11-7-2011

Infants' Selective Attention to Faces and Prosody of Speech: The Roles of Intersensory Redundancy and Exploratory Time

Irina Castellanos
Florida International University, icast003@fiu.edu

DOI: 10.25148/etd.FI11120902

FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

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A dissertation submitted in partial fulfillment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY

in

PSYCHOLOGY

by

Irina Castellanos

2011

To: Dean Kenneth G. Furton
College of Arts and Sciences

This dissertation, written by Irina Castellanos, and entitled Infants' Selective Attention to Faces and Prosody of Speech: The Roles of Intersensory Redundancy and Exploratory Time, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

Robert Lickliter

Mary J. Levitt

Charles Bigger

Lorraine E. Bahrick, Major Professor

Date of Defense: November 7, 2011

The dissertation of Irina Castellanos is approved.

Dean Kenneth G. Furton
College of Arts and Sciences

Dean Lakshmi N. Reddi
University Graduate School

Florida International University, 2011

DEDICATION

I dedicate this dissertation to my wonderful family.

This dissertation is as much yours as it is mine.

ACKNOWLEDGMENTS

I wish to acknowledge my committee members, Dr. Robert Lickliter, Dr. Mary J. Levitt, and Dr. Charles Bigger, for providing insightful suggestions throughout the dissertation. I would also like to acknowledge Dr. Lorraine E. Bahrick, my major professor and committee chair, for providing outstanding training, fostering ideas, and supporting my research efforts.

I wish to express my gratitude to the National Institutes of Health and the MBRS RISE fellowship program for providing funding and for allowing me to participate in an excellent biomedical research community. I wish thank Melissa Argumosa and Mariana Vaillant-Molina for being part of this journey.

ABSTRACT OF THE DISSERTATION

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Irina Castellanos

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Professor Lorraine E. Bahrick, Major Professor

One of the overarching questions in the field of infant perceptual and cognitive development concerns how selective attention is organized during early development to facilitate learning. The following study examined how infants' selective attention to properties of social events (i.e., prosody of speech and facial identity) changes in real time as a function of intersensory redundancy (redundant audiovisual, nonredundant unimodal visual) and exploratory time. Intersensory redundancy refers to the spatially coordinated and temporally synchronous occurrence of information across multiple senses. Real time macro- and micro-structural change in infants' scanning patterns of dynamic faces was also examined.

According to the Intersensory Redundancy Hypothesis, information presented redundantly and in temporal synchrony across two or more senses recruits infants' selective attention and facilitates perceptual learning of highly salient amodal properties (properties that can be perceived across several sensory modalities such as the prosody of speech) at the expense of less salient modality specific properties. Conversely, information presented to only one sense facilitates infants' learning of modality specific properties (properties that are specific to a particular sensory modality such as facial features) at the expense of amodal properties (Bahrick & Lickliter, 2000, 2002).

Infants' selective attention and discrimination of prosody of speech and facial configuration was assessed in a modified visual paired comparison paradigm. In redundant audiovisual stimulation, it was predicted infants would show discrimination of prosody of speech in the early phases of exploration and facial configuration in the later phases of exploration. Conversely, in nonredundant unimodal visual stimulation, it was predicted infants would show discrimination of facial identity in the early phases of exploration and prosody of speech in the later phases of exploration. Results provided support for the first prediction and indicated that following redundant audiovisual exposure, infants showed discrimination of prosody of speech earlier in processing time than discrimination of facial identity. Data from the nonredundant unimodal visual condition provided partial support for the second prediction and indicated that infants showed discrimination of facial identity, but not prosody of speech. The dissertation study contributes to the understanding of the nature of infants' selective attention and processing of social events across exploratory time.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE PAGE

LIST OF ACRONYMS

1. ADS: Adult-directed Speech
2. ANOVA: Analysis of Variance
3. APGAR: Appearance, Pulse, Grimace, Activity, and Respiration
4. ERP: event-related potentials
5. IDS: Infant-directed Speech
6. IRH: Intersensory Redundancy Hypothesis
7. Nc: negative central component
8. PALT: Proportion of Available Looking Time
9. PTLT: Proportion of Total Looking Time
10. VPC: Visual Paired Comparison

CHAPTER I

INTRODUCTION

"In the normal environment there is always more information than the organism is capable of registering. There is a limit to the attentive powers of even the best educated human perceiver" (Gibson, 1969, p. 75). Neurological research on the visual cortex indicates that the brain is unable to process the great amount of visual information (10^8-10^9 bits per second) entering the retina (Deco, Pollatos, Zihl, 2002). Since all properties of our multimodal environment cannot be processed simultaneously attention is allocated to some properties while others are ignored. This processing bottleneck has a great influence on infants, who enter the world with immature sensory systems and with very limited attentional resources that can be easily exhausted by the richness of the multimodal environment. Research in this area is crucial to developing an understanding of perceptual and cognitive development, as selective attention sets the foundation for what information is perceived, learned, and remembered (Bahrick, 2010; Bahrick & Lickliter, in press). In the current chapter, I review research on the factors that influence the allocation of selective attention.

Selective Attention

Our perception of the world is organized by an interplay between extrinsic factors (e.g., the environment) and factors intrinsic to the organism (e.g., the organism's capabilities, goals, and intentions). Extrinsic factors such as intersensory redundancy (Bahrick, Walker, & Neisser, 1981; Bahrick & Lickliter, 2000, 2002; Bahrick, Lickliter, & Flom, 2004), stimulus complexity (Fagan, 1974), color (Treisman & Gormican, 1988), motion (Bahrick, Gogate, & Ruiz, 2002; Bahrick & Newell, 2008), task demands/ difficulty (Bahrick, Lickliter, Castellanos, Vaillant-Molina, 2010; Berger, 2004), and amount of exposure/familiarization (Rose, 1983; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982) can influence selective attention. Selective attention can also be influenced by factors intrinsic to the organism such as age (Fagan, 1974, Richards, 1997), goals (Rochat, 2007), and motor control (Berger, 2004; Smith, Thelen, Titzer, & McLin, 1999).

Researchers have posited salience hierarchies or priority maps at both the neural and behavioral levels to explain why certain properties of the environment are selected and processed versus ignored (e.g., Adler, Gerharstein, & Rovee-Collier, 1998; Bahrick, Gogate, et al., 2002; Bahrick & Newell, 2008; Craik & Lockhart, 1972; Desimone & Duncan, 1995; Koch & Ullman, 1985). Due to limited attentional and perceptual capabilities, selective attention is initially directed to the most salient properties in the environment and progresses to increasingly less salient properties across exploratory time.

Gottlieb, Kusunoki, & Goldberg (1998) have shown that the salience of visual stimuli influences neural responding. In monkeys, neurons in the lateral intraparietal area produce significantly greater responses to more salient visual stimuli (such as the sudden onset of stimuli in the visual field) than to less salient visual stimuli (such as the progressive appearance of stimuli in the visual field). Desimone & Duncan (1995) have proposed a biased competition model in which visual input competes for neural resources and control of behavior. Desimone & Duncan (1995, p. 195) state that "objects in the visual field compete for processing within a network of 30 or more cortical visual areas." Neural competition is driven by saliency. Salience can come from the physical attributes of the stimulus object and from the organism's cognitive processes (e.g., an understanding of the task requirements, goals, memory). Salient stimuli are said to be "processed preferentially at nearly all levels of the visual system" (Desimone & Duncan, 1995, p. 201).

Craik and colleagues (Craik & Byrd, 1982; Craik & Lockhart, 1972) describe the hierarchical effects of selective attention on information encoding and retrieval. They argue that less processing resources available to the perceiver (as a result of dividing attention between tasks during encoding, increased task difficulty, and/or age related changes) negatively affects the depth of processing and leads to subsequent difficulties retrieving information and poorer memory (Craik, Luo, & Sakuta, 2010).

Intersensory Redundancy Hypothesis

Bahrick and colleagues (Bahrick, 2010; Bahrick & Lickliter, 2000, 2002, in press; Bahrick, Lickliter, et al., 2004) have proposed the intersensory redundancy hypothesis (IRH) to explain how salience hierarchies might organize and guide selective attention and perceptual learning within episodes of exploration and across development. According to the IRH, stimulus properties are attended to and processed in order of their relative salience. The most salient properties are attended to and processed first and, as exploration continues, less salient properties are attended to and processed. The following section contains a review of the four predictions of the IRH and the research supporting each.

Intersensory Facilitation

According to the first prediction of the IRH, information presented redundantly and in temporal synchrony across two or more sensory modalities (intersensory redundancy) recruits selective attention and facilitates perceptual learning of highly salient amodal properties (e.g., rhythm, tempo) at the expense of less salient modality specific properties (e.g., features of the face, color, pattern, timbre and pitch) (Bahrick, 2010; Bahrick & Lickliter, 2000, 2002; in press; Bahrick, Lickliter, & Flom, 2004). Intersensory redundancy refers to the spatially coordinated and temporally synchronous presentation of invariant amodal information across multiple sensory modalities. Amodal properties are properties such as rhythm, tempo, duration, and intensity that can be perceived through several sensory modalities (i.e., bimodally or multimodally specified). Prosody of speech (the acoustic and melodic patterns of speech consisting of temporal, rhythmic, intensity/stress patterns, duration, and affect) is an amodal property because prosody is invariant across visual (facial) and auditory (vocal) stimulation. Detection of amodal properties such as temporal synchrony (Bahrick, 1988, 2001), intensity, prosody of speech (Bahrick, Castellanos, & Argumosa, 2011, Castellanos, 2007), affect (Flom & Bahrick, 2007), tempo (Bahrick, Flom, & Lickliter, 2002; Bahrick et al., 2010; Castellanos, Vaillant-Molina, Lickliter, & Bahrick, 2006), and rhythm (Bahrick & Lickliter, 2000) is promoted when intersensory redundancy is available and attenuated when intersensory redundancy is absent (referred to as intersensory facilitation).

Several studies provide evidence of intersensory facilitation for the detection of amodal properties. Three-month-old infants can perceive a change in tempo following redundant audiovisual, but not following nonredundant (unimodal auditory or unimodal visual) stimulation (Bahrick, Flom, et al., 2002). Four-month-old infants' discrimination of affect is promoted under conditions of redundant audiovisual stimulation as compared to nonredundant (unimodal auditory, unimodal visual, or asynchronous audiovisual) stimulation. Similarly, 5-month-old infants show discrimination of rhythm following redundant audiovisual exposure as compared to nonredundant exposure (Bahrick & Lickliter, 2000). These findings indicate evidence of intersensory facilitation, the enhanced detection of amodal properties following redundant but not nonredundant simulation.

Evidence of intersensory facilitation has also been found in the domain of speech perception. Bahrick et al. (2011) examined predictions of intersensory facilitation for the amodal properties specifying prosody of speech (tempo, rhythm, intensity/stress covariation, duration, and affect). We assessed whether 4-month-old infants could perceive a change in meaning from passages conveying prohibition to passages conveying approval or vice versa when presented with redundant audiovisual speech versus when presented with nonredundant (unimodal auditory or asynchronous audiovisual) speech. Infants in the redundant audiovisual condition were presented with a video of an actress speaking who produced natural and synchronous speech sounds. Those in nonredundant unimodal auditory condition were presented with still images of the actress' face while concurrently hearing the spoken passages. Infants in the nonredundant asynchronous audiovisual condition were presented with temporally asynchronous information in that the dynamic face and the spoken passages were out of synchrony with respect to one another. The asynchrony was achieved by presenting the visual information approximately 3-s before the onset of the auditory information. It was predicted that detection of a prosody change would be facilitated by redundant audiovisual speech presentations and attenuated by both nonredundant presentations (unimodal auditory and asynchronous audiovisual speech) if intersensory redundancy was important for early prosody perception. Results suggest intersensory facilitation for the detection of prosody of speech. Infants who received redundant audiovisual stimulation significantly discriminated the changes in prosody, whereas infants who received nonredundant (unimodal auditory or asynchronous audiovisual) stimulation did not show significant evidence of discrimination.

The findings provide support for the first prediction of the intersensory redundancy hypothesis and demonstrate that 4-month-old infants are able to discriminate changes in prosodic patterns conveying approval and prohibition in the presence of redundancy, provided by a synchronously moving face, but not in its absence. Furthermore, these findings provide evidence against the notion that infants show greater detection of prosody in redundant audiovisual than in nonredundant unimodal auditory presentations simply because redundant audiovisual presentations offer more information about an event. Infants in the nonredundant asynchronous audiovisual condition were provided with the same amount and type of stimulation (both the auditory and visual information) as infants in the redundant audiovisual condition, but were unable to discriminate a change in prosody. The failure to discriminate the change in prosody is likely due to the lack of intersensory redundancy, i.e., the disruption of temporal synchrony between the visual and auditory displays. These results suggest that synchronous audiovisual presentations, as compared with nonredundant presentations, provide better information for amodal properties such as affect, duration, patterns consisting of tempo, rhythm and intensity changes in speech, which are important for distinguishing between prosodic patterns conveying approval and prohibition.

Intersensory Facilitation - The Pop Out Effect

Intersensory redundancy also aids infants in segregating two concurrent streams of visual stimulation (Bahrick et al., 1981). Intersensory redundancy recruits infants' attention to amodal properties, such as temporal synchrony, causing these properties to "pop out" and become perceptual foreground while other properties become perceptual background. On the basis of intersensory redundancy, infants selectively attend to one of two superimposed dynamic visual events while ignoring the other (Bahrick et al., 1981). In this study, 4-month-old infants were presented with a film of two superimposed events occupying the same spatial location (e.g., a person playing a toy xylophone and a hand clapping game) while the soundtrack to one of the two events was presented in temporal synchrony with its movements. Infants selectively followed the movements of the redundantly specified event while the other event was ignored and treated as novel during test trials. Intersensory redundancy caused the audiovisual event to "pop out" and became perceptual foreground, drawing infants' attention away from the second silent and irrelevant visual event.

Similarly, intersensory redundancy aids infants in segregating two competing streams of auditory stimulation (Bahrick, Shuman, & Castellanos, 2008; Hollick, Newman, & Jusczyk, 2005). Bahrick et al. (2008) showed that 4-month-old infants can selectively listen to one of two female voices played concurrently when the voice of one is presented in temporal synchrony with a dynamically moving face. Although both speech streams consisted of women reciting the same nursery rhyme, in the same infant-directed intonation, at equal amplitudes, when the voices were played separately during test trials, infants treated the previously synchronized voice as familiar and the non-synchronized voice as novel. These findings suggest that intersensory redundancy caused the voice synchronized with the face to "pop out" and become perceptual foreground, while causing the non-synchronized voice to become perceptual background. Taken together, these studies reveal the organizing role of intersensory redundancy in infants' selective attention to amodal temporal properties.

Unimodal Facilitation

According to the second prediction of the IRH, information presented to only one sensory modality or nonredundantly (temporal asynchrony) across several sensory modalities recruits selective attention and learning of modality specific properties at the expense of amodal properties (Bahrick, 2010; Bahrick & Lickliter, 2000, 2002; in press; Bahrick, Lickliter, & Flom, 2004). Modality specific properties are detected more easily in nonredundant stimulation than in redundant audiovisual stimulation (referred to as unimodal facilitation) because there is no competition from more salient amodal properties. Modality specific properties are properties that can only be specified in one sensory modality. Color, for example, is a modality specific property because it offers information to only the visual sensory modality. Nonredundant (unimodal or temporally asynchronous) presentations provide information about modality specific properties such as orientation (Bahrick, Lickliter, & Flom, 2006), color (Vaillant-Molina, Gutierrez, Bahrick, 2005), pitch (Vaillant, Bahrick, & Lickliter, 2008), information that underlies person identification such as facial features and their arrangement (Bahrick, Argumosa, Lopez, & Todd, 2009; Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004a; Vaillant-Molina, Newell, Castellanos, Bahrick, & Lickliter, 2006), and voice identification such as pitch and timbre (Bahrick, Lickliter, Shuman, Batista, & Grandez, 2003).

Studies assessing infants' perception and discrimination of modality specific properties suggest evidence of unimodal facilitation (enhanced detection of modality specific properties in nonredundant as compared with redundant audiovisual stimulation). Two-month-old infants can perceive a change in person following nonredundant (unimodal visual and asynchronous audiovisual) stimulation, but not following redundant audiovisual stimulation (Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004a; Vaillant-Molina et al., 2006). Infants failed to show discrimination of faces following redundant audiovisual stimulation because redundant audiovisual stimulation is thought to attract attention to amodal properties, such as prosody of speech, at the expense of attention to the modality specific properties underlying person identification. Similarly, 4-year-old children show memory for faces following nonredundant unimodal visual exposure as compared to redundant audiovisual exposure (Bahrick et al., 2009). Evidence of unimodal facilitation has also been found in the domain of voice identification. Three-month-old infants discriminated between the voices of two unfamiliar women speaking following nonredundant unimodal auditory stimulation, but not following redundant audiovisual stimulation (Bahrick et al., 2003). Nonredundant unimodal stimulation facilitates attention to modality specific properties of events more so than redundant audiovisual stimulation. Discrimination of faces (a task specific to vision) is enhanced when the faces are seen but not heard and discrimination of voices (a task specific to audition) is enhanced when the voices are heard but not seen.

Developmental Improvements

According to the third prediction of the IRH, across development, infants' increased attention and perceptual flexibility lead to detection of both amodal and modality specific properties in redundant audiovisual and nonredundant (unimodal visual, unimodal auditory, asynchronous audiovisual) conditions (Bahrick, 2010; Bahrick & Lickliter, in press; Bahrick et al., 2010). Infants' attention becomes more flexible with age and experience (e.g., Mayes & Kessen, 1989; Shaddy & Colombo, 2004), allowing for the simultaneous processing of both salient and less salient properties of stimulation.

For example, 4-month-old infants discriminate changes in the prosody of speech in the presence of intersensory redundancy but not in its absence (Castellanos, Shuman, & Bahrick, 2004). However, at 6 months of age, infants discriminate changes in the prosody of speech in both redundant audiovisual and nonredundant unimodal auditory stimulation (Bahrick et al., 2011). Infants' discrimination of affect (Flom & Bahrick, 2007), tempo (Bahrick, Flom, et al., 2002; Bahrick & Lickliter, 2004; Bahrick et al., 2010), and rhythm (Bahrick & Lickliter, 2000, 2004) also extend from being detected exclusively in redundant audiovisual stimulation to nonredundant unimodal stimulation as infants age and gain experience with events.

Research also indicates developmental improvements in infants' perception and discrimination of modality specific properties. For example, 2-month-old infants show unimodal facilitation for detection of person identification (Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004a). However, at 3 months of age, infants discriminate unfamiliar faces in both nonredundant unimodal and redundant audiovisual stimulation (Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004b). Infants' discrimination of voices (Bahrick, Lickliter, Shuman, Batista, Castellanos, & Newell, 2005) and orientation (Bahrick et al., 2006) also extend from being more easily detected in nonredundant unimodal stimulation to redundant audiovisual stimulation across development.

<u>Task Difficulty Across the Lifespan</u>

The last prediction of the IRH addresses the role of intersensory and unimodal facilitation in tasks of high difficulty. In tasks of low difficulty, where attentional and cognitive load is low, attention progresses more quickly down the salience hierarchy and perceivers may attend to both salient and less salient properties. However, tasks of high difficulty require greater attentional resources. In these tasks, attention progresses more slowly down the salience hierarchy and perceivers may only attend to the most salient properties at the expense of less salient properties. Therefore, it is proposed that the effects of intersensory and unimodal facilitation are evident across the life span especially when tasks of high difficulty tax perceivers' attentional and cognitive capabilities

(Bahrick, 2010; Bahrick & Lickliter, in press; Bahrick et al., 2010). Both infants and adults should benefit from intersensory facilitation for discrimination of amodal properties in tasks of high difficulty (such as when a monolingual adult is asked to discriminate the phonological differences of two dialects of a foreign language). Similarly, infants and adults should benefit from unimodal facilitation for discrimination of modality specific properties in tasks of high difficulty (such as when a music novice is asked to discriminate the pitch differences of the viola and violin, two musical instruments that produce similar pitch patterns).

A recent study examined the effects of task difficulty on infants' ability to discriminate the amodal property of tempo (Bahrick et al., 2010). Previous research has shown that 3-month-old infants show intersensory facilitation for discrimination of tempo changes produced by a toy hammer (Bahrick, Flom, et al., 2002). We tested older, 5-month-old infants' ability to discriminate tempo contrasts of low difficulty (the same tempo contrast used in the prior study, a tempo difference of more than 100%), moderate difficulty (a tempo difference of 38%), and tempo contrasts of high difficulty (a tempo difference of 17%). Results indicate that when tested with tempo contrasts of low and moderate difficulty, 5-month-old infants display discrimination of tempo changes in both redundant audiovisual and nonredundant unimodal stimulation. However, when the tempo contrasts differed by only 17% (the high difficulty condition), 5-month-old infants reverted to patterns of intersensory facilitation shown by the 3-month-old infants. These findings suggest that intersensory facilitation is a function of task difficulty in relation to the attentional and cognitive abilities of the perceiver.

Summary

Selective attention provides a basis for what information is perceived and how well it is learned (Bahrick, 2010; Bahrick & Lickliter, in press). Various extrinsic and intrinsic factors influence selective attention across the lifespan. The current chapter focused on the role of intersensory redundancy in recruiting selective attention across development. The studies reviewed in this chapter indicate the critical role of intersensory redundancy for guiding selective attention, perception, and memory to amodal properties. Redundant audiovisual contexts highlight amodal properties such as tempo, rhythm, and the prosody of speech to a greater extent than nonredundant contexts (e.g., those contexts that offer no audiovisual synchrony including unimodal auditory and unimodal visual stimulation). In contrast, nonredundant contexts highlight modality specific properties such as those underlying person identification, orientation, color, and pitch.

Research is just beginning to investigate how extrinsic factors such as intersensory redundancy (redundant audiovisual, nonredundant unimodal visual stimulation) provided by the stimulus event, stimulus properties (amodal, modality specific), and exploratory time affect selective attention and, in turn, contribute to the organization of development across the lifespan. The dissertation study is the first to examine the effects of attentional salience hierarchies on the deployment of attention across exploratory time at a single point in development. It examined young infants' selective attention to amodal and modality specific properties of social events (i.e., prosody of speech and facial identity) and how attention allocation to these properties changes in real time as a function of whether intersensory redundancy is present or absent.

CHAPTER II

METHODS FOR INVESTIGATING INFANT PROCESSING

The two most common methods used in the field to examine infant discrimination and categorization are the habituation/dishabituation and visual paired comparison (VPC) paradigms. These paradigms have become powerful tools for testing basic perceptual and cognitive abilities because they are noninvasive and do not require participants to have acquired language, thus allowing these paradigms to be used with infants, clinical populations, and across species. The habituation/dishabituation and VPC paradigms also allow for the presentation of different events (e.g., social, nonsocial stimulus events) and to vary the contexts in which the events are presented (e.g., redundant audiovisual, nonredundant unimodal). The habituation/dishabituation and VPC paradigms are built around the notion that when infants have sufficiently processed a stimulus event, they will prefer novel stimuli over a repeatedly presented familiar stimulus. This chapter discusses similarities and differences between the two paradigms and reviews relevant literature supporting the use of each.

The Habituation/Dishabituation Paradigm

Habituation is described as a progressive decrease in response following repeated exposure to a stimulus that is not affected by sensory adaptation or fatigue (Harris, 1943; Rankin et al., 2009; Thompson & Spencer, 1966). Dishabituation refers to the spontaneous recovery of the inhibited response following the removal of the stimulus (Rankin et al., 2009; Thompson & Spencer, 1966). Habituation can occur in behaviors such as reflexes (sweating, muscle contractions), cardiac, respiratory, visual responses, and even in neuroendocrine system (Caron & Caron, 1969; Graham, Clifton, & Hatton, 1968; Engen & Lipsitt, 1965; Rankin et al., 2009).

In the following section, I focus on research examining infants' visual and audiovisual habituation. The most widely used form of the habituation/dishabituation paradigm is the infant-controlled habituation procedure (Horowitz, Paden, Bhana, & Self, 1972). The infant-controlled habituation procedure is designed to allow infants to control the length of each trial with their looking behavior. Research has shown that infant fussiness and attrition is reduced when infants are allowed to control the stimulus duration with their looking behavior as compared to when trials are presented for a fixed length of time and controlled by the experimenter (Horowitz et al., 1972). Trials begin in the infant-controlled habituation procedure when infants visually fixate on the habituation stimulus (usually presented on a monitor) and terminate when infants look away or when a certain amount of time elapses, whichever occurs first. Infants are said to be habituated or fully familiarized to a stimulus event after their attention decreases to a preset habituation criterion. Typically, the habituation criterion is set to a 50% decrement, meaning that infants will be considered habituated after their visual fixations decrease by 50% relative to their initial or baseline interest in the habituation stimulus. Once the habituation criterion is met some researchers present infants with post-habituation trials. These additional trials are identical to the habituation trials and are presented to reduce the possibility of chance habituation and to allow for spontaneous regression toward the mean (see Bertenthal, Haith, & Campos, 1983, for a discussion of regression effects in habituation/dishabituation designs).

Following the habituation training, infants are presented with test trials depicting a stimulus novelty. Since habituation training induces a decrease in visual responding to the habituated stimulus then any visual recoveries occurring during test are associated with properties of the test stimulus. Visual recovery (increases in visual fixation from looking during habituation to test trial looking) serves as the primary dependent variable in habituation studies. Positive visual recovery scores are associated with discriminating the test stimuli from the habituated stimuli (dishabituation). Negative or null visual recovery scores are associated with treating the habituated and test stimuli as similar (stimulus generalization).

The habituation parameters described above are controlled by the experimenter and can be adjusted infants' age. Research has shown that younger infants require more time to habituate to stimulus events than older infants (Schoner & Thelen, 2006). As a result, researchers may shorten the length of trials, decrease the amount of looking away required to terminate a trial, or increase the amount of visual decrement necessary for habituation to be reached. Flom & Pick (2010) examined the amount of visual decrement necessary (50% vs. 70%) for infants to display discrimination of musical excerpts. Five and seven-month-old infants were habituated to a musical excerpt rated as affectively happy or sad. Two experiments where conducted: Experiment 1 required infants to reach a 50% visual decrement relative their visual fixation on baseline and Experiment 2 required infants to reach a 70% decrement relative their visual fixation on baseline before presenting test trials depicting a novel but affectively similar musical excerpt. Infants who were required to reach a 70% visual decrement discriminated the change in musical excerpt, whereas infants who were only required to reach a 50% visual decrement did not. These experiments indicate that infants' visual discrimination is affected by the habituation parameters set by the experimenter and thus the amount of habituation infants receive.

Several studies have examined infants' looking behavior during habituation as a function of age, stimulus redundancy condition (redundant audiovisual, nonredundant unimodal), and stimulus complexity. For example, Mayes & Kessen (1989) examined changes in infants' looking behavior across four time periods (at 3, 4, 5, & 6 months of age). Infants were habituated to one of two photographs of an affectively neutral woman's face. Several measures of attention taken during habituation were analyzed. Results indicate that length of baseline looking, length of longest look, and total looking time remained stable across 3 and 4 months of age. Differences emerged between 3 and 6 months of age. Length of baseline looking, length of longest look, length of second criterion look, and amount of total looking time decreased across 3 and 6 months of age. These results suggest that across the span of 3 months, infants become more efficient at attending and processing information.

Shaddy & Colombo (2004) examined the developmental changes in infants' look duration as it relates to dynamic versus static events. Four- and 6-month-old infants were randomly assigned and habituated to one of three possible stimulus redundancy conditions: 1) a redundant audiovisual condition where they could see and hear a woman speaking, 2) a nonredundant unimodal visual condition where they could see a woman speaking silently, and 3) a static mute condition where they could see static images of a woman smiling. Results indicate that the redundant audiovisual, as compared to the nonredundant unimodal visual or the static mute stimulus redundancy conditions, garnered more of the infants' attention during habituation. Additionally, across all three conditions, the overall amount of time spent looking during the habituation paradigm decreased between 4 - 6 months of age, suggesting that infants process information more rapidly as they age.

The Visual Paired Comparison Paradigm

Infants' discrimination, rate of processing, and memory for stimuli is frequently examined using the visual paired comparison (VPC) paradigm (Fantz, 1964). The VPC paradigm involves presenting a stimulus event, image, or object for a period of time (familiarization) and then pairing the familiar target side-by-side with a novel distractor. Infants' visual fixations towards the familiar target and novel distractor are measured and compared. Discrimination and memory for the familiarized target is inferred by a novelty preference score, which is defined as significantly greater looking to the novel distractor than the cumulative looking to both the familiarized target and novel distractor (Fagan, 1974).

The VPC paradigm has been successfully used to examine preterm and full-term infants' attention (Rose, 1983; Rose, Feldman, & Jankowski, 2003), attentional skills across infancy and adulthood (Fagan & Haiken-Vasen, 1997, Richmond, Sowerby, Colombo, & Hayne, 2004; Rose, Feldman, & Jankowski, 2009), the attention of clinical populations (Chawarska & Shic, 2009; Chawarska & Volkmar, 2007), and animal models (Pascalis & Bachevalier, 1999).

One of the major differences between the VPC and infant-controlled habituation paradigm is the amount of experience required with the familiarized stimulus before testing with a novel exemplar. As discussed in the previous section, the infant-controlled habituation paradigm requires the infant to be fully familiarized or habituated to the stimulus event before the presentation of test trials depicting a novel exemplar. There are times, however, when infants' "recognition may be accomplished long before any reliable decline over trials can be demonstrated, perhaps even by the end of the first 'habituation' trial" (Fagan, 1974, p. 356). The VPC paradigm aims to partially familiarize the infant before each test trial to examine processing and recognition as a function of familiarization time. Each VPC test trial (which pairs the familiar target side-by-side with a novel distractor) contributes to a data point (a novelty preference score) for analyzing infants' discrimination and preference of the familiarized target. The number of data points for analyses is another difference between the VPC and the infant-controlled habituation paradigm. Typically, the infant-controlled habituation paradigm provides one discrimination score (a visual recovery score) upon task completion, whereas studies using the VPC paradigm can track how discrimination scores change across the course of the experiment.

The amount of familiarization provided (e.g., 5 - 60-s) can vary (Fagan, 1974; Rose, 1983; Rose et al., 1982), the length of the familiarization can be preset to a specific amount of elapsed time or until the infant accumulates a certain amount of looking (Fagan, 1974; Richards, 1997; Rose et al., 1982), and the time period between familiarization and test can be immediate or delayed (Bahrick & Pickens; 1995; Bahrick, Hernandez-Reif, & Pickens, 1997; Fagan, 1973; Hunter, Ames, & Koopman, 1983).

The earliest description of infants' novelty preference come from Fantz (1964) showing that following repeated exposure, infants of 2 to 6 months of age will look more to a novel than a familiar stimulus event. Infants showed an increase in their attention to the novel event while decreasing their attention to the familiar event. Since then, researchers have documented a shift in infants' preferences that progresses from familiarity to null to novelty. Research has examined shifts in familiarity to novelty preferences as a function of age, familiarization time, and stimulus complexity (e.g., Fagan, 1974; Hunter et al., 1983; Hunter, Ross, & Ames, 1982; Rose et al., 1982). For instance, Fagan (1974) examined 5- to 6-month-old infants' recognition memory of line drawings of faces, photographs of faces, multidimensional, and patterned arrangements. It was found that the length of familiarization and complexity of the stimuli altered infants' novelty preferences scores. Shorter familiarization times elicited familiarity or null preferences and longer familiarization times elicited novelty preferences. Infants also shifted from familiarity to novelty preferences faster following familiarization to less complex stimuli. When recognition of less complex stimuli such as a patterned arrangement was examined, 10-s of familiarization was sufficient to elicit novelty preferences. When recognition of more complex stimuli such as photographed faces were examined, 20-s of familiarization was required to elicit viewing the novel over the familiar photograph.

Similarly, Richards (1997) showed that 14- to 26-week-old infants displayed familiarity or null preferences following short familiarization exposures (2.5 - 5-s) and shifted to novelty preferences following longer familiarization exposures (7.5 - 20-s). Older infants also shifted more quickly from familiarity to novelty preferences. 26-week-old infants displayed novelty preferences after only 7.5-s of familiarization. In contrast, 14- and 20-week-old infants required 10-s of familiarization to prefer the novel exemplar over the familiar. In general, research indicates that older infants require less familiarization time to show novelty preferences than younger infants (e.g., Colombo, Mitchell, Horowitz, 1988; Rose, 1983)

Rose et al. (1982) have proposed that a significant preference for the familiar stimulus event indicates partial processing of the familiar event. Whereas, a significant preference for the novel stimulus event indicates more complete processing and discrimination of the familiar event. Several studies provide support for this hypothesis. For example, Hunter and colleagues (1982, 1983) indicate that 8- and 12-month-old infants display looking and manipulation preferences towards familiarized toys when their habituation is interrupted and they are only able to partially process information about the toys. When infants are allowed to fully habituate before presenting the novel and familiar toys side-by-side, they display looking and manipulation preferences towards the novel toys.

Added support for the hypothesis that greater looking to the familiar over the novel exemplar is associated with weaker or incomplete processing comes from work with heart rate measures and event-related potentials (ERPs). Richards (1997) examined the relationship between 3- to 6-month-old infants' novelty preferences towards computer generated patterns and heart-rate defined phases of attention (sustained attention and attention termination). During sustained attention the heart rate decelerates and infants are said to be intensely engaged with the stimuli and less distractible. More complete processing of information is predicted to occur during this phase of active attention (Richards, 1997; Lansink & Richards, 1997). During attention termination the heart is said to return to pre-stimulus levels and infants are said to be inattentive and "more resistant to information acquisition" (Richards, 1997, p. 23). Results supported predictions and indicate that infants showed significant novelty preferences when in sustained attention and showed familiarity preferences when in attention termination.

Similarly, research using event-related potentials (ERPs) provide support for the notion that novelty preferences are representative of more advanced or complete processing. Work using ERPs indicates that the negative central (Nc) component is related to activation of prefrontal cortical areas involved in visual attention and that Nc amplitudes increase across age (Reynolds, Courage, & Richards, 2010; Richards, 2003). Infants of 4.5, 6, and 7.5 months of age who displayed greater novelty preferences during a VPC task also showed greater Nc amplitude in response to novel versus familiar exemplars (Reynolds et al., 2010).

Infants' long-term memory has also been investigated with the VPC paradigm. Bahrick & Pickens (1995) and Bahrick et al. (1997) have examined 3-month-old infants' memory for object motion following 1-min, 1-day, 2-weeks, 1-month, and 3-month delays. They predicted that infants' novelty and familiarity preferences would alter as a function of retention time. Results indicate that as retention time increases, infants' preferences shift from novelty (tested 1-min familiarization) to null (tested 1-day or 2-weeks following familiarization) to familiarity (tested 1-month or 3-months following familiarization to the object motion) (Bahrick & Pickens, 1995). Bahrick & Pickens (1995) and Bahrick et al. (1997) proposed a four-phase attention model: recent memory (more accessible) is expressed by significant novelty preferences, intermediate memory is expressed by null preferences, and remote memory (less accessible) is expressed by significant familiarity preferences. They argue that as infants' memory for the novel exemplar begins to wane, the familiar exemplar regains infants' interest thus causing a significant familiarity preference following long retention intervals (Bahrick & Pickens, 1995; Bahrick et al., 1997).

Summary

The habituation/dishabituation and visual paired comparison (VPC) have become two of the most popular paradigms for investigating perception and cognition during infancy. Research has examined how age, familiarization time, stimulus complexity, and retention time can affect infants' selective attention and processing of images and events. It has been proposed, and research has found, that a significant preference for the familiar stimulus event indicates partial processing of and less accessible memory for the familiar event. Whereas, a significant preference for the novel stimulus event indicates more complete processing of and more accessible memory for the familiar event (e.g., Bahrick et al., 1997; Rose et al., 1982). The VPC paradigm was used in the dissertation study to examine how intersensory redundancy affects infants' novelty and familiarity preferences for social events (i.e., prosody of speech and facial identification) across an episode of exploration. The following chapter reviews literature investigating infants' perception and discrimination of prosody of speech and facial identification.

CHAPTER III

LITERATURE REVIEW

Typical social interactions are multimodal in nature and involve a speaker who uses gestures and facial movements that are spatially and temporally coordinated with their speech sounds. However, the majority of research on infants' perception of social events has been conducted within the contexts of nonredundant unimodal (visual alone or auditory alone) stimulation. For example, research on infants' perception of facial identity has been primarily conducted with line drawings of faces, black-and-white photographs of faces, or static, nonmoving images of faces (e.g., Mondloch et al., 1999). Similarly, infants' perception of prosody of speech has been conducted using disembodied voices paired with black-and-white checkerboards (e.g., Cooper & Aslin, 1990; Spence & Moore, 2003). These studies can be faulted for being low in ecological validity (how they approximate real world situations/environments) because they examine infants' perception of social events with impoverished stimulus presentations that often lack movement and audiovisual synchrony. In the following sections, I review studies on infants' perception and discrimination of facial identity and prosody of speech, with a particular focus on studies using more naturalistic contexts.

Facial Identity Discrimination

Shortly following birth, newborns display interest in faces. Studies using static presentations indicate that newborns orient to and track schematic face-like drawings to a greater extent than drawings that convey a scrambled face or a blank image (Johnson, Dziurawiec, Ellis, & Morton, 1991), look significantly longer to cards depicting markings created to resemble a human face over cards that depict the markings upside-down (Mondloch et al., 1999), and prefer upright black-and-white photographs of women over photographs depicting upside-down or scrambled faces (Cassia, Turati, & Simion, 2004). In this section, I focus on studies examining infants' discrimination of faces under more naturalistic stimulus conditions (e.g., live, dynamic, or speaking).

Several studies demonstrate that newborns discriminate and prefer their mothers' face over the faces of strangers (Bushnell, 2001; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). When presented with a live and non-moving display of their mother's face paired side-by-side with the face of a stranger, newborns display significantly greater looking to their mother than the stranger (Bushnell, 2001; Pascalis et al., 1995). Newborns also display memory for their mother's face over the face of a stranger following short delays (e.g., 3 - 15-min) between their last exposure to their mother and testing (Bushnell, 2001; Pascalis et al., 1995).

Several extrinsic factors aid newborns in facial identity discrimination. For instance, newborns use external visual information (e.g., hairline, hair color, and hair style) to aid them in discriminating their mother's face over the face of a stranger (Pascalis et al., 1995). Pascalis et al. (1995) presented newborns a live and non-moving display of their mother's face paired side-by-side with the face of stranger, both wearing scarfs over their hair to mask external cues about their identity. Newborns failed to show discrimination of their mother, suggesting that newborns ability to discriminate their mother's face over the face of a stranger relied on external visual cues. Studies examining eye scanning patterns indicate that young infants scan more often the external versus the internal features of the face (Haith, Bergman, & Moore, 1977; Maurer & Salapatek, 1976). However, as infants age, they scan more often the internal than the external features of the face (Haith et al., 1977; Maurer & Salapatek, 1976) and can discriminate between mother and stranger even when external visual information is masked (Layton & Rochat, 2007).

Newborns use redundant audiovisual information to aid them in discriminating and preferring their mother's face over the face of a stranger (Sai, 2005). Sai (2005) examined newborns ability to discriminate their mother's face over the face of a stranger under one of two conditions: newborns were allowed to see their mother's face and hear her speak prior to testing or newborns were allowed to see their mother's face but not experience her voice prior to testing. Newborns that were allowed to see and hear their mothers speak displayed discrimination and preference for their mother's face over the face of the stranger. In contrast, newborns that were allowed to see their mother's face but not hear her speak displayed no discrimination or preference for their mother's face over the face of the stranger. This study demonstrates that newborns require synchronous audiovisual postnatal experience with their mother's voice in order to make an intermodal association between her face and the salient voice they experienced in utero.

Bahrick, Lickliter, Vaillant, Shuman, & Castellanos (2004a, 2004b) have also examined the role of redundant audiovisual information in young infants' discrimination of faces. Infants at 2 months of age can discriminate two unfamiliar women following habituation to dynamic films of women speaking silently (Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004a) and, at 3 months of age, infants can discriminate two unfamiliar women following habituation to dynamic films of women speaking audibly (Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004b). These studies suggest that the intersensory redundancy provided by a stimulus event alters infants' selective attention and discrimination of facial identity.

Facial motion also provides information about the facial identity of an individual. Studies suggest that infants' ability to discriminate faces improves as a function of facial motion (Layton & Rochat, 2007; Otsuka, Konishi, Kanazawa, Yamaguchi, Abdi, & O'Toole, 2009). Three- to 4-month-old infants display significant novelty preferences to a novel face following 30-s of familiarization to a moving face. In contrast, infants who were presented static faces required 90-s of familiarization to reach comparable levels of novelty preferences to a novel face (Otsuka et al., 2009). When viewing conditions are not optimal, infants rely on motion to aid them in discriminating faces (Layton & Rochat, 2007). Layton & Rochat (2007) presented infants with either negative contrast static photos or negative contrast dynamic videos of faces to examine the role of motion in non optimal viewing conditions. Eight-month-old infants displayed facial identity discrimination following exposure to the negative contrast dynamic video but not the static photo negative. Adults experience similar recognition enhancements following exposure to facial motion when viewing conditions are not optimal (Lander, Christie, & Bruce, 1999; O'Toole, Roark, & Abdi, 2002). Together, infant and adult studies suggest that facial motion provides invariant structural information (information that remains constant across transformations) that can aid in identifying an individual (Lander et al., 1999; Layton & Rochat, 2007; O'Toole et al., 2002; Otsuka et al., 2009).

The role of motion on infants' selective attention and memory for faces versus actions was investigated recently (Bahrick, Gogate, et al., 2002; Bahrick & Newell, 2008). In the Bahrick, Gogate, et al. (2002) study, infants were familiarized to dynamic videos of one of three women engaging in everyday repetitive activities (i.e., blowing bubbles, brushing hair, and brushing teeth). Following a delay (1-min and 7-weeks after familiarization), infants' discrimination and memory for the faces and actions was tested. To assess face discrimination and memory, the familiar person's face was paired side-by-side with a novel person's face performing the same activity. To assess action discrimination and memory, the familiar action was paired side-by-side with a novel action, both performed by the familiar person. Infants who were familiarized to dynamic videos displayed significant memory for the actions and no evidence of memory for the faces. Memory for the familiar face was only found when, in a control study, infants were familiarized to the static images of the faces. Bahrick, Gogate, et al. (2002) argue that during dynamic presentations, actions became more salient than faces. As a result of motion saliency, actions were attended to and remembered significantly more than the faces. Bahrick, Gogate, et al. (2002) suggest that stimulus presentations (dynamic vs. static) impact the salience of stimulus properties and differentially influence infants' selective attention.

Eye gaze plays an important role in infants' ability to discriminate facial identity (Farroni, Csibra, Simion, & Johnson, 2002; Farroni, Massaccesi, Menon, & Johnson, 2007). Newborns look significantly longer and orient more frequently to faces that are looking at them (direct gaze) over faces that are looking away from them (averted gaze)

(Farroni, et al., 2002). Farroni et al. (2007) examined infants' ability to discriminate between two novel women following habituation to a dynamic video depicting the women displaying direct versus averted eye gaze. Four-month-old infants displayed discrimination of the women only in the direct eye gaze condition. Similarly, children and adults show enhanced facial identification when presented with faces displaying direct versus averted eye gaze (Hood, Macra, Cole-Davies, & Dias, 2003). Taken together, these studies suggest that infants are sensitive to eye gaze and that eye information aids infants in discriminating facial identity.

Summary

Several extrinsic factors such as the external features of the face, facial motion, intersensory redundancy, and eye gaze play a significant role in modulating young infants' ability to discriminate faces. In early development, newborns show visual preferences to their mother's face over the face of a stranger as a function of redundant audiovisual stimulation (Sai, 2005) and rely particularly on external features such as the hairline and hair color to discriminate their mother's face from the face of a stranger (Pascalis et al., 1995). Infants also rely on direct eye gaze when discriminating unfamiliar women (Farroni et al., 2007). Facial motion provides invariant structural information specifying the identity of an individual and can aid infants in discriminating faces (Layton & Rochat, 2007; Otsuka et al., 2009), whereas motion produced by actions (i.e., blowing bubbles, brushing hair, and brushing teeth) can detract young infants' selective attention away from faces (Bahrick, Gogate, et al., 2002; Bahrick & Newell, 2008).

Prosody of Speech Discrimination

Research examining infants' perception of prosody of speech has focused on infant-directed speech (IDS), a form of prosodic speech that highlights the melody or prosodic contours by exaggerating the tempo, rhythm, and pitch of speech over time. Infant-directed speech is characterized by higher pitch, wider pitch range, slower tempo, longer pauses, shorter phrases, exaggerated vowel length, and more prosodic repetition than adult-directed speech (Fernald, 1989). Research indicates that across languages adults use infant-directed speech, suggesting that these prosodic modifications function as cross-linguistic universals (Fernald, Taeschner, Dunn, & Papousek, 1989; Grieser & Kuhl, 1988; Papousek, Papousek, & Symmes, 1991).

Infants' perception of prosody of speech emerges prenatally (DeCasper & Fifer, 1980; Fifer & Moon, 1995) and unfolds postnatally in dynamic and multimodal face-to-face interactions that typically involve a speaker who uses facial expressions, touch, gesture, and body movements that are coordinated with their speech sounds. In fact, research has shown that infant-directed speech is often accompanied by infant-directed facial expressions (Chong, Werker, Russell, & Caroll, 2003), hand gestures (Bekken, 1989; Gogate, Bahrick, & Watson, 2000; Iverson, Capirci, Longobardi, & Caselli, 1999; McNeill, 1992), and actions (Brand, Baldwin, & Ashburn, 2002).

Fernald (1984) has postulated and research has shown that the exaggerated prosodic contours characteristic of infant-directed speech are important for modulating infants' attention and state (Fernald, 1984; Stern, Spieker, Barnett, & Mackain, 1983; Stern, Spieker, & MacKain, 1982), conveying affect and intention in speech (Fernald, 1989; Fernald, 1993; Fernald & Kuhl, 1987; Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990; Trainor, Austin, & Desjardins, 2000; Werker & McLeod, 1989), aiding infants in parsing the speech stream and facilitating learning of sound-meaning relations (Christophe, Gout, Peperkamp, & Morgan, 2003; Fernald & Mazzie, 1991; Gerkin & Aslin, 2005; Hirsh-Pasek et al., 1987; Jusczyk, Hirsch-Pasek, Kemler Nelson, & Kennedy, 1992; Mandel, Kemler Nelson, & Jusczyk, 1996; Morgan, 1996; Nazzi, Kemler Nelson, Jusczyk, & Jusczyk, 2000; Shafer, Shucard, & Jaeger, 1999).

The exaggerated prosodic contours characteristic of infant-directed speech (IDS) are of great interest to young infants and they engage their attention more than the prosodic contours characteristic of adult-directed speech (ADS). Infants as young as 2-days old look longer at a checkerboard pattern when it produced infant-directed speech over adult-directed speech (Cooper & Aslin, 1990). In a study where the speech was filtered so that only the prosodic contours could be heard, infants preferred to listen to the prosodic contours of filtered infant-directed speech over the prosodic contours of filtered adult-directed speech (Fernald & Kuhl, 1987). When redundant audiovisual stimulation is provided, infants also prefer to listen and view an actor who is speaking in infant-directed speech over adult-directed speech (Werker & McLeod, 1989). These studies suggest that infants prefer the prosodic contours characteristic of infant-directed speech over adult-directed speech across various types of sensory stimulation.

The exaggerated prosodic contours characteristic of infant-directed speech have been postulated to communicate affect and intentions (Fernald, 1989; Fernald & Kuhl, 1987). Infants of 4 to 9 months of age respond with significantly more positive affect while hearing infant-directed speech than adult-directed speech (Werker & McLeod, 1989). Fernald (1993) examined 5-month old infants' affective responses to infant-directed speech conveying approval and prohibition. In this experiment, native (English) and foreign (German and Italian) infant-directed speech samples were accompanied by black-and-white photographs of affect-neutral women. Results indicate that, across all three languages, 5-month-old infants respond with significantly more positive affect while hearing infant-directed phrases conveying approval than when conveying prohibition and conversely, respond with significantly more negative affect while hearing infant-directed phrases conveying prohibition than when conveying approval (Fernald, 1993). Infants differentially attend more to phrases conveying approval than prohibition. Three to 4-month-old infants prefer to listen to infant-directed phrases that specify approval than prohibition (Castellanos, 2007; Papousek et al., 1990) and look away more often from phrases that specify prohibition than approval (Castellanos, 2007). These studies demonstrate that the prosodic contours characteristic of infant-directed speech over adult-directed speech allow affect and intention to be more accessible to infants.

Spence & Moore (2003) examined infants' ability to categorize infant-directed utterances conveying approval versus comfort. Infants were presented with flashing black-and-white checkerboards accompanied by infant-directed utterances. Results indicate that 6-month but not 4-month-old infants categorize infant-directed utterances conveying approval versus comfort. When presented with redundant audiovisual stimulation, as compared with nonredundant unimodal auditory and asynchronous audiovisual, 4-month-old infants categorize infant-directed passages conveying approval versus prohibition (Bahrick et al., 2011; Castellanos et al., 2004), suggesting that IDS conveys intention to young infants.

The slower tempo, elongated pauses, exaggerated vowel length, and the frequent repetition characteristic of infant-directed speech are thought to contribute to infants' development of language acquisition and comprehension (Hirsh-Pasek et al., 1987; Morgan, 1996). Behavioral and physiological studies show that the prosodic contours characteristic of infant-directed speech are so dramatic and highlighting (contain exaggerated tempo, rhythm, and pitch changes over time), as compared to adult-directed speech, that they facilitate infants' ability to parse the speech stream (Nazzi et al., 2000; Shafer et al., 1999; Morgan, 1996).

Parsing the speech stream is defined as the ability to abstract holistic units (i.e., specific words) from continuous speech. Parsing continuous speech into units is considerably difficult for naïve perceivers because pauses do not reliably separate individual words (Christophe et al., 2003; Gerken & Aslin, 2005). Thus, naïve perceivers often are unable to rely on pauses as signals for when one word ends and the next begins. Naïve perceivers can rely, however, on prosody instead of pauses to parse continuous speech into units. Infants are highly sensitive to the pitch changes and frequent pauses characteristic of infant-directed speech that mark boundaries of prosodic units (Christophe et al., 2003). For example, infants of 4.5 months of age are able to discriminate and react to disruptions in normal prosodic boundaries (Hirsch-Pasek et al., 1987; Jusczyk et al., 1992). Two-month-old infants increase their visual fixation to a change in word order more so when they listen to sentences that are spoken using natural prosody to link the words of the sentence together (causing words to be prosodically linked) as compared to when the same words of the sentence were simply listed one after the other and as compared to when they listen to sentence fragments, concatenated from two separate sentences, depicting incoherent prosody (Mandel et al., 1996). This study provides evidence suggesting that young infants can abstract holistic units or words from a stream of continuous speech when words are prosodically linked.

The methods by which parents introduce novel sound-meaning relations also contribute to speech parsing and language acquisition. Research has shown that when engaging with their infants, mothers introduce new labels for unfamiliar objects at the peaks of their prosodic contours (Fernald & Mazzie, 1991). For example, the label "socks" was presented at an increasingly high pitch peak when speaking the phrase "Then he put on his yellow socks." This action facilitates infants' perceptual and attentional development by highlighting words of importance within the stream of continuous speech. Parents also use synchrony between labeling an object using infant-directed speech and showing an object to help infants learn novel sound-referent relations (Gogate et al., 2000) and research indicates that infants benefit from this synchrony (Gogate & Bahrick, 1998).

Summary

The studies reviewed in this section suggest that the development of infants' ability to detect changes in prosodic speech patterning is a prerequisite for understanding their caregiver's intent and signals (Fernald, 1989; Fernald, 1993; Fernald & Kuhl, 1987; Papousek et al., 1990; Trainor et al., 2000; Werker & McLeod, 1989), for learning to parse the speech stream (Christophe et al., 2003; Gerkin & Aslin, 2005; Jusczyk et al.,1992; Mandel et al., 1996; Morgan, 1996; Nazzi et al., 2000), and for learning sound-meaning relations (Fernald & Mazzie, 1991; Gogate & Bahrick, 1998; Gogate et al.,2000). Research on infant-directed speech has primarily been conducted on infants' perception of nonredundant unimodal auditory speech (e.g., Cooper & Aslin, 1990; Spence & Moore, 2003). These studies can be faulted for being low in ecological validity because they examine infants' perception of disembodied sounds (Walker-Andrews & Bahrick, 2001). Such studies infer infants' acoustic preferences by measuring their visual attention to lights, black-and-white checkerboards, or black-and-white photographs that are paired with auditory recordings. However, speech is typically multimodal and involves a speaker who uses gestures and facial movements that are coordinated with their speech sounds. Research on redundant audiovisual events indicates that intersensory redundancy in the form of temporal synchrony between auditory and visual stimulation recruits attention and facilitates perceptual learning of the amodal properties (e.g., affect, duration, patterns consisting of tempo, rhythm, and intensity changes) available in infant-directed speech more successfully than when the same information is presented nonredundantly (Bahrick et al., 2011; Castellanos, 2007; Castellanos & Bahrick, 2008; Castellanos et al., 2004).

Summary of Chapter

Research conducted using redundant audiovisual and nonredundant unimodal stimulus presentations have been instrumental to our general understanding of infants' perceptual abilities. However, redundant audiovisual stimulus presentations are more ecologically relevant to infants' typical experiences in the real world. To gain a more comprehensive understanding of infants' perception of social events (e.g., facial identity and prosody of speech), we must examine the differential effects of redundant audiovisual versus nonredundant unimodal stimulation. Furthermore, until now, research has not examined the relationship between infants' selective attention to facial identity and prosody of speech. The following chapter presents the dissertation study, which was designed to examine how infants' selective attention to facial identity and prosody of speech changes as a function of intersensory redundancy and exploratory time.

CHAPTER IV

RESEARCH DESIGN

As reviewed earlier, research has demonstrated intersensory and unisensory improvements for amodal and modality specific properties across development. As a function of infants' increased attention and perceptual flexibility, amodal properties extend from being detected exclusively in redundant audiovisual stimulation to nonredundant unimodal stimulation, and modality specific properties extend from being detected exclusively in nonredundant unimodal stimulation to redundant audiovisual stimulation (e.g., Bahrick & Lickliter, 2004; Bahrick et al., 2006; Bahrick et al., 2005; Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004b; Flom & Bahrick, 2007). The intersensory redundancy hypothesis also predicts improvements in infants' attention and perception of amodal and modality specific properties within an episode of exploration (Bahrick, 2010; Bahrick & Lickliter, in press; Bahrick et al., 2010). To date, research has not directly investigated if intersensory and unisensory improvements (processing of both salient and less salient properties of stimulation) occur across shorter timescales.

The dissertation study was designed to examine how young infants' selective attention changes in real time across an episode of exploration. In this case, an episode of exploration consisted of each infants' visual exploratory behavior during the course of the 6-min experiment. Specifically, the study examined how infants' selective attention to amodal (i.e., prosody of speech) and modality specific properties (i.e., features of the face) of social events changes across 6 minutes of exploratory time as a function of intersensory redundancy (redundant audiovisual, nonredundant unimodal visual stimulation). The secondary purpose was more exploratory in nature and examined real time macro- and micro-structural change (via an eye tracking apparatus) in infants' looking patterns relative to exploratory time and stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual). The following research questions were addressed in the dissertation (see Table 1 for a summary of the predicted results):

Question #1: During exploration of a redundant audiovisual event, are amodal (the prosody of speech) and modality specific (facial configuration) properties discriminated during the early or later phases of exploration?

Hypothesis #1: In redundant audiovisual contexts, amodal properties are highly salient and detected more easily than modality specific properties (Bahrick, 2010; Bahrick & Lickliter, 2000, 2002, in press; Bahrick, Lickliter, & Flom, 2004). Therefore, it was predicted that prosody of speech, an amodal property, would receive processing priority while facial configuration, a modality specific property, would not be attended until after prosody has been processed. Specifically, it was predicted that during exploration of an audiovisual event, infants would show intersensory facilitation (this is defined as greater detection in redundant audiovisual than in nonredundant visual stimulation) for discrimination of prosodic speech in the early phases of exploration and discrimination of facial configuration in the later phases of exploration.

Question #2: During exploration of a nonredundant unimodal visual event (visual speech), are modality specific (facial configuration) and amodal (prosody of speech) properties discriminated during the early or later phases of exploration?

Hypothesis #2: In nonredundant unimodal contexts, modality specific properties are more salient and detected more easily than amodal properties (Bahrick, 2010; Bahrick & Lickliter, 2000, 2002, in press; Bahrick, Lickliter, & Flom, 2004). Consistent with predictions of unimodal facilitation, modality specific properties which underlie face identification are more easily discriminated when intersensory redundancy is not available because there is no competition from more salient amodal properties (Bahrick, Lickliter, Vaillant, Shuman, & Castellanos, 2004a). Thus, infants should be free to attend to facial configuration before progressing down the "salience hierarchy." Specifically, it was predicted that during exploration of a nonredundant unimodal visual event, infants would show unimodal facilitation (this is defined as greater detection in nonredundant visual than in redundant audiovisual stimulation) for discrimination of facial configuration in the early phases of exploration and discrimination of prosodic speech in the late phases of exploration.

Question #3: Does infants' visual scanning of dynamic faces change as a function of stimulus redundancy and exploratory time?

Hypothesis #3: Research indicates infants' attentional and perceptual capacities increase, become more efficient, and flexible across development (e.g., Frick, Colombo, & Saxon, 1999; Mayes & Kessen, 1989; Shaddy & Colombo, 2004). It was predicted that the same attentional improvements could be observed across an episode of exploration. During the early blocks of exploration, infants were predicted to display more dispersed visual scanning patterns and, as exploration of the dynamic face continued, it was predicted that infants would display more constrained/focused scanning of the face (indicative of more efficient processing).

Methodology

Participants

Sixty-four 3½-month-old infants (32 males and 32 females) with a mean age of 108 days (*SD* = 15.23) were included in the final sample. Forty-five of the infants were Hispanic White, 9 were Non-Hispanic White, 4 were African American, 3 were Asian, and 3 were Multiracial. Infants were recruited through birth records from the Department of Health in Miami-Dade County. All infants were healthy and had no known complications at delivery, had a gestational period of at least 38 weeks, and an APGAR score of 9 or greater. The APGAR exam is performed by medical professionals at birth and rates infants' appearance, pulse, grimace, activity, and respiration; a score of 9 or greater indicates that the infant is in good health and did not require immediate medical care (see Apgar, 1953, for more information). Eight additional infants were tested, but their data were excluded from the final sample as a result of experimenter error (*n* = 5) and computer failure (*n* = 3). Signed informed consent for testing, eye tracking, and video recording was obtained for all participants.

Stimulus Events

The stimulus events consisted of dynamic color videotaped recordings of two female adults. The actresses were approximately the same age (e.g., late twenties through early thirties) and shared similar physical characteristics (e.g., skin tone, eye and hair color). The films depict the actresses' face, head, neck, and shoulder area against a uniform blue background. Actresses were filmed wearing a baseball cap to mask external information (e.g., hair color and hairline cues) about their identity. They were filmed reciting a passage, comprised of three phrases, using infant-directed speech to convey two different prosodic patterns specifying approval and prohibition and the corresponding affect was visible. The phrases consist of “Look at you,” “Come over here by me,” and “Where’s the baby going?” each spoken in an intonation conveying approval and prohibition (same phrases used by Bahrick et al., 2011; Castellanos, 2007; Castellanos & Bahrick, 2008).

The stimulus events were edited with audiovisual editing software (Adobe Premier Pro CS3 and Adobe Audition 1.5). Edited versions of the recordings were created for the redundant audiovisual condition and for the nonredundant unimodal visual condition. The redundant audiovisual displays depict a videotaped recording of an actress wearing a baseball cap producing natural and synchronous infant-directed speech. The nonredundant unimodal visual displays depict a videotaped recording that is visually identical to the redundant audiovisual displays, however, the actress’ spoken speech was eliminated thereby depicting the actress speaking silently. Additionally, a control display depicting a dynamic, audiovisual green and white toy turtle was presented.

Apparatus

Infants sat on their parent’s lap facing a color computer monitor approximately 70 cm away. The stimulus events were presented using Tobii Studio 2.1.14 software on a 46-inch flat panel widescreen LCD computer monitor (NEC MultiSync P461) with a resolution of 1920 x 1080 pixels. Video soundtracks were presented from matching stereo speakers (M Audio Studiophile Bx5a) placed centrally underneath the monitor so that the sound could not be localized at one side of the screen or the other. A video camera placed behind the computer monitor recorded the infants' face. Black curtains surrounded the computer monitor and obscured the speakers and video camera from view. Trained observers depressed buttons on a joystick, recording the length of infants' visual fixations. The joystick was connected to a Dell Precision T3400 computer, which collected the data on line.

Eye tracking data was collected using a Tobii x120 eye tracking apparatus. The Tobii x120 uses corneal reflection to map in real time the scanning patterns of infants with respect to the video display and samples data at 120 Hz. The eye tracker was placed centrally underneath the computer monitor and directly in front of infants (approximately 60 cm away) to measure visual scanning patterns. The eye tracker was connected to a Mac Pro 4,1 8-Core computer for data acquisition, storage, and analyses. The Tobii x120 was not physically connected to infants.

Design

The research questions were investigated using a 2 (stimulus redundancy condition: redundant audiovisual, nonredundant unimodal visual) x 2 (test type: facial identity, prosody) x 3 (exposure block: first, second, third) factorial design. Stimulus redundancy condition served as the between-subjects factor. Test type and familiarization exposure block served as the repeated measures.

Procedure

Eye Tracking Calibration

Infants participated initially in an eye tracking calibration session. The calibration session was necessary to adjust the eye tracker to each infant's eye characteristics. It consisted of presenting infants with an attention grabbing audiovisual stimulus event (toy duck) that moved across the computer screen at five calibration points (top left, top right, bottom left, bottom right, and center). The calibration stimulus event was designed to be appealing to infants.

Modified Visual Paired Comparison Paradigm

Infants' discrimination of prosodic speech (approval versus prohibition) and facial identity (actress A versus actress B) was examined using a modified visual paired comparison (VPC) paradigm. The VPC procedure began with an attention grabbing audiovisual toy turtle presented centrally on the monitor and continued with three blocks of familiarization and test trials. Infants were randomly assigned to one of two stimulus redundancy conditions: the redundant audiovisual (n = 32) or the nonredundant unimodal visual condition (n = 32). In the redundant audiovisual condition, infants viewed video displays during familiarization and test trials depicting a dynamically moving actress producing natural and synchronous infant-directed speech. In the nonredundant unimodal visual condition, infants viewed video displays during familiarization and test depicting a dynamically moving actress silently speaking in infant-directed speech. The three exposure blocks were identical to one another and each contained eight 15-s trials: four familiarization trials and four test trials occurring in pairs and in an alternating pattern

(2 familiarization trials, 2 test trials depicting the familiar stimulus alongside the novel stimulus event, 2 familiarization trials, 2 test trials depicting the familiar stimulus alongside the novel stimulus event). Consequently, test trials were presented following every 30-s of familiarization exposure (30, 60, 90, 120, 150, 180-s, see Figure 1 for an example). The familiarization stimulus was displayed in the center of the computer monitor. The test trials presented the novel and familiar stimulus events side-by-side on the computer monitor.

Half of the infants in each stimulus redundancy condition were familiarized to passages conveying approval and half were familiarized to passages conveying prohibition. The actress (actress A vs. actress B) reciting the passages during familiarization was also counterbalanced across infants. All infants received both test types (2 test trials assessing facial identity discrimination and 2 test trials assessing prosody discrimination) in each bock. Test type order (facial identity vs. prosody tests occurring first within each block) was counterbalanced across subjects so that half of the infants received test trials depicting a change in person occurring first in the block (novel actress side-by-side with familiar actress) followed by test trials depicting a change in prosody (familiar actress speaking in the novel prosody side-by-side with familiar actress speaking in the familiar prosody) and vise versa. The lateral positions of the familiar and novel stimulus events during test was counterbalanced across test trials and across subjects. A final control trial depicting a toy turtle ended the testing session. Infants' looking behavior was collected in real time by trained observers and from an eye tracking apparatus (Tobii x120).

To make certain that infants were not fatigued, their visual fixations to the initial and final control trials was mathematically compared. Infants were judged as fatigued if their visual fixation to the final control trial was less than 35% of their fixation level to the initial control trial (see Bahrick, Flom, et al., 2002; Bahrick & Newell, 2008). Two observers monitored 22 (34%) of the infants and a Pearson product-moment correlation between the scores of the two observers served as our measure of inter-observer reliability. The Pearson product-moment correlation between the two observers averaged .90 (*SD* = .09).

CHAPTER V

RESULTS

Visual Paired Comparison

Proportion of Available Looking Time

Proportion of available looking time (PALT) was assessed during each familiarization exposure block to determine infants' interest in the familiarization display. It was calculated by dividing the time spent looking at the familiarization display by the total time the familiarization display was presented (see Table 2 for *M*s and *SD*s). To evaluate if infants' interest in the familiarization display differed as a function of the stimulus condition, a repeated measures analysis of variance (ANOVA) on PALT with stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual) as the between-subjects factor and familiarization exposure (block 1, block 2, block 3) as the repeated measure was conducted. Infants' PALT spent fixating on the familiarization display did not differ across conditions ($F(1, 62) = 1.10$, $p = .30$), suggesting that both stimulus events were equally engaging. Additionally, a significant linear effect of PALT indicated that, across conditions, infants' interest in the familiarization display decreased across time ($F(1, 62) = 11.86$, $p = .001$). Planned comparisons revealed that infants' PALT was highest in exposure block 1 when compared to exposure blocks 2 and 3 ($p = .001$, $p = .001$, respectively).

Proportion of Total Looking Time

Primary Analyses

Proportion of total looking time (PTLT) to the novel stimulus event was assessed during each paired-comparison test trial and served as the primary dependent variable for evaluating discrimination of amodal and modality specific properties of prosody of speech and facial configuration, respectively. Infants' PTLT scores were calculated by dividing the time spent looking at the novel stimulus event by the total time spent looking at both the familiarized and novel stimulus events. Infants' preference for the familiar stimulus event (a PTLT score below 50% chance) indicates evidence of partial processing of the familiar event. In contrast, infants' preference for the novel stimulus event (a PTLT score above 50% chance) indicates evidence of more complete processing and discrimination of the familiar from the novel event (Bahrick & Pickens; 1995; Bahrick et al., 1997; Hunter et al., 1983; Hunter et al., 1982; Rose et al., 1982; Richards, 1997). Thus, a novelty preference was predicted in the dissertation study as an indication of discrimination.

To address the first research question, whether 3½-month-old infants discriminated amodal (prosody of speech) and modality specific (facial configuration) properties during the early or later phases (blocks of exposure) of audiovisual exploration, single-sample t-tests on infants' PTLT scores against the chance value of 50% were conducted (see Figure 2 for *M*s and *SD*s). Results revealed that infants in the redundant audiovisual condition demonstrated significant PTLTs to the novel prosody in exposure block 1, following 30 - 60-s of familiarization exposure ($t(31) = 3.05$, $p = .01$), but not in exposure blocks 2 and 3, following 90 - 120-s and 150 - 180-s of familiarization exposure ($t(31) = -1.29$, $p = .21$, $t(31) = 0.77$, $p = .45$, respectively). However, infants did not demonstrate significant PTLTs to the novel face in exposure blocks 1, 2, or 3, following as much as 180-s of familiarization exposure (all ps > .05).

In redundant audiovisual contexts, attention is recruited to amodal properties such as prosody of speech to a greater extent than modality specific properties such as facial configuration. Discrimination of prosodic speech is initially fostered in redundant audiovisual contexts and is later extended to nonredundant unimodal contexts (Castellanos, 2007; Castellanos & Bahrick, 2008). As a result of this processing salience hierarchy, it was predicted that prosody of speech would become perceptual foreground early in processing while facial configuration, a modality specific property, would become background and thus would be processed later during exploration of the stimulus event. Results provide partial support for the hypothesis. During exploration of an audiovisual event, infants demonstrated significant PTLTs to the novel prosody in the first block of exposure (following 30 - 60-s of familiarization), but failed to demonstrate significant PTLTs to the novel face even after 180-s of familiarization exposure. It is likely that, as a group, infants required longer than 180-s of familiarization exposure to discriminate the present facial stimuli in redundant audiovisual stimulation. Thus, these findings indicate that in redundant audiovisual stimulation, detection of prosody of speech emerges earlier in processing time than the detection of facial configuration.

Similarly, single-sample t-tests on infants' PTLT scores against the chance value of 50% were conducted to addresses the second research question, whether 3½-month-old infants discriminated modality specific (facial configuration) and amodal (prosody of speech) properties during the early or later phases (blocks of exposure) of nonredundant unimodal visual exploration (see Figure 3 for *M*s and *SD*s). Results revealed that infants in the nonredundant unimodal visual condition demonstrated significant PTLTs to the novel face in exposure block 3, following 150 - 180-s of familiarization exposure ($t(31) = 2.50$, $p = .02$), but not in exposure blocks 1 or 2 ($t(31) = 0.02$, $p = .99$, $t(31) = 1.66$, $p = .11$, respectively). In contrast, infants did not demonstrate significant PTLTs to the novel prosody in exposure blocks 1, 2, or 3, even after 180-s of familiarization exposure (all ps > .05). It is possible that as a group, infants required longer familiarization exposures (more than 180-s) to demonstrate evidence of prosody discrimination in nonredundant unimodal visual exposure (without the benefit of intersensory redundancy). These findings support the prediction that in nonredundant unimodal contexts, where there is no competition from intersensory redundancy, attention is facilitated to modality specific properties such as facial configuration. Further, they indicate that in nonredundant unimodal visual stimulation detection of facial configuration emerges earlier in processing time than the detection of prosody of speech.

Preliminary ANOVAs were conducted to determine the effects of the familiarized target actress (actress A, actress B) and lateral position of the novel exemplar during test (pattern A, pattern B) on infants' PTLTs. No significant main effects or interactions were found (all ps > .05). Given no differences, data were collapsed across these two factors for all subsequent analyses.

To evaluate the primary research questions of intersensory and unimodal facilitation, analyses were conducted to compare discrimination across groups and familiarization time. A 2 x 2 x 3 repeated measures ANOVA on novelty preference scores was performed with stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual) as the between-subjects factor and test type (discrimination of facial identity, prosody) and familiarization exposure (block 1, block 2, block 3) as the repeated measures. A 2-way Stimulus condition x Test type interaction was predicted. Infants in the redundant audiovisual condition were predicted to demonstrate the effects of intersensory facilitation as evidenced by greater PTLTs to the novel prosody than infants in the nonredundant unimodal visual condition. Conversely, it was predicted that infants in the nonredundant unimodal visual condition would demonstrate the effects of unimodal facilitation as evidenced by greater PTLTs to the novel face than infants in the redundant audiovisual condition. Although results are in the predicted direction, they revealed a nonsignificant Stimulus condition x Test type interaction ($F(1, 62) = 1.55$, $p = .22$). Infants in the nonredundant unimodal visual condition displayed greater PTLTs to the novel face ($M = .54$, $SD = .03$) than to the novel prosody ($M = .49$, $SD = .01$, $p = .03$), however, their performance did not significantly differ from infants in the redundant audiovisual condition. Infants in the redundant audiovisual and in the nonredundant unimodal visual conditions displayed similar PTLTs to the novel prosody ($M = .52$ and $M = .49$, respectively) and the novel face ($M = .53$ and $M = .54$, respectively).

Infants' discrimination of prosody and faces was compared across groups as a function of familiarization exposure (block 1, block 2, block 3). A 3-way Stimulus condition x Test type x Exposure block interaction was predicted. Infants in the redundant audiovisual condition were predicted to demonstrate greater PTLTs to the novel prosody than infants in the nonredundant unimodal visual condition during the exposure block where they first detected a prosody change. In contrast, it was predicted that infants in the nonredundant unimodal visual condition would demonstrate greater PTLTs to the novel face than infants in the redundant audiovisual condition during the exposure block where they first detected a face change. Although results are in the predicted direction, they revealed a nonsignificant Stimulus condition x Test type x Exposure block interaction ($F(2, 124) = 0.84$, $p = .43$).

Analyses of simple effects for each exposure block individually on the Stimulus condition x Property type interaction provide partial support for the predictions. Results revealed that during the early phases of familiarization exposure (block 1), where infants in the redundant audiovisual condition showed significant detection of prosody according to t-tests, they also demonstrated the effects of intersensory facilitation as evidenced by greater PTLTs to the novel prosody than infants in the nonredundant unimodal visual condition ($p = .01$, see Figure 4). Similarly, the performance of infants in the nonredundant unimodal visual condition was compared with that of infants in the redundant audiovisual condition during the last block of familiarization exposure (where, according to t-tests, they first showed significant detection of a face change). Although in the predicted direction, results failed to indicate unimodal facilitation for the detection of facial configuration (*p* = .15, see Figure 4). No other comparison of intersensory versus unimodal facilitation within a familiarization exposure block reached significance (all *p*s > .05).

Fine-grained Analyses of Familiarization Exposure Time

In the previous section of the analyses, each familiarization exposure block was comprised of aggregated PTLTs (e.g., familiarization exposure block 1 consisted of aggregating the PTLTs to the novel prosody following 30 and 60-s of familiarization). To determine whether discrimination of prosody of speech and facial identity was evident initially or emerged later during each exposure block, in the current section, a more fine-grained approach was taken and PTLTs following each familiarization exposure time (30, 60, 90, 120, 150, 180-s) were analyzed separately.

Single-sample t-tests on infants' PTLTs against the chance value of 50% were conducted following each familiarization exposure time (30, 60, 90, 120, 150, 180-s). Analyses of the redundant audiovisual condition revealed that following only 30-s of familiarization exposure, infants showed robust evidence of prosody discrimination ($t(15) = 3.61$, $p = .002$). Infants in the redundant audiovisual condition did not show evidence of prosody discrimination following any other familiarization exposure time (all *p*s > .05). Results also indicate that infants in the redundant audiovisual condition demonstrated significant novelty preferences for the novel face during the later portion of exposure block 1. Infants demonstrated a preference for the novel face when the face test trials followed, but not preceded, the prosody test trials (following 60-s of exposure to the familiar stimulus event, $t(15) = 2.10$, $p = .05$). The first set of familiarization trials in exposure block 1 provided infants with additional exposure to the familiar face, perhaps allowing them to compare and contrast the novel and familiar faces, promoting facial configuration discrimination. As predicted, in redundant audiovisual stimulation, infants' attention was recruited to prosody of speech before facial configuration. Evidence of this processing sequence was found in that during exploration of an audiovisual event infants demonstrated a significant novelty preference for the novel prosody following 30-s of exposure, but only demonstrated a significant novelty preference for the novel face following 60-s of exposure. Infants in the redundant audiovisual condition did not show evidence of facial configuration discrimination following any other familiarization exposure time (all *p*s > .05). See Figure 5 for *M*s and *SD*s.

Conversely, in the nonredundant unimodal visual condition, infants did not demonstrate evidence of a similar processing sequence. Infants in the nonredundant unimodal visual condition only demonstrated significant novelty preferences for the novel face following 120 and 150-s ($t(15) = 2.58$, $p = .02$, $t(15) = 2.10$, $p = .05$), but not following any other familiarization exposure time (all *p*s > .05). Additionally, infants in the nonredundant unimodal visual condition did not demonstrate significant novelty preferences for the novel prosody following any familiarization exposure time (all *p*s > .05). See Figure 6 for *M*s and *SD*s.

Two-way ANOVAs were conducted on novelty preference scores with stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual) and test type (discrimination of facial identity, prosody) as between-subjects factors for each familiarization exposure time (30, 60, 90, 120, 150, 180-s) to examine intersensory and unimodal facilitation on a finer-grained level.

<u>30-s of familiarization exposure time</u>

Results revealed a trending Stimulus condition x Test type interaction following 30-s of familiarization exposure time ($F(1, 60) = 2.91$, $p = .09$). Analyses of simple effects revealed that following only 30-s of redundant audiovisual exposure, infants' attention and processing was greater to prosody of speech than facial configuration. Infants in the redundant audiovisual condition showed significantly higher PTLTs to the novel prosody than to the novel face following 30-s of familiarization exposure ($p = .02$, see Figure 5). Intersensory facilitation was also evident following 30-s of familiarization exposure. Infants in the redundant audiovisual condition demonstrated significantly higher PTLTs to the novel prosody than infants in the nonredundant unimodal visual condition ($p = .008$, see Figure 7). No effect of unimodal facilitation for facial configuration was found following 30-s of familiarization exposure ($p > .05$).

<u>60-s of familiarization exposure time</u>

Although results from the two-way ANOVA at 60-s of familiarization exposure time were in the predicted direction, they indicated a nonsignificant Stimulus condition x Test type interaction ($F(1, 60) = 0.71$, $p = .41$). Analyses of simple effects indicated that the same group of infants who received redundant audiovisual stimulation and showed intersensory facilitation for prosody of speech following 30-s of exposure also showed greater PTLTs to facial configuration than prosody of speech following 60-s of exposure ($p = .05$, see Figure 5). These results are in line with predictions and indicate that, in redundant audiovisual stimulation, infants' attention was initially recruited to prosody of speech before moving down the "salience hierarchy," to facial configuration. No effect of unimodal facilitation for facial configuration was found following 60-s of familiarization exposure ($p > .05$).

<u>90-s of familiarization exposure time</u>

The two-way ANOVA at 90-s of familiarization exposure time revealed a nonsignificant Stimulus condition x Test type interaction ($F(1, 60) = 0.57$, $p = .45$). Analyses of simple effects also revealed nonsignificant Stimulus condition x Test type interactions, indicating no effects of intersensory facilitation for prosody of speech nor effects of unimodal facilitation for facial configuration following 90-s of familiarization exposure (all *p*s > .05).

<u>120-s of familiarization exposure time</u>

ANOVA results revealed a nonsignificant Stimulus condition x Test type interaction following 120-s of familiarization exposure time ($F(1, 60) = 0.99$, $p = .32$) and a significant Stimulus condition x Test type interaction following 150-s of familiarization exposure time ($F(1, 60) = 3.98$, $p = .05$). Although the Stimulus condition x Test type interaction following 120-s of familiarization exposure did not reach significance, analyses of simple effects revealed that following 120-s and 150-s of nonredundant unimodal visual exposure (but not redundant audiovisual exposure), infants showed significantly higher PTLTs to the novel face than the novel prosody ($p = .01$, $p = .02$, respectively, see Figure 6). Also following 120-s and 150-s of nonredundant unimodal visual exposure, infants showed significantly higher PTLTs to the novel face than infants in the redundant audiovisual condition ($p = .04$, $p = .05$, respectively, see Figure 7), providing evidence of unimodal facilitation. No effect of intersensory facilitation for prosody of speech was found following 120 - 150-s of familiarization exposure (all *p*s > .05).

<u>180-s of familiarization exposure time</u>

The ANOVA at 180-s of familiarization exposure time revealed a nonsignificant Stimulus condition x Test type interaction ($F(1, 60) = 0.24$, $p = .62$). Similarly, analyses of simple effects revealed nonsignificant Stimulus condition x Test type interactions, indicating no effects of intersensory facilitation for prosody of speech nor effects of unimodal facilitation for facial configuration following 180-s of familiarization exposure (all *p*s > .05).

<u>Analyses of "Learners"</u>

In the final stage of PTLT analyses, the subset of infants who showed evidence of learning to detect the changes in prosody of speech and facial identity were analyzed separately in order to make a more fine-grained evaluation of the patterns of attention and perceptual learning. Infants were classified as "fast leaners," "learners," or "non learners," based on the rate at which they showed discrimination of prosody of speech and facial identity. "Fast learners" showed discrimination (PTLT scores above .55) of both prosody of speech and facial identity within the first block of exposure. Seven infants were classified as "fast learners" (4 in the redundant audiovisual condition and 3 in the nonredundant unimodal visual condition). "Learners" were infants who appeared to learn to discriminate information across exploratory time and showed discrimination of one property type at a time. Fifty-two infants were classified as “learners” (25 in the redundant audiovisual condition and 27 in the nonredundant unimodal visual condition). “Non learners” failed to show discrimination of either test type (all PTLT scores fell below .55) during the experiment. Five infants were classified as “non learners” (3 in the redundant audiovisual condition and 2 in the nonredundant unimodal visual condition).

The research questions addressed in this dissertation regarding which property infants selectively attend as they move down the salience hierarchy can best be answered by evaluating the performance of “learners,” infants who discriminated one property (amodal: prosody of speech, modality specific: facial identity) at a time. The task was too easy for infants classified as “fast learners,” as they progressed quickly through the salience hierarchy and demonstrated discrimination of both properties at the outset of exploratory time. Conversely, the task was too difficult for infants classified as “non learners,” as they never showed discrimination of either property. Therefore, this section of the analyses only includes the data for infants classified as “learners.” It was predicted that the effects of intersensory and unimodal facilitation would be magnified in infants classified as “learners.”

To assess how much familiarization time infants required to show discrimination of prosody of speech and facial identity, single-sample t-tests on PTLTs against the chance value of 50% were conducted following each familiarization exposure time (30, 60, 90, 120, 150, 180-s). Results revealed that infants in the redundant audiovisual condition demonstrated a significant novelty preference for the novel prosody following 30-s ($t(10) = 3.11$, $p = .01$), but not following any other familiarization exposure time (all *p*s > .05). Infants in the redundant audiovisual condition did not demonstrate significant novelty preferences for the novel face following any familiarization exposure time (all *p*s > .05). Conversely, infants in the nonredundant unimodal visual condition demonstrated significant novelty preferences for the novel face following 120 and 150-s ($t(12) = 3.25$, $p = .01$, $t(13) = 3.54$, $p = .004$, respectively), but not following any other familiarization exposure time (all *p*s > .05). However, infants classified as "learners," in the nonredundant unimodal visual condition did not demonstrate significant novelty preferences for the novel prosody following any familiarization exposure time (all *p*s > .05), mirroring the results obtained in the previous section in which the full sample of infants ($N = 64$) were analyzed. See Figures 8 and 9 for *M*s and *SD*s.

To address the question of whether infants in the redundant audiovisual condition displayed greater PTLTs to the novel prosody than face, 2-way ANOVAs were conducted on novelty preference scores with stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual) and test type (discrimination of facial identity, prosody) as between-subjects factors for each familiarization exposure time (30, 60, 90, 120, 150, 180-s). Results revealed a significant Stimulus condition x Test type interaction following 30-s of familiarization exposure time ($F(1, 48) = 4.84$, $p = .03$). Following 30-s of redundant audiovisual exposure, infants classified as "learners," showed significantly higher PTLTs to the novel prosody than to the novel face ($p = .04$, see Figure 8). Additionally, following 30-s of redundant audiovisual exposure, infants showed intersensory facilitation for prosody of speech as evidenced by significantly higher PTLTs to the novel prosody than infants in the nonredundant unimodal visual condition (p = .002, see Figure 10). No other effect of intersensory facilitation for prosody of speech was found following 60 - 180-s of familiarization exposure (all ps > .05). Taken together, these results converge with those obtained from the full sample of infants.

The performance of infants in the nonredundant unimodal visual condition was analyzed to reveal if they displayed greater PTLTs to facial configuration than prosody of speech. ANOVA results revealed a trending Stimulus condition x Test type interaction following 120-s of familiarization exposure time ($F(1, 48) = 1.79$, p = .19) and a significant Stimulus condition x Test type interaction following 150-s of familiarization exposure time ($F(1, 48) = 9.70$, p = .003). Following 120-s and 150-s of nonredundant unimodal visual exposure, infants showed significantly higher PTLTs to the novel face than the novel prosody (p = .002, p = .001, respectively, see Figure 9). Further, following 120 and 150-s of nonredundant unimodal visual exposure, infants showed unimodal facilitation for facial configuration as evidenced by significantly higher PTLTs to the novel face than infants in the redundant audiovisual condition (p = .04; p = .01, respectively, see Figure 10). No other effect of unimodal facilitation for facial configuration was found following 60, 90, or 180-s of familiarization exposure (all ps > .05). Again, the results of infants classified as "learners," converge with those obtained from the full sample of infants.

Summary of PTLT Analyses

Taken together, the results revealed intersensory facilitation for prosody of speech following just 30-s of familiarization exposure. Following 30-s of redundant audiovisual exposure, infants showed robust discrimination of prosody (comprised of amodal properties such as affect, duration, patterns of tempo and rhythm, and intensity changes) at the expense of discrimination of facial identification. These results provide support for the IRH and indicate that intersensory redundancy recruits infants' selective attention and facilitates perceptual learning of highly salient amodal properties at the expense of less salient modality specific properties (Bahrick, 2010; Bahrick & Lickliter, 2000, 2002; in press; Bahrick, Lickliter, & Flom, 2004). Furthermore, following 60-s of redundant audiovisual exposure, the same infants showed discrimination of facial identification at the expense of discrimination of prosody of speech. These results provide support for hypothesis that infants' selective attention to properties of social events progresses down a salience hierarchy as a function of intersensory redundancy. When intersensory redundancy is available, attention is initially directed to the most salient amodal properties (i.e., prosody of speech) and, as exploration continues, less salient modality specific properties (i.e., facial configuration) are attended to and processed.

The results also revealed unimodal facilitation for facial identification following 120-s and 150-s of familiarization exposure. Infants in the nonredundant unimodal visual condition showed discrimination of facial identification (comprised of modality specific properties such as facial features and their arrangement) at the expense of discrimination of prosody of speech. Nonredundant stimulation facilitates infants' selective attention to modality specific properties of events more so than redundant audiovisual stimulation. Infants' discrimination of facial identification (a task specific to vision) was enhanced when the faces were seen but not heard. Data are consistent with the view that in nonredundant unimodal visual stimulation, detection of modality specific properties (i.e., facial configuration) emerges earlier in processing time than the detection of amodal properties (i.e., prosody of speech). However data are not conclusive because infants showed no evidence of detecting prosody of speech even after 180-s of familiarization exposure time.

Eye Tracking

Eye tracking data were collected for 32 of the infants (14 in the redundant audiovisual condition and 18 in the nonredundant unimodal visual condition). Approximately 41% of infants' gaze data (42% in the redundant audiovisual condition and 39% in the nonredundant unimodal visual condition) were collected and analyzed. The remaining 59% of infants' gaze data were excluded from analyses because of poor tracking quality (i.e., a validity code of 3 or 4, indicating that the gaze data were incorrect, corrupted, or missing).

<u>Shannon Entropy</u>

As reviewed earlier, infants' attentional and perceptual capacities increase, become more efficient, and flexible across development. Evidence of developmental improvements in attentional and processing efficiency come from studies indicating that infants habituate more rapidly, orient and shift attention more quickly, and disengage more often from a stimulus event as they age (Frick et al., 1999; Mayes & Kessen, 1989; Shaddy & Colombo, 2004).

Eye movements play a role in organizing our attention and, in the current dissertation study, attentional improvements were examined across an episode of exploration using the Shannon entropy of fixation distribution. Entropy is measured in bits of information and reflects the amount of certainty in predicting the distribution of eye movements (Frank, Vul, & Johnson, 2009). Studies suggest that lower entropy reflects more constrained and less random scanning distributions, and higher entropy reflects more dispersed and more random scanning distributions (Frank et al., 2009). Thus, lower entropy was predicted to emerge across exploratory time as an indication of infants' increasing attentional and scanning efficiency.

To evaluate infants' scanning patterns across exploratory time, entropy was calculated for each familiarization trial and entered into a repeated measures ANOVA with stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual) as the between-subject factor and familiarization exposure (block 1, block 2, block 3) as the repeated measure. During the early blocks of exposure, infants were predicted to display more dispersed visual scanning patterns as evidenced by higher entropy. As exploration of the dynamic face continued across the blocks of exposure, it was predicted that infants would display more constrained scanning of the face as evidenced by lower entropy.

Results support predictions and revealed a main effect of familiarization exposure block and a significant linear decrease of familiarization exposure block ($F(2, 60) = 3.70$, $p = .03$, $F(1, 30) = 4.99$, $p = .03$, respectively). As exposure to a dynamic face increased, infants exploratory scanning of the faces became significantly less random and more predictable as evidenced by decreasing entropy scores (see Figure 11). Planned comparisons indicated that entropy scores were significantly lower in the last than in the first exposure block ($p = .03$). Work by Frank et al. (2009) demonstrates that infants' scanning of faces become more constrained across development. The present results converge with previous work and indicate that infants' scanning of dynamic faces also becomes more efficient and constrained across a 6-min episode of exploration. No significant main effects of stimulus redundancy condition (redundant audiovisual, nonredundant unimodal visual) or interaction between stimulus redundancy condition and familiarization exposure (block 1, block 2, block 3) were found ($F(1, 30) = 1.06$, $p = .31$, $F(2, 60) = 0.98$, $p = .38$, respectively).

CHAPTER VI

DISCUSSION

Perceivers have limited attentional resources and are unable to attend to and process all properties of our multimodal environment simultaneously. Therefore, some properties of our environment take processing priority and become perceptual foreground whereas others become perceptual background and/or are processed later during episodes of exploration. This processing sequence is exaggerated in naive perceivers because they have *more* limited attentional resources and are *more* influenced by extrinsic than intrinsic factors (e.g., personal goals) than experienced perceivers. My dissertation study assessed how intersensory redundancy provided by the stimulus event (redundant audiovisual, nonredundant unimodal visual) and property type (amodal, modality specific) contributes to the organization of infants' selective attention across exploratory time during early development to facilitate learning. It was the first study to explore shifts across exploratory time in attention and processing of amodal and modality specific properties as a function of intersensory redundancy.

Visual Paired Comparison

The Intersensory Redundancy Hypothesis predicts that the presence or lack of intersensory redundancy influences developmental and real time selectively and processing sequences. However, until now, no data were available on how infants' attentional and perceptual selectively changes in real time across an episode of exploration. The present dissertation provides several findings that support the predictions of the IRH (intersensory and unimodal facilitation). They indicate that within the early phases of exploration infants who received redundant audiovisual, but not nonredundant unimodal visual, stimulation showed robust evidence of abstracting the amodal information necessary for discriminating between the novel and familiar prosody. As exploration of a redundant audiovisual event continued, infants who showed detection of prosody of speech (specifying approval and prohibition) following 30-s of exposure also showed detection of facial configuration following 60-s of exposure. Intersensory redundancy directed infants' real time selective attention and exploration of the social event (i.e., a women speaking) in a coordinated and efficient manner. For infants in the redundant audiovisual condition, attention progressed down the salience hierarchy and they were able to attend to both the salient amodal (prosody of speech) and, subsequently, to the less salient modality specific information (facial configuration).

Conversely, infants who received nonredundant unimodal visual stimulation showed discrimination of the novel over the familiar face during the later phases of exploration. A significant interaction between stimulus condition and property type indicated that facial identity was detected more easily and significantly better in nonredundant unimodal visual than in redundant audiovisual stimulation (evidence of unimodal facilitation). Perception and discrimination of prosody of speech was attenuated at all phases of nonredundant unimodal visual exploration. Since infants did not show evidence of discrimination of prosody of speech in nonredundant unimodal visual stimulation, the research question of whether modality specific and amodal properties are discriminated during the early or later phases of exploration cannot be clearly addressed. However, the available data suggests that in nonredundant unimodal visual stimulation, detection of facial configuration emerges earlier in processing time than the detection of prosody of speech. Infants' discrimination of prosody of speech is likely to occur following longer than the 180-s of nonredundant unimodal visual exposure time available in the current experiment.

Eye Tracking

The field of infant perceptual and cognitive development has been criticized for focusing on macro-structural change while ignoring micro-structural change (Aslin, 2007). My dissertation study addressed this need by using an eye tracking apparatus that served as a complement to the traditional looking time methods used in the area of infant research. The data collected from the eye tracking apparatus allowed for exploratory analyses of frame-by-frame micro-structural change in looking patterns across time that provided information on how selective attention as a function of stimulus redundancy condition and exploratory time influences visual information gathering. Results from the eye tracking portion of the dissertation indicated that infants' scanning of a dynamic face becomes increasingly more focused/constrained across exploratory time. Attentional improvements were observed across a 6-min episode of exploration, mirroring results obtained from studies indicating attentional improvements across development.

Limitations

In the current study, the face identification task presented the two actresses side-by-side wearing baseball caps. Baseball caps were used to remove external information about their identity. In order to discriminate between the two actresses, infants needed to rely on the internal configuration of the actresses' features. Although it is difficult to operationally equate task difficulty across different stimulus events, it is possible that for 3½-month-old infants the face identification task might have been too difficult in relation to the prosody discrimination task.

Eye tracking infant participants is relatively state-of-the-art in the field of perceptual and cognitive development. As a field we are learning together and establishing standards for what constitutes "good" eye tracking data and procedures. As discussed in chapter two, certain paradigms have become standard for addressing specific research questions (the habituation/dishabituation paradigm is a standard for tackling questions about discrimination and categorization). To date, the field has not agreed upon how best to collect and examine infants' eye tracking data. Infant eye tracking paradigms are currently being developed and refined (for example, eye tracking has yet to be successfully incorporated with the habituation/dishabituation paradigm).

Although not uncommon in infant eye tracking research, the percentage of eye gaze data collected compared to the percentage of eye gaze data lost due to poor tracking quality was rather high. In the current dissertation study, eye tracking data collection was not invasive and infants were allowed to freely look at and look away from the stimulus events. As adults, we can shift our eye gaze direction without moving our heads. This is not the case for young infants. In the current VPC paradigm, the novel and familiar stimulus events were presented side-by-side and it was necessary for infants to move their head and neck so that they may view both stimulus events. While the percentage of eye gaze data lost due to poor tracking quality would decrease if infants' head and neck were restricted from moving, this would be incompatible with paradigms similar to the VPC.

Future Directions

It appears that the facial identification task, in relation to the prosody discrimination task, might have been too taxing for infants of this age group. Infants in the nonredundant unimodal condition required 120-s of exposure to show discrimination of facial identity. On the other hand, infants in the redundant audiovisual condition only required 30-s of exposure to show discrimination of prosody of speech, suggesting that the prosody discrimination task may have been easier. Since it is difficult to operationally equate the difficulty level of both facial and prosody discrimination tasks, a future study should compare older infants' (e.g., 4 - 5 months old) processing and discrimination of prosody of speech and facial configuration. As infants age their attention becomes more flexible, they are able to process information more quickly, and are likely to process both less and more salient aspects of information. A pilot study addressing this issue is currently underway.

Summary

The current dissertation provides insight into how stimulus conditions promote versus attenuate 3½-month-old infants' real time attentional and perceptual processing of social events (i.e., prosody of speech and facial identification). Continued research in this area is valuable as it has the potential to reveal how early patterns of selective attention are likely to result in varying developmental trajectories. Infants' early experience with social events (e.g., faces and speech) contributes to language, social, emotional, and cognitive capabilities. Having a more comprehensive understanding of the origins and nature of infants' selective attention and processing of events may aid researchers in identifying how development may go awry such as in autism, and may facilitate interventions and novel teaching techniques geared towards individuals who suffer from deficits related to selective attention such as those with unilateral brain damage and attention-deficit/hyperactivity disorder (Douglas, 1999; Driver, 2001).

LIST OF REFERENCES

Adler, S. A., Gerharstein, P., & Rovee-Collier, C. (1998). Levels-of-processing effects in infant memory? *Child Development, 69,* 280-294.

Apgar, V. (1953). A proposal for a new method of evaluation of the newborn infant. *Current Researches in Anesthesia and Analgesia, 32*, 260-267.

Aslin, R. N. (2007). What's in a look? *Developmental Science, 10,* 48-53.

Bahrick, L. E. (1988). Intermodal learning in infancy: Learning on the basis of two kinds of invariant relations in audible and visible events. *Child Development, 59*, 197-209.

Bahrick, L. E. (2001). Increasing specificity in perceptual development: Infants' detection of nested levels of multimodal stimulation. *Journal of Experimental Child Psychology, 79*, 253-270.

Bahrick, L. E. (2010). Intermodal perception and selective attention to intersensory redundancy: Implications for typical social development and autism. In G. Bremner & T. D. Wachs (Eds.), *The Wiley-Blackwell Handbook of Infant Development: Volume 1: Basic Research* (2nd ed., pp. 120-166). Oxford, England: Blackwell Publishing.

Bahrick, L. E., Argumosa, M., Lopez, H., & Todd, J. T. (2009, October). *Face discrimination in preschool-age children.* Poster presented at the Cognitive Developmental Society meeting, San Antonio, TX.

Bahrick, L. E., Castellanos, I., & Argumosa, M. A. (2011). Intersensory redundancy facilitates infants' perception of meaning in speech passages. Manuscript in preparation.

Bahrick, L. E., Flom, R., & Lickliter, R. (2002). Intersensory redundancy facilitates discrimination of tempo in 3-month-old infants. *Developmental Psychology, 41*, 352-363.

Bahrick, L. E., Gogate, L. J., & Ruiz, I. (2002). Attention and memory for faces and actions in infancy: The salience of actions over faces in dynamic events. *Child Development, 73,* 1629-1643.

Bahrick, L. E., Hernandez-Reif, M., & Pickens, J. N. (1997). The effect of retrieval cues on visual preferences and memory: Evidence for a four-phase attention function. *Journal of Experimental Child Psychology, 67,* 1-20.

Bahrick, L. E., & Lickliter, R. (2000). Intersensory redundancy guides attentional selectivity and perceptual learning in infancy. *Developmental Psychology, 36,* 190-201.

Bahrick, L. E., & Lickliter, R. (2002). Intersensory redundancy guides early perceptual and cognitive development. In R. V. Kail (Ed.), *Advances in child development and behavior* (Vol. 30, pp. 153-187). New York: Academic Press.

Bahrick, L. E., & Lickliter, R. (2004). Infants' perception of rhythm and tempo in unimodal and multimodal stimulation: A developmental test of the intersensory redundancy hypothesis. *Cognitive, Affective, & Behavioral Neuroscience, 4,* 137-147.

Bahrick, L. E., & Lickliter, R. (in press). The role of intersensory redundancy in early perceptual, cognitive, and social development. In A. Bremner, D. J. Lewkowicz, & C. Spence (Eds.), *Multisensory development* (pp. xxx-xxx). New York: Oxford University Press.

Bahrick, L. E., Lickliter, R., Castellanos, I., Vaillant-Molina, M. (2010). Increasing task difficulty enhances effects of intersensory redundancy: testing a new prediction of the Intersensory Redundancy Hypothesis. *Developmental Science, 13,* 731-737.

Bahrick, L. E., Lickliter, R., & Flom, R. (2004). Intersensory redundancy guides the development of selective attention, perception, and cognition in infancy. *Current Directions in Psychological Science, 13,* 99-102.

Bahrick, L. E., Lickliter, R., & Flom, R. (2006). Up versus down: The role of intersensory redundancy in the development of infants' sensitivity to the orientation of moving objects. *Infancy, 9*, 73-96.

Bahrick, L. E., Lickliter, R., Shuman, M. A., Batista, L. C., Castellanos, I., & Newell, L. (2005, November). *The development of infant voice discrimination: From unimodal auditory to bimodal audiovisual stimulation.* Poster presented at the International Society of Developmental Psychobiology, Washington, D.C.

Bahrick, L. E., Lickliter, R., Shuman, M. A., Batista, L. C., Grandez, C. (2003, April). *Infant discrimination of voices: Predictions from the intersensory redundancy hypothesis*. Poster presented at the Society for Research in Child Development, Tampa, FL.

Bahrick, L. E., Lickliter, R., Vaillant, M., Shuman, M. A., & Castellanos, I. (2004a, May). *Infant discrimination of faces in the context of dynamic, multimodal, events: Predictions from the intersensory redundancy hypothesis*. Poster presented at the International Conference on Infant Studies, Chicago, IL.

Bahrick, L. E., Lickliter, R., Vaillant, M., Shuman, M. A., & Castellanos, I. (2004b, June). *The development of face perception in dynamic, multimodal events: Predictions from the intersensory redundancy hypothesis*. Poster presented at the International Multisensory Research Forum, Barcelona, Spain.

Bahrick, L. E., & Newell, L. C. (2008). Infant discrimination of faces in naturalistic events: Actions are more salient than face. *Developmental Psychology, 44*, 983-996.

Bahrick, L. E., & Pickens, J. N. (1995). Infant memory for object motion across a period of three months: Implications for a four-phase attention function. *Journal of Experimental Child Psychology, 59,* 343-371.

Bahrick, L. E., Shuman, M., & Castellanos, I. (2008, March). *Audiovisual temporal synchrony directs selective listening in four-month-old infants.* Poster presented at the International Conference on Infant Studies, Vancouver, B.C.

Bahrick, L. E., Walker, A. S., & Neisser, U. (1981). Selective looking by infants. *Cognitive Psychology, 13,* 377-390.

Bekken, J. (1989). *Is there motherese in gesture?* Unpublished doctoral dissertation, The University of Chicago, Chicago, IL.

Berger, S. E. (2004). Demands on finite cognitive capacity cause infants' perseverative errors. *Infancy, 5,* 217-238.

Bertenthal, B. I., Haith, M. M., & Campos, J. J. (1983). The partial-lag design: A method for controlling spontaneous regression in the infant-control habituation paradigm. *Infant Behavior and Development, 6*, 331-338.

Brand, R. J., Baldwin, D. A., & Ashburn, L. A. (2002). Evidence for 'motionese': modifications in mothers' infant-directed action. *Developmental Science, 5,* 72-83.

Bushnell, I. W. R. (2001). Mother's face recognition in newborn infants: Learning and memory. *Infant and Child Development, 10,* 67-74.

Caron, R. F., & Caron, A. J. (1969). Degree of stimulus complexity and habituation of visual fixation in infants. *Psychonomic Science, 14,* 78-79.

Cassia, V. M., Turati, C., & Simion, F. (2004). Can a nonspecific bias toward top-heavy patterns explain newborns' face preference? *American Psychological Society, 15,* 379-383.

Castellanos, I. (2007). *Intersensory redundancy educates human infants' attention to the prosody of speech* (Unpublished master's thesis.) Florida International University, Miami, FL.

Castellanos, I., & Bahrick, L. E. (2008, November). *Educating infants' attention to the amodal properties of speech: The role of intersensory redundancy*. Poster presented at the International Society for Developmental Psychobiology, Washington, D.C.

Castellanos, I., Shuman, M. A., & Bahrick, L. E. (2004, May). *Intersensory redundancy facilitates infants' perception of meaning in speech passages*. Poster presented at the International Conference on Infant Studies, Chicago, IL.

Castellanos, I., Vaillant-Molina, M., Lickliter, R., & Bahrick, L. E. (2006, October). *Intersensory redundancy educates infants' attention to amodal information during early development.* Poster presented at the International Society for Developmental Psychobiology, Atlanta, GA.

Chawarska, K., Shic, F. (2009). Looking but not seeing: Atypical visual scanning and recognition of faces in 2 and 4-year-old children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 39,* 1663-1672.

Chawarska, K., Volkmar, F (2007). Impairments in monkey and human face recognition in 2-ear-old toddlers with autism spectrum disorder and developmental delay. *Developmental Science, 10*, 266-279.

Chong, S. C. F., Werker, J. F., Russell, J. A., & Carroll, J. M. (2003). Three facial expressions mothers direct to their infants. *Infant and Child Development, 12,* 211-232.

Christophe, A., Gout, A., Peperkamp, S., & Morgan, J. (2003). Discovering words in the continuous speech stream: The role of prosody. *Journal of Phonetics, 31,* 585-598.

Colombo, J., Mitchell, D. W., Horowitz, F. D. (1988). Infant visual attention in the paired-comparison paradigm: Test-retest and attention-performance relations. *Child Development, 59*, 1198-1210.

Cooper, R. P., & Aslin, R. N. (1990). Preference for infant-directed speech in the first month after birth. *Child Development, 61*, 1584-1595.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In Craik, F. I. M., & S. E. Trehub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum Press.

Craik, F. I. M., & Lockhart, J. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11,* 671-684.

Craik, F. I. M., Luo, L., & Sakuta, Y. (2010). Effects of aging and divided attention on memory for items and their contexts. *Psychology and Aging, 25*, 968-979.

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208,* 1174-1176.

Deco, G., Pollatos, O., Zihl, J. (2002). The time course of selective visual attention: theory and experiments. *Vision Research, 42,* 2925-2945.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18,* 193-222.

Douglas, V. (1999). Cognitive control processes in attention-deficit/hyperactivity disorder. In H. Quay & A. Hogan (Eds.), *Handbook of disruptive behavior disorders* (pp. 105-138). New York: Kluwer Academic.

Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology, 92,* 53-78.

Engen, T., & Lipsitt, L. P. (1965). Decrement and recovery of responses to olfactory stimuli in the human neonate. *Journal of Comparative and Physiological Psychology, 59,* 312-316.

Fagan, J. F. (1973). Infants' delayed recognition memory and forgetting. *Journal of Experimental Child Psychology, 16,* 424-450.

Fagan, J. F. (1974). Infant recognition memory: The effects of length of familiarization and type of discrimination task. *Child Development, 45,* 351-356.

Fagan, J., & Haiken-Vasen, J. (1997). Selective attention to novelty as a measure of information processing across the life span. In J. Burack & J. Enns (Eds.), *Attention, development, and psychopathology* (pp. 55-73). New York: Guilford Press.

Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science, 146*, 668-670.

Farroni, T., Csibra, G., Simion, F., Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America, 99,* 9602-9605.

Farroni, T., Massaccesi, S., Menon, E., Johnson, M. H. (2007). Direct gaze modulates face recognition in young infants. *Cognition, 102,* 396-404.

Fernald, A. (1984). The perceptual and affective salience of mothers' speech to infants. In L. Feagans, C. Garvey, & R. Golinkoff (Eds.), *The origins and growth of communication* (pp. 5-29). Norwood, NJ: Ablex.

Fernald, A. (1989). Intonation and communicative intent in mothers' speech to infants: Is the melody the message? *Child Development, 60,* 1497-1510.

Fernald, A. (1993). Approval and disapproval: Infant responsiveness to vocal affect in familiar and unfamiliar languages. *Child Development, 64,* 657-674.

Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental Psychology, 27*, 209-221.

Fernald, A., & Kuhl, P. K. (1987). Acoustic determinants of infant preference for motherese speech. *Infant Behavior and Development, 10*, 279-293.

Fernald, A., Taeschner, T., Dunn, J., & Papousek, M. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language, 16,* 477-501.

Fifer, W. P., & Moon, C. (1995). The effects of fetal experience with sound. In J. P. Lecanuet, N. A. Krasnegor, W. P. Fifer & W. P. Smotherman (Eds.), *Fetal behavior: A psychobiological perspective* (pp. 351-366). Hillsdale, New Jersey: Erlbaum.

Flom, R., & Bahrick, L. E. (2007). The development of infant discrimination of affect in multimodal and unimodal stimulation: The role of intersensory redundancy. *Developmental Psychology, 43*, 238-252.

Flom, R., & Pick, A. (2010, March). *Dynamics of infant habituation: Infants' discrimination of musical excerpts.* Poster presented at the International Society for Infant Studies, Baltimore, M.D.

Frank, M., Vul, E., & Johnson, S. P. (2009). Development of infants' attention to faces during the first year. *Cognition, 110,* 160-170.

Frick, J. E., Colombo, J., & Saxon, T. F. (1999). Individual and developmental differences in disengagement of fixation in early infancy. *Child Development, 70*, 537-548.

Gerken, L., & Aslin, R. N. (2005). Thirty years of research on infant speech perception: The legacy of Peter W. Jusczyk. *Language Learning and Development, 1*, 5-21.

Gibson, E. J. (1969). *Principles of perceptual learning and development*. East Norwalk, CT: Appleton-Century-Crofts.

Gogate, L. J., & Bahrick, L. E. (1998). Intersensory redundancy facilitates learning of arbitrary relations between vowel sounds and objects in seven-month-old infants. *Journal of Experimental Child Psychology, 69*, 1-17.

Gogate, L. J., Bahrick, L. E., & Watson, J. D. (2000). A study of multimodal motherese: The role of temporal synchrony between verbal labels and gestures. *Child Development, 71,* 878-894.

Gottlieb, J. P., Kusunoki, M., & Goldberg, M. E. (1998). The representation of visual salience in monkey parietal cortex. *Nature, 391,* 481-484.

Graham, F. K., Clifton, R. K., & Hatton, H. M. (1968). Habituation of heart rate response to repeated auditory stimulation during the first five days of life. *Child Development, 39,* 35-52.

Grieser, D. L. & Kuhl, P. K. (1988). Maternal speech to infants in a tonal language: Support for universal prosodic features in motherese. *Developmental Psychology, 24*, 14-20.

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. *Science, 198,* 853-855.

Harris, J. D. (1943). Habituatory response decrement in the intact organism. *Psychological Bulletin, 40,* 385-422.

Hirsh-Pasek, K., Kemler Nelson, D. G., Jusczyk, P. W., Cassidy, K. W., Druss, B., & Kennedy, L. (1987). Clauses are perceptual units for young infants. *Cognition, 26,* 269-286.

Hollich, G., Newman, R. S., & Jusczyk, P. W. (2005). Infants' use of synchronized visual information to separate streams of speech. *Child Development, 76*, 598-613.

Hood, B. M., Macrae, C. N., Cole-Davies, V., & Dias, M. (2003). Eye remember you: the effects of gaze direction on face recognition in children and adults. *Developmental Science, 6,* 67-71.

Horowitz, F. D., Paden, L., Bhana, K., & Self, P. (1972). An infant-control procedure for studying infant visual fixations. *Developmental Psychology, 7,* 90.

Hunter, M. A., Ames, E. W., & Koopman, R. (1983). Effects of stimulus complexity and familiarization time on infant preferences for novel and familiar stimuli. *Developmental Psychology, 19,* 338-352.

Hunter, M. A., Ross, H. S., & Ames, E. W. (1982). Preferences for familiar or novel toys: Effects of familiarization time in one-year-olds. *Developmental Psychology, 18,* 519-529.

Iverson, J. M., Capirci, O., Longobardi, E., & Caselli, M. C. (1999). Gesturing in mother-child interactions. *Cognitive Development, 14,* 57-75.

Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition, 90,* 1-19.

Jusczyk, P. W., Hirsch-Pasek, K., Kemler Nelson, D. G., & Kennedy, L. J. (1992). Perception of acoustic correlates of major phrasal units by young infants. *Cognitive Psychology, 24,* 252-293.

Koch, C., & Ullman, S. (1985). Shifts in selective visual attention: towards the underlying neural circuitry. *Human Neurobiology, 4,* 219-227.

Lansink, J. M., & Richards, J. E. (1997). Heart rate and behavioral measures of attention in six-, nine-, and twelve-month-old infants during object exploration. *Child Development, 68,* 610-620.

Lander, K., Christie, F., Bruce, V. (1999). The role of movement in the recognition of famous faces. *Memory & Cognition, 27,* 974-985.

Layton, D., & Rochat, P. (2007). Contribution of motion information to maternal face discrimination in infancy. *Infancy, 12,* 257-271.

Mandel, D. R., Kemler Nelson, D. G., & Jusczyk, P. W. (1996). Infants remember the order of words in a spoken sentence. *Cognitive Development, 11,* 181-196.

Maurer, D., & Salapatek, P. (1976). Developmental changes in the scanning of faces by young infants. *Child Development, 47,* 523-527.

Mayes, L., & Kessen, W. (1989). Maturational changes in measures of habituation. *Infant Behavior and Development, 12,* 437-450.

McNeil, D. (1992). *Hand and mind: What gesture reveals about thought.* Chicago: University of Chicago Press.

Mondloch, C. J., Lewis, T. L., Budreau, D. R., Maurer, D., Dannemiller, J. L., Stephens, B. R., & Kleiner-Gathercoal, K. A. (1999). Face perception during early infancy. *Psychological Science, 10,* 419-422.

Morgan, J. L. (1996). Prosody and the roots of parsing. *Language & Cognitive Processes, 11,* 69-106.

Nazzi, T., Kemler Nelson, D. G., Jusczyk, P. W., & Jusczyk, A. M. (2000). Six- month-olds' detection of clauses embedded in continuous speech: Effects of prosodic well-formedness. *Infancy, 1,* 123-147.

O'Toole, A. J., Roark, D. A., & Abdi, H. (2002). Recognizing moving faces: a psychological and neural synthesis. *TRENDS in Cognitive Sciences, 6,* 261-266.

Otsuka, Y., Konishi, Y., Kanazawa, S., Yamaguchi, M. K., Abdi, H., & O'Toole, A. J. (2009). Recognition of moving and static faces by young infants. *Child Development, 80,* 1259-1271.

Papousek, M., Bornstein, M. H., Nuzzo, C., Papousek, H., & Symmes, D. (1990). Infant responses to prototypical melodic contours in parental speech. *Infant Behavior and Development, 13*, 539-545.

Papousek, M., Papousek, H., & Symmes, D. (1991). The meanings of melodies in motherese in tone and stress languages. *Infant Behavior and Development, 14*, 415-440.

Pascalis, O., & Bachevalier, J. (1999). Neonatal aspiration lesions of the hippocampal formation impair visual recognition memory when assessed by paired-comparison task but not by delayed nonmatching-to-sample task. *Hippocampus, 9,* 609-616.

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and an extension. *Infant Behavior and Development, 18,* 79-85.

Rankin, C. H., Abrams, T., Barry, R. J., Bhatnagar, S., Clayton, D. F., Colombo, J. et al., (2009). Habituation revisited: An updated and revised description of behavioral characteristics of habituation. *Neurobiology of Learning & Memory, 92,* 135-138.

Reynolds, G. D., Courage, M. L., & Richards, J. E. (2010). Infant attention and visual preferences: Converging evidence from behavior, event-related potentials, and cortical source localization. *Developmental Psychology, 46,* 886-904.

Richards, J. E. (1997). Effects of attention on infants' preference for briefly exposed visual stimuli in the paired-comparison recognition-memory paradigm. *Developmental Psychology, 33,* 22-31.

Richards, J. E. (2003). Attention affects the recognition of briefly presented visual stimuli in infants: An ERP study. *Developmental Science, 6,* 312-328.

Richmond, J., Sowerby, P., Colombo, M., & Hayne, H. (2004). The effect of familiarization time, retention interval, and context change on adults' performance in the visual paired-comparison task. *Developmental Psychobiology, 44,* 146-155.

Rochat, P. (2007). Intentional action arises from early reciprocal exchanges. *Acta Psychologica, 124,* 8-25.

Rose, S. A. (1983). Differential rates of visual information processing in full-term and preterm infants. *Child Development, 54,* 1189-1198.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2003). Infant visual recognition memory: Independent contributions of speed and attention. *Developmental Psychology, 39,* 563-571.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2009). Information processing in toddlers: Continuity from infancy and persistence of preterm deficits. *Intelligence, 37,* 311-320.

Rose, S. A., Gottfried, A. W., Melloy-Carminar, P., & Bridger, W. H. (1982). Familiarity and novelty preferences in infant recognition memory: Implications for information processing. *Developmental Psychology, 18,* 704-713.

Sai, F. Z. (2005). The role of the mother's voice in developing mother's face preference: Evidence for intermodal perception at birth. *Infant and Child Development, 14,* 29-50.

Schoner, G., & Thelen, E. (2006). Using dynamic field theory to rethink infant habituation. *Psychological Review, 113,* 273-299.

Shaddy, D. J., & Colombo, J. (2004). Developmental changes in infant attention to dynamic and static stimuli. *Infancy, 5,* 355-365.

Shafer, M. J., Shucard, D. W., & Jaeger, J. J. (1999). Electrophysiological indices of cerebral specialization and the role of prosody in language acquisition in three-month-old infants. *Developmental Neuropsychology, 15,* 73-109.

Smith, L. B., Thelen, E., Titzer, R., & McLin, D. (1999). Knowing in the context of action: The task dynamics of the A-not-B error. *Psychological Review, 106,* 235-260.

Spence, M. J., & Moore, D. S. (2003). Categorization of infant-directed speech: Development from 4 to 6-months. *Developmental Psychobiology, 42,* 97-109.

Stern, D. N., Spieker, S., Barnett, R. K., & MacKain, K. (1983). The prosody of maternal speech: Infant age and context related changes. *Journal of Child Language, 10*, 1-15.

Stern, D. N., Spieker, S., & MacKain, K. (1982). Intonation contours as signals in maternal speech to prelinguistic infants. *Developmental Psychology, 18*, 727-735.

Thompson, R. F., & Spencer, W. A. (1966). Habituation: A model phenomenon for the study of neuronal substrates of behavior. *Psychological Review, 73,* 16-43.

Trainor, L. J., Austin, C. M., & Desjardins, R. N. (2000). Is infant-directed speech prosody a result of the vocal expression of emotion? *Psychological Science, 11,* 188-195.

Treisman, A., & Gormica, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review, 95,* 15-48.

Vaillant, J., Bahrick, L. E., & Lickliter, R. (2008, November). *Detection of modality-specific properties in unimodal and bimodal events*. Poster presented at the International Society for Developmental Psychobiology, Washington, D.C.

Vaillant-Molina, M., Gutierrez, M. E., & Bahrick, L. E. (2005, November). *Infant memory for modality-specific properties of contingent and noncontingent events: The role of intersensory redundancy in self perception*. Poster presented at the International Society for Developmental Psychobiology, Washington, D.C.

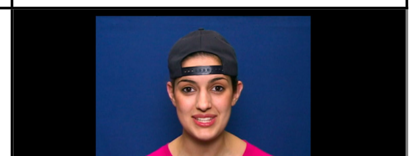
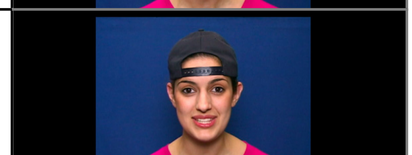
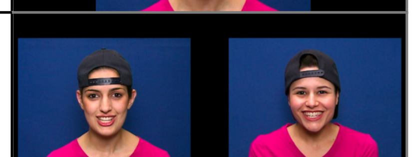
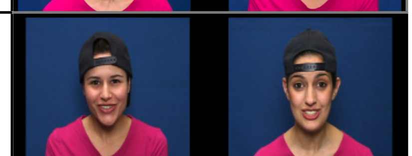
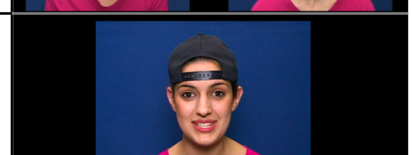
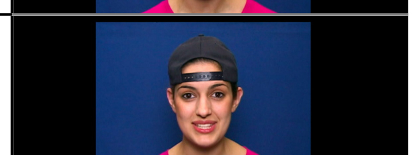
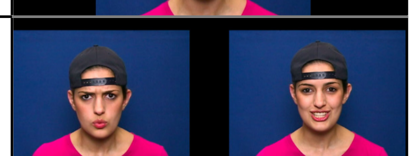
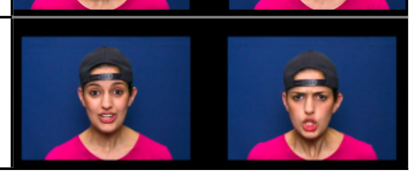
Vaillant-Molina, M., Newell, L. C., Castellanos, I., Bahrick, L. E., & Lickliter, R. (2006, June). *Intersensory redundancy impairs face perception in early development.* Poster presented at the International Conference on Infant Studies, Kyoto, Japan.

Walker-Andrews, A.S., & Bahrick, L.E. (2001). Perceiving the real world: Infants' detection of and memory for social information. *Infancy, 2,* 469-481.

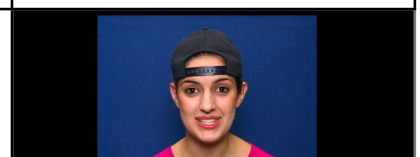
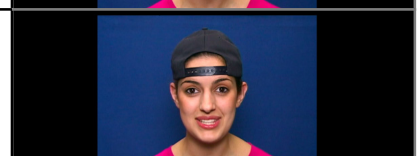
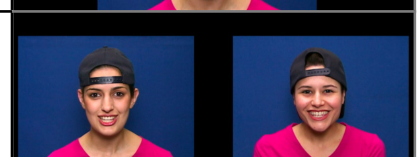
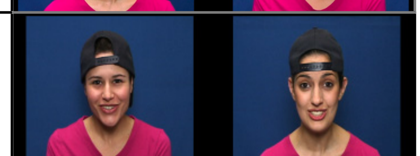
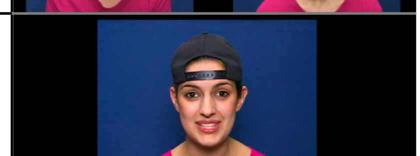
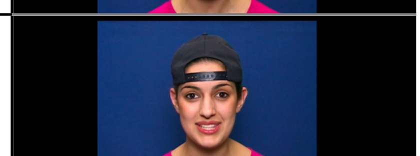
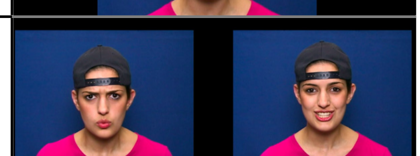
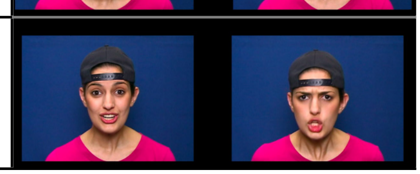
Werker, J. F., & McLeod, P. J. (1989). Infant preferences for both male and female infant-directed talk: A developmental study of attentional and affective responsiveness. *Canadian Journal of Psychology, 43,* 230-246.

Figure 1. An example of one of the possible conditions an infant may have participated in. All trials ended after 15-s elapsed. Test trials were presented following every 30-s of familiarization exposure (30, 60, 90, 120, 150, 180-s). Exposure block 1 was identical to exposure blocks 2 and 3 for each subject.

Time (in seconds)

Exposure Block 1			
DV	**Phase**	**Trial Number**	**Stimulus Display**
	Familiarization	1	
		2	
x$= 30-s Face Test	VPC Face Test Phase: Familiar (left), Novel (right)	3	
	Novel (left), Familiar (right)	4	
	Familiarization	5	
		6	
x$= 60-s Prosody Test	VPC Prosody Test Phase: Novel (left), Familiar (right)	7	
	Familiar (left), Novel (right)	8	

Time (in seconds)

Exposure Block 2			
DV	**Phase**	**Trial Number**	**Stimulus Display**
	Familiarization	9	
		10	
x$= 90-s Face Test	VPC Face Test Phase: Familiar (left), Novel (right)	11	
	Novel (left), Familiar (right)	12	
	Familiarization	12	
		14	
x$= 120-s Prosody Test	VPC Prosody Test Phase: Novel (left), Familiar (right)	15	
	Familiar (left), Novel (right)	16	

Time (in seconds) ↓

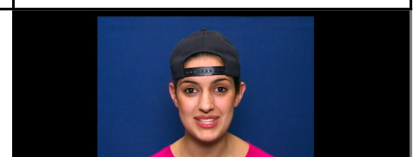
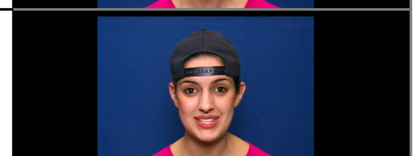
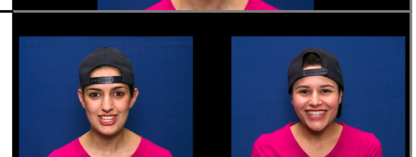
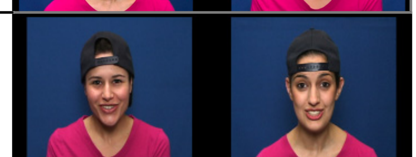
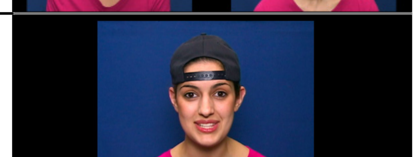
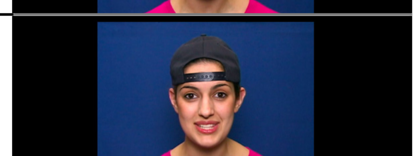
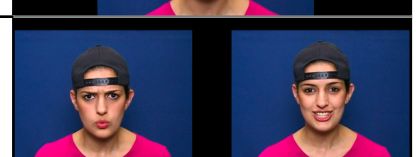
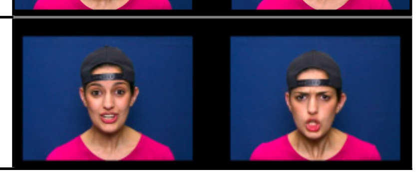
Exposure Block 3			
DV	**Phase**	**Trial Number**	**Stimulus Display**
	Familiarization	17	
		18	
x$= 150-s Face Test	VPC Face Test Phase: Familiar (left), Novel (right)	19	
	Novel (left), Familiar (right)	20	
	Familiarization	21	
		22	
x$= 180-s Prosody Test	VPC Prosody Test Phase: Novel (left), Familiar (right)	23	
	Familiar (left), Novel (right)	24	

Figure 2. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of familiarization exposure (block 1, block 2, block 3) for infants in the redundant audiovisual condition (n = 32).

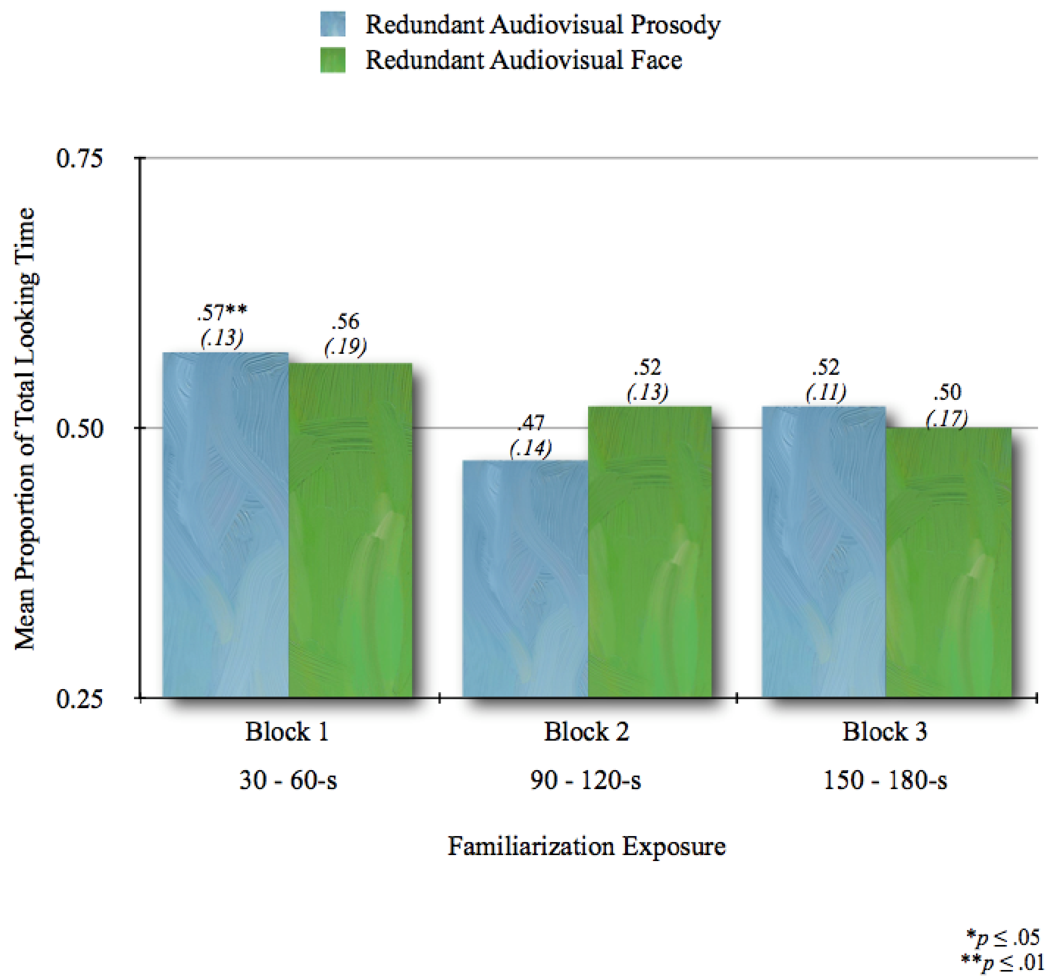


Figure 3. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of familiarization exposure (block 1, block 2, block 3) for infants in the nonredundant unimodal visual condition (n = 32).

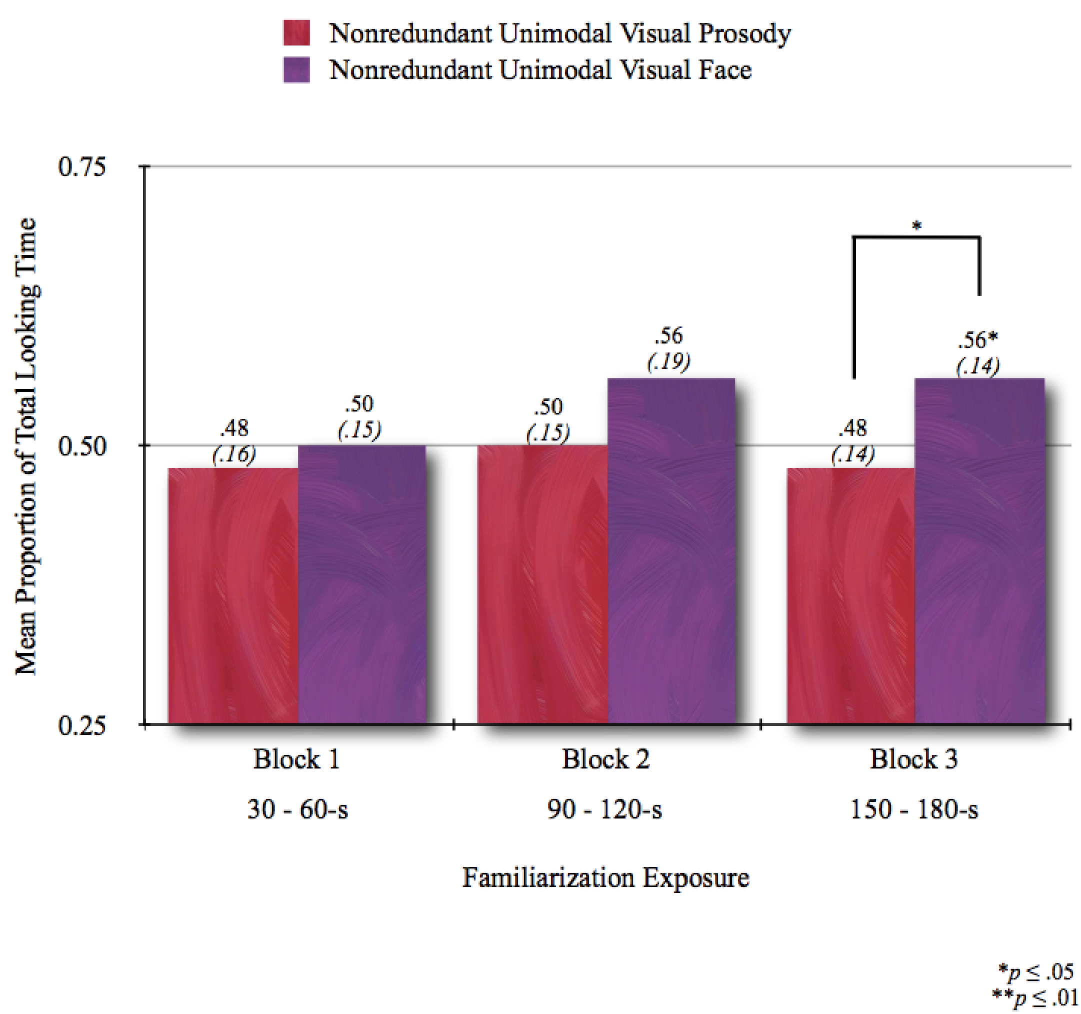


Figure 4. Infants' (N = 64) mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of stimulus condition (redundant audiovisual, nonredundant unimodal visual) and familiarization exposure (block 1, block 2, block 3).

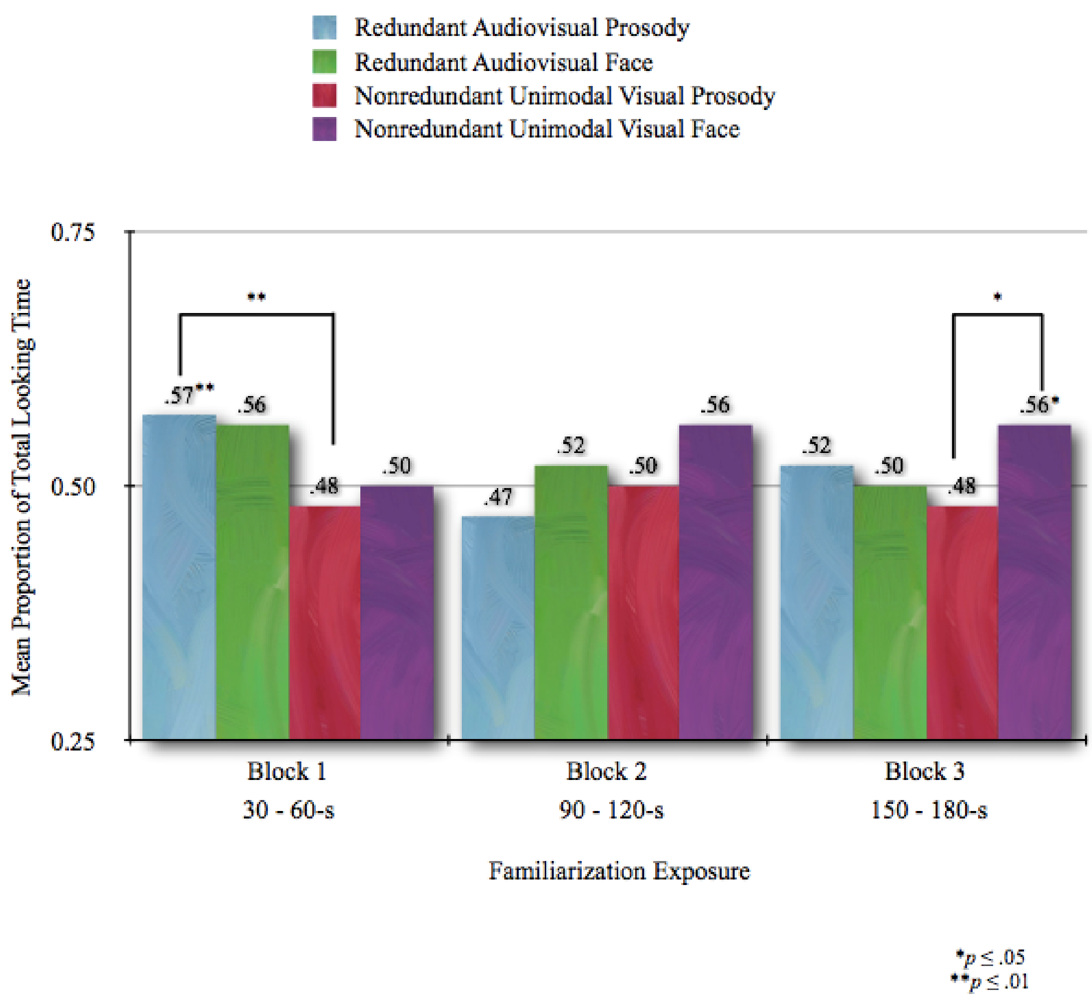


Figure 5. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of familiarization exposure time (30, 60, 90, 120, 150, 180-s) for infants in the redundant audiovisual condition ($n = 32$).

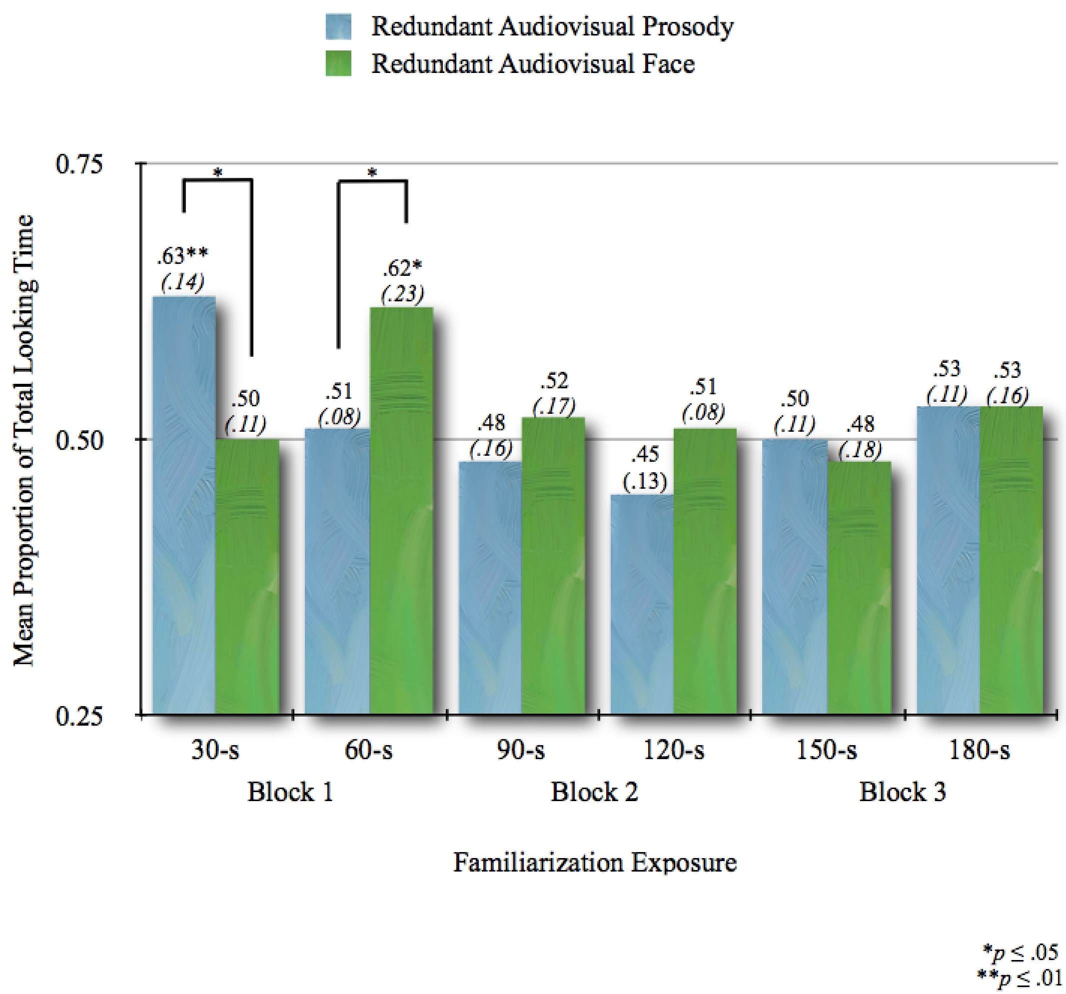


Figure 6. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of familiarization exposure time (30, 60, 90, 120, 150, 180-s) for infants in the nonredundant unimodal visual condition (n = 32).

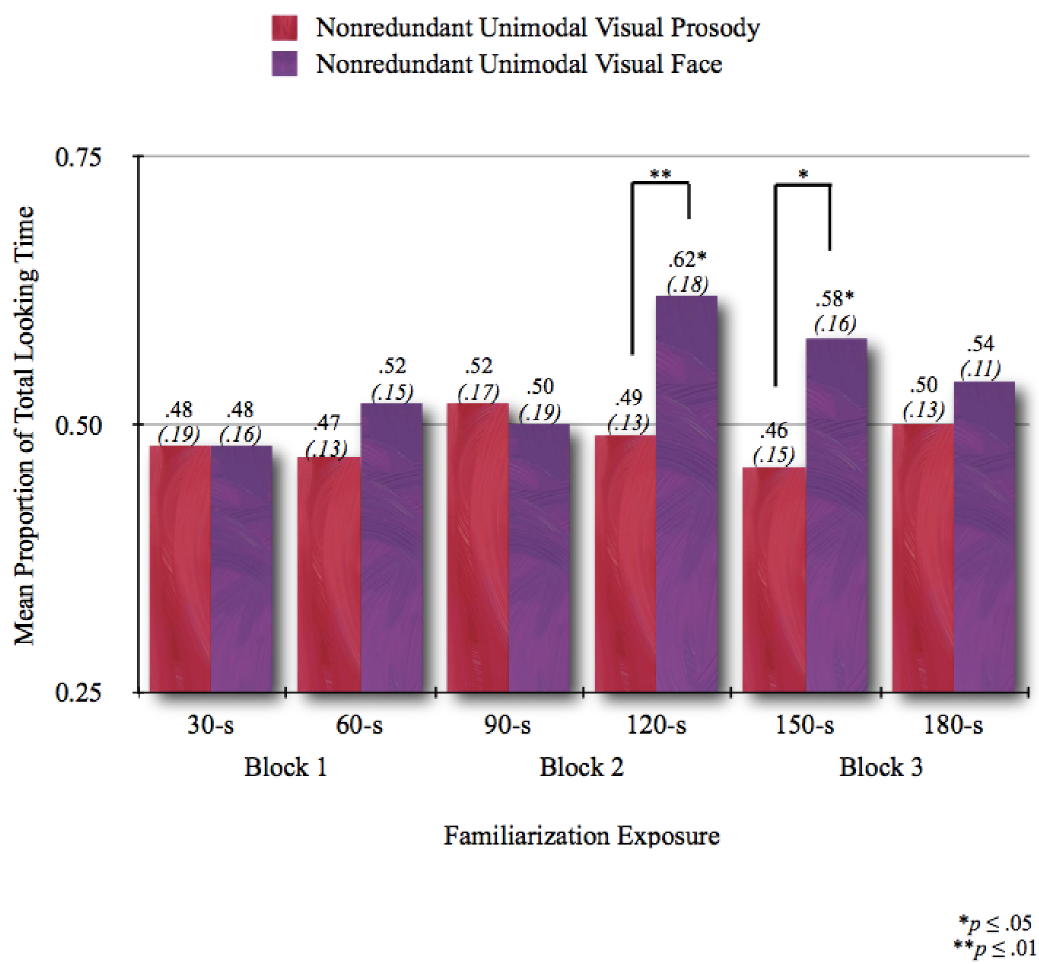


Figure 7. Infants' ($N = 64$) mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of stimulus condition (redundant audiovisual, nonredundant unimodal visual) and familiarization exposure time (30, 60, 90, 120, 150, 180-s).

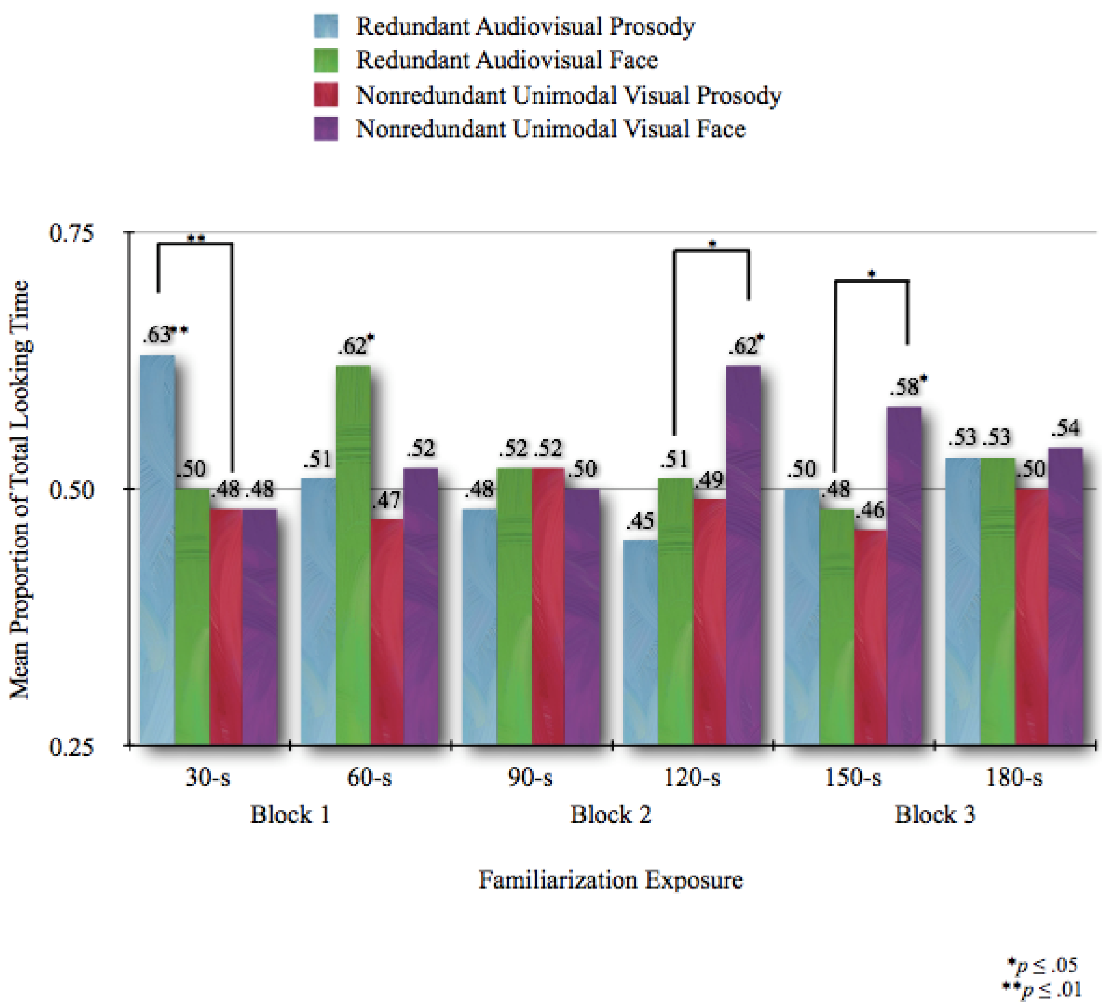


Figure 8. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of familiarization exposure time (30, 60, 90, 120, 150, 180-s) for infants classified as "learners" in the redundant audiovisual condition (n = 25).

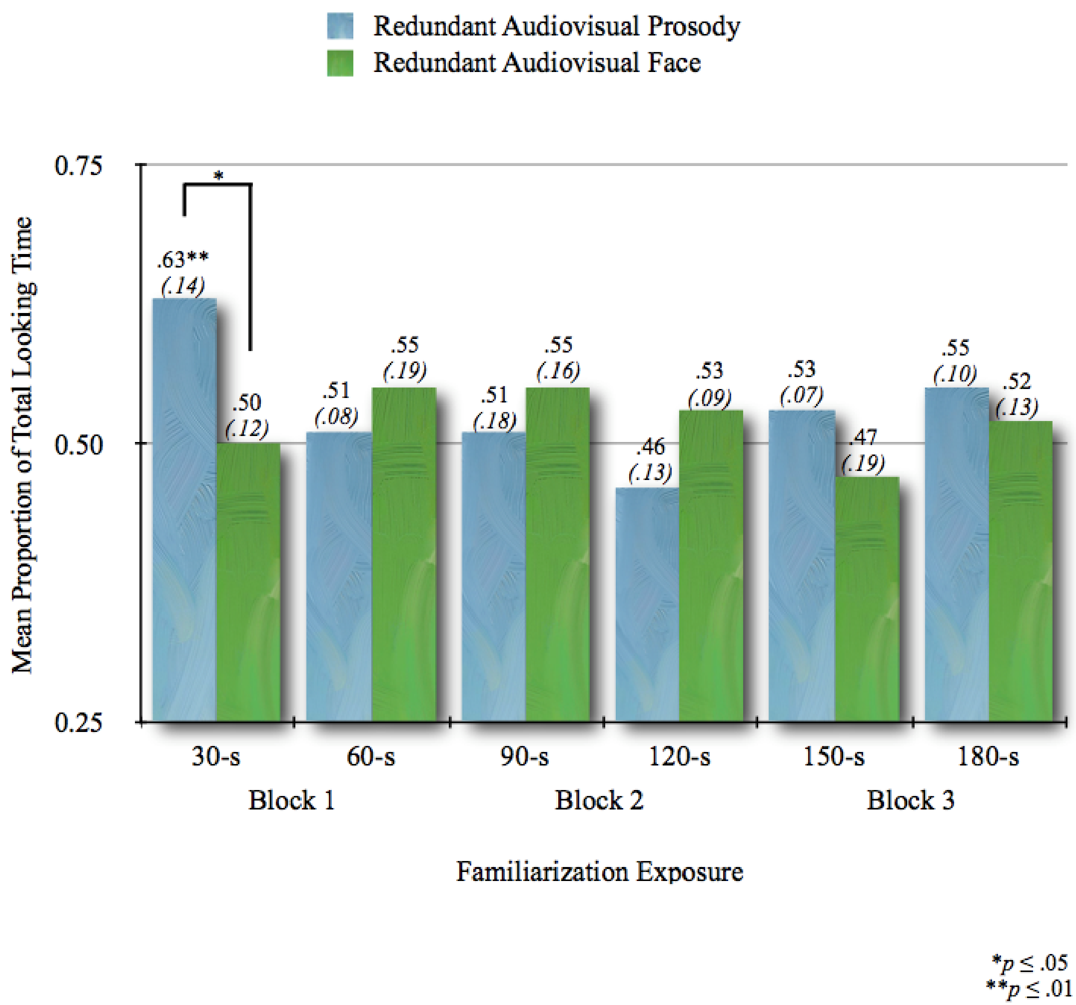


Figure 9. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of familiarization exposure time (30, 60, 90, 120, 150, 180-s) for infants classified as "learners" in the nonredundant unimodal visual condition (n = 27).

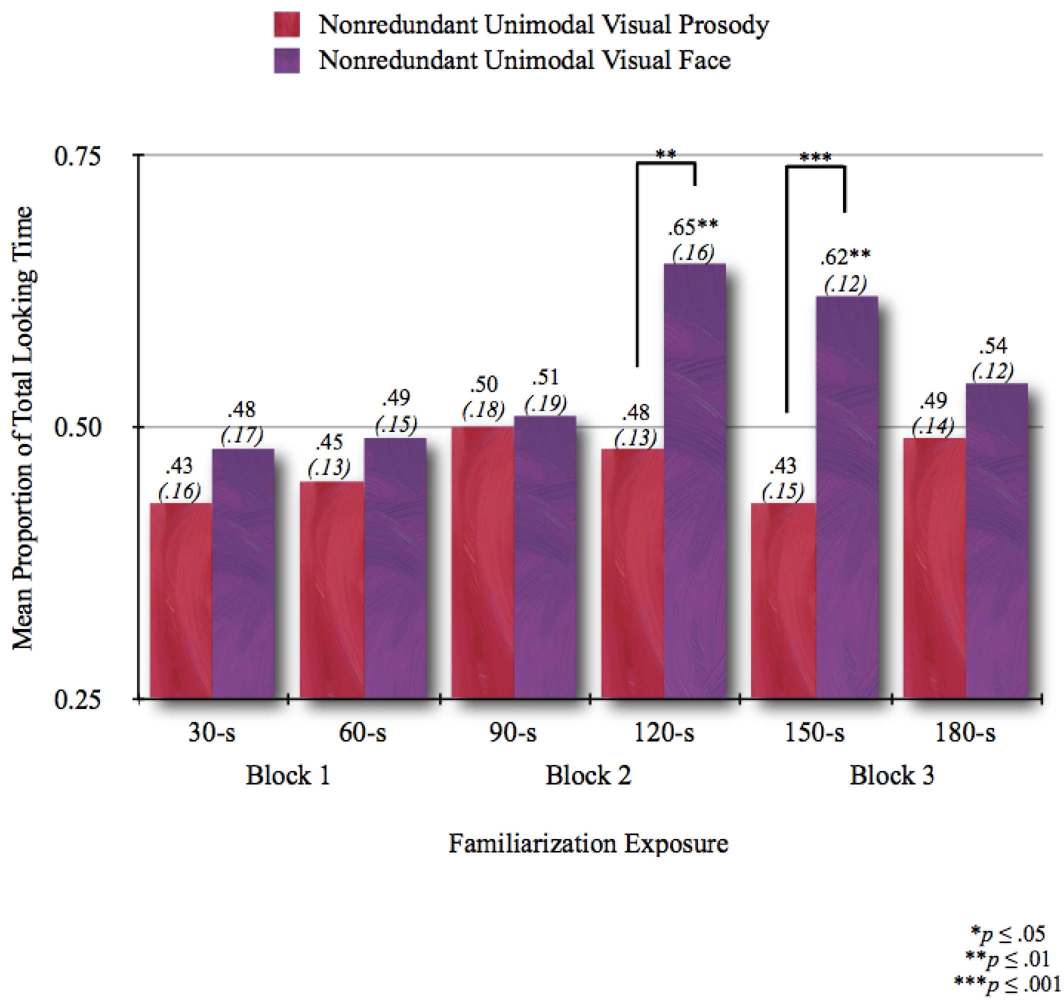


Figure 10. Mean proportion of total looking time (PTLT) to the novel prosody and novel face as a function of stimulus condition (redundant audiovisual, nonredundant unimodal visual) and familiarization exposure time (30, 60, 90, 120, 150, 180-s) for infants classified as “learners” (n = 52).

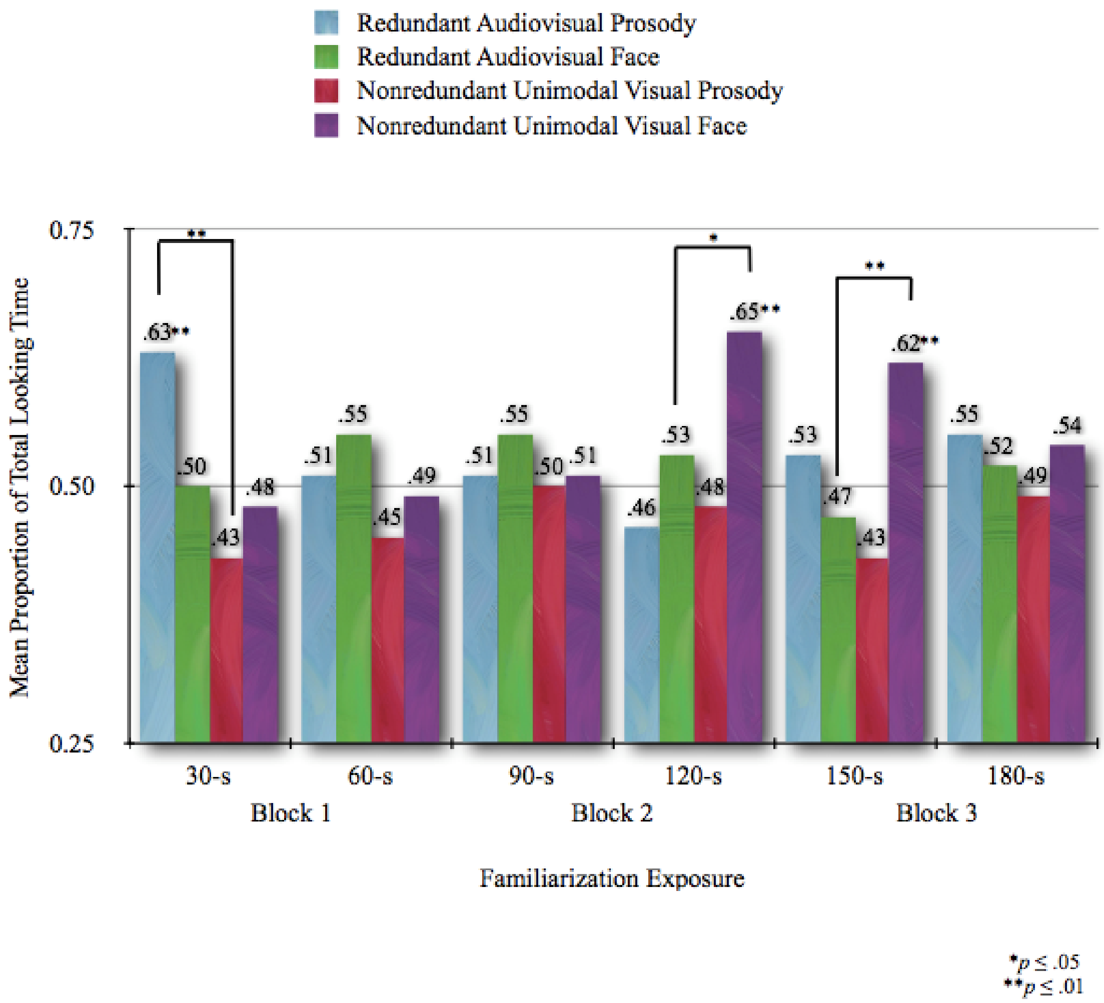


Figure 11. Infants' (n = 32) mean entropy as a function of stimulus condition (redundant audiovisual, nonredundant unimodal visual) and familiarization exposure (block 1, block 2, block 3). The plotted line indicates the significant linear decrease of familiarization exposure block.

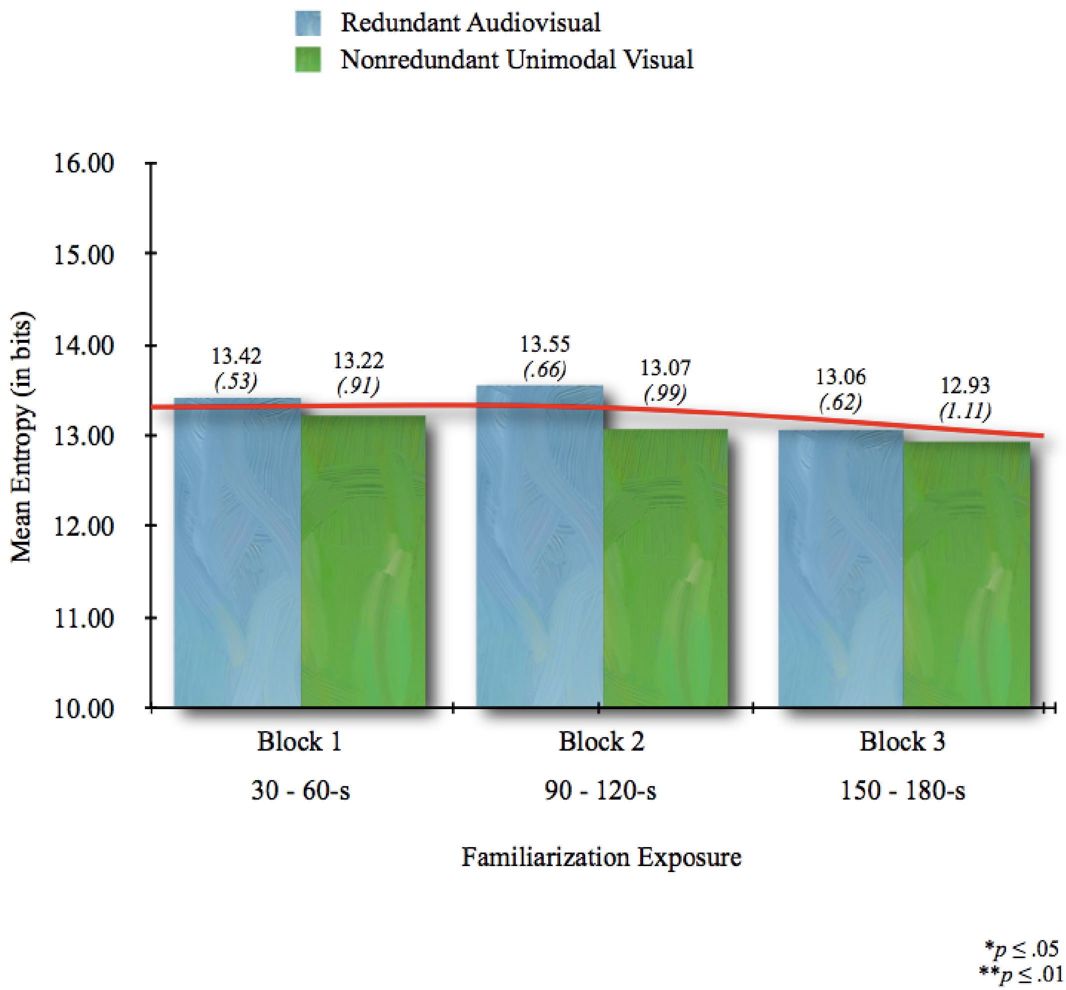


Table 1. Predicted results for infants' discrimination of prosody of speech and facial identity as a function of stimulus condition (redundant audiovisual, nonredundant unimodal visual). It was predicted that infants in the redundant audiovisual condition would display discrimination of prosody of speech before discrimination of facial identity. Conversely, it was predicted that infants in the nonredundant unimodal visual condition would display discrimination of facial identity before discrimination of prosody of speech.

Stimulus Condition	Congruent with Hypothesis	Incongruent with Hypothesis
Redundant Audiovisual	Prosody First → Facial Identity Second	Facial Identity First → Prosody Second
Nonredundant Unimodal Visual	Facial Identity First → Prosody Second	Prosody First → Facial Identity Second

Table 2. Infants' (*N* = 64) mean proportion of available looking time (PALT) (and *SD*) as a function of stimulus condition (redundant audiovisual, nonredundant unimodal visual) and familiarization exposure (block 1, block 2, block 3).

Stimulus Condition	**Block 1**	**Block 2**	**Block 3**
Redundant Audiovisual	.89 *(.10)*	.83 *(.14)*	.81 *(.17)*
Nonredundant Unimodal Visual	.85 *(.18)*	.78 *(.21)*	.78 *(.19)*

VITA

IRINA CASTELLANOS

2004	B.A., Psychology, *Cum Laude* Florida International University Miami, FL
2004	National Institutes of Health (NIH) Travel Award International Society on Infant Studies
2005-2006	Graduate Student Scholarship Florida International University Miami, FL
2006-2011	MBRS Research Initiative for Scientific Enhancement (RISE) Fellowship Funded by the National Institutes of Health (NIH) Florida International University Miami, FL
2006	National Institutes of Health (NIH) Travel Award International Society for Developmental Psychobiology
2007	M.S., Life-Span Developmental Science Florida International University Miami, FL
2011	National Institutes of Health (NIH) Travel Award International Society for Developmental Psychobiology.

PUBLICATIONS

Bahrick, L. E., Lickliter, R., Castellanos, I., & Vaillant-Molina, M. (2010). Tempo discrimination in infants: The roles of intersensory redundancy, task difficulty, and expertise. *Developmental Science 13,* 731-737.

PUBLISHED ABSTRACTS AND SELECTED PRESENTATIONS

Bahrick, L. E., Lickliter, R., & Castellanos, I. (2011). Intersensory redundancy educates infants' attention to the amodal property of tempo. *Developmental Psychobiology, 53,* 739.

Castellanos, I., & Bahrick, L. E. (2008). Educating infants' attention to the prosody of speech: The role of intersensory redundancy. *Developmental Psychobiology, 50,* 724.

Castellanos, I., & Bahrick, L. E. (2007, March). *Intersensory redundancy educates infants' attention to amodal properties in speech during early development*. Poster presented at the Society for Research in Child Development, Boston, MA.

Castellanos, I., Vaillant-Molina, M., Bahrick, L. E., & Lickliter, R. (2006). Intersensory redundancy educates infants' attention to amodal information during early development. *Developmental Psychobiology, 48,* 607.