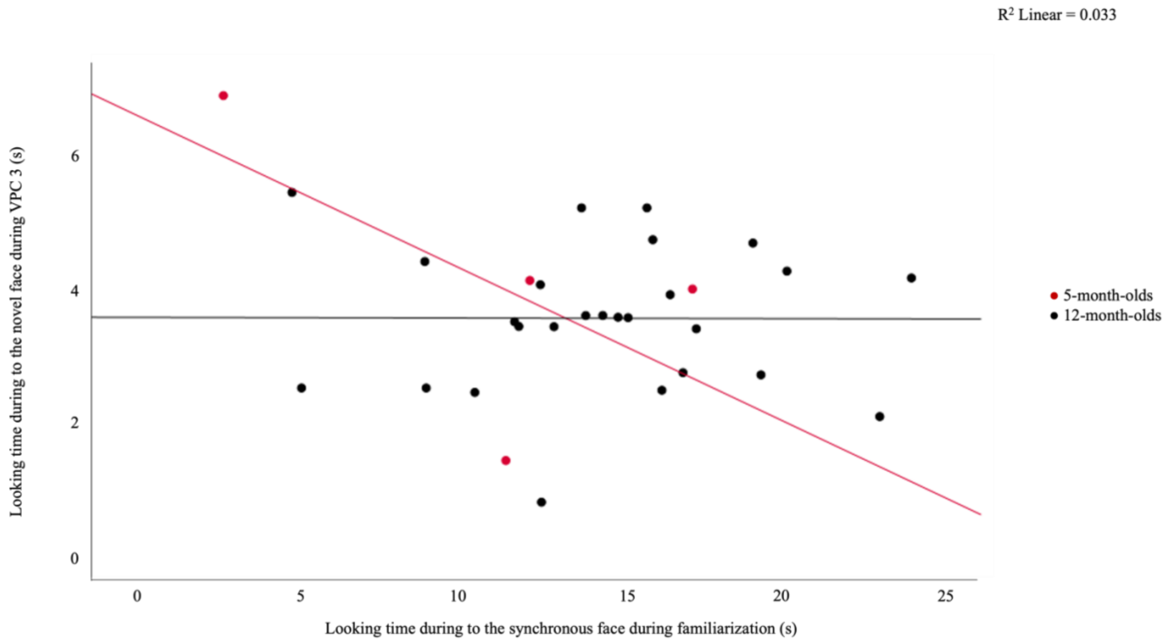



Figure 6. Scatterplot of looking times for IR face during familiarization and novel face during VPC 3 (experimental group).



**Control Group**

In the control group, 5-month-olds’ looking time to the right asynchronous face (versus left asynchronous face) during familiarization was significantly and positively correlated with their looking time to the left asynchronous face (versus right asynchronous face) during VPC 1 ($r$ = .531, $N$ = 18, $p$ = .023). Additionally, their looking time to the left asynchronous face (versus right asynchronous face) during familiarization was significantly and positively correlated with the looking time to the right asynchronous face (versus left asynchronous face) during VPC 1 ($r$ = .545, $N$ = 18, $p$ = .019) as displayed in Figure 2, and negatively correlated with the looking time to the left asynchronous face (versus right asynchronous face) during VPC 1 ($r$ = -.554, $N$ = 18, $p$ = .017). Moreover, looking time to the left asynchronous face (versus right asynchronous face) during familiarization was significantly and positively correlated with the looking time to the left asynchronous face (versus novel face) during VPC 2 ($r$ = .550, $N$ = 22, $p$ = .008), and negatively correlated with the looking time to the novel face (versus left asynchronous face) during VPC 2 ($r$ = -.527, $N$ = 22, $p$ = .012), as displayed in Figure 3. Table 4 shows the correlations between patterns of looking during familiarization and the VPC trials for 5-month-olds in the control group.

Twelve-month-olds in the control group showed a significant and positive correlation between the total looking times during familiarization and looking time to the right asynchronous face (versus left asynchronous face) during VPC 1 ($r$ = .750, $N$ = 24, $p$ < .001), and a negative correlation between the total looking times during familiarization and looking time to the left asynchronous face ($r$ = -.577, $N$ = 24, $p$ = .003), as displayed in Figure 2. Table 5 shows the correlations between patterns of looking during familiarization and the VPC trials for 12-month-olds in the control group.

## Analysis 4: Interactions Between Age and Familiarization Condition

### Familiarization

Two-way ANOVAs were conducted to examine the effect of IR condition and age on looking time during familiarization and VPC trials. For the total look time during familiarization, there was a significant main effect of age on total looking time, such that 12- month-old infants in both experimental and control conditions looked longer during familiarization (*M* = 29.18 s) than 5-month-olds in both conditions (*M* = 27.85 s), *F* (1, 81) = 7.778, *p* = .007, *partial* $\eta^2$ = .08. Figure 7 shows that looking was longer among 12-month-olds than 5-month-olds across the experimental and control conditions. Total look duration appears to be more discrepant based on age in the experimental condition than the control condition.

### Visual Paired Comparison 1

During VPC 1, where two familiar faces were presented, there was a significant main effect of age on looking time with a large effect size, *F* (1, 71) = 8.482, *p* = .005, *partial* $\eta^2$ = .107. Twelve-month-olds in both conditions spent a longer time looking in total (*M* = 7.12 s) compared to 5-month-olds (*M* = 6.47 s). Figure 8 shows that 12-month-olds had a longer average looking time compared to 5-month-olds during VPC 1, in both conditions.

During VPC 1, there was a statistically significant interaction between age and IR condition on looking time to the asynchronous-familiar face compared to the synchronous-familiar face (for the experimental condition) and left asynchronous-familiar face compared to the right asynchronous-familiar (for the control condition) with a small to medium effect size, *F* (1, 71) = 4.075, *p* = .047, *partial* $\eta^2$ = .054. On average, 12-month-olds in the experimental condition looked at the asynchronous-familiar face the longest (*M* = 3.93 s), followed by 12-month-olds in the control group (*M* = 3.42 s), 5-month-olds in the control group (*M* = 3.31 s), and 5-month-olds in the experimental group (*M* = 2.27 s). There was also a main effect of

Table 2. Correlation coefficients for looking times 5-month-olds (experimental group).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Familiarization total | - | | | | | | | | | | | |
| 2. Familiarization right | -.536 | - | | | | | | | | | | |
| 3. Familiarization left | .840 | -.908* | - | | | | | | | | | |
| 4. VPC 1 total | .388 | .545 | -.167 | - | | | | | | | | |
| 5. VPC 1 asynchronous | -.289 | .747 | -.623 | .541 | - | | | | | | | |
| 6. VPC 1 synchronous | .683 | .052 | .295 | .749 | -.152 | - | | | | | | |
| 7. VPC 2 total | .414 | .187 | .086 | .752 | -.052 | .924 | - | | | | | |
| 8. VPC 2 asynchronous | .761 | -.752 | .860 | -.269 | -.774 | .294 | .502 | - | | | | |
| 9. VPC 2 novel | -.640 | .978** | -.945* | .479 | .718 | -.004 | -.003 | -.866 | - | | | |
| 10. VPC 3 total | .841 | -.169 | .442 | -.776 | -.454 | -.965 | .887 | .789 | -.376 | - | | |
| 11. VPC 3 synchronous | -.672 | .836 | -.875 | .999* | .927 | .554 | -.302 | -.940 | .898 | -.573 | - | |
| 12. VPC 3 novel | .837 | -.618 | .775 | -1.000* | -.903 | -.604 | .622 | .984* | -.758 | .850 | -.919 | - |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 3. Correlation coefficients for looking times 12-month-olds (experimental group).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Familiarization total | - | | | | | | | | | | | |
| 2. Familiarization right | .183 | - | | | | | | | | | | |
| 3. Familiarization left | .223 | -.915** | - | | | | | | | | | |
| 4. VPC 1 total | -.040 | .145 | -.144 | - | | | | | | | | |
| 5. VPC 1 asynchronous | -.084 | -.126 | .070 | .075 | - | | | | | | | |
| 6. VPC 1 synchronous | .060 | .172 | -.121 | .337 | -.911** | - | | | | | | |
| 7. VPC 2 total | .182 | -.111 | .180 | .660** | -.090 | .357 | - | | | | | |
| 8. VPC 2 asynchronous | -.253 | -.430* | .332 | .436* | -.152 | .321 | .472* | - | | | | |
| 9. VPC 2 novel | .439* | .209 | -.015 | .095 | .071 | -.026 | .303 | -.582** | - | | | |
| 10. VPC 3 total | -.392* | .175 | -.332 | -.032 | -.271 | .216 | .071 | .173 | -.219 | - | | |
| 11. VPC 3 synchronous | -.017 | -.001 | -.014 | -.057 | .054 | -.051 | -.027 | -.028 | -.018 | .008 | - | |
| 12. VPC 3 novel | -.146 | -.004 | -.042 | .035 | -.163 | .135 | .081 | .155 | .003 | .386* | -.889** | - |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4. Correlation coefficients for looking times 5-month-olds (control group).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Familiarization total | - | | | | | | | | | | | |
| 2. Familiarization right | .365 | - | | | | | | | | | | |
| 3. Familiarization left | .163 | -.859** | - | | | | | | | | | |
| 4. VPC 1 total | .736** | .142 | .234 | - | | | | | | | | |
| 5. VPC 1 left | -.055 | .531* | -.554* | -.098 | - | | | | | | | |
| 6. VPC 1 right | .499* | -.294 | .545* | .696** | -.783** | - | | | | | | |
| 7. VPC 2 total | .161 | -.151 | .244 | .114 | -.500* | .426 | - | | | | | |
| 8. VPC 2 left | .090 | -.484* | .550** | .262 | -.570* | .561* | .509* | - | | | | |
| 9. VPC 2 novel | -.032 | .491* | -.527* | .-262 | .436 | -.466 | -.145 | -.925** | - | | | |
| 10. VPC 3 total | .375 | .060 | .139 | .382 | .064 | .176 | .073 | -.343 | .448 | - | | |
| 11. VPC 3 right | .078 | .162 | -.141 | .136 | .342 | -.175 | .120 | -.050 | .117 | .414 | - | |
| 12. VPC 3 novel | .074 | -.152 | .214 | .086 | -.400 | .348 | -.105 | -.060 | .023 | -.029 | -.922** | - |

**Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5. Correlation coefficients for looking times 12-month-olds (control group).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Familiarization total | - | | | | | | | | | | | |
| 2. Familiarization right | .108 | - | | | | | | | | | | |
| 3. Familiarization left | .518** | -.790** | - | | | | | | | | | |
| 4. VPC 1 total | .384 | -.124 | .292 | - | | | | | | | | |
| 5. VPC 1 left | -.577** | -.201 | -.158 | .259 | - | | | | | | | |
| 6. VPC 1 right | .750** | .154 | .291 | .174 | -.901** | - | | | | | | |
| 7. VPC 2 total | -.002 | -.201 | .184 | .443* | .409 | -.215 | - | | | | | |
| 8. VPC 2 left | .267 | -.049 | .187 | -.051 | -.040 | .017 | .198 | - | | | | |
| 9. VPC 2 novel | -.298 | .013 | -.171 | .214 | .209 | -.117 | .233 | -.876** | - | | | |
| 10. VPC 3 total | -.013 | -.054 | .043 | .630** | .348 | -.022 | .668** | .031 | .376 | - | | |
| 11. VPC 3 right | -.014 | -.269 | .242 | .361 | .639** | -.537* | .333 | .441 | -.335 | .319 | - | |
| 12. VPC 3 novel | .063 | .133 | -.089 | .248 | -.323 | .539* | .261 | -.439* | .588** | .369 | -.701** | - |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Figure 7. Looking time for familiarization.

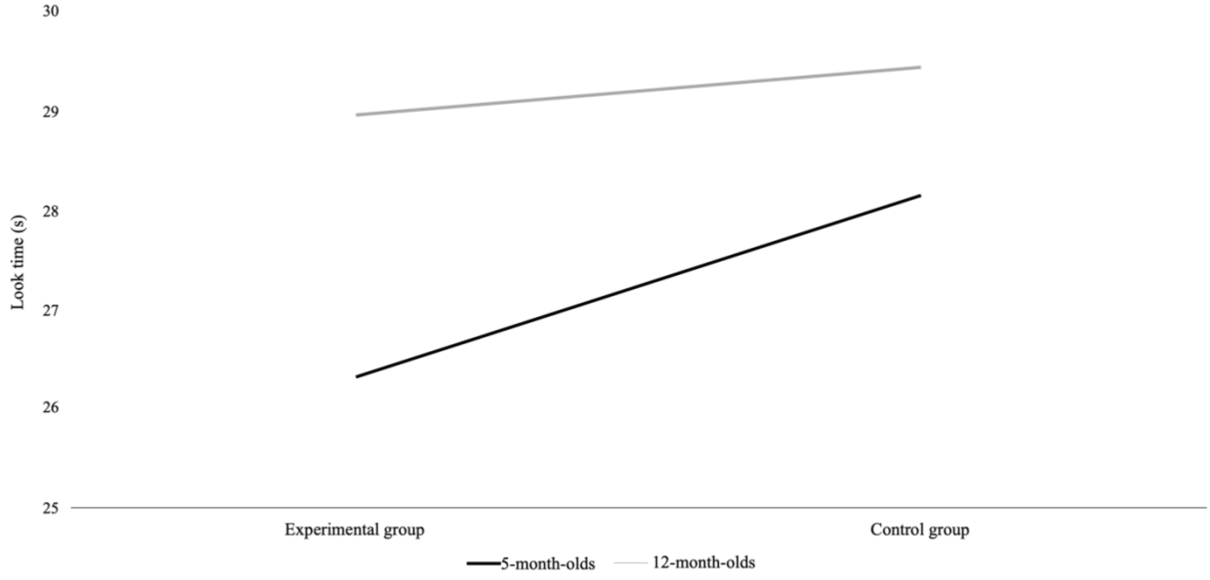
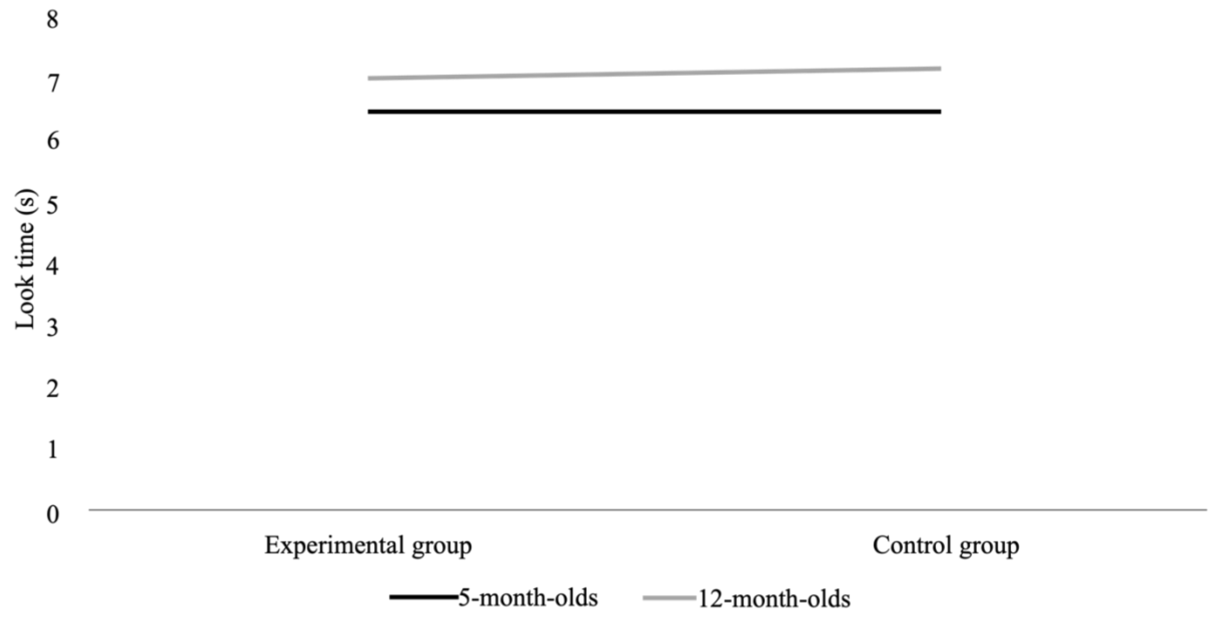
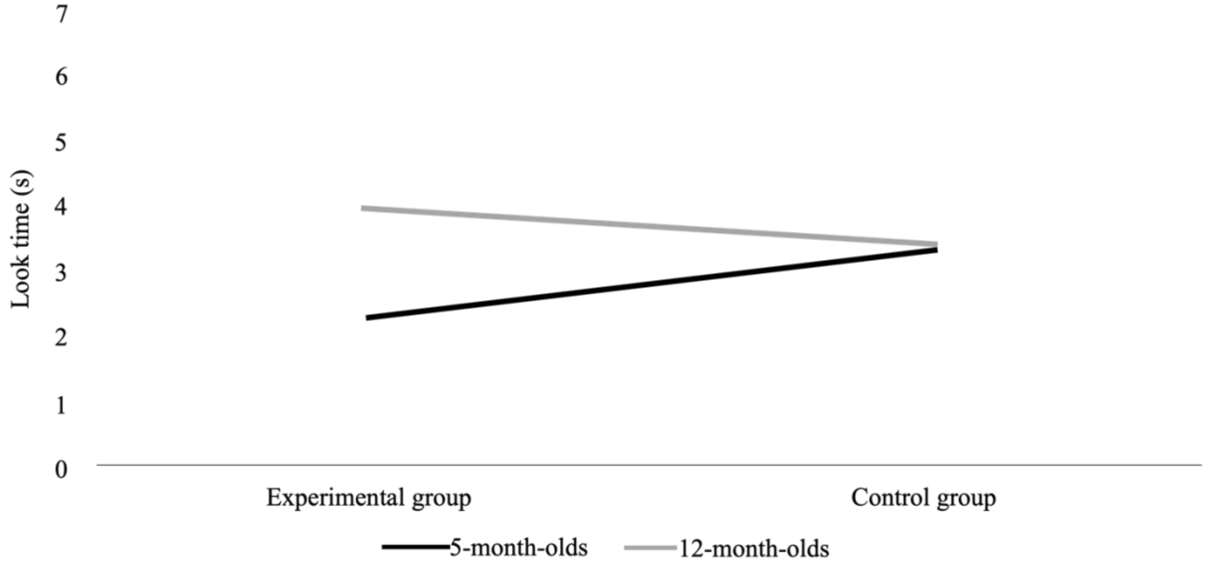



Figure 8. Looking time for VPC 1.




age, such that when presented with two familiar faces during VPC 1, 12-month-old infants spent a longer time (*M* = 3.68 s) looking at the asynchronous-familiar compared to the synchronous-familiar face (the experimental group) or the left asynchronous-familiar compared to the right asynchronous-familiar face (control group), compared to 5-month-olds (*M* = 3.31 s), *F* (1, 71) = 5.239, *p* = .025, *partial* $\eta^2$ = .07. Paired sample t-tests revealed no significant differences in looking time between the two faces during VPC 1 for 5-month-olds in the experimental group, *t*(3) = -2.309, *p* = .104, *d* = 1.756, 12-month-olds in the experimental group, *t*(26) = 1.627, *p* = .116, *d* = .61, 5-month-olds in the control group, *t*(18) = .283, *p* = .780, *d* = .12, and 12-month-olds in the control group, *t*(24) = -.664, *p* = .513, *d* = .26. Figure 9 shows average looking times during VPC 1 to asynchronous-familiar face (experimental group) or the left asynchronous-familiar face (control group). The total look duration is the longest for the 12-month-olds in the experimental group, followed by 12-month-olds in the control group, 5-month-olds in the control group, and 5-month-olds in the experimental group.

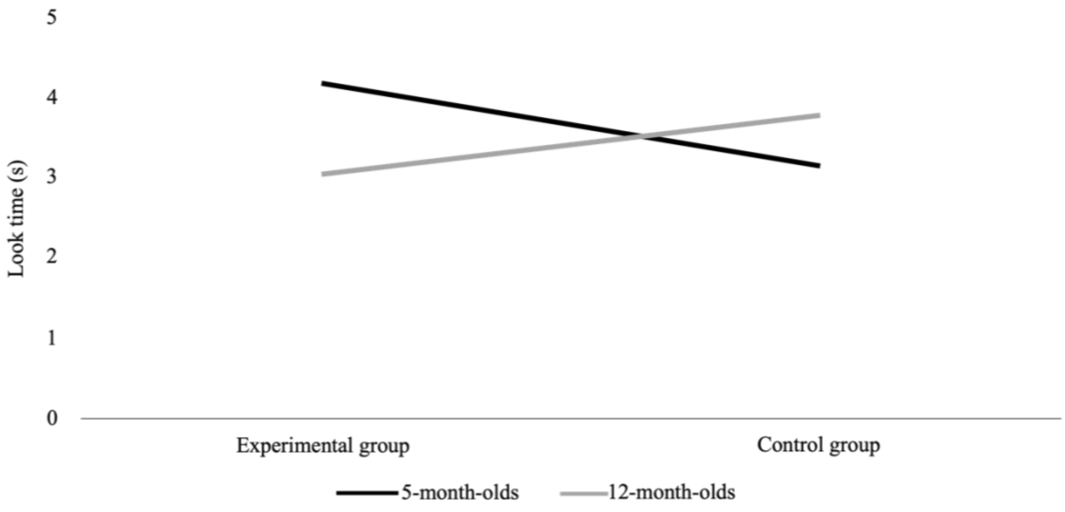
Figure 9. Looking time for VPC 1 – asynchronous (experimental) or asynchronous left (control).




For VPC 1, the interaction effect of age and IR condition on the total looking time to the synchronous-familiar face (experimental condition) or the right asynchronous-familiar face (control condition) approached significance (*p* = .053, *partial* $\eta^2$ = .05). Overall, 5-

month-olds in the experimental condition displayed the longest looking time (*M* = 4.17 s), followed by 12-month-olds in the control condition (*M* = 3.76 s), 5-month-olds in the control condition (*M* = 3.16 s), and 12-month-olds in the experimental condition (*M* = 3.07 s). Figure 10 shows that looking was the longest for 5-month-olds in the experimental group, followed by 12-month-olds in the control group, 5-month-olds in the control group, and 12-month-olds in the experimental group.

Figure 10. Looking time for VPC 1 – synchronous (experimental) or asynchronous right (control).

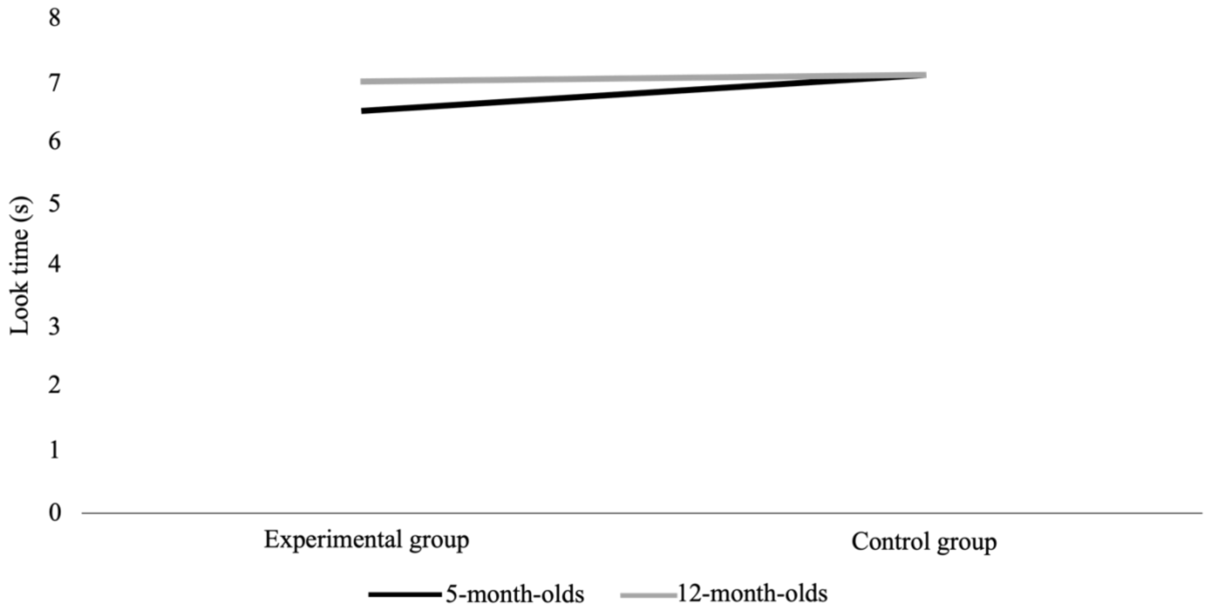



**Visual Paired Comparison 2**

Main effects analyses also showed that for VPC 2 (asynchronous-familiar versus novel for the experimental group, asynchronous-familiar left versus novel for the control group), the main effect of IR condition on total looking time approached significance, *F* (1, 77) = 3.649, *p* = .06, *partial* $\eta^2$ = .05. Overall, infants in the control group spent a longer time looking at the stimuli (*M* = 7.12 s), than the ones in the experimental group (*M* = 6.87 s). Paired samples t-test showed that the difference between the looking time to each face was not significant in 5-month-olds in the experimental group, *t*(4) = -.035, *p* = .974, *d* = .03, 12-month-olds in the experimental group, *t*(27) = -.367, *p* = .717, *d* = .12, 5-month-olds in the control group, *t(*22) = -.214, *p* = .832, *d* = .08, or 12-month-olds in the control group, *t*(24) = -1.278, *p* = .213, *d* =

.49. Figure 11 displays that on average, 12-month-olds spent a longer total looking time than 5-month-olds during VPC 2. The difference between looking times within age groups was larger for 5-month-olds.

Figure 11. Looking time for VPC 2.



# CHAPTER FOUR

# DISCUSSION

This study aimed to investigate the role of face specialization in the first year of life in processing of dynamic faces presented with or without intersensory redundancy. Specifically, I looked at how synchronous and asynchronous presentation of speaking faces affect attention to faces and facial recognition in 5- and 12-month-old infants. Most of the previous studies on infant face processing use static, unimodal stimuli to understand how infants attend to and perceive faces. Because we usually interact with faces in audiovisual contexts (i.e., with the presence of speech), using multimodal facial stimuli is a more ecologically valid way of studying face processing in infancy.

The results show that neither 5- or 12-month-olds showed evidence of novelty preferences during the VPCs. Past research findings indicated that as infants get older, they become better at guiding their attention in the presence of multimodal stimulation (Bahrick & Lickliter, 2004) and become better in processing and recognizing multimodal faces (e.g., Flom & Bahrick, 2007). Based on these, the hypothesis for this study was that 12-month-old infants would be better and more efficient than 5-month-olds in recognizing faces, specifically the ones who were exposed to a synchronous presentation of one of the faces. Lewkowicz and Hansen-Tift (2012) reported that 12-month-old infants attend more to the speaker's eyes, whereas 4- and 8-month-olds may be focusing more on the dynamic properties of the face. Thus, it was predicted that 12-month-olds would be able to move beyond the amodal information and attend to the facial features of the actor speaking.

Although there were some differences in looking times during familiarization and VPC trials, the findings indicated that these differences were not significant in any of the groups. It was observed that during VPC 1 (synchronous-familiar versus asynchronous-familiar face), 12-month-olds in the experimental group looked longer at the asynchronous face. This difference was nonsignificant, however, keeping in mind that this group of infants spent a longer time looking at the IR face during familiarization, it could mean that they recognize the IR face and thus show a novelty preference by looking longer towards the asynchronous face. Similarly, their longer looking time towards the novel face during VPC 2 (synchronous-familiar versus novel) may possibly indicate a recognition of the IR face, however, this difference was also nonsignificant. During VPC 3 (asynchronous-familiar versus novel), they looked longer to the asynchronous face, compared to the novel face. This could be because they have prior exposure to the asynchronous face (i.e., during familiarization), recognize it, but are still interested in it due to incomplete processing. This trend was also nonsignificant. These trends were not observed for 5-month-olds in the experimental condition. Although results from this age group can be explored with more data, it is difficult to interpret these results due to the very small sample size.

Twelve-month-olds in the control condition did not demonstrate significant differences in their looking times between the pairs of stimuli during familiarization and VPC trials. They looked longer to the right asynchronous face both during familiarization and VPC 1 (right asynchronous-familiar versus left asynchronous-familiar face), compared to the left asynchronous face, but as predicted, this difference was not significant. During VPC 2 (left asynchronous-familiar versus novel), they displayed a longer looking time towards the novel face compared to the asynchronous face they had already viewed during familiarization. This could indicate that the exposure to the asynchronous face during familiarization did result in some processing of that face, leading to a novelty preference, but these findings were not significant. During VPC 3 (right asynchronous-familiar versus novel), there was longer looking towards the asynchronous face, compared to the novel face. Even though this result was also nonsignificant, it might show that the asynchronous face was not fully processed during familiarization. Additionally, the findings from 5-month-old participants in the control group showed that during VPC 2 (left asynchronous-familiar versus novel), they looked longer at the novel face. Although nonsignificant, this finding may indicate that they might be showing some recognition for the asynchronous face which they viewed during familiarization. As with the results from the experimental group, these results from the control group were not significant and should only be considered from an exploratory perspective.

Presentation of complex, multimodal information can lead infants' attention to amodal properties of the stimulus, while driving attention away from the components relevant for recognizing faces. Hillairet de Boisferon et al. (2021) recently found that when 9- and 12-month-old infants were familiarized with dynamic, speaking faces, they showed no evidence of face discrimination based on native language. However, when they were familiarized with still faces paired with a soundtrack, they were better able to discriminate the face paired with their native language from a novel face. Their results show that even towards the end of the first year of life, presence of intersensory redundancy may guide infants' attention away from the properties related to face recognition. The stimuli used in the current study were more complex (i.e., two dynamic faces presented simultaneously) than previous studies. It is possible that this led the infants to be more distracted and shifted their attention away from the unimodal features of the faces. Another potential reason for the infants' lack of novelty preference can be the fact that the participants completing the study in their home environment and being more distractible, causing more noise in the data.

Although neither 5- nor 12-month-olds demonstrated novelty preferences during the VPCs, ANOVAs comparing looking across groups revealed some age-related effects. The results showed that 12-month-old infants in both control and experimental groups looked at the stimuli significantly longer during familiarization and VPC 1 (i.e., two familiar faces), compared to 5-month-olds. This indicates that 12-month-old infants may be more engaged with the stimuli than 5-month-old infants.  In addition, when results were broken down by IR condition, it was revealed that 12-month-olds in the control group spent a longer total time looking at the screen than 5-month-olds in the control condition during the first VPC trial (right asynchronous-familiar vs. left asynchronous-familiar face). Moreover, ANOVAs comparing looking time across groups during VPC 1 displayed a significant interaction effect of IR condition and age on looking time to one of the faces (asynchronous familiar for the experimental group, left asynchronous-familiar for the control group). Twelve-month-olds in the experimental group and control group looked at the stimuli the longest, attending more to the stimuli, compared to 5-month-olds in the control and experimental groups. These findings are in line with past research, which found that towards the end of the first year of life, more complex stimuli (e.g., faces) or multimodal presentation of stimuli can be more engaging for infants (Courage et al., 2006; Reynolds et al., 2013). Additionally, 5-month-old infants may be less specialized in their face processing. As studies that used neural measures demonstrate, older infants show an increased face specialization on a neural level (e.g., Conte et al., 2020; Guy et al., 2016), which may be associated with greater attention to faces on a behavioral level.

The correlations showed that there may be a relationship between looking times during familiarization and VPC trials. Five-month-olds in the experimental group displayed a negative relationship between looking time to the asynchronous face during familiarization and the novel face during VPC 2 (versus asynchronous face). This indicates that at this age infants may require additional time to fully process the face presented without IR. The same group of infants also displayed a positive relationship between looking time to the synchronous face during familiarization and the novel face during VPC 2 (versus asynchronous face), which shows that although they may need additional time to fully process the asynchronous face, they still display signs of recognition, by looking longer to the novel face in the VPC trial. Although 5-month-olds in this group did not display any significant correlations between looking times during familiarization and looking times during VPC 1 or VPC 3, the correlations were in the expected directions (e.g., total looking time during familiarization was positively correlated with total looking time during both VPC 1 and VPC 2, total looking time during familiarization was positively correlated with looking time to the novel face during VPC 3 (versus the synchronous)). The non-significance of results can be because of the small sample size of this group of participants.

Five-month-olds in the control group showed a positive relationship between looking times to the left asynchronous face during familiarization and right asynchronous face (versus left asynchronous face), and negative relationship between looking times to the left asynchronous face during familiarization and left asynchronous face (versus right asynchronous face) during VPC 1. This could show that even with asynchronous presentation of both faces, infants show some recognition of the face they looked longer during familiarization, indicated by longer looking time to the other face during the VPC. They also showed a significant positive relationship between looking time to the left face during familiarization and left face during VPC 2 (versus novel), which might show that they still need more time to process the familiar-asynchronous face and thus spend more time looking at it. The same positive relationship was observed between looking time to the right face during familiarization and right face during VPC 3 (versus novel), however, it was not significant.

Twelve-month-olds in neither group showed significant, strong correlations between looking patterns during familiarization and VPC trials. This might show that for younger infants, the looking and scanning patterns during familiarization may play a larger role in what stimulus recruits their attention during the VPC trials, compared to older infants. The only exception was that for the control group, total looking time during familiarization was significantly and positively correlated with looking time to the right face during VPC 1, and significantly and negatively correlated with looking time to the left face during VPC 1.

Many past studies on infant face specialization and recognition have used unimodal, static face stimuli to understand these processes. In the current study, I used multimodal (i.e., audiovisual) face stimuli. Multimodal face stimuli help to have a more accurate understanding of the factors that play a role in face recognition, by providing a more naturalistic representation of how infants encounter faces in real life. This study contributes to our understanding of face processing by exploring face processing and specialization, using ecologically valid stimuli.

## Limitations and Future Directions

There is still much to learn about infants' multimodal perception of faces. Compared to measures that depend on the infants' behavior, measuring the brain activity can provide a more nuanced understanding of the development of their attention to and processing of multimodal presentation of faces. The findings reported here are still preliminary and the non-significant novelty preference analyses may be affected by the small sample size. While the 12-month-old sample is typical for lab-based infant visual attention experiments (e.g., Reynolds et al., 2013), completion of the study in the home environment may have further introduced noise in the data through environmental variability and the increased presence of distractions. The Lookit platform is still very new and only one study using Lookit has been published thus far (Yoon & Frank, 2019). This study was conducted with 23-31 preschool children per group (Yoon & Frank, 2019). Although these group sizes are similar to ours, preschool children are able to follow experimenter's instructions and are likely to be more to comply with data collection. To strengthen the number of 5-month-olds in the experiment, data collection is ongoing for the experimental group.

Additionally, it is possible that infants did not display a novelty preference because of the complexity of the familiarization stimuli. It is possible that the stimulation provided by simultaneously viewing two dynamic faces was too complex and impeded attention being shifted to the unimodal features of the face, which would facilitate recognition. To explore if the infants are moving beyond the amodal information and shift their attention to the relevant properties, future studies can consider familiarizing infants with one dynamic face (i.e., with or without IR) and investigate if single presentations of faces allow infants' attention to be better allocated, thus facilitating unimodal facial information.

Moreover, although the majority of participants in the sample of this study identified only as Caucasian or White (67% of the participants), the sample consisted of participants from a variety of different ethnic and racial backgrounds. Additionally, about a third of the participants were exposed to at least one other language than English. Many past studies on infant and toddler face processing have used less racially diverse samples (e.g., Cashon et al., 2013; Cassia et al., 2012; Di Giorgio et al., 2012; Dixon et al., 2019; Durand et al., 2020; Guy et al., 2018). Although participation to the study was not restricted by country, the results reported here were observed in a sample that is representative of racial and ethnic groups in the US, making these effects more generalizable. It is also important to note that although this sample is more diverse than some other studies on face processing, our results have not addressed the possible effects of this. For example, past research shows that infants show a preference for own-race faces (Bar-Haim et al., 2006; Kelly et al., 2005). Caucasian faces were used in this study to familiarize and test infants' face recognition skills, however, their prior exposure to Caucasian faces or how frequently they interact with own- or other-race faces were not assessed, which might have affected the interest and attention to faces.

This line of research can also benefit from using neural methods, such as event-related potentials (ERPs), to have a more nuanced approach to understand face specialization over the first year of life. By looking at ERP components that are related to infant face processing (e.g., N290, P400) (Conte et al., 2020; de Haan et al., 2002; 2003, Guy et al., 2016) and infant attention (e.g., the Nc) (Carver et al., 2003; de Haan & Nelson, 1997; Reynolds et al., 2010), more subtle differences in attention to and recognition of faces can be identified. Past studies have shown that when used together, ERPs proved to be a more sensitive measure and revealed recognition patterns that looking time did not (e.g., de Haan & Nelson, 1997; Nelson & Collins, 1992), while some studies have shown more consistency between looking behavior and ERP measures (e.g., Reynolds et al., 2010). As research has shown that more cortical specialization is observed towards the end of the first year of life, using ERPs to study the development of face specialization in 12-month-old infants could help to understand neural sensitivity in face processing.

When interpreting the results from this study, it is important to consider the current situation of the world, with the COVID-19 pandemic. When data collection started in December 2020, mask use had been a common practice in many communities. Infants' interactions with people during the first months of their lives have been impacted by these practices, in a way that may limit their exposure to faces due to spending less time outside and seeing fewer people, decreasing their exposure to intersensory redundancy of a speaking face as a result of seeing people's faces covered with masks, as well as seeing many people through screens more often, instead of the typical real-life interactions (e.g., family and friends). The difference in the nature of these social interactions due to the pandemic have impacted how infants are exposed to faces and in turn may have affected the way they process them, which could be one potential explanation for why we did not see the effects we expected to see in this study.

Overall, the results from the current study indicate that 12-month-olds may have been more engaged during familiarization and VPC 1 than 5-month-olds. The longer looking time of 12-month-olds shows that they may have increased face specialization compared to 5-month-olds, and that complex stimuli such as faces are more engaging for them. However, the exposure during familiarization was not sufficient for face processing in either age group. It is possible that the stimuli were too complex to be processed during the familiarization period or that the multimodal stimulus presentation attracted infants' attention to other stimulus properties and away from the features relevant to face processing.

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