# SPEECH ACCENT CATEGORIZATION IN INFANCY


by

Ting-ting Chung

Psychology, BS, National Taiwan University, 1995

Information Science, MSIS, University of Pittsburgh, 2001


Submitted to the Graduate Faculty of

Arts and Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy


University of Pittsburgh

2002

UNIVERSITY OF PITTSBURGH

FACULTY OF ARTS AND SCIENCES

This dissertation was presented

by

Ting-ting Chung

It was defended on

November 21, 2002

and approved by

Celia Brownell, Ph.D.

Carl Johnson, Ph.D.

David Rakison, Ph.D.

Mark Strauss, Ph.D.
Dissertation Director

Speech Accent Categorization in Infancy

Ting-ting Chung, PhD

University of Pittsburgh, 2002

The goal of this thesis is to investigate the period of time during which infants begin to categorize accents in natural speech, and the role of experience in mediating the development of speech accent categorization. The approach consists of establishing the adult state of speech accent categorization and measuring infants' speech accent categorization at 4 and 10 months using the infant-controlled visual habituation paradigm. The studies presented here were designed to examine if infants and adults can discriminate a local accent from a novel accent in the native language, if they can discriminate two novel accents in the native language, and if they can discriminate two accents in an unfamiliar language. Study 1 examined discrimination of the Western Pennsylvania accent, the Hispanic New York Bronx accent, and the Chinese accent in the English language by 26 native English speakers from Western Pennsylvania, and 17 native Chinese speakers from Taiwan. The same participants also categorized the Mainland and Taiwanese accents in the Chinese language. Participants in both linguistic groups were equally competent at categorizing accents in their native language, and they were equally poor at categorizing accents in the foreign language. Study 2 examined discrimination of the Western Pennsylvania accent and the Hispanic New York Bronx accent in the English language in 18 4-month-old and 20 10-month-old infants from the greater Pittsburgh area. The 10-month-old infants showed significant discrimination of the familiar accent from the novel one, whereas the 4-month-old infants failed to do so. Study 3 examined discrimination of the Hispanic New York Bronx accent and the Chinese accent in the English language in 16 10-month-old infants. These infants showed significant discrimination between the two unfamiliar accents. Study 4 examined discrimination of the Mainland and Taiwanese accents in the Chinese language in 20 4-month-old and 16 10-month-old infants. Both groups failed to discriminate accents in this foreign language. These studies demonstrate that the ability to categorize speech accent emerges by 10 months of age, is language-specific, and results from experience with the native language.

ACKNOWLEDGEMENTS

I am in debt to many people intellectually, but most of all to Dr. Peter Gordon and Dr. Mark Strauss. Peter introduced me to the fascinating world of research on language acquisition; he was also instrumental in my journey to becoming a scientific writer. After Peter relocated, Mark continued to nurture my thinking in developmental psychology. He broadened my perspective to include infancy research, and encouraged me to study language development from diverse perspectives. Mark's generous support and invaluable guidance was key in the successful planning and execution of this research project. Both advisors provided an ideal environment for creative thinking and scholarly work. The friendships with them are immeasurable.

Special thanks go to Dr. Jenny Ganger and Dr. Suzanne Curtin for continuously challenging my ideas, and offering expertise in their areas. I would also like to thank Dr. Celia Brownell, Dr. Carl Johnson, and Dr. David Rakison for their service on my dissertation committee and their dedication to perfect the theoretical framework and empirical designs of the studies presented here.

I am deeply grateful to Lisa Newell, M.S., Catherine Best, and numerous undergraduate research assistants at the University of Pittsburgh Infant and Toddler Development Center for their assistance in recruiting and testing infants, Pei-chih Chung for recruiting and testing adult participants in Taiwan for this research, and Lisa Marcano for obtaining the Hispanic New York Bronx stimuli. I would also like to recognize the parents who brought more than 100 infants to participate in the studies at the center, for little reward other than the knowledge that they had contributed to the scientific understanding of speech perception development.

I would like to thank Dr. Zara Ambadar, Dr. Sallie Boggs, Dr. Marike Essl, and Dr. Yao-ting Sung for their insightful feedback on an early draft, and Dr. Erika Forbes and Amy Lin for proofreading this thesis. I am also thankful to Steve Galles, Vicki Gettinger and Dr. Garrick Wallstrom for statistical and technical assistance, and Bethany Peters for her assistance with phonological analyses. I appreciate their friendships and generosity.

Finally, my profound gratitude goes to my father Bo-chih Chung, my mother Chung-hui Huang, my sister Pei-chih Chung, my brother Chi-jieh Chung, and my husband Dennis Chang for their unconditional love and support.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## INTRODUCTION

When someone speaks, adults almost inevitably begin to categorize the voice in terms of gender, age, accent[1], and other dimensions of voice quality. Do infants do the same? The present paper offers an examination of developmental changes in speech accent perception during infancy. Speech accent perception is a robust psychological phenomenon in adults (Fledge & Hammond, 1982; Fledge, 1984). There is even evidence that 5 ½-month-old infants are capable of distinguishing British-accented and American-accented English speech stimuli (Nazzi, Jusczyk & Johnson, 2000). The mechanism underlying the development of this ability, however, has never been investigated systematically in the literature. The goal of the present paper, therefore, is to provide a theoretical discussion of the topic and empirical data from studies designed to examine if infants and adults can discriminate a local accent from a novel accent in the native language, if they can discriminate two novel accents in the native language, and if they can discriminate two accents in an unfamiliar language. Ultimately, the present paper hopes to offer evidence for the role of experience in the development of accent perception.

There are two ways of conceptualizing accent perception development. It can be viewed as the product of continual refinement in the speech perception system. Discrimination of fine phonological features may increase with age, and older infants' superior discriminatory skills may lead to perception of distinctions such as accent differences that may be unavailable to younger infants. Alternatively, younger infants may possess innate perceptual capabilities that allow them to make fine speech distinctions such as accent differences, which older infant may fail to perceive. In this view, the ability to perceive a change in accent would be subject to age-related changes in speech perceptual capabilities.

---

[1] In this thesis, the term "accent" refers broadly to pronunciation variations among linguistic groups. This includes variations in regional dialects (e.g., the Southern accent vs. the Brooklyn accent of the English language) as well as accents of non-native speakers (e.g., speech accent of native Chinese speakers speaking English.)

In addition to perceiving a change in accent from one speaker to another, accent perception may lead to a tendency to put speech input into distinct categories that are based on accent differences. Consequently, one would not simply notice accent differences in individual speakers, one would also be able to group certain speakers together on the basis of shared accent. Therefore, accent perception development can also be viewed as a process of categorization, which evokes the same mechanisms that underlie categorization in other domains such as natural kinds. The two processes, speech perception and categorization, are not, however, mutually exclusive. In fact, researchers such as Eimas, Siqueland, Jusczyk, and Vigorito (1971) showed categorical perception of consonantal contrasts. Kuhl (1993) also showed prototype-based vowel categorization in infancy. The two traditions, nonetheless, can predict different developmental trajectories. The present paper will begin with a discussion on what phonological features contribute to a speech accent. This will be followed by an examination of developmental models of accent perception predicted under each view.

**Accent Perception in Adulthood and Infancy**

What is a speech accent? A common use of the term "speech accent" refers to the unique qualities that characterize the identity of a linguistic group, as opposed to the unique qualities of an individual speaker. Particularly, speech accent is often categorized on a geographical basis (e.g., British English, Vietnamese-accented French, etc.), or an ethnic basis (e.g., Black English). It seems that accent portrays speech attributes that are common within a particular linguistic group and that set the group apart from others. Although the Chomskyan tradition tends to treat speech accent as a small and insignificant aspect of grammar (Chomsky, 1962, cited in Labov, 1991), others have suggested that the listener's ability to comprehend unfamiliar accents provides supporting evidence for a grammar that is applicable in all possible expansions of the phonological domain (Labov, 1972, cited in Labov, 1991).

Major (2001) observes that a foreign accent usually results from differences in a combination of individual nonnative phonetic segments (e.g., /ɛ/ in *Stella*), sequences of nonnative phonetic segments (e.g., the inability to produce the three onset consonants in *strong*), and nonnative prosody. Likewise, Foulkes and Docherty (1999) define accent as "differences of segmental or suprasegmental pronunciation and/or phonology" (p. 5). Anderson-Hsieh, Johnson and Koeler (1992) found that prosody, as opposed to segmentals and syllable structure, showed the strongest effect on perceived accent, although all three properties showed significant influence on pronunciation ratings. These findings are based on studies of foreign accents, but they are probably applicable to native regional accents (e.g., the New York accent of English).What characterizes a speech accent, however, varies dramatically from one accent to another, and from one language to another. For example, voice onset time is inversely correlated with the perceived degree of foreign accent in Brazilian Portuguese speakers learning English (Major, 1987), and among Japanese speakers learning English (Riney & Takagi, 1999). Vowel quality, on the other hand, seems to be the most critical feature defining the accent of Vietnamese children learning Australian English (Ingram & Pittam, 1987). In their ratings of Spanish-accented speech, vowel quality, consonant manner changes (e.g., /tʃ/ versus /ʃ/), and lexical and phrasal stress (Magen, 1998) are among the strongest factors for American adults.

The studies presented here used speech accents in two languages and the accents differed in many respects within each language. The same English paragraphs were read by speakers who grew up in Western Pennsylvania, native New York Bronx speakers of Hispanic descent, and native speakers of Mandarin Chinese who grew up in Mainland China. Phonological transcriptions of these paragraphs in Mandarin Chinese were read by native Chinese speakers from Mainland China and Taiwan, two groups of speakers that demonstrated distinct accents.

The Hispanic New York Bronx accent stimuli used in the studies presented here contain features related to segmental pronunciation often noted in the accent perception literature. One of them is the most well known feature of the New York accent, the derhotacized /r/[2] at syllable endings in words such as *her, four* and *store*. Other notable features include roundedness in the vowel sounds in words such as *all*, *frog*, and *also*. The Western Pennsylvania accent, in contrast, shows the rhotacized /r/ sound and a more centralized vowel production. On the other hand, the Chinese-accented English stimuli reveal quite different phonological features. Most notably, the Chinese speakers tended to demonstrate final consonant deletion. Consonant deletion was also common in consonant clusters (e.g., deletion of the /l/ sound in *blue*). In addition to segmental pronunciation, the Chinese speakers also displayed prosody and stress patterns that deviated from standard English.

The two accents in the Chinese language used in the present studies differ from each other quite significantly as well. For example, compared to the Taiwanese speakers, the Mainland Chinese speakers showed much stronger rhotacized /r/ sounds. They also exhibited more gliding in their pronunciation. In some instances, they displayed lower vowel sounds, which in turn caused lower consonant sounds as a result of coarticulation. The two accent groups demonstrated quite distinct place of tongue in pronunciation.[3]

Speech accent perception is robust in adults: Adult listeners can detect the French accent after exposure to a sample speech as short as 30 milliseconds (Fledge & Hammond, 1982;

---

[2] A rhotacized vowel is a vowel colored with the sound of an *r*; a derhotacized vowel is a vowel with reduced sound of an *r*. The British English, for instance, is well known for its derhotacized *r* at syllable endings.

[3] This informal phonological analysis of the speech accents used in the present studies was confirmed by a speech pathologist in training.

Fledge, 1984). Even untrained listeners make accurate foreign accent judgments reliably (Magen, 1998). Listeners of accented speech, however, are unreliable when asked to provide introspections about what features constitute the perception of a speech accent (Calla McDermott, 1986, cited in Magen, 1998). This suggests that accent perception is a psychologically real phenomenon, but its process is highly implicit.

The ability to detect a speech accent requires expectation of a typical manner of speech. Even within the same linguistic community, speakers talk with considerable variation in voice, speaking rate and frequency. Yet these speakers often share certain speaking qualities that are distinct from the way members of another linguistic community speak. These qualities, in turn, define what people refer to as speech accent. Perception of a speech accent thus requires attention to the speech norm. It is as if the listener has a prototype construct of the native speech signals (Fledge, 1984).

There are good reasons to believe that infants may have the ability to perceive different speech accents. Infants have demonstrated abilities to detect vowel change at as early as one month of age (Trehub, 1973), abilities to discriminate consonantal contrasts at as early as one month of age (e.g., Eimas et al., 1971), sensitivity to speech prosody soon after birth (e.g., Nazzi et al., 1998), and sensitivity to coarticulation by 7 months of age (Curtin, Mintz, & Byrd, 2000). Since these phonological qualities have been demonstrated to play a critical role in defining a speech accent, it is reasonable to believe that infants have the physical capacity to perceive a foreign speech accent.

There is some evidence that children, and even infants, demonstrate speech accent perception or acquisition. Several studies have reported that children as young as three to 4 years old show signs of acquiring a novel accent following family relocation (Payne, 1980; Roberts,

1997) and lowered comprehension due to an unfamiliar accent (Nathan, Wells, & Donlan, 1998). Nazzi, Jusczyk, and Johnson (2000) have also found a small but significant difference in American 5 ½ -month-old infants' looking behavior when presented with American and British English[4]. Thus, the ability to detect a speech accent must emerge at some point in development.

If the infant can perceive speech accent, when does the ability appear? What is the developmental trend? The following sections review additional evidence suggesting the likelihood of accent perception in infancy, and the different developmental trends that can be predicted from existing literature.

**Developmental models based on speech perception in infancy**

There is no question that experiences with the native language play a significant role in shaping the development of speech perception. Accent is a specific type of the native language. Accent perception, therefore, can be subject to similar influences from exposure to the native language. The following review on currently available accounts of speech perception at the phonemic and continuous speech levels suggests the following:

1. Accent perception occurs in infancy
2. Accent perception may increase or decrease as a function of age
3. Accent perception may undergo a developmental change at around 10 months of age

Most of the current research on speech perception abilities during the first year of life focuses on the infant's increasing knowledge about the native language (Aslin, Jusczyk, & Pisoni, 1998). However, available research suggests that basic speech perception capacities are in place soon after birth, even before experience begins to have much impact on speech perception. Pioneering work by Eimas et al. (1971) has demonstrated that infants as young as 1

[4] Nazzi et al. (2000), however, treated British English as a foreign language in the same rhythmic class as American English.

month old are sensitive to the subtle phonetic contrast between /ba/ and /pa/. Their finding has led to a series of investigation on perception of consonantal contrasts. Researchers now believe that the ability to discriminate various kinds of place of articulation contrasts is present at birth (see Jusczyk, Houston, & Goodman 1998, for a review.) Similarly, 1-month-olds are able to discriminate vowel sounds such as /a/ and /i/ (Trehub, 1973). More impressively, infants are capable of discriminating non-native speech contrasts that adults may fail to hear. For example, Japanese adults are known to have difficulty discriminating the English /r/ versus /l/ sounds (Miyawaki, Strange, Verbrugge, Liberman, Jenkins, & Fujimura, 1975). Trushima, Takizawa, Sasaki, Siraki, Nishi, Kohno, Menyuk, and Best (1994, cited in Jusczyk et al., 1998), however, have shown that Japanese infants are able to discriminate these two sounds at six to eight months, although this ability is lost in 10- to 12-month-olds. Werker and Tees (1984) reported a similar decline in sensitivity to nonnative consonantal contrasts in English-learning infants. Polka and Werker (1994), however, reported sensitivity to nonnative vowel contrasts in 4- to 6-month-old infants. The ability to discriminate nonnative vowel contrasts also declined at an earlier point in development.

In contrast, Lasky, Syrdal-Lasky, and Klein (1975) found that the initial voicing categories of Spanish-learning infants in Guatemala were in fact closer to those used in English than to those used in Spanish. The phonetic categories with which the infant is born, thus, do not necessarily map directly onto those used in the target language. Exposure to the native language, therefore, must play a critical role in shaping adult-like categories that infants eventually possess. These studies suggest that infants are probably endowed with an array of discriminatory abilities to differentiate potential speech sounds and patterns. These abilities are fine-tuned later in life by speech input towards the target language, causing an increase of fine discrimination among native sounds and a loss of discrimination between nonnative contrasts.

In addition to sound discrimination at the phonemic level, newborns are sensitive to the prosodic features of linguistic input. Supporting evidence comes from the observation that even newborn infants can discriminate their native language from a foreign language (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988; Moon, Penneton-Cooper, & Fifer, 1993). They can even discriminate between two foreign languages if the two languages differ rhythmically and if one of the languages is prosodically close to the maternal language (Nazzi, Bertoncini, & Mehler, 1998). These initial discriminations are largely based on the rhythmic properties of the native language (Nazzi et al., 1998). At 4 months of age, infants of bilingual families have no problem discriminating the two target languages, even if the two languages are prosodically similar to each other, such as Spanish and Catalan (Bosch and Sebastian-Galles, 1997, 2001). These findings suggest that sensitivity to prosody, and rhythm in particular, is present from very early on. It is fine-tuned over time by language experience.

These two lines of research, although at different levels of speech processing, point to the same fact: Exposure to the native language constantly interacts with the infant's innate discriminatory abilities to prepare the child for learning the native language. The research on phonetic contrast perception suggests that the speech perception system is initially overloaded with redundant capabilities which get sharpened toward the target language. The findings on language discrimination, however, paint a picture of broad, prosody- and rhythm-based identification skills that become more narrowly focused on the target language. Since speech accents are often marked by phonemic or prosodic features, it is possible that the development of accent perception goes through the same course of refinement over time.

In addition to segmental pronunciation and prosody, word and syllabic segmentation is also important in accent perception. For example, the ability to detect a derhotacized /r/ sound at syllable endings depends on the ability to identify syllable boundaries. Similarly, unusual syllabic stress patterns are noticeable only if syllables are properly segmented. Impressively, by 8 months of age, infants appear to have the capacity to achieve word segmentation by paying attention to transitional statistics (Saffan, Aslin, & Newport, 1996a), distributional cues (Saffran, Newport, & Aslin, 1996b) and speech cues such as coarticulation and stress (Johnson & Jusczyk, 2001). Coarticulation cues are also used by 7-month-old infants for processing syllable sequences (Curtin et al., 2000). Segmentation, therefore, is part of the infant's speech processing system, although it may not be available until the second half of the first year of age.

Two models of accent perception development are conceivable under the current understanding of speech perception in infancy. On one hand, if accent perception is a highly instinctive process that relies on innate speech perception capabilities, a younger infant may demonstrate discrimination of any accent contrast. As the infant grows older, increased exposure to the native language would cause attrition in the discrimination of accents the infant never hears. Under this model, the trajectory of accent perception development would parallel that of phonemic discrimination with a sharp decrease in the discrimination of low-frequency contrasts at the age of 10 to12 months.

On the other hand, prosody plays an important role in defining an accent as well. The increased sensitivity to prosodic cues over time implies that accent perception may show improvement with age. Besides, loss of sensitivity to non-native contrasts may suggest increase in sensitivity to native contrasts that the infant has experienced. Accent detection is categorical perception of within-language differences. If the infant becomes increasingly sensitive to within-language contrasts, he or she may also become more prone to hearing a difference in accent. Adding to this developmental progression the ability to segment syllables and words, accent perception should become more likely as the infant grows older. Besides, although sensitivity to separate speech cues increases over time, the infant does not show coordination of simultaneous use of multiple sources of information until 10 months (Diamond, Werker, & Lalonde, 1994; Lalonde & Werker, 1995). On these accounts, accent perception could be modeled as increasingly stronger over time, with 10 months as a potential turning point.

Both models are consistent with the "attunement" theory proposed by Aslin and colleagues (Aslin & Pisoni, 1980; Aslin et al., 1998) to explain how experience contributes to the development of speech perception. They suggest that infants are born with rudimentary speech perception abilities. These abilities are partially developed at birth. Experience with the native language facilitates development, and maintains discriminatory abilities for the native language. At the same time, the abilities not utilized in the months after birth are lost in the attunement process. It is not clear if the ability to perceive speech accent could be considered as a "rudimentary" skill. It may or may not be present at birth. However, since accent perception is strong in adulthood, the skill must become available some time during development, and be maintained through experience. If experience plays a critical role in accent perception, the effect would be language-specific. The studies presented in this paper were designed to test these ideas.

Both models are also consistent with Werker and Tees' (1999) speculation that speech perception undergoes a fundamental shift, a "functional reorganization," (p. 525) at 10 months. Before 10 months, infants seem to be able to attend to only one speech cue at a time when given a speech task. During and after 10 months, they begin to integrate two or more cues, at least in a word segmentation task (Lalonde & Werker, 1995). Therefore, a change in behavior should be observable between the 4- and 10-month-olds tested in the present studies, whether it is an increase or decline over time.

**Developmental model based on categorization**

An alternative way of conceptualizing accent perception is to view it as a categorization process. When one distinguishes one group of speaker from another on the basis of speech accent, one is categorizing speech into different categories. What happens is probably similar to the process of distinguishing poodles from golden retrievers within the dog category. In a way, the native language can be conceived as a category at the basic level by Rosch and Mervis's (1975) definition in the linguistic domain. Subsequently, accent perception could be construed as categorization at the subordinate level. The following review of available evidence about infant categorization suggests the following:

1. Infants are able to categorize speech input at the basic level.
2. Infants are able to categorize speech input at the subordinate level, and as a consequence, are able to categorize accent.
3. Infants are able to form speech prototypes, which may allow them to develop accent-based prototype constructs.
4. Accent categorization results from experience with the native language, and is not a mere product of maturation.
5. Accent categorization is limited to accent contrasts in the native language.

Infants certainly can categorize speech information. This is manifest in their categorical perception of phonemes such as /ba/ and /pa/ (Eimas, Siqueland, Jusczyk, and Vigorito, 1971). Nonetheless, can infants categorize speech input on a higher order? Considering the native language as a category, one could imagine an internal structure with a typicality distribution centered around a prototype. The most typical accent, the local accent, is perhaps the way a person would most likely expect others to speak, and would serve as a prototype of the category, with other accents as members of the same category deviating from the prototype to varying degrees. Under this view, accent perception would be contingent upon the ability to categorize at a more specific level.

If the view that the native language is a basic-level category is accepted, the construct of the native language category plausibly develops in the first year of life. The basis of this speculation is twofold. First, it is based on the finding that infants can form basic-level categories of concrete objects, such as dogs, cats, and chairs, by three months (Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993). Notably, the authors argue that these early categories are perceptually based, forming as a result of available visual cues, as opposed to conceptual understanding that gives the categories meanings. If infants are able to form the native language category, it is probably perceptual in nature, or at least so initially.

Second, the observation that infants can distinguish different languages based on their rhythmic properties (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988; Moon, Penneton-Cooper, & Fifer, 1993) suggests that infants begin to form a broad concept of the native language based on global, less specified information about the speech input. Although these studies do not offer direct evidence for the construct of the native language category, they do indicate the infant has the potential capabilities to do so. Taken together, the infants' ability to categorize at the basic level, and their ability to distinguish the native language from others (in a broad sense) indicate the construct of the native language category is likely to emerge by the end of the first year of life.

Similarly, if the view that accent categories represent levels of abstraction subordinate to the natural language category is empirically valid, it is possible that infants can categorize accent. This is because there is evidence for subordinate-level categorization of at least some natural kinds. By 8 months, infants can distinguish male and female faces if they are highly typical (Newell, 2001). If one considers the human face a basic-level construct, the infant's sex categorization represents a subordinate process. Similarly, Eimas, Quinn and Cowan (1994) demonstrated that 3- to 4-month-old infants' category of "cats" excluded female lions, indicating subordinate-like categorization. Both findings derive from natural categories (i.e., human faces and cats). Speech is a natural kind; thus subordinate categorization of speech input may be possible in infancy.

If infants can categorize accent, however, their accent categories must be perceptually based, rather than conceptually based. The phonological features in the linguistic input may be distinct enough for the infant to notice a change in accent, but by no means would one expect the infant to associate an accent with a meaningful linguistic group, such as the Hispanic New York speakers, as adults do. Although it is still debatable if perceptual categorization can be a process independent from conceptual categorization (Mandler, 2000; Quinn, Johnson, Mareschal, Rakison, & Younger, 2000), early accent categorization would be clearly perceptually based. Once demonstrated, infant accent categorization would also be evidence supporting the view that perceptual categories can precede conceptual ones.

Language categorization poses the same normalization problem that categorization of concrete objects faces. Every dog is distinct; however, somehow, at some level, people put all dogs in one category, and all cats into another. Similarly, everyone speaks with unique qualities. Nonetheless, listeners group all instances of spoken English into one category, and all instances of spoken French into another. The process of normalizing diverse linguistic samples and recognizing a common language across them is not a trivial task. The same obstacles apply to speech categorization at segmental levels. In fact, speaker variability presents one of the greatest challenges to automatic speech recognition devices (Rodman, 1999). Even so, empirical data reveal that infants are also able to ignore irrelevant speaker variations while discriminating vowel categories (Jusczyk, Pisoni, & Mullennix, 1992; Kuhl, 1979, 1983; Kuhl & Miller, 1982), although sometimes at the expense of reduced memory.

If infants can construe the native language as a basic-level category, would the category be prototype based? Before answering this question, we must consider if the infant is capable of forming prototypes in the speech domain at all. Remarkably, prototyping is conceivable at various levels of speech processing in infancy. At the phonemic level, Kuhl's (1993) Natural Language Magnet theory suggests that prototypes are formed in infant vowel categories. Specifically, Grieser and Kuhl (1989) trained 6-month-old infants with either a good (prototypical, adult-rated) or a poor exemplar from a vowel category. They found that subsequently 6-month-old infants showed greater generalization to novel members of the category following exposure to the prototypical exemplar. The infants showed significantly less generalization to novel members of the category following exposure to a poor exemplar (see also Kuhl, 1991). They use this finding to argue that infants form prototypes of phonemic categories, which may contribute to the efficient processing of speech information. This suggests that infants not only perceive many of the adult phonemic categories, they are also sensitive to the internal structure of these categories. This also suggests that phonemic categories, like other categories, may be organized around prototypes. It is not clear if similar prototypes exist for consonant categories. Nevertheless, Kuhl and colleagues' research demonstrates the infant's prototyping process at the phonemic level.

At the syllabic level, a prototype-based model was developed by Mehler, Dupous, and Segui (1990) to explain the acquisition of a lexicon. The model consists of a syllabic filter, a phonetic analyzer, and a word boundary detector. The syllabic filter, in particular, allows only legal syllable structures, such as CV (Consonant-Vowel, such as /pa/), CVC (e.g., /pat/) and CCVC (e.g., /bruk/) in English, to pass. The phonetic analyzer, on the other hand, describes the phonetic structure of a syllable. The word boundary detector then uses syllabic representations along with other information to compute word boundaries. Most importantly, the model postulates two specialized mechanisms that account for changes in the infant's capacity to process the native language. One is unlearning, or selective stabilization. This refers to the system's gradual adaptation to the syllables, phonetic contrasts, and word boundaries that work best for the language. The other mechanism is compilation, the process of storing syllable templates into long-term memory. In essence, Mehler et al.'s (1990) model provides explanations for speech prototyping at the syllabic level. Syllabic templates, or prototypes, although not empirically established, are theoretically conceivable.

Similarly, a prototype-based model is available for word recognition. Suomi (1993) proposes that each word entry in the lexicon consists of a motor plan and an auditory prototype. The prototypes are normalized, and contain the essential auditory details of the word across different contexts. Jusczyk's (1992) model of word recognition and phonetic structure acquisition makes similar assumptions, although he argues that listeners store specific instances of words they hear, rather than abstract prototypes. The main problem with a system that stores individual instances, as opposed to prototypes, is the potential explosions in the amount of information in the lexicon. Nevertheless, whether the listener stores prototypes or individual instances, these mental representations of speech input would eventually lead to a normalized representation of words in the native language.

There is, however, little indication as to whether infants can form prototypes at the sentential level. The stimuli used in the present studies were conversational speech that contained whole sentences. Therefore, to perceive accent change in these stimuli may require prototype formation at the sentential level, or at least across a string of syllables. Nevertheless, continuous speech consists of phonemes, syllables, and individual words. Since infants form prototypes of these elements of continuous speech, very likely they are also capable of forming prototypes, particularly speech accent with continuous speech.

Taken as a whole, empirical and theoretical work available thus far strongly suggests that infants can categorize speech input, and form prototypes at various speech levels. Following the notion that the local accent represents a prototype of the native language category, infants' ability to categorize and form prototypes establishes the possibility that the infant would be sensitive to the accent differences within the native language.

If infants categorize accent, what abilities would allow them to accomplish the task? Speech perception seems to be a well developed system that allows infants to begin sampling information in the environment even before birth (DeCasper & Spence, 1986). Based on the speech sounds in the surrounding environment, infants can soon begin to establish expectations of sounds in their native language. Experience with the native language eventually allows the infant to form a native language category similar to an adult-like basic level category. Increasing experience provides content to the category. Infants' category-formation capacities, in turn, act on the experience, calculate the range of possible values for speech sounds, extract typicality distribution, and form boundaries of the category. The infant's experience, nevertheless, is likely to be restricted to the local accent. Therefore, pronunciation of the local accent serves as the foundation of the native language category. The more experience the infant has with the local accent, the more likely it would influence his or her prototype of the category. Furthermore, extensive experience with the native language attunes the infants' knowledge about the language, thus allowing the infant to make subtle discriminations between subordinate categories within the main category. On the other hand, since subtler discrimination results from experience with native language, and not a mere maturational process, the hypothesis also predicts that infants would not show a parallel increase in discrimination of subordinate categories within a non-native language.

To summarize, accent perception seems to be a manageable task for infants, either from a speech perception point of view, or from a categorization point of view. The question is at what point of time in infancy the ability would emerge, and what the developmental trajectory would be. The studies presented here tested 4- and 10-month-old infants because speech perception seems to undergo fundamental changes around 10 months, and therefore it was interesting to evaluate what the infant can accomplish around and before that time. Moreover, whether the infant shows accent perception at 4 or 10 months, the discriminatory abilities should be restricted to the native language, due to the role of experience in speech perception.

This thesis presents four studies designed to test these hypotheses. Study 1 examined the adult state of speech accent perception. Studies 2, 3 and 4 assessed infants' performance on similar discriminatory tasks.

In particular, Study 1 measured the ability of adult native speakers from the greater Pittsburgh area to distinguish the Western Pennsylvania (Ep) from the New York City/Hispanic

(Eny) accented speech samples. These samples were produced in the English language, and they were to be used in Study 2. These same adults also categorized two non-local accents: New York (Eny) and that of native Chinese speakers speaking English (Ec). These samples, again, were both produced in the English language. They were to be used in Study 3. Furthermore, these adult participants were instructed to categorize two accents of the Chinese language, produced in Chinese, not English, by native speakers of Chinese from Mainland China (Cm) and Taiwan (Ct). These were samples to be used in Study 4.

Study 2 examined whether 4- and 10-month-old infants born in Pittsburgh to native English-speaking parents were capable of discriminating the local speech accent they were familiar with (Ep) from the novel New York accent (Eny).

Study 3 examined whether 10-month-old infants born in Pittsburgh to native English-speaking parents can discriminate two novel accents of the English language. The New York (Eny) and Chinese (Ec) accents were presumably both unfamiliar to these infants.

Study 4 investigated whether Pittsburgh-born infants of native English-speaking parents can discriminate two accents in a foreign language (Chinese). The two accents were of speakers from Mainland China (Cm), and speakers from Taiwan (Ct).

Table 1 summarizes the comparisons conducted in Studies 2-4.

# STUDY 1

## Introduction

The purpose of Study 1 was to ensure that stimuli used in the following studies were acoustically discriminable to adult native speakers. Particularly, this study verified that the two pairs of American accents used in Study 2 (Western Pennsylvania, Ep, and Hispanic New York Bronx, Eny) and Study 3 (Hispanic New York Bronx, Eny, and Chinese, Ec) were equally discriminable to adult native speakers of English. It also confirmed that these three American English accents (Ep, Eny and Ec) used in Studies 2 and 3, and the two accents in the Chinese language (Cm and Ct) used in Study 4, were equally discriminable to their respective native speakers.

## Method

### *Participants*

Forty-five adults participated in this study. Twenty-six adult native speakers of English (age range=17-32 years, *M*=19.27 years, *SD*=2.78,) from the greater Pittsburgh area were recruited through the Introduction to Psychology subject pool. Fourteen of them were females (*M*=18.57 years, *SD*=1.02) and 12 were males (*M*=20.08 years, *SD*=3.87). They received course credit for their participation.

Nineteen adult native speakers of Mandarin Chinese from Taiwan who had never been in an English-speaking country for more than one year were recruited through word of mouth and tested in Taiwan. The majority of the Chinese participants received at least 3 years of mandatory education on English as a Second Language in school. English is commonly available in commercial advertisements, the news, and entertainment. However, English is not a common spoken language in Taiwan. These Chinese participants' exposure to the English language was roughly equivalent to an average native English-speaking adult's exposure to Spanish in certain parts of California such as Los Angeles, where people commonly read or hear fragments of Spanish. They received US$3.00 of compensation for their participation.

Two of the Chinese native speakers were excluded from the data analyses because their data suggested they were outliers. Their answers were incorrect on all items in their native language, indicating they did not understand the instructions or were unwilling to cooperate. The remaining 17 Chinese-speaking participants had an average age of 24.53 years (*SD*=4.09, range=18-30 years). Ten of them were females (*M*=24.30 years, *SD*=4.11), and seven were males (*M*=24.86 years, *SD*=4.38). The Chinese-speaking participants were significantly older than the English-speaking participants ($F(1,41)=25.28$, $p<.01$).

***Stimuli***

<u>*English speech samples for Studies 1, 2 and 3*</u>

Weinberger's (1999) accent elicitation passage was chosen to record speech accent samples of adult English speakers. Weinberger's speech accent archive is a collection of speech samples by speakers from various linguistic backgrounds. The elicitation passage used in the archive contains most of the speech sounds and clusters found in standard American English and includes only common English words. This passage is suitable for the purpose of the present experiment and thus was chosen to elicit the speech accents. The passage reads as follows:

*Please call Stella. Ask her to bring these things with her from the store: Six spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a snack for her brother Bob. We also need a small plastic snake and a big toy frog for the kids. She can scoop these things into three red bags, and we will go meet her Wednesday at the train station.*

The passage was modified into six slightly different versions (see Appendix I) as a way to counterbalance the order in which sequences of words appeared in each sample. These versions differed only in terms of the order of the sentences and things Stella was supposed to bring, with two exceptions: The sentence "Please call Stella" was changed into "Please call her" in passage 5, and it was incorporated into another sentence in passage 3:

*Please also call Stella and ask her to bring a big toy frog and a small plastic snake with her from the store for the kids.*

Six native English speakers from Western Pennsylvania, six native English-speaking Hispanic descents from the Bronx area of New York City, who considered English as their first and primary language, and six native Chinese speakers who considered English as their second language were assigned to read one of the elicitation passages. Therefore, a total of six speech samples were constructed in each accent category. All speakers were female and between the ages of 18 and 45. Note that the Chinese speakers read the passages in English. Speech samples were comparable in duration and quality of voice. See Table 2 for speaker age and duration of the speech samples. Durations were not significantly different across the three accent categories ($F(2,15)=.09$, $p=.92$).

*Chinese speech samples for Studies 1 and 4*

The Chinese elicitation passage was an approximate phonetic transcription of the six English elicitation passages. Phonetic transcription was chosen as an attempt to control for the distribution of phonological properties across the two languages. Chinese syllables with approximate pronunciation of syllables in the English stimuli were chosen to construct the

Chinese sentences. Since Chinese syllables contain semantic content, the syllables in the Chinese stimuli were readable and meaningful to the Chinese reader. Some of them even formed meaningful phrases. The sentences, however, were pronounceable but nonsense[5] because the syllables, albeit meaningful, did not form meaningful sentences because they were sequenced to match the syllables in the English stimuli and thus lacked grammatical and semantic coherence (see Appendix II). An equivalent of such sentences in English would be something like *Ashiko river sudden no soul*, although meaning was available more at the syllabic level in Chinese.

Six native Chinese speakers from Taiwan and six native Chinese speakers from Mainland China were assigned to read one of the elicitation passages. As a result, six speech samples were constructed in each accent category. All speakers were females between the ages of 18 and 45. Note that the speakers read the passages in Chinese. These speech samples were comparable in duration and quality of voice. Sample durations did not differ significantly across the accent categories ($F(1,10)=.10$, $p=.76$). See Table 3 for speaker age and duration of the speech samples.

***Apparatus***

The participants listened to voice recordings through a headphone connected to a Gateway PC in a computer classroom. They entered their responses by pressing designated keys on a keyboard.

***Procedure***

Up to 4 participants completed the study in the same room at the same time, although they each worked at their own pace. A survey of the participant's linguistic background was administered to ensure only native speakers of English from Western Pennsylvania, and native speakers of Chinese participated. The participants listened to the speech samples individually

[5] The Chinese stimuli were nonsense to native speakers of Chinese because preservation of phonological features is critical to the design of the studies and it could not be done without sacrificing semantics. Besides, even if the semantic content were preserved, it would be intelligible to the infants unless they understood Chinese.

once. The order in which the speech samples were presented was randomized across subjects. The participants' then heard the same speech samples again in the same order. During the replay, however, they saw two buttons labeled "Category 1" and "Category 2" on the computer monitor. They were instructed to sort the speech samples into two categories on the basis of speech accent after each sample was replayed.

Participants from both linguistic backgrounds were randomly assigned to two English conditions:

1. the Ep-Eny condition, where they categorized the Western Pennsylvania (Ep) versus New York (Eny) samples, or
2. the Eny-Ec conditions, where they categorized the New York (Eny) versus Chinese (Ec) accent samples.

There was only one Chinese condition. All participants participated in the Cm-Ct condition, where they all categorized the Mainland (Cm) and Taiwanese (Ct) accents in the Chinese language. The order of presentation was randomized across participants. Their categorization and reaction time were recorded through the computer program.

**Results**

***Error Rate Calculation.*** Error rate was calculated for individual participants. Table 4 shows an example of the error rate calculation. CT01-CT06 are six versions of the Taiwanese-accented Chinese stimuli; CM01-CM06 are six versions of the Mainland-accented Chinese stimuli. In this example, the scoring began with category 2, the category that received more votes. The first sample in category 2, CM03, was a Chinese-Mainland sample, and thus determined category 2 to be the Chinese-Mainland category, and category 1 to be the Chinese-Taiwanese category. Subsequently, each stimulus received an error score of 0 if it was categorized correctly and an error score of 1 if it was categorized incorrectly. The total error score was then divided by 12, the total number of stimulus files, to determine the rater's error rate. This ratio can be as low as 0%, but only as high as 50%, with the chance level established at 25%. The same error rate calculation was applied to categorization data on stimuli in the English language.

***Error Rate Results.*** Figure 1 demonstrates the error rate of each speaker group on the categorization tasks. Since age differed significantly across groups, all between-group comparisons were conducted with age as a covariate.

A one-sample t test demonstrated that the English speakers showed an error rate significantly less than chance ($t(13)=-6.92$, $p<.01$) in the Ep-Eny condition. Similarly, their error rate in the Eny-Ec condition was less than chance ($t(11)=-.47$, $p=0.01$). A one-way ANOVA indicated that the error rate of English native speakers did not differ significantly between the Ep-Eny condition and the Eny-Ec condition ($F(1,24)=2.04$, $p=.17$). Thus, the PN and NC comparisons were both easily discriminable to native speakers of English.

The Chinese speakers were equally adept at discriminating accents in their native language. A one-sample t test revealed that their error rate in the Cm-Ct condition was significantly less than chance ($t(16)=-3.27$, $p<.01$).

Comparison across the two linguistic groups revealed that the English and Chinese samples were equally discriminable to their respective native speakers. An ANOVA test of the participant's error rate on stimuli in their native language with native language as the between-subject variable and age as a covariate revealed that the Chinese speakers and the English speakers did not differ significantly on error rate in accent categorization in their native language ($F(1,40)=1.79$, $p=.19$).

Additional within-subject analyses indicated that the English speakers were significantly better at categorizing the English samples than the Chinese samples ($F(1,25)=121.29$, $p<.01$). Similarly, the Chinese participants showed a much lower error rate with the Chinese samples than the English samples ($F(1,18)=10.23$, $p<.01$).

With respect to both languages, between-language-group analyses with age as a covariate indicated that the native speakers performed much better than their non-native counterparts. The English-speaking participants performed significantly better than the Chinese-speaking participants on the discrimination of accents in English ($F(1,40)=32.73$, $p<.01$). Conversely, the Chinese-speaking participants performed much better than their English counterparts on the Chinese stimuli ($F(1,40)=34.73$, $p<.01$).

***Reaction Time Results.*** Table 5 summarizes mean reaction time of speakers from both linguistic groups by experiment condition and stimulus type.

When the two linguistic groups were analyzed separately, most tests revealed insignificant differences, except for one condition: The native English speakers were much slower when categorizing the Western Pennsylvania accent than the New York accent in the Ep-Eny condition ($t(12)=3.42$, $p<.01$). The English speakers' reaction time did not differ significantly between the New York and Chinese accents in the Eny-Ec condition ($t(12)=1.35$, $p=.20$), or the Mainland and Taiwan accents in the Cm-Ct condition ($t(25)=-0.74$, $p=.46$). Similarly, the Chinese speakers' reaction time differences between the Western Pennsylvania and New York accents ($t(8)=-0.55$, $p=.60$), the New York and Chinese accents ($t(7)=0.41$, $p=.69$), and the Mainland and Taiwan accents ($t(16)=-0.96$, $p=.35$) were not significant.

The New York accent was used in both English conditions Ep-Eny, and Eny-Ec. Interestingly, although not expected a priori, the English speakers were much faster with the

New York stimuli in the Ep-Eny condition than the Eny-Ec condition ($F(1,24)=9.05$, $p<.01$). The Chinese participants did not show the same effect ($F(1,15)=0.01$, $p=.92$).

To examine if there was an overall difference between the two languages, data were collapsed across accent categories within each language. The main effect in a repeated measures ANOVA with age as a covariate was not significant ($F(1, 40)=0.01$, $p=.95$), but its interaction with the speaker's native language was marginally significant ($F(1,40)=3.53$, $p=.07$). The performance was better when the participants were tested in their native language. Overall, the Chinese ($M$=8.64 seconds, $SD$=4.71) and English speakers ($M$=8.65 seconds, $SD$=3.19) were comparable in terms of reaction time ($F(1,40)=0.16$, $p=.69$).

**Discussion**

Results from Study 1 clearly showed the effect of native language on accent categorization. The participants showed low error rates when categorizing speech accents in their native language. They showed high error rates when categorizing speech accents from a foreign language. This was true whether the native language was English or Chinese. The two linguistic groups were also comparable in performance, indicating that one language was not acoustically harder to categorize than the other.

The reaction time data largely corroborated the error rate data. It also showed that in most cases reaction time to the two stimulus types within an experimental condition was comparable. However, the English speakers were slower in categorizing the Western Pennsylvania accent than the New York accent in the Ep-Eny condition. One explanation of this discrepancy is the familiarity effect. The English-speaking participants were all from Western Pennsylvania, and therefore they were familiar with the Western Pennsylvania accent, and unfamiliar with the Hispanic New York Bronx accent. The New York accent may have contained distinctive features that stood out against the familiar Pennsylvania accent, making them easier to distinguish. Although this explanation needs further exploration, the participants obviously reacted differently to the familiar accent than to the unfamiliar accent.

This speculation is consistent with the finding that reaction time to the New York accent is much slower in the Eny-Ec condition than in the Ep-Eny condition. Both the New York and the Chinese accents were unfamiliar in the Eny-Ec condition. It is possible that features that stood out in the two accents competed with one another, slowing down reaction time to both. Hence, although error rate did not differ significantly between Eny-Ec and Ep-Eny, reaction time data provide evidence that the Eny-Ec condition may evoke intrinsically less automatic processes, and present a potentially harder task, than the Ep-Eny condition to the Western Pennsylvanians.

The Chinese speakers, however, did not demonstrate the familiarity effect. All participants were from Taiwan, so they should have been more familiar with the Taiwanese accent than the Mainland accent. One possible explanation is that the increasing interaction between the two regions in recent years decreased the familiarity effect, although this speculation cannot be confirmed without additional research.

Overall, Study 1 confirmed the validity of the stimuli to be used in the following studies. The stimuli are comparable cross-linguistically, with the Eny-Ec condition possibly being slightly harder than Ep-Eny.

## STUDY 2

### Introduction

Study 1 established that the Western Pennsylvania accent and the Hispanic New York Bronx accent in English were perceptually discriminable to native English speakers who grew up in Western Pennsylvania. Study 2 extended the task to 4- and 10-month-old infants born in the same area. If these infants paid attention to language input in their surrounding environment, they should have found the Western Pennsylvania accent fairly familiar. In contrast, it was relatively safe to assume that the Hispanic New York Bronx accent was unfamiliar to these infants.

Using the habituation paradigm, Study 2 explored developmentally the point at which infants began to discriminate the familiar accent from an unfamiliar one. Four- and 10-month-old infants were tested. As reviewed in the Introduction, 4- and 10-month-old infants differ in a number of ways regarding speech perception. The goal of Study 2 was to provide empirical evidence for developmental changes in accent perception that occur between these two time periods in the first year of life.

### Method

#### *Participants*

Fifty-seven infants from the greater Pittsburgh area participated in the study. Data analyses excluded 19 infants, including eight for fussing, five for technical problems, 2 for failure to reach habituation criterion, 2 for lack of interest in the procedure, one for sleepiness, and one for non-native-English-speaking parents. The remaining 38 infants consisted of 18 4-month-old (9 females, 9 males, age range = 107-135 days, *M* = 121.89 days, *SD* = 8.44) and 20 10-month-old (9 females, 11 males, age range = 280-328 days, *M* = 300.15 days, *SD* = 13.09) infants. All participants were full-term infants with no birth complications. A marketing company supplied the infant names, which reflected the ethnic distribution of the area. Parents were contacted first by a letter describing the research and then by a phone call to schedule an appointment.

One criterion for participant inclusion was that English must be the only language spoken in the household. Eighteen infants (49%) had both parents from Western Pennsylvania. Nine infants (24%) had one parent from Western Pennsylvania, and one from other regions of the country. Neither parent of the remaining 11 infants (29%) was from Western Pennsylvania[6]. None of the parents was Hispanic descent from Bronx, New York City.

***Stimuli***

Samples of the Western Pennsylvania accent and the New York accent evaluated in Study 1 served as stimuli in this experiment. They were recordings of the "Please call Stella" passages by female speakers from Western Pennsylvania, and Hispanic female native speakers of English from the Bronx area of New York City. Five of the six speech recordings in one accent were randomly chosen across subjects to habituate the infant. The remaining recording and a randomly chosen recording from the contrasting accent were used in the test phase. During the stimulus presentation, a visual display of a bull's eye that blinked roughly every second accompanied the speech sample playback. An animated, captivating, brown-colored tunnel against a black background that turned three-dimensionally was used to attract the infant's attention to the computer monitor in the beginning of the study and between trials. Playful sounds were also played occasionally between trials, when necessary, to engage the infant.

[6] The rationale for including infants of non-Western Pennsylvanians is that infants may sample speech input from sources other than their parents. Anecdotes of children of first-generation immigrants often demonstrate that they speak without their parents accent (Harris, 1998). This suggests that other speakers in the community serve as important sources of linguistic input for the child learning the target language. Whether this is true in infancy is an empirical question that was examined in the present studies by including infants of non-Western Pennsylvanians.

### *Apparatus*

Testing took place in an enclosed test booth within a sound-attenuated laboratory room, next to a control station where the experiment was conducted. The test booth was almost completely dark. Looking behavior was recorded in the dark, captured by a video camera in infra-red conditions, and monitored on a 13-inch TV monitor. Light from the monitor illuminated the infant's eyes when he or she looked at the screen. This created a bright dot of light in the centers of the eyes, allowing the experimenter to determine whether the infant was looking at the visual stimuli. Visual stimuli and the inter-trial stimulus were presented on a 22-inch Gateway PC monitor. Auditory stimuli played through two Boston Sonic loudspeakers hidden above the monitor. Volume levels for the auditory presentation were set constant at the level of normal speech conversation throughout the entire study. Infants' looking behavior was continuously recorded through a computer program on a Gateway PC for later statistical analyses. A chair for the mother and the infant was placed at a distance of approximately 18-24 inches from the monitor. A computer program designed for the habituation paradigm was used to present audio-visual stimuli and record looking times on a Gateway PC.

### *Procedure*

Visual Habituation (Horowitz, 1975) is known for its sensitivity to assess subtle speech discriminatory abilities (see Werker, Shi, Desjardins, Pegg, Polka, & Patterson, 1998, for a discussion) and therefore was selected for the evaluation of accent discrimination. The present study used the infant controlled visual habituation paradigm. In other words, the habituation criterion was determined by the infant's own performance over the initial trials, rather than an arbitrary level set by the experimenter. Thus, instead of being a constant value, the habituation criterion varied across infants.[7]

The infant and the parent came in the laboratory for a single session. The experimenter interviewed the parent on a simple survey of the infant's linguistic background (see Appendix III). After the interview, the infant was tested while sitting on the parent's lap in the chair in the test booth. The parent wore headphones and listened to music during the entire session so that she or he was unaware of the presentation materials. The experimenter wore headphones for the same reason to prevent bias. The experimenter faced one of the TV monitors in order to monitor and record the infant's looking behavior on the computer continuously throughout the entire session. The computer program also controlled the stimulus presentation.

The computer procedure began with the inter-trial stimulus (the turning tunnel) used to attract the infant's visual attention. If the infant was not oriented to the screen, the experimenter played various sounds to center the infant's gaze. The experiment began when the infant looked at the screen. The experiment consisted of a habituation phase immediately followed by a test phase. The infant's looking times were recorded and maintained by the computer program.

***Habituation*.** The habituation phase began when the infant's gaze was centered at the PC monitor. When the infant looked centered, the experimenter pressed a mouse button to hide the inter-trial stimulus and bring up the habituation stimulus. As long as the infant was looking at the screen, the experimenter pressed and held down the button to record the infant's looking time. During each trial, the infant watched the bull's eye display and listened to a speech sample. The speech sample looped continuously as long as the infant looked at the screen. The experimenter

[7] The main advantage of the infant-controlled paradigm was that it accommodated individual differences among infants. Some infants may sustain a significant amount of attention over repeated stimuli, whereas others may quickly lose interest. The infant-controlled design, therefore, ensured saturation of stimulation from the habituation items by the time the test trials began and no infant was still interested in the familiar items.

released the button when the infant looked away for more than one second; otherwise the same trial continued. The bull's eye stayed on the screen, and the speech samples continued playing as long as the infant looked away for less than one second.[8] The part of the trial when the infant looked away for less than one second was excluded from looking time calculation for that trial. Once the infant looked away for more than one second, the trial ended. Both the visual and auditory stimuli ended, and the inter-trial stimulus reappeared to start a new trial. The time the infant spent listening to the speech stimulus, therefore, corresponded to the time looking at the bull's eye contingently.

Valid trials must be at least half a second long. Trials shorter than half a second were discarded and repeated. The infant reached the habituation criterion when the average of the last three valid looking times was less than 50% of the average of the first three valid looking times during the habituation phase. The test phase began as soon as the infant reached the habituation criterion. The program repeated the five accent samples in the same order if more than five trials were necessary to habituate the infant. The whole process repeated until the infant's looking time reached habituation criterion. If the infant did not habituate within 30 trials, the habituation phase ended anyway and the program proceeded to the test phase. However, the data of the non-habituated infants were excluded from data analyses.

The order in which the five accent stimuli were presented during habituation was randomized across infants.

*Test.* As mentioned above, the test phase began as soon as the infant reached the habituation criterion or if the infant failed to habituate within 30 trials. The test phase consisted

---

[8] The minimum requirement for look-away duration was implemented in an attempt to ensure that trials ended as a result of boredom (when the infant would likely sustain a looking orientation away from the monitor for more than one second), and not simply a result of involuntary head movement (when the infant would likely turn back to the screen within a second).

of eight trials. A novel sample of the habituated accent, and a sample from the contrasting accent played alternately for four times. Looking time was recorded for each trial in the same fashion with at least one second of look-away time, and half of a second minimum for trial duration. The program ended after the eighth test trial was presented.

The rationale behind the habituation paradigm was that if the infant had extracted a common representation of the habituation stimuli, a novelty effect should be observed if the infant perceived the test stimulus as representing a different speech accent. In this case, the infant would dishabituate and display an increase in looking time to the novel, but not to the familiar accent.

**Results**

***Habituation Data.*** During the habituation phase, the mean looking time over the initial three trials was used to establish habituation criterion. The mean looking time over the initial three trials and the number of trials it took the infant to reach habituation criterion are summarized in Table 6. In 4-month-olds, females (mean initial looking time = 44.62 seconds, $SD$=27.44; mean number of trials to habituate = 7.1, $SD$=7.4) and males (mean initial looking time = 25.72 seconds, $SD$= 35.64; mean number of trials to habituate = 6.2, $SD$=2.3) did not differ significantly, in terms of either the habituation criterion ($F(1,15)=0.18$, $p=.68$) or the number of trials to reach criterion ($F(1,15)=0.14$, $p=.71$). Similarly, no sex difference was significant in 10-month-olds with respect to either measure.

The 4-month-olds had significantly longer initial looking times than the 10-month-olds ($F(1,35)=21.20$, $p<.01$). However, the two age groups did not differ significantly with respect to the number of trials needed to reach habituation criterion ($F(1,35)=2.19$, $p=.15$).

Interestingly, the number of trials it took the 10-month-old infants to reach criterion differed by the habituated accent. It took the 10-month-olds 12.2 trials on average ($SD$=8.2) to habituate to the Pennsylvania accent, but only 6.7 trials ($SD$=2.6) to habituate to the New York accent. The difference was marginally significant ($F(1,18)=4.09$, $p=.06$). The 4-month-olds, on the contrary, did not demonstrate differences in the number of trials to habituate to the Pennsylvania accent ($M$=7.3, $SD$=6.6) and to the New York accent ($M$=5.7, $SD$=2.0) ($F(1,16)=0.52$, $p=.48$).

***Test Trial Data.*** Looking times to the novel test items were compared to the looking times to the familiar test items. Note that half of the infants received the Pennsylvania accent as the familiar item (they were habituated to the Pennsylvania accent), and the other half received the New York accent as the familiar item. Therefore, looking time calculation was collapsed between the two conditions. Mean looking times over the first pair of test trials, first 2 pairs of test trials, the first 3 pairs of test trials, and all 4 pairs of test trials were examined for this study. Since looking times are bound within a minimum (half a second) but no maximum, natural log transformations were performed on raw looking times to obtain normalized looking scores and to reduce variance. This approach would also make it less likely to violate statistical assumptions of ANOVA. Therefore, mean looking scores of the first pair of test trials, mean looking scores of the first 2 pairs of test trials, mean looking scores of the first 3 pairs of test trials, and mean looking scores of all 4 pairs of test trials were also examined in analyses for this study and all future analyses.

Half of the infants received a new instance of the familiar accent as the first test trial, and the other half received an instance of the unfamiliar accent. This strategy to counterbalance the presentation order effect, however, may influence the amount of dishabituation. Infants who received the novel accent immediately after the habituation phase may show a higher dishabituation rate. On the other hand, the familiar accent as the first test item may act as another habiatuation item, giving the infant additional sampling of the familiar accent, leading to a larger amount of disabituation. Therefore, in all data analyses below, the order of test trials will be entered as a between-subject factor.

*Anaylses of Raw Looking Times*

Figure 2 shows raw looking times of 4-month-olds and 10-month-olds during the first pair of test trials. ANOVA for repeated measures were performed separately for the two age groups with sex and test trial order as between-subject variables. Table 7 shows raw looking times of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect ($F(1,14)=0.08$, $p=.79$). Furthermore, the infant's sex did not interact with the novelty factor significantly ($F(1, 14)=1.10$, $p=.31$), and nor did the order of the test trials ($F(1,14)=0.23$, $p=.64$).

Table 8 shows raw looking times during the first test trial of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds looked significantly longer at the novel items ($M=11.14$ seconds, $SD=.8.68$) than at the familiar items ($M=7.42$ seconds, $SD=4.80$) ($F(1,16)=6.00$, $p=.03$). Sex showed a significant interaction with the main effect, with the female infants demonstrating a stronger novelty effect than the males ($F(1,16)=9.15$, $p=.01$). Whether the familiar or novel accent was presented first during test trials failed to show any significant effect ($F=2.61$, $p=.13$).

Figure 3 shows raw looking times of 4-month-olds and 10-month-olds during the first 2 pairs of test trials. ANOVA for repeated measures were performed separately for the two age groups with sex and test trial order as between-subject variables. Table 9 shows raw looking times of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect (*F*(1,14)=0.26, *p*=.62). Furthermore, the infant's sex did not interact with the novelty factor significantly (*F*(1,14)=0.60, *p*=.45), and nor did the order of the test trials (*F*(1,14)=0.01, *p*=.94).

Table 10 shows raw looking times over the first 2 test trials of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds looked significantly longer at the novel items than at the familiar items (*F*(1,16)=12.00, *p*<.01). Sex showed a significant interaction with the main effect, with the female infants demonstrating a stronger novelty effect than the males (*F*(1,16)=9.76, *p*=.01). Whether the familiar or novel accent was presented first during test trials failed to show significance (*F*=2.75, *p*=.12).

Figure 4 shows raw looking times of 4-month-olds and 10-month-olds during the first 3 pairs of test trials. ANOVA for repeated measures were performed separately for the two age groups with sex and test trial order as between-subject variables. Table 11 shows raw looking times of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect (*F*(1,14)=0.21, *p*=.66). Furthermore, the infant's sex did not interact with the novelty factor significantly (*F*(1,14)=1.11, *p*=.31), and nor did the order of the test trials (*F*(1,14)=0.12, *p*=.73).

Table 12 shows raw looking times over the first 3 test trials of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds looked significantly longer at the novel items than at the familiar items (*F*(1,16)=9.83, *p*=.01). Sex showed a significant interaction with the main effect, with the female infants demonstrating a stronger novelty effect than the males (*F*(1,16)=7.24, *p*=.02). Whether the familiar or novel accent was presented first during test trials failed to show significance (*F*=0.29, *p*=.60).

Figure 5 shows raw looking times of 4-month-olds and 10-month-olds during all 4 pairs of test trials. ANOVA for repeated measures were performed separately for the two age groups with sex and test trial order as between-subject variables. Table 13 shows raw looking times of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect ($F(1,14)=0.21$, $p=.66$). Furthermore, the infant's sex did not interact with the novelty factor significantly ($F(1,14)=1.11$, $p=.31$), and nor did the order of the test trials ($F(1,14)=0.12$, $p=.73$).

Table 14 shows raw looking times over all 4 test trials of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds looked significantly longer at the novel items than at the familiar items ($F(1,16)=7.95$, $p=.01$). Sex showed a significant interaction with the main effect, with the female infants demonstrating a stronger novelty effect than the males ($F(1,16)=11.13$, $p<.01$). Whether the familiar or novel accent was presented first during test trials failed to show significance ($F(1,16)=0.52$, $p=.48$).

Figure 6 shows looking time difference between the familiar and novel trials in the first, second, third and fourth pairs of test trials. The difference seems to gradually decrease over time, but the difference among the four pairs of test trials is not significant ($F(3,108)=0.39$, $p=.76$). Age group shows no significant interaction with the difference ($F(3,108)=0.05$, $p=.99$).

*Anaylses of Log Transformed Looking Scores*

Figure 7 shows mean log transformed looking scores of 4-month-olds and 10-month-olds during the first test trial. ANOVA for repeated measures were performed separately for the two age groups with sex and test trial order as between-subject variables. Table 15 shows log transformed looking scores of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect ($F(1,14)=0.93$, $p=.35$). Furthermore, the infant's sex did not interact with the novelty factor significantly (*F*(1,14)=0.20, *p*=.66), and nor did the order of the test trials (*F*(1,14)=0.02, *p*=.89).

Table 16 shows mean log transformed looking scores during the first pair of test trials of 10-month-olds summarized by sex and the order of test trials. The 10-month-olds looked marginally significantly longer at the novel items than at the familiar items (*F*(1,16)=3.42, *p*=.08). Sex showed a significant interaction with the main effect, with the female infants demonstrating a stronger novelty effect than the males (*F*(1,16)=6.88, *p*=.02). Whether the familiar or novel accent was presented first during test trials failed to show significance (*F*=1.94, *p*=.18).

Figure 8 shows mean log transformed looking scores over the first 2 pairs of test trials of 4-month-olds and 10-month-olds. ANOVA for repeated measures were performed separately for the two age groups with sex and test trial order as between-subject variables. Table 17 shows log transformed looking scores of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect (*F*(1,14)=0.00, *p*=.95). Furthermore, the infant's sex did not interact with the novelty factor significantly (*F*(1,14)=0.00, *p*=.97), and nor did the order of test trials (*F*(1,14)=0.13, *p*=.72).

Table 18 shows mean log transformed looking scores during the first 2 pairs of test trials of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds looked significantly longer at the novel items than at the familiar items (*F*(1,16)=9.98, *p*=.01). Sex showed a significant interaction with the main effect, with the female infants demonstrating a stronger novelty effect than the males (*F*(1,16)=5.93, *p*=.03). The order of test trials showed a marginally significant interaction with the novelty effect (*F*(1,16)=3.92, *p*=.07).

Figure 9 shows mean log transformed looking scores of the first 3 pairs of test trials of 4-month-olds and 10-month-olds. ANOVA for repeated measures were performed separately for the two age groups with sex as a between-subject variable. Table 19 shows mean log transformed looking scores of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect ($F(1,14)=.04$, $p=.85$). Furthermore, the infant's sex did not show a significant interaction with the main novelty effect ($F(1,14)=.16$, $p=.69$), and nor did the order of test trials ($F(1,14)=.09$, $p=.77$).

Table 20 shows mean log transformed looking scores during the first 3 pairs of test trials of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds looked significantly longer at the novel items than at the familiar items ($F(1,16)=8.18$, $p=.01$). Sex showed a significant interaction with the main novelty effect, again with the female infants demonstrating a stronger novelty effect than the males ($F(1,16)=5.90$, $p=.03$). The order of test trials showed no significant interaction with the novelty effect ($F(1,16)=1.20$, $p=.29$).

Figure 10 shows mean looking scores of all 4 pairs of test trials of 4-month-olds and 10-month-olds. ANOVA for repeated measures were performed separately for the two age groups with sex as a between-subject variable. Table 21 shows mean log transformed looking scores of 4-month-olds summarized by sex and the order of test trials. The 4-month-old group did not show any novelty effect ($F(1,14)=0.08$, $p=.78$). Furthermore, the infant's sex did not show a significant interaction with the main novelty effect ($F(1,14)=0.83$, $p=.38$), and nor did the order of test trials ($F(1,14)=0.68$, $p=.42$).

Table 22 shows mean log transformed looking scores during all 4 pairs of test trials of 10-month-olds summarized by sex and the order of test trials. In contrast, the 10-month-olds again looked significantly longer at the novel items than at the familiar items ($F(1,16)=5.13$,

$p$=.04). Consistent with the previous analyses, sex interacted significantly with the main novelty effect, with the female infants demonstrating a stronger novelty effect than the males ($F(1,16)=11.72$, $p<.01$). The order of test trials did not show any significant interaction with the novelty effect ($F(1,16)=.39$, $p=.54$).

Figure 11 shows looking score difference between the familiar and novel trials in the first, second, third and fourth pairs of test trials. Again the difference seems to gradually decrease over time, but the difference among the four pairs of test trials is not significant ($F(3,108)=1.05$, $p=.38$). Age group shows no significant interaction with the difference ($F(3,108)=.86$, $p=.46$).

To summarize, 10-month-olds discriminated the Pennsylvania accent from the New York accent, whereas the 4-month-olds failed to do so. This was true whether the first 1, 2, 3 or all 4 pairs of test trials were examined, and whether the analysis was based on raw looking times or log transformed data. Sex showed a consistent and significant interaction with the novelty effect in 10-month-olds, again across all analyses. The order of test trials only showed marginally significant interaction with the main effect in 2 out of the 8 analyses. It probably did not have much effect on dishabituation.

***Parental Linguistic Background.*** Using looking scores from the first 3 trials, additional analyses revealed that whether or not both parents were originally from Western Pennsylvania did not have an effect on the amount of novelty preference (difference between looking time to the novel item and looking time to the familiar item) in the 4-month-old ($F(1,16)=0.74$, $p=.40$) or the 10-month-old group ($F(1,18)=0.32$, $p=.58$). This was true whether the mother and the father's effects were examined together or separately. Similarly, the number of parents (per child) from Western Pennsylvania did not significantly correlate with the infants' novelty response for the first three test trials, either in the 4-month-old group (Spearman's *rho*=.17, *p*=.51), or the 10-month-old Spearman's *rho*=-.08, *p*=.72). Analyses with the first 2 or all 4 trials yielded similar insignificant results.

**Discussion**

This study revealed that, while infants were unable to discriminate the local accent from the novel (Hispanic New York Bronx) accent at 4 months, they were able to do so at 10 months. The phenomenon was remarkably strong, showing robust significance in 7 out of the 8 analyses presented here.

It is interesting to note that, with both raw looking times and log transformed data, the main effect was strongest when the first 2 pairs of test trials were examined. The effect decreased slightly as more pairs of test trials were examined, although all comparisons reached significance. However, the effect was weakest when only the first pair of test trials was examined. With log transformation, the first pair of test trials only showed marginal significance.

Consistent with available reports in the literature, the older infants were much shorter lookers than their younger counterparts. This is probably due to their superior processing speed and capacity, and their superior memory, which in turn led to reduced attention span. The sex effect observed in the first 2 and 3 trials was also consistent with findings in the literature that girls tend to be ahead of boys in language development, although this advantage disappeared when all 4 test trials were examined.

The post-hoc observation that it took 10-month-old infants more trials to habituate to the local accent than to the novel accent is puzzling. In addition, the lack of such a difference in 4-month-olds represents an interesting developmental trend. It mirrors the familiarity effect observed in the English-speaking adults who categorized these two accents. One explanation is that the local accent is closer to the normalized speech represented by the infant, making it more difficult for the infant to extract something unique about the local accent stimuli. The novel accent, on the other hand, possesses distinct features to which the infant may pay closer attention. These distinct features may have facilitated categorization. At the same time, the larger number of habituation trials to the local accent may indicate preference for familiar stimulation over the habituation phase. Since the 4-month-old may have not formed a normalized representation of speech based on the local accent, familiarity with the local accent did not matter. Whether these explanations account for the observed differences is an empirical question. However, the fact that these differences exist indicates that by 10-month-olds infants have already begun to respond differentially to the local accent, possibly as a result of familiarity.

Whether the familiar or the novel accent was presented first during test trials did not have an effect on the amount of dishabituation in infants. The order of presentation was randomized across infants. However, one concern was that this would lead to difference in dishabituation, as discussed earlier. Therefore, the lack of such an effect strengthened the validity of the results.

The lack of influence from the parents' linguistic background suggests that 10-month-olds do not merely pay attention to language input from parents alone. In fact, they probably sample speech input from everyone in the surrounding environment, such as people in the grocery store, at daycare, or in the hospital, in addition to their own parents. This lack of parental influence also lends support to the idea that infants tested in this study all had some degree of familiarity with the Western Pennsylvania accent, whether their parents were originally from the region or not.

To summarize, the ability to discriminate the local accent from a novel one develops some time between 4 and 10 months of age. This ability develops regardless of the parents' accent.

## STUDY 3

### Introduction

Study 2 confirmed discriminability of the local accent and a novel accent in 10-month-old infants. Study 3 explored accent categorization further by presenting 10-month-olds with an even more challenging task – discrimination of two novel accents in the native language. Results from Study 1 suggest that discrimination between the New York and Chinese accents may be potentially harder than discrimination between the local accent and the New York one to the adult speakers from Western Pennsylvania. Hence, Study 3 examined whether this was true with 10-month-old infants born in the same region.

Since 4-month-olds failed to discriminate the local and a novel accent in Study 2, they were unlikely to show discrimination in this harder task. Therefore, only 10-month-olds participated in Study 3.

### Method

#### *Participants*

Twenty-six 10-month-old infants from the greater Pittsburgh area participated in the study. Data analyses excluded 10 infants, including 5 for fussing, 2 for failure to reach habituation criterion, 2 for lack of interest in the procedure, and 1 for a non-English speaking parent. The remaining 16 infants (range=293-320 days, *M*=304.94 days, *SD*=8.95) included 8 females (range=293-313 days, *M*=300.25 days, *SD*=6.76), and 8 males (rage=294-320 days, *M*=309.63 days, *SD*=8.7). All participants were full-term infants with no birth complications. Again, English must be the only language spoken in the household. Nine infants (56%) had both parents from Western Pennsylvania. Three infants (19%) had one parent from Western Pennsylvania, and from other regions of the country. The remaining 4 infants (25%) had both parents from outside Western Pennsylvania. None of the parents was Hispanic descent from

Bronx, New York City or spoke English with a Chinese accent (all parents were native speakers of English).

***Stimuli, Apparatus and Procedure***

The six New York and six Chinese accented English samples compiled in Study 1 were used. The apparatus and procedure were identical to those used in Study 2

**Results**

***Habituation Data.*** During the habituation phase, the mean looking time over the initial three trials was used to establish habituation criterion, similar to Study 2. The infants looked 14.82 seconds ($SD$=7.4) per trial over the initial three habituation trials. It took them an average of 11.35 trials ($SD$=6.75) to reach habituation criterion. Female and male infants did not differ significantly on initial looking times ($F(1,14)=2.88$, $p=.11$) or the number of trials to reach criterion ($F(1,14)=2.54$, $p=.13$).

The number of trials it took the infants to reach criterion did not differ by the habituated accent ($F(1,14)=2.26$, $p=.16$). It took the infants 8.88 trials on average ($SD$=5.03) to habituate to the Chinese accent, and 13.75 trials ($SD$=7.67) to habituate to the New York accent.

***Test Trial Data.*** Similar to Study 2, the present study examined mean looking times over the first pair, the first 2 pairs, the first 3 pairs and all 4 pairs of test trials. It also examined natural log transformation of the first 1, 2, 3, and all 4 pairs of familiar versus novel test trials. Half of the infants received the New York accent as the familiar stimulus, whereas the other half received the Chinese accent as the familiar stimulus. Thus, data were collapsed between the two counterbalancing conditions. ANOVA for repeated measures were performed for all of the following comparisons with sex and the order of test trials as between-subject variables.

*Analyses of Raw Looking Times*

Table 23 and Figure 12 show looking times over the first pair of familiar and novel test trials. Looking times to the novel test trial were marginally longer than those to the familiar trial ($F(1,12)=3.18$, $p=.10$). Sex showed a marginally significant interaction with the main effect ($F(1,12)=3.74$, $p=.08$), but the order of the test trials did not ($F(1,12)=0.67$, $p=.43$).

Table 24 and Figure 13 show mean looking times over the first 2 pairs of familiar and novel test trials. Looking times to the novel test trials did not differ significantly from those to the familiar trials ($F(1,12)=0.62$, $p=.45$). Sex showed a significant interaction with the main effect ($F(1,12)=4.96$, $p=.05$), but the order of the test trials did not ($F(1,12)=0.00$, $p=.97$). Additional analyses revealed that the sex by main effect interaction was due to female infants' discrimination between the novel and familiar test trials ($F(1,6)=6.71$, $p=.04$) and the male infants' lack of doing so ($F(1,6)=0.78$, $p=.41$).

Table 25 and Figure 14 show mean looking times over the first 3 pairs of familiar and novel test trials. Looking times to the novel test trials were marginally longer than those to the familiar trials ($F(1,12)=3.99$, $p=.07$). Sex did not show a significant interaction with the main effect ($F(1,12)=0.56$, $p=.47$), and nor did the order of the test trials ($F(1,12)=0.09$, $p=.77$).

Table 26 and Figure 15 show mean looking times over all 4 pairs of familiar and novel test trials. Looking times to the novel test trials were marginally longer than those to the familiar trials ($F(1,12)=3.68$, $p=.08$). Sex did not show a significant interaction with the main effect ($F(1,12)=0.03$, $p=.86$), and nor did the order of the test trials ($F(1,12)=0.16$, $p=.69$).

Figure 16 shows looking time difference between the familiar and novel trials in the first, second, third and fourth pairs of test trials. The difference does not seem to gradually decrease over time, and the difference among the four pairs of test trials is not significant ($F(3,45)=0.84$, $p=.48$).

*Analyses of Log Transformed Looking Scores*

Table 27 and Figure 17 show mean log transformed looking scores over the first pair of familiar and novel test trials. Looking scores to the novel test trial were marginally higher than those to the familiar trial ($F(1,12)=3.48$, $p=.09$). Sex did not show a significant interaction with the main effect ($F(1,12)=1.52$, $p=.24$), and nor did the order of test trials ($F(1,12)=1.03$, $p=.33$).

Table 28 and Figure 18 show mean log transformed looking scores over the first 2 pairs of familiar and novel test trials. Looking scores to the novel test trials were not significantly higher than those to the familiar trial ($F(1,12)=2.62$, $p=.13$). Sex did not show a significant interaction with the main effect ($F(1,12)=1.29$, $p=.28$), and nor did the order of test trials ($F(1,12)=0.43$, $p=.52$).

Table 29 and Figure 19 show mean log transformed looking scores over the first 3 pairs of familiar and novel test trials. Looking scores to the novel test trials were significantly higher than those to the familiar trial ($F(1,12)=5.15$, $p=.04$). Sex did not show a significant interaction with the main effect ($F(1,12)=0.03$, $p=.86$), and nor did the order of test trials ($F(1,12)=0.04$, $p=.84$).

Table 30 and Figure 20 show mean log transformed looking scores over all 4 pairs of familiar and novel test trials. Looking scores to the novel test trials were marginally significantly higher than those to the familiar trial ($F(1,12)=4.39$, $p=.06$). Sex did not show a significant interaction with the main effect ($F(1,12)=0.14$, $p=.72$), and nor did the order of test trials ($F(1,12)=0.03$, $p=.87$).

Figure 21 shows looking score difference between the familiar and novel trials in the first, second, third and fourth pairs of test trials. The difference does not seem to gradually decrease over time, and the difference among the four pairs of test trials is not significant ($F(3,45)=0.89$, $p=.45$).

In summary, 10-month-old infants showed discrimination of two unfamiliar accents in their native language, and the effect was statistically significant in one, and marginally significant in 5 out of the 8 analyses. Different from Study 2 findings, sex did not seem to be a significant factor. Similar to Study 2, the order of test trials was not a significant factor.

***Parental Linguistic Background.*** Parents' linguistic background did not demonstrate a significant effect on the infant's discriminatory abilities over the first three trials ($F(1,14)=0.33$, $p=.58$). This was true when the two parents' effects were examined together or separately. Similarly, the amount of novelty effect was not significantly correlated with the number of parents from Western Pennsylvania (Spearman's $rho=-.17$, $p=.54$). The first 2 or all 4 trials yielded similar not significant results.

**Discussion**

Study 3 provided remarkable evidence that 10-month-olds were capable of distinguishing the Hispanic New York Bronx accent from the Chinese accent, although the effect is less robust that that from Study 2. These infants presumably had little experience with either accent, since none of them had parents that were Hispanic descents from Bronx, New York City or spoke English with a Chinese accent (all parents were native speakers of English). Therefore, these 10-month-olds must have performed discrimination between these two novel accents on-line.

Building upon results from Study 2, Study 3 shows that, by 10 months, infants not only tell a novel accent from a familiar one, they are also able to tell two unfamiliar accents apart.

Discriminating two novel accents, however, does seem to be a more difficult task, since the effect was not as robust as that observed in Study 2. Consistent with findings from Study 2, the infants demonstrated discriminatory abilities regardless of their parents' linguistic background. Contrary to Study 2, however, girls and boys were comparable in their discriminatory abilities. Interestingly, the number of trials it took the infant to habituate did not differ by the habituated accent. Since neither accent used in this study was familiar to the infant, this lack of difference was consistent with the familiarity explanation for the larger number of habituation trials in Study 2 when the infant was habituated to the local accent.

10-month-old infants' performance in Studies 2 and 3 is impressive, but it may have been merely a product of maturation. In other words, as the infant grows older, physical growth may naturally afford more advanced speech perceptual capabilities, whether there is experience with a particular language or not. Alternatively, increased contact with the native language may be essential for the development of fine discriminatory skills specific to the target language. To examine the psychological validity of these competing hypotheses, one can examine whether the infant demonstrates comparable discrimination in an unfamiliar language. This was addressed in Study 4.

# STUDY 4

## Introduction

Studies 2 and 3 established infants' discrimination of familiar or novel accents in their native language by 10 months. However, it was not clear if this skill was due to accumulated experience with the native language, or a mere consequence of maturation. It is possible that by 10 months, infants' speech discriminatory abilities are mature enough to distinguish two accents that bear sufficiently different physical features. Therefore, Study 4 set out to examine if 10-month-olds would show parallel discrimination between two equally distinct accents in a foreign and therefore unfamiliar language.

Since 4-month-old infants have demonstrated discrimination between nonnative contrasts (e.g., Eimas et al., 1971), they were also tested as an attempt to see if similar developmental trend would be observable in accent perception.

If discrimination of accents in a nonnative language is contingent upon the ability to discriminate nonnative contrasts, the 4-month-old infants should demonstrate performance superior to their 10-month-old counterparts. Alternatively, if accent discrimination is a direct result of maturation, the 10-month-old infants should perform better than the 4-month-old infants, showing a pattern similar to that observed in Study 2. A third possibility is that accent perception is language-specific, contingent upon experience with the target language. In this case, neither age group should demonstrate significant discrimination due to lack of knowledge in the foreign language.

## Method

### *Participants*

Fifty-three infants participated in the study. Seventeen of them were excluded from analyses due to non-habituation ($n$=3), fussing ($n$=9), sleepiness ($n$=2) and technical problems

($n$=3). Of the remaining 36 infants, 20 were 4-month-olds (10 females, 10 males), and 16 were 10-months-olds (7 females, 9 males). The 4-month-olds were 124 days old on average ($SD$=0.97, range=107-136 days); the 10-month-olds were 300.19 days old on average ($SD$=9.25, range=287-316 days). All participants were full-term infants with no birth complications. English must be the only language spoken at home. Nineteen infants (53%) had both parents from Western Pennsylvania. Nine infants (25%) had one parent from Western Pennsylvania, and one parent from other regions of the country. Eight infants (22%) had both parents from outside Western Pennsylvania.

#### ***Stimuli, Apparatus and Procedure***

The six Mainland Chinese accent samples and the six Taiwanese Chinese accent samples, all produced in the Chinese language from Study 1, were used. The apparatus and procedure were identical to that used in Study 2.

### Results

***Habituation Data.*** During the habituation phase, the mean looking time over the initial three trials was used to establish habituation criterion. See Table 9 for means and standard deviations of the total duration of the first three habituation looks, and the number of trials it took to habituate the infant, organized by age groups. It took fewer trials to habituate the 4-month-olds than the 10-month-olds ($F(1,34)=5.83$, $p=.02$). Also, 4-month-olds had much longer initial looking times than the 10-month-olds ($F(1,34)=11.55$, $p<.01$). On the other hand, the number of trials it took to habituate the infant did not vary by the habituated accent in the 4-month-old group ($F(1,18)=0.17$, $p=.69$) or the 10-month-old group ($F(1,14)=0.11$, $p=.75$).

***Test Trial Data.***

Similar to Studies 2 and 3, the present study examined mean looking times over the first 1, 2, 3 and all 4 pairs of test trials, and the natural log transformation of these trials. Half of the infants received the Mainland accent as the familiar stimulus, whereas the other half received the Taiwanese accent as the familiar stimulus. Thus, data were collapsed between the two counterbalancing conditions.

*Analyses of Raw Looking Times*

Figure 22 shows looking times by 4- and 10-month-olds over the first pair of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 31 summarizes 4-month-olds' looking times to the first pair of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F(1,16)=0.89$, $p=.36$). Furthermore, the infant's sex did not interact with the novelty factor significantly ($F(1,16)=0.47$, $p=.51$), and nor did the order of test trials ($F(1,16)=0.12$, $p=.74$).

Table 32 summarizes 10-month-olds' looking times to the first pair of test trials by test trial order and sex. Similar to the 4-month-olds, and contrary to the 10-month-olds in Studies 2 and 3, the 10-month-old infants in Study 4 did not look significantly longer at the novel items than at the familiar items ($F(1,12)=0.00$, $p=.97$). Sex did not show a significant interaction with the main novelty effect ($F(1,12)=0.77$, $p=.40$), and nor did the order of test trials ($F(1,12)=0.05$, $p=.83$).

Figure 23 shows mean looking times by 4- and 10-month-olds over the first 2 pairs of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 33 summarizes 4-month-olds' mean looking times to the first 2 pairs of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F$(1,16)=1.44, $p$=.25). Furthermore, the infant's sex did not interact with the novelty factor significantly ($F$(1,16)=1.50, $p$=.24), and nor did the order of test trials ($F$(1,16)=.71, $p$=.41).

Table 34 summarizes 10-month-olds' mean looking times to the first 2 pairs of test trials by test trial order and sex. Similar to the 4-month-olds, and contrary to the 10-month-olds in Studies 2 and 3, the 10-month-old infants in Study 4 did not look significantly longer at the novel items than at the familiar items ($F$(1,12)=0.00, $p$=.96). Sex did not show a significant interaction with the main novelty effect ($F$(1,12)=1.12, $p$=.31), and nor did the order of test trials ($F$(1,12)=0.25, $p$=.62).

Figure 24 shows mean looking times by 4- and 10-month-olds over the first 3 pairs of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 35 summarizes 4-month-olds' mean looking times to the first 3 pairs of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F$(1,16)=1.25, $p$=.28). Furthermore, the infant's sex did not interact with the novelty factor significantly ($F$(1,16)=2.55, $p$=.13), and nor did the order of test trials ($F$(1,16)=1.33, $p$=.27).

Table 36 summarizes 10-month-olds' mean looking times to the first 3 pairs of test trials by test trial order and sex. Similar to the 4-month-olds, and contrary to the 10-month-olds in Studies 2 and 3, the 10-month-old infants in Study 4 did not look significantly longer at the novel items than at the familiar items ($F$(1,12)=0.01, $p$=.93). Sex did not show a significant interaction with the main novelty effect ($F$(1,12)=1.97, $p$=.19), and nor did the order of test trials ($F$(1,12)=0.92, $p$=.36).

Figure 25 shows mean looking times by 4- and 10-month-olds over all 4 pairs of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 37 summarizes 4-month-olds' mean looking times to all 4 pairs of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F(1,16)=1.04$, $p=.32$). Furthermore, the infant's sex showed a marginally significant interaction with the novelty factor ($F(1,16)=3.92$, $p=.07$), but the order of test trials did not ($F(1,16)=2.26$, $p=.15$).

Table 38 summarizes 10-month-olds' mean looking times to all 4 pairs of test trials by test trial order and sex. Again they did not look significantly longer at the novel items than at the familiar items ($F(1,12)=0.03$, $p=.86$). Sex did not show a significant interaction with the main novelty effect ($F(1,12)=0.26$, $p=.62$), and nor did the order of test trials ($F(1,12)=0.31$, $p=.59$).

Figure 26 shows looking time difference between the familiar and novel trials in the first, second, third and fourth pairs of test trials. The difference seems to gradually decrease over time, but the difference among the four pairs of test trials is not significant ($F(3,102)=0.29$, $p=.83$). Age group has no significant interaction with the main difference ($F(3,102)=0.14$, $p=.93$).

*Analyses of Log Transformed Looking Scores*

Figure 27 shows mean log transformed looking scores by 4- and 10-month-olds over the first pair of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 39 summarizes 4-month-olds' mean looking times to the first pair of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F(1,16)=0.08$, $p=.79$). Furthermore, the infant's sex showed no significant interaction with the novelty factor ($F(1,16)=0.63$, $p=.44$), and so did the order of test trials ($F(1,16)=0.03$, $p=.86$).

Table 40 summarizes 10-month-olds' mean log transformed looking scores to the first pair of test trials by test trial order and sex. Again they did not look significantly longer at the novel items than at the familiar items ($F(1,12)=0.32$, $p=.58$). Sex did not show a significant interaction with the main novelty effect ($F(1,12)=1.86$, $p=.20$), and nor did the order of test trials ($F(1,12)=0.00$, $p=1.00$).

Figure 28 shows mean log transformed looking scores by 4- and 10-month-olds over the first 2 pairs of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 41 summarizes 4-month-olds' mean looking times to the first 2 pairs of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F(1,16)=0.08$, $p=.78$). Furthermore, the infant's sex showed no significant interaction with the novelty factor ($F(1, 16)=1.84$, $p=.19$), and so did the order of test trials ($F(1,16)=0.14$, $p=.71$).

Table 42 summarizes 10-month-olds' mean log transformed looking scores to the first 2 pairs of test trials by test trial order and sex. Again they did not look significantly longer at the novel items than at the familiar items ($F(1,12)=0.05$, $p=.83$). Sex did not show a significant interaction with the main novelty effect ($F(1,12)=1.78$, $p=.21$), and nor did the order of test trials ($F(1,12)=0.06$, $p=.82$).

Figure 29 shows mean log transformed looking scores by 4- and 10-month-olds over the first 3 pairs of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 43 summarizes 4-month-olds' mean looking times to the first 3 pairs of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F(1,16)=0.10$, $p=.76$).

Furthermore, the infant's sex showed marginally significant interaction with the novelty factor ($F(1,16)=3.85$, $p=.07$), although the order of test trials did not ($F(1,16)=1.17$, $p=.30$).

Table 44 summarizes 10-month-olds' mean log transformed looking scores to the first 3 pairs of test trials by test trial order and sex. Again they did not look significantly longer at the novel items than at the familiar items ($F(1,12)=0.08$, $p=.78$). Sex did not show a significant interaction with the main novelty effect ($F(1,12)=2.43$, $p=.15$), and nor did the order of test trials ($F(1,12)=0.34$, $p=.57$).

Figure 30 shows mean log transformed looking scores by 4- and 10-month-olds over all 4 pairs of test trials. ANOVA for repeated measures was performed separately for the two age groups with sex and the order of test trials as between-subject variables. Table 45 summarizes 4-month-olds' mean looking times to all 4 pairs of test trials by test trial order and sex. The 4-month-old group did not show any novelty effect ($F(1,16)=0.02$, $p=.90$). Furthermore, the infant's sex showed marginally significant interaction with the novelty factor ($F(1,16)=3.85$, $p=.07$), although the order of test trials did not ($F(1,16)=0.92$, $p=.35$).

Table 46 summarizes 10-month-olds' mean log transformed looking scores to all 4 pairs of test trials by test trial order and sex. Again they did not look significantly longer at the novel items than at the familiar items ($F(1,12)=0.10$, $p=.76$). Sex did not show a significant interaction with the main novelty effect ($F(1,12)=0.56$, $p=.47$), and nor did the order of test trials ($F(1,12)=0.21$, $p=.66$).

Figure 31 shows looking time difference between the familiar and novel trials in the first, second, third and fourth pairs of test trials. The difference does not seem to gradually decrease over time, and the difference among the four pairs of test trials is not significant ($F(3,102)=0.12$,

$p$=.95). Age group has no significant interaction with the main difference ($F$(3,102)=0.05, $p$=.98).

To summarize, 4-month-old infants were unable to discriminate two accents of the Chinese language, even though they had been shown to discriminate nonnative consonantal and vowel contrasts. Likewise, 10-month-olds were unable to discriminate two accents of the Chinese language, even though these Chinese stimuli were direct phonetic transcription of the English stimuli that they were able to discriminate. The lack of significance was consistent when the first 1, 2, first 3 or all 4 pairs of test trials, and log transformations of these trials were examined. Sex had a marginally significant interaction with the main novelty effect 3 out of 8 analyses for the 4-month-old group, but no sex and main effect interaction was found in 10-month-olds. Since the main novelty effect was absent, it is unclear how these marginal interactions could be explained. Besides, because they are small in number, a more conservative conclusion would be no sex interaction unless future studies show otherwise.

***Parental Linguistic Backround.*** Additional analyses indicated that whether or not the parents were originally from Western Pennsylvania did not have an effect on novelty preference in the fourth-month-old ($F$(1,18)=0.06, $p$=.81) or the 10-month-old group ($F$(2,13)=1.08, $p$=.37). This was true whether the mother and the father's effects were examined together or separately. Similarly, the amount of novelty preference over the first three test trial did not significantly correlate with the number of parents from Western Pennsylvania in the fourth-month-olds (Spearman's $rho$=0.09, $p$=.71) or 10-month-olds (Spearman's $rho$= -0.12, $p$=.72).

**Discussion**

Study 4 supplied clear evidence that 10-month-olds' accent discrimination in Studies 2 and 3 were not simply due to maturation. If it were, similar discrimination would have been observed in 10-month-olds between two equally distinctive accents in a different language. This was despite the fact that these stimuli were a phonological transcription of the English stimuli, containing phonemes similar to those present in the English paragraphs. Note also that, although these accents in the Chinese language were indistinguishable to the English speakers, they were as distinguishable to their native speakers as the Pennsylvania, New York, and Chinese accents were to native speakers of English.

In addition, the lack of discrimination in 4-month-olds suggests that, although they are able to discriminate nonnative contrasts, this ability is insufficient for differentiate accents presented in continuous speech.

Taken together as a whole, Studies 2, 3 and 4 presented here clearly showed native language accent discrimination by 10 months as a consequence of experience with the native language accumulated over the first year of life.

## GENERAL DISCUSSION

The present studies provide striking evidence that by 10 months of age, infants are capable of distinguishing accents in their native language, whether they are familiar with the accent or not. The discriminatory abilities, however, are limited to the native language, rendering the two accents in an unfamiliar language indistinguishable, although they are highly distinctive to their adult native speakers.

The perception of speech accent, however, is absent in 4-month-old infants. This suggests that, although younger infants can discriminate nonnative phonetic contrasts, these abilities are insufficient when it comes to detecting an accent change. The complex accent stimuli presented in these studies involve more than variations in individual phonemes. To hear the differences in the novel accent from the various samples of the accent presented during the habituation phase, the infant must average across samples from five different speakers, form a normalized representation common across the five speakers, and then decide that the novel accent is sufficiently different from the averaged norm of the habituation stimuli. The continuous speech stimuli also contain more information than the minimal pairs such as /ra/ and /la/ used in nonnative phonetic discrimination studies. These stimuli spread out over time. They can vary along multiple dimensions, including phonemic pronunciation, prosody and stress patterns. The ability to detect a multitude of these changes, integrate the diverse sources of information, and ignore irrelevant differences such as idiosyncratic features in individual speakers, obviously takes time to develop. Given the processing demand, it is impressive that this ability is already present in 10-month-olds.

How are 10-month-old infants able to discriminate accent? Consider what we know about their speech perceptual capabilities. Their language-specific knowledge about prosodic cues, stress patterns and phonetic distinctions is well established in the literature. They have also demonstrated competencies in applying these cues to various tasks such as phrase identification (Jusczyk et al., 1992), word recognition (Jusczyk, Newsome & Houston, 1999), and language discrimination (Nazzi et al., 1998). Most critically, they are able to integrate two or more sources of information simultaneously, which allows them to perform on considerably more complex tasks (Lalonde & Werker 1995). In contrast, the 4-month-olds hear more nonnative phonetic contrasts than the 10-month-olds. They are able to deal with speaker variability such as speaking rate (Eimas & Miller, 1980; Miller & Eimas, 1983). They show sensitivity to prosody when recognizing their native language (Nazzi et al., 1998, 2000). Nevertheless, the system is not powerful enough to process multiple speech cues simultaneously in order to identify the change in accent that encompasses a wide range of phonological differences. In addition, the 10-month-olds' ability to segment syllables and words (Johnson & Jusczyk, 2001; Saffran et al., 1996a, 1996b) probably allowed them to focus on speech cues that are in more appropriate locations. For example, an unusual stress pattern is alarming only if word boundaries are properly degmented. Similarly, a less rhotacized /r/ sound at the word endings is unusual only if the word boundary is properly detected right after the /r/ sound ends.

Given the 10-month-olds' speech perceptual capabilities, their discrimination of unfamiliar accents in English (Hispanic New York vs. Chinese) is nevertheless remarkable. This shows that the present studies do not simply demonstrate a novelty effect. It shows that linguistic experience with the local accent does not limit discrimination to only contrasts with the local accent. Instead, knowledge of the local accent seems sufficient to allow the infants to perform more detailed analyses of the phonological features within the native language, leading to improvements in discriminating accents within that language.

The 10-month-old infants' discrimination of accents in the native language is in sharp contrast to their inability to distinguish accents in a foreign language. This disparity, however, is strong evidence that the infant's increasing speech processing competencies are highly language-specific. The two accents in Chinese, although acoustically distinct to their adult native speakers, differ in considerably different ways from the extent to which the accents in English differ from each other, as discussed earlier. Besides, the Chinese language differs from the English language in prosody and phonotactics (how sounds can be sequenced within words), among other phonological properties. Although the Chinese stimuli were made of phonological transcripts of the English stimuli as an attempt to control for the distribution of phonological properties, the Chinese speakers would still introduce segmental and stress patterns distinct from those used by English speakers. Besides, Chinese is a tonal language, so the stimuli reflected tonal changes that were natural to the Chinese language. Tones are essentially changes in pitch, which are not that different from stress changes. Therefore, the English and Chinese stimuli contained pitch changes that were natural to the particular language. The infants would be unsuccessful, however, if they attempted to parse the Chinese sentences using strategies they had developed to handle pitch changes such as stress patterns in English.

Taken as a whole, these results bear striking similarities to and interesting differences from research on rhythm-based language discrimination (Nazzi et al., 1998; Nazzi et al., 2000). Nazzi and colleagues found that 5-month-old infants discriminated their native language (i.e. stress-based English) from a language in a different rhythmic class (i.e., mora-based Japanese), or a foreign language in the same rhythmic class (i.e., stress-based Dutch). The infants also discriminated two foreign languages from different rhythmic classes (syllable-based Italian vs. mora-based Japanese). They were, however, unable to discriminate two foreign languages in the same rhythmic class as their native language (i.e., Dutch vs. German, both stress-based). As noted earlier, their study also showed that 5-month-olds noticed the differences between the British accent from the standard American accent (although Nazzi et al. regarded the British English as a "foreign" language from the same rhythmic class). Nazzi and colleagues therefore concluded that, at least at five months or earlier, infants are mainly knowledgeable about the rhythmic properties of their native language, rather than the common properties of the native rhythmic class as a whole.

In contrast, the present studies showed that the 10-month-olds' familiarity with the local accent does not restrict their discriminatory capabilities only to contrasts with the local accent. As long as the accent contrast is still within the native language, the infant notices the differences (although whether this is true only when the accents are sufficiently distinct from each other remains an empirical question.) On the surface, the two sets of studies reported opposite effects of the familiar linguistic input. Nazzi et al.'s 5-month-old infants demonstrated language-specific knowledge about rhythmic properties based only on the language with which they are familiar, whereas the 10-month-old infants in the present studies showed enough sensitivity to phonological variations within the native language that is not limited only to the accent with which they are familiar. The two lines of research, however, complement each other in one important way: Both demonstrate the significance of the native language in shaping the infant's phonological knowledge, although the effects manifested at different levels. It seems that at five months, infants' knowledge about rhythmic properties is structured around the native language. They can also tell an unfamiliar accent from the familiar accent. By 10 months, their knowledge about the native language grows deeper, allowing them to hear subtle differences within the native language, but not in another language.

Given the adult participants' poor categorization of accents in a foreign language in Study 1, the ability to do so may never develop unless a fundamental change occurs to the person's language input. It is worth noting that the majority of the Chinese participants in Study 1 had college-level education, which meant that most of them had received at least six years of English education as a foreign language. Besides, English speech is widely available on TV, radio, and other public media. Thus, formal instruction of English and a nonnative environment obviously provide a type of experience to the adults that qualitatively differs from the experience that English-learning infants receive from their natural habitat. On the other hand, accent perception may be subject to the same age constraints on accent production in second language acquisition (Fledge, Yeni-Komshian, & Liu, 1999).

The present studies not only offer significant contribution to the speech perception literature, they also shed light on the categorization research. Specifically, the data provide positive evidence for categorization at the subordinate level by 10 months, given the assumption that accents represent subordinate categories within the basic-level native language domain.

The notion that accent perception represents categorization at the subordinate level, nonetheless, must be accepted with caution. As Rakison (2000) argues, the hierarchical relationships among the basic, subordinate and superordinate levels are part of the definition of these concepts in their adult forms. Infants, however, obviously have little appreciation of their relations and rules that govern them, despite their abilities to perceive categorical differences within these levels. Similarly, the present thesis by no means intends to argue that 10-month-old infants are aware of the fact that the Pennsylvania, New York, and Chinese accent stimuli all belong to the same category, the American English, which in turn, belongs to superordinate categories such as the different rhythmic classes of world languages. Nevertheless, accent perception within the native language still offers confirmation of fine discriminatory capabilities that characterize subordinate categorization.

It seems that increased experience with the native language causes a downward shift in the entry point to categorization. Four-month-old infants are able to categorize continuous speech at the "whole language" level (i.e., native versus foreign), but they are unable to do so at more subordinate levels of abstraction. With time, infants develop expertise with their native language, shifting recognition to a subtler level within the language. This is consistent with Takana and Gauthier's (1997) claim that the entry point of object and face recognition is a function of domain-specific expertise. Takana and Gauthier (1997) propose that expertise causes a downward shift in the entry point of object recognition. For example, the entry point to the dog category, to most adults, is the basic level "dogs" (as opposed to cats, for example). Dog experts, on the contrary, can categorize a picture of a chiwawa as a "chiwawa" as quickly as they would categorize it as a "dog". In Takana and Gauthier's terms, dog experts' entry point to the dog category is no longer "dogs" at the basic level. Their entry point would be at a level subordinate to the basic level.

Whereas few people are experts in dogs, Carey (1992) and Tanaka and Gauthier (1997) suggest that virtually all adults are experts in face recognition. The entry point to the face domain, therefore, is at the very bottom of the categorization hierarchy where individual faces are in their own categories. This adult state, however, is a developmental consequence of experiences with faces accumulated over the life span. Similarly, it is quite possible that all adults are experts in voice recognition as well, although the expertise may be language-specific. If adults indeed have an entry point to voice recognition at a subordinate level as a result of life-long experience with the native language, the effect experience has on accent discrimination in present studies suggests that expertise in voice recognition probably has its developmental roots in infancy.

Moreover, it is evident from the present studies that development of expertise with the native language is not simply due to exposure to parents' language input. In fact, the parents' accent does not seem to have much to do with the infant's accent categorization. This is strong indication that infants sample experience from diverse sources, including, but certainly not limited to, their own parents. Speech sampling from people other than parents obviously begins as early as infancy. This view also explains the anecdotal observation that children of first-generation immigrants who speech English with a foreign accent usually end up with the accent of their peers, and rarely develop their parents' accent (Harris, 1998).

Although the present studies provide empirical evidence for accent perception in infancy, several issues remain to be explored. For example, the notion that the native language is equivalent to a basic-level category remains a hypothesis. Similarly, it is not clear if the local accent indeed represents a prototype of the native language. Additional experiments are necessary to answer these questions. For example, an experiment analogous to that of Grieser and Kuhl (1989) would shed light on the prototype issue. A higher habituation rate, a larger degree of dishabituation, or a faster reaction time to the local accent, rather than an unfamiliar accent, on a similar generalization task would be indicative of sensitivity to accent-based typicality structure within the native language domain with the local accent being a stronger candidate as the prototype of the category. Once the ideas of the native language category and the local accent prototype are confirmed, the data presented here would be consistent with such a model.

Alternatively, it is an interesting possibility that the New York and Chinese accents may have been so different from each other, that the infant no longer thought that they belonged to the same language category. In fact, the distinct prosody in the Chinese-accented English stimuli may have made it harder for the infant to recognize it as English. If the infant had a hard time recognizing familiar words from the input stream, he or she could have treated it as a foreign language. Similarly, it is an empirical question as to whether the infant recognized the New York accent as English. In this case, the discrimination between the New York accent and the Chinese accent would be at the basic level, not the subordinate level. The discrimination of the local accent and the New York accent would have to be interpreted differently as well. To find out if the infant regards accented speech as English or a foreign language, we must pit accented English speech against samples of a foreign language. If after habituation to various English accents, the infant dishabituates to a foreign language, this would be evidence that they consider the accents as a group, or a category, that is distinct from the foreign language. Moreover, not only would it support the native language category, it would show the infant's simultaneous sensitivity to between- and within-category differences. This would demonstrate the infant's ability to alternate between different levels of processing in response to task demand.

On a separate note, although the conversational speech stimuli used in the present studies have a number of advantages, they may also have inadvertently made the task particularly hard for the infants. Continuous speech offers strong ecological validity, allows assessment of speech processing at the sentential level, and provides rich speech cues for accent. At the same time, however, due to its comprehensive collection of phonological contrasts and combinations, the stimuli bear a great deal of within-category variation, on top of the inevitable speaker variability[9]. Hence, the task demand is considerably higher than that of most infant speech perception studies. One way to reduce the task demand is to present single words that still bear clear accent features. For example, the word *Stella* seems to elicit strong differences among all three speaker groups (i.e., Western Pennsylvanians, Hispanic descents from Bronx, New York City, and native speakers of Chinese). Presenting the word in isolation would eliminate the need for segmentation, allowing younger infants to devote more attentional resources to features relevant to accent. Likewise, presenting the Chinese stimuli in small chunks may also lead to different results. Doing so, however, would sacrifice accent information available only at the sentential level. Reduction to word presentation would also run the risk of altering the task into phonetic discrimination.

Even if the infant manages to form categorical perception of accent despite within-category variability, it is important to ensure that behavioral measures reflect true categorical formation, as opposed to differential variability across categories. It is conceivable that variability within one category is considerably larger than variability within another. For example, the Hispanic New York Bronx accent samples may differ from one another in more distinctive ways than the ways the Western Pennsylvania accent samples differ from one other. Differences in looking time, therefore, may indicate a response to change in variability rather than categorical perception.

In addition, the two accents of English, Hispanic New York Bronx and Chinese, may differ prosodically. Although the speakers were reading in English, they may have used the prosody of the Spanish language and the Chinese language. If the two speaker groups differed sufficiently in prosody, the two accent categories could have been differentiated based on

[9]To ensure dishabituation was not simply due to change of speaker voice, the stimuli were produced by multiple speakers, which inevitably introduced speaker variability. This must be done, however, unless someone can produce multiple accents authentically.

prosody alone. If this was the case, infants may be able to show significant discrimination of these two accents at 4 months. Since 4-month-old infants were excluded from Study 3, additional studies would be necessary to find out if this is the case. If 4-month-olds could discriminate the Hispanic New York Bronx accent from the Chinese accent, it is very likely that they do so on the basis of prosody, given that prosody is one of the few features about the native language to which they are sensitive. These methodological issues, therefore, should be addressed with care in future studies of accent perception.

The synthesis of research on speech perception and categorization also raises the issue of whether accent categorization is a product of domain-general categorization skills, or that of a language-specific mechanism. Although the traditional language acquisition literature favors specialized mechanisms for acquiring linguistic structures (Chomsky, 1975), domain-general sensitivity to transitional probabilities and statistical values seems sufficient for word segmentation (Saffran et al., 1996a, 1996b) and the discovery of grammatical morphemes (Maratsos & Chalkley, 1980). Saffran, Johnson, Aslin and Newport (1999) even demonstrated that infants' sensitivity to statistical information is applicable to parsing tone sequences, stimuli in a non-linguistic domain. Thus, similar domain-general abilities may have been evoked to calculate variability in featural differences on the accent perception tasks.

Accent perception addresses the interesting question as to the kind of information infants retain from the speech input. Infants receive a large amount of speech input from adults around them, and they must learn and retain various sorts of information about speech signals. At the same time, however, they must ignore variability in speech to achieve a normalized representation. In particular, they need to abstract the common regularities across speakers that are linguistically relevant, despite variations in the way individuals speak, including their differences in pronunciation (Kuhl, 1979), speaking rate (Eimas and Miller, 1980), or gender (Jusczyk, Pisoni, and Mullennix, 1992).

Yet, individual differences are also important to the infant, child, or adult who must also be able to recognize voices of familiar people, or categorize voices in meaningful ways. Speech accent, among other things, is usually a strong clue about the speaker's identity. Like gender, age, or emotional state, the speech accent can be an "indexical property" (Aslin et al., 1998, p. 186) that gives the listener additional information about the speech message. In fact, word recognition is more accurate when the listener is familiar with the voice being presented (Nygaard, Sommers, & Pisoni, 1994). Thus, speech accent can be one of the speaker variations that infants should disregard when trying to figure out the words and syntax in the target language, but it should be key information infants attend to when they attempt to track individual identities. In a way, the acoustic details of a voice retained by a listener probably actively contribute to speech processing.

Because at least one of the accents being contrasted in the present studies is novel, the 10-month-old infants must have categorized the accent stimuli on-line. It is not clear, however, if infants actively register accent as part of the speech processing routine. One way to find out if they do so is to examine if a distinct accent enhances voice recognition. If it does, this would suggest that infants utilize accent to trace speaker identities.

Taken together, the current studies provide an exciting opportunity to observe infants integrating known speech perception capacities and applying them to a common speech perception task. They have also successfully broadened our understanding of speech perception by adding credence to the notion that even infants can abstract accent differences in complex, continuous speech. The findings lend additional support to the notion that simultaneous use of multiple sources of speech information begins by 10 months (Lalonde & Werker, 1995; Werker & Tees, 1999). Furthermore, following a stream of studies on the role of the native language in shaping the infant's perceptual experiences (Nazzi et al., 1998, 2000), the current studies illustrate one more time that growing knowledge of the native language continuously enriches the developing speech perception system.

# APPENDICES

**Appendix I. English accent elicitation passages used in Studies 1, 2 and 3.**

(1) Please call Stella. Ask her to bring these things with her from the store: Six spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a snack for her brother Bob. We also need a small plastic snake and a big toy frog for the kids. She can scoop these things into three red bags, and we will go meet her Wednesday at the train station.

(2) Ask Stella to bring five thick slabs of blue cheese, a snack for her brother Bob, and maybe six spoons of fresh snow peas with her from the store. We also need a big toy frog and a small plastic snake for the kids. We will go meet her Wednesday at the train station. Please call her. She can scoop these things into three red bags.

(3) We need five thick slabs of blue cheese, a snack for her brother Bob, and maybe six spoons of fresh snow peas. Please also call Stella and ask her to bring a big toy frog and a small plastic snake with her from the store for the kids. She can scoop these things into three red bags. We will go meet her Wednesday at the train station.

(4) Ask Stella to bring six spoons of fresh snow peas, a snack for her brother Bob and maybe five thick slabs of blue cheese with her from the store. Please call her. We also need a small plastic snake and a big toy frog for the kids. She can scoop these things into three red bags, and we will go meet her Wednesday at the train station.

(5) Ask Stella to bring with her from the store a small plastic snake and a big toy frog for the kids. She can scoop these things into three red bags. We also need a snack

for her brother Bob, six spoons of fresh snow peas, and maybe five thick slabs of blue cheese. And we will go meet her Wednesday at the train station. Please call her.

(6) Please call Stella. Ask her to bring these things with her from the store: a small plastic snake and a big toy frog for the kids. We also need six spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a snack for her brother Bob. She can scoop these things into three red bags, and we will go meet her Wednesday at the train station.

**Appendix II. Chinese accent elicitation passages used in Studies 1 and 4.**

(1) pi li she ko se te la. A ci ke he tu bu ling de she ding se wei se he fu lan she to. Shi ke she pu she fa la she ci nou pi zi. Fa fu si ke se la bi ci bu lu chi ci, an de mai bi er ci nei ke fu he bu ro she ba bu. Wu ai sho ni de er ci mong pu la ci ti ke ci nei ke an di bi ge to ying fu lou ke fu er de chi zhi. Xu kan ci ku pou di ci xing ying to xi rei rei de ba ge se. an de wei wei le go mi he wan si dei a te de tu ran si dei xiang.

(2) A ci ke se te la tu bu ling fa fu si ke se la bi ci bu lu chi ci, er ci nei ke fu he bu ro she ba bu, an de mai bi shi ke she pu she fa la she ci nou pi zi wei se he fu lan she to. Wu ai sho ni de er bi ge to ying fu lou ke an di er ci mong pu la ci ti ke ci nei ke fu er de chi zhi. wei wei le go mi he wan si dei a te de tu ran si dei xiang. pi li she ko he. Xu kan ci ku pou di ci xing ying to xi rei rei de ba ge se.

(3) Wu ni de fa fu si ke se la bi ci bu lu chi ci, er ci nei ke fu he bu ro she ba bu, an de mai bi shi ke she pu she fa la she ci nou pi zi. pi li she ai sho ko se te la an de a ci ke he tu bu ling er bi ge to ying fu lou ke an de er ci mong pu la ci ti ke ci nei ke wei se he fu lan she to fu er de chi zhi. Xu kan ci ku pou di ci xing ying to xi rei rei de ba ge se. wei wei le go mi he wan si dei a te de tu ran si dei xiang.

(4) A ci ke se te la tu bu ling shi ke she pu she fa la she ci nou pi zi, er ci nei ke fu he bu ro she ba bu an de mai bi fa fu si ke se la bi ci bu lu chi ci wei se he fu lan she to. pi li she ko he. Wu ai sho ni de er ci mong pu la ci ti ke ci nei ke an di bi ge to ying fu lou ke fu er de chi zhi. Xu kan ci ku pou di ci xing ying to xi rei rei de ba ge se, an de wei wei le go mi he wan si dei a te de tu ran si dei xiang.

(5) A ci ke se te la tu bu ling wei se he fu lan she to er ci mong pu la ci ti ke ci nei ke an di bi ge to ying fu lou ke fu er de chi zhi. Xu kan ci ku pou di ci xing ying to xi rei rei de ba ge se. Wu ai

sho ni de er ci nei ke fu he bu ro she ba bu, shi ke she pu she fa la she ci nou pi zi, an de mai bi Fa fu si ke se la bi ci bu lu chi ci. An de wei wei le go mi he wan si dei a te de tu ran si dei xiang. pi li she ko he.

(6) pi li she ko se te la. A ci ke he tu bu ling de she ding se wei se he fu lan she to: er ci mong pu la ci ti ke ci nei ke an di bi ge to ying fu lou ke fu er de chi zhi. Wu ai sho ni de shi ke she pu she fa la she ci nou pi zi, fa fu si ke se la bi ci bu lu chi ci, an de mai bi er ci nei ke fu he bu ro she ba bu. Xu kan ci ku pou di ci xing ying to xi rei rei de ba ge se, an de wei wei le go mi he wan si dei a te de tu ran si dei xiang.

**Appendix III. Survey of Linguistic Background administered to the parent during the visit by the experimenter, before the experimental procedure began.**

Child's Name _______________________ Subject Number ____________________

Birth Date _________________________ Today's Date ______________________

_____ Female _____ Male

1. What is the primary language spoken at home?

___ English
___ Mandarin Chinese – China
___ Mandarin Chinese - Taiwan
___ Taiwanese (the dialect)
___ Cantonese
___ Other. Please specify: _____________________________________________

2. Does your child show signs of understanding the above language?
_____ Yes _____ No

3. Does anyone in the family speak a language other than the primary language in 1.?
_____ Yes _____ No
If you answer no, skip to question 4.

a. What language is it? ________________
b. Who speaks it? ________________________________ (relation to child)
c. How often does the person speak this language?
____ Most of the time ____ Often ____ Occasionally ____ Rarely
d. Does the person speak this language to the child? _____ Yes _____ No
e. Does the child seem to understand the language? _____ Yes _____ No

If more than one person speaks another language or more than one language other than the primary one is spoken at home, please ask the experimenter for assistance.

4. When the child's father speaks English, does he speak with a West Pennsylvania accent? In other words, when the father talks, does he sound like he is from West Pennsylvania?
_____ Yes _____ No
If your answer is no, specify the father's accent ____________________________

5. When the child's mother speak English, does she speak with a West Pennsylvania accent? In other words, when the mother talks, does she sound like she is from West Pennsylvania?
_____ Yes _____ No
If your answer is no, specify the mother's accent ____________________________

6. Does anyone else in the family (including older siblings) speak with an accent other than West Pennsylvania?
_____ Yes _____ No

If you answer yes, the person is ________________ (relation to the child) and the accent is __________________.
How much time on average does the person spend with the child a day?
____ less than 30 minutes _____ between 30 minutes and 2 hours
_____ between 2 to 5 hours _____ more than 5 hours

7. Answer this question only if you or your spouse is a non-native speaker of English.
   a. If the father is the non-native speaker, What is the father's native language? __________________________

If the mother is the non-native speaker, What is the mother's native language? ______________

# BIBLIOGRAPHY

## Bibliography

Anderson-Hsieh, J., Johnson, R., & Koehler, K. (1992). The relationship between native speaker judgments of nonnative pronunciation and deviance in segmentals, prosody, and syllable structure. *Language Learning, 42(4)*, 529-555.

Aslin, R.N., Jusczyk, P.W., & Pisoni, D.B. (1998). Speech and auditory processing during infancy: Constraints on and precursors to language. In D. Kuhn & R. Siegler (Eds.), *Handbook of Child Psychology, Fifth edition. Volume 2: Cognition, Perception and Language* (W. Damon, series editor). New York: Wiley, pp. 147-198.

Aslin, R. N. & Pisoni, D. B. (1980). Some developmental processes in speech perception. In G. H. Yeni-komshian, J. F. Kavanagh, & C, A. Ferguson (Eds.), *Child phonology: Perception (Vol. 2)*. New York: Academic Press.

Bosch, L. & Sebastian-Galles, N. (1997). Native-language recognition abilities in 4-month-old infants from monolingual and bilingual environments. *Cognition, 65,* 33-69.

Bosch, L. & Sebastian-Galles, N. (2001). Evidence of early language discrimination abilities in infants from bilingual environments. *Infancy, 2(1),* 21-49.

Calla McDermott, W. E. (1986). *The Scalability of Degrees of Foreign Accent*. Ph.D. dissertation, Cornell University.

Carey, S. (1992). Becoming a face expert. *Philosophical transactions Royal Society of London, B, 335,* 395-403.

Chomsky, N. (1964). Comments for Project Literacy Meeting. *Project Literacy Reports No. 2.* Cornell University, Ithaca, NY.

Curtin, S., Mintz, T. H., & Byrd, D. (2000). Coarticulatory cues enhance infants' recognition of syllable sequences in speech. *Proceedings of the 25$^{th}$ Annual Boston University Conference on Language Development.* November, 2000. Boston, MA.

DeCasper, A. J. & Spence, M. J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant Behavior and Development, 9,* 133-150.

Diamond, A., Werker, J. F., & Lalonde, C. E. (1994). Toward understanding commonalities in the development of object search, detour navigation, and speech perception. In K. W. Fischer & G. Dawson (eds.), *Human Behavior and the Developing Brain*. New York: Guilford.

Eimas, P. D. & Miller, J. L. (1980). Contextual effects in infant speech perception. *Science, 209,* 1140-1141.

Eimas, P. D. & Quinn, P. C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child Development, 65*, 903-917.

Eimas, P. D., Quinn, P. C. & Cowan, P. C. (1994). Development of exclusivity in perceptually based categories of young infants. *Journal of Experimental Child Psychology, 58,* 418-431.

Eimas, P. D., Siqueland, E. R., Jusczyk, P. W., & Vigorito, J. (1971). Speech perception in infants. *Science, 171,* 303-306.

Fledge, J. E. (1984). The detection of French accent by American listeners. *Journal of the Acoustical Society of America, 76,* 692-707.

Fledge, J. E. & Hammond, R. (1982). Mimicry of non-distinctive phonetic differences between language varieties. *Studies in Second Language Acquisition, 5,* 1-18.

Fledge, J. E., Yeni-Komshian, G. H. & Liu, S. (1999). Age constraints on second-language acquisition. *Journal of Memory and Language, 41*, 78-104.

Foulkes, P. & Docherty, G. (1999). Urban Voice – Overview. In P. Foulkes & G. Docherty (Eds.), *Urban Voice.* London: Arnold.

Grieser, D. & Kuhl, P. K. (1989). Categorization of speech in infants: Support for speech-sound prototypes. *Developmental Psychology, 25(4),* 577-588.

Harris, J. R. (1998). *The Nurture Assumption.* New York: The Free Press.

Hepper, P. G., Scott, D., & Shahidullah, S. (1993). Newborn and fetal response to maternal voice. *Journal of Reproductive and Infant Psychology, 11,* 147-153.

Horowitz, F. D. (1975). Infant attention and discrimination: Methodological and substantive issues. *Monographs of the Society for Research in Child Development, 39 (Serial no. 158).*

Houston, D.M., & Jusczyk, P.W. (2000). The role of talker-specific information in word segmentation by infants. *Journal of Experimental Psychology: Human Perception and Performance, 26(5)*, 1570-1582.

Ingram, J. & Pittam, J. (1987). Auditory and acoustic correlates of perceived accent change: Vietnamese school children acquiring Australian English. *Journal of Phonetics, 15*, 127-145.

Johnson, E. K. & Jusczyk, P. W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory and Language, 44*, 1-20.

Jusczyk, P. W. (1997). *The Discovery of Spoken Language.* Cambridge, MA: MIT Press/Bradford Books.

Jusczyk, P. W., Friederici, A. D., Wessels, J., Svenkerud, V. Y., & Jusczyk, A. M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language, 32*, 402-420.

Jusczyk, P. W., Houston, D. & Goodman, M. (1998). Speech perception during the first year. In A. Slater (ed.), *Perceptual Development: Visual, Auditory, and Speech Perception in Infancy*. East Sussex, U.K.: Psychology Press.

Jusczyk, P.W., Houston, D.M., & Newsome, M. (1999). The beginnings of word segmentation in English-learning infants. *Cognitive Psychology, 39,* 159-207.

Jusczyk, P. W., Pisoni, D. B. & Mullennix, J. (1992). Some consequences of stimulus variability on speech processing by 2-month-old infants. *Cognition, 43,* 253-291.

Kuhl, P. K. (1979). Speech perception in early infancy: Perceptual constancy for spectrally dissimilar vowel categories. *Journal of the Acoustic Society of America, 66,* 1668-1679.

Kuhl, P. K. (1983). Perception of auditory equivalence classes for speech in early infancy. *Infant Behavior and Development, 6,* 263-285.

Kuhl, P. K. (1991). Human adults and infants exhibit a "perceptual magnet effect" for speech sounds, monkeys do not. *Perception and Psychophysics, 50*, 93-107.

Kuhl, P. K. & Miller, J. D. (1982). Discrimination of auditory target dimensions in the presence or absence of variation in a second dimension by infants. *Perception and Psychophysics, 31,* 279-292.

Kuhl, P. K. (1993). Innate predispositions and the effects of experiences in speech perception: The native language magnet theory. In B. D. Boysson-Bardies, S. D. Schoen, P. Jusczyk, P. McNeilage, & J. Morton (eds.), *Developmental neurocognition: Speech and face processing in the first year of life.* Dordrecht, The Netherlands: Kluwer.

Labov, W. (1972). Where do grammars stop? In R. Shuy (ed.), *Georgetown Monograph on Language and Linguistics, 25*, 43-88.

Labov, W. (1991). The three dialects of English. In P. Eckert (ed.), New Ways of Analyzing Sound Change. New York:Academic Press.

Lalonde, C. & Werker, J. F. (1995). Cognitive influences on corss-language speech perception in infancy. *Infant Behavior Development, 18*, 459-476.

Lasky, R. E., Syrdal-Lasky, A., & Klein, R. E. (1975). VOT discrimination by four to six and a hald month old infants from Spanish environments. *Journal of Experimental Child Psychology, 20,* 215-225.

Magen, H. S. (1998). The perception of foreign-accented speech. *Journal of Phonetics, 26*, 381-400.

Major, R. C. (1987). English voiceless stop production by speakers of Brazilian Portuguese. *Journal of Phonetics, 15*, 197-202.

Major, R. C. (2001). *Foreign Accent: The Ontogeny and Phylogeny of Second Language Phonology.* Mahwah, New Jersey: LEA.

Mandler, J. M. (2000). What global-before-basic trend? Commentary on perceptually based approached to early categorization. *Infancy, 1(1)*, 99-110.

Maratsos, M. & Chalkley, M. A. (1980). The internal language of children's syntax: the ontogenesis & representation of syntactic categories. In K. Nelson (ed.), *Children's Language, Vol. 2*. New York: Gardner Press.

Mehler, J., Jusczyk, P. W., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29,* 144-178.

Mehler, J., Dupoux, E., & Segui, J. (1990). Constraining models of lexical access: The onset of word recognition. In G. T. M. Altmann (Ed.), *Cognitive models of speech processing.* Hillsdale, NJ: Erlbaum.

Miller, J. L. & Eimas, P. D. (1983). Studies on the categorization of speech by infants. *Cognition, 13,* 135-165.

Miyawaki, K., Strange, W., Verbrugges, R., Liberman, A. M., Jenkins, J. J., & Fujimura, O. (1975). An effect of linguistic experience: The discrimination of /r/ and /l/ by native speakers of Japanese and English. *Perception and Psychophysics, 18,* 331-340.

Moon, C., Panneton-Cooper, R., & Fifer, W. P. (1993). Two-day-olds prefer their native language. *Infant Behavior and Development, 16*, 495-500.

Munro, M. J. (1995). Nonsegmental factors in foreign accent, *Studies in Second Language Acquisition, 17,* 17-34.

Munro, M. J. & Derwing, T. M. (1995). Foreign accent, comprehensibility, and intelligibility in the speech of second language learners, *Language Learning, 45,* 73-97.

Nathan, L., Wells, B., & Donlan, C. (1998). Children's comprehension of unfamiliar regional accents: a preliminary investigation. *Journal of Child Language, 25,* 343-365.

Nazzi, T., Bertoncini, J., & Mehler, J. (1998). Language discrimination by newborns: Towards an understanding of the role of rhythm. *Journal of Experimental Psychology: Human Cognition and Performance, 24(3),* 756-766.

Nazzi, T., Jusczyk, P. W., & Johnson, E. K. (2000). Language discrimination by English-learning 5-month-olds: Effects of rhythm and familiarity. *Journal of Memory and Language, 43*, 1-19.

Newell, L. C. (2002). *Infant's ability to discriminate gender on the bases of internal facial features.* Unpublished 1st and 2nd year project.

Nygaard, L. C., Sommers, M., S., & Pisoni, D. B. (1994). Speech perception as a talker contingent process. *Psychological Science, 5,* 42-46.

Payne, A. C. (1980). Factors controlling the acquisition of the Philadelphia dialect by out-of-state children. From W. Labov (ed.), *Locating Language in Time and Space*. New York: Academic Press.

Polka, L., & Werker, J. F. (1994). Developmental changes in perception of non-native vowel contrasts. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 421-435.

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception, 22,* 463-475.

Quinn, P. C., Johnson, M. H., Mareschal, D., Rakison, D. H., & Younger, B. A. (2000). Understanding early categorization: One process or two? *Infancy, 1(1)*, 111-122.

Rakison, D. H. (2000). When a rose is just a rose: The illusion of taxonomis in infant categorization. *Infancy, 1(1),* 77-90.

Roberts, J. (1997). Hitting a moving target: Acquisition of sound change in progress by Philadelphia children. *Language Variation and Change, 9*, 249-266.

Rodman, R. D. (1999). *Computer Speech Technology*. Boston, MA: Artech House Publishers.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996a). Statistical learning by 8-month-old infants. *Science, 274*, 1926-1928.

Saffran, J. R., Newport, E. L., & Aslin, R. N. (1996b). Word segmentation: The rold of distributional cues. *Journal of Memory and Language, 35*, 606-621.

Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition, 70*, 27-52.

Suomi, K. (1993). An outline of a model of adult phonological organization and behavior. *Journal of Phonetics, 21,* 29-60.

Tanaka, J. W., & Gauthier, I. (1997). Expertise in object and face recognition. In R. L. Goldstone¸ P. G. Schyns & D. L. Medin. (eds.), *Mechanisms of Perceptual Learning, Vol. 36,* p. 83-125. San Diego: Academic Press.

Trehub S. E. (1973). Infants' sensitivity to vowel and tonal contrasts. *Developmental Psychology, 9,* 91-96.

Trushima, T., Takizawa, O., Sasaki, M., Siraki, S., Nishi, K., Kohno, M., Menyuk, P., & Best, C. (1994). Discrimination of English /r-l/ and /w-y/ by Japanese infants at 6-12 months: Language-specific developmental changes in speech perception abilities. *Paper presented at the International Conference on Spoken Language Processing,* Yokohama, Japan.

Ward, C. D. & Cooper, R. P. (1999). A lack of evidence in 4-month-old human infants for paternal voice preference. *Developmental Psychobiology, 35,* 49-59.

Weinberger, S. (1999). *Speech Accent Archive*. Retrieved November 10, 2002, from. http://classweb.gmu.edu/accent/

Weinberger, S. (2000). Speech Accent Archive: Issues and Methods. Paper presented at Workshop on Web-Based Language Documentation and Description. 12-15 December, 2000. Philadelphia, PA.

Werker, J. F. (1991). The ontogeny of speech perception. In I. G. Mattingly & M. Studdert-Kennedy (Eds.), *Modularity and the Motor Theory of Speech Perception*. Hillsdale, NJ: Erlbaum.

Werker, J. F., Shi, R., Desjardins, R., Pegg, J. E., Polka, L., & Patterson, M. (1998). Three methods for testing infant speech perception. In A. Slater (ed.), *Perceptual Development: Visual, Auditory, and Speech Perception in Infancy*. East Sussex, U.K.: Psychology Press.

Werker, J. F. & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*, 49-63.

Werker, J. F. & Tees, R. C. (1999). Influences on infant speech processing: Towards a new synthesis. *Annual Review of Psychology, 50*, 509-535.

**Table 1. Summary of contrasts in Studies 2-4.**

| | 4-month-old infants | 10-month-old infants |
|---|---|---|
| Study 2 | Ep vs. Eny | Ep vs. Eny |
| Study 3 | | Eny vs. Ec |
| Study 4 | Cm vs. Ct | Cm vs. Ct |

Note: Ep= the Western Pennsylvania accent; Eny = the Hispanic Bronx/New York accent; Ec = the Chinese accent of the English language; Cm = the Mainland China accent of the Chinese language; Ct = the Taiwan accent of the Chinese language.

**Table 2. Speaker age (in years) and sample duration (in seconds) of the accented English speech stimuli used in Studies 1, 2 and 3.**

| | Age (years) | Duration (seconds) |
|---|---|---|
| Hispanic NY Bronx | 33.67 (8.80) | 23.77 (1.88) |
| Pennsylvania | 19.50 (1.52) | 23.41 (1.64) |
| Chinese | 28.50 (5.58) | 23.28 (1.11) |

**Table 3. Speaker age (in years) and sample duration (in seconds) of the accented Chinese speech stimluli used in Studies 1 and 4.**

| | **Age (years)** | Duration (seconds) |
|---|---|---|
| **Chinese-Mainland** | 32.83 (8.98) | 39.82 (8.61) |
| Chinese-Taiwan | 27.83 (6.40) | 38.62 (3.92) |

**Table 4. Raw data and error scores of an adult rater in Study 1.**

| Stimulus ID | Categorization | Error Score |
|---|---|---|
| CTO2 | 1 | 0 |
| CM04 | 1 | 1 |
| CM03 | 2 | 0 |
| CM05 | 2 | 0 |
| CT06 | 1 | 0 |
| CT04 | 2 | 1 |
| CT01 | 1 | 0 |
| CM06 | 2 | 0 |
| CM01 | 2 | 0 |
| CM02 | 2 | 0 |
| CT03 | 1 | 0 |
| CT05 | 2 | 1 |
| **Subtotal** | | 3 |
| **Error Rate (Error/12)** | | 0.25 |

Note: CT01-06 are six versions of the Taiwanese-accented Chinese stimuli; CM01-06 are six versions of the Mainland-accented Chinese stimuli. In this example, the scoring began with category 2, the category that received more votes. The first sample in category 2, CM03, was a Chinese-Mainland sample, and thus determined category 2 to be the Chinese-Mainland category, and category 1 to be the Chinese-Taiwanese category. Subsequently, each stimulus received an error score of 0 if it was categorized correctly, and an error score of 1 if it was in the wrong category. The total error score was then divided by 12, the total number of stimulus files, to determine the rater's error rate. This ratio can only be as high as 50%.

**Table 5. Mean reaction time of participants in Study 1 by experiment condition and stimulus type.**

| Condition | Accent Type | English speakers | Chinese Speakers |
|---|---|---|---|
| Ep-Eny | West. Penn. | 7.69 (5.04) | 9.10 (1.12) |
| | N.Y. | 5.14 (2.96) | 11.31 (5.08) |
| Eny-Ec | N.Y. | 9.93 (4.91) | 12.00 (12.94) |
| | Chinese | 8.64 (3.94) | 10.22 (7.37) |
| Cm-Ct | Mainland | 9.23 (4.33) | 6.22 (.66) |
| | Taiwan | 9.66 (4.56) | 7.07 (.86) |

Note: Standard Deviations in parentheses.

**Table 6. Total looking time of the initial three habituation trials, and the number of trials it took the infant to habituate in Study 2**

| | Age Goup | |
|---|---|---|
| | **4-month-olds** | **10-month-olds** |
| **initial 3 looks** | 29.98 (21.65) | 11.14 (5.07) |
| **# trials to habituate** | 7.5 (2.7) | 11.7 (7.3) |

Note: Standard Deviations are in parentheses.

**Table 7. Looking times (in seconds) of 4-month-olds to the familiar and novel stimuli during the first pair of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1 | FAMILIAR FIRST | F | 7.5797 | 4.63505 | 5 |
| | | M | 8.4180 | 5.91439 | 5 |
| | | Total | 7.9988 | 5.02893 | 10 |
| | NOVEL FIRST | F | 9.2002 | 7.36783 | 4 |
| | | M | 5.2715 | .88257 | 6 |
| | | Total | 6.8430 | 4.75853 | 10 |
| | Total | F | 8.2999 | 5.64164 | 9 |
| | | M | 6.7017 | 4.13299 | 11 |
| | | Total | 7.4209 | 4.80178 | 20 |
| N1 | FAMILIAR FIRST | F | 13.4023 | 10.28008 | 5 |
| | | M | 5.5703 | 3.16222 | 5 |
| | | Total | 9.4863 | 8.27359 | 10 |
| | NOVEL FIRST | F | 22.8740 | 2.46973 | 4 |
| | | M | 6.0710 | 3.55759 | 6 |
| | | Total | 12.7922 | 9.18455 | 10 |
| | Total | F | 17.6120 | 8.94693 | 9 |
| | | M | 5.8434 | 3.22435 | 11 |
| | | Total | 11.1393 | 8.67518 | 20 |

Note: Looking time variables: F1=familiar test trial 1, N1=novel test trial 1; Sex: F=Female, M=Male.

**Table 8. Looking times (in seconds) of 10-month-olds to the familiar and novel stimuli during the first pair of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1 | FAMILIAR FIRST | F | 15.8086 | 8.38207 | 5 |
| | | M | 23.1750 | 25.83826 | 5 |
| | | Total | 19.4918 | 18.52074 | 10 |
| | NOVEL FIRST | F | 11.9160 | 6.43175 | 4 |
| | | M | 10.4033 | 6.54800 | 4 |
| | | Total | 11.1597 | 6.06286 | 8 |
| | Total | F | 14.0786 | 7.40616 | 9 |
| | | M | 17.4987 | 19.87955 | 9 |
| | | Total | 15.7886 | 14.65890 | 18 |
| N1 | FAMILIAR FIRST | F | 35.2188 | 53.56149 | 5 |
| | | M | 15.1156 | 14.56628 | 5 |
| | | Total | 25.1672 | 38.49152 | 10 |
| | NOVEL FIRST | F | 12.2734 | 11.43949 | 4 |
| | | M | 6.9912 | .58416 | 4 |
| | | Total | 9.6323 | 8.01261 | 8 |
| | Total | F | 25.0208 | 40.36999 | 9 |
| | | M | 11.5048 | 11.16026 | 9 |
| | | Total | 18.2628 | 29.56188 | 18 |

Note: Looking time variables: F1=familiar test trial 1, N1=novel test trial 1; Sex: F=Female, M=Male.

**Table 9. Mean looking times (in seconds) of 4-month-olds to the familiar and novel stimuli during the first 2 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12 | FAMILIAR FIRST | F | 12.0398 | 3.97849 | 5 |
| | | M | 17.6723 | 14.48669 | 5 |
| | | Total | 14.8561 | 10.44606 | 10 |
| | NOVEL FIRST | F | 12.8350 | 6.30987 | 4 |
| | | M | 12.7256 | 12.22329 | 4 |
| | | Total | 12.7803 | 9.00550 | 8 |
| | Total | F | 12.3932 | 4.79794 | 9 |
| | | M | 15.4737 | 12.95212 | 9 |
| | | Total | 13.9335 | 9.60675 | 18 |
| N12 | FAMILIAR FIRST | F | 22.9879 | 28.52380 | 5 |
| | | M | 12.0547 | 8.72628 | 5 |
| | | Total | 17.5213 | 20.70388 | 10 |
| | NOVEL FIRST | F | 13.6514 | 7.18571 | 4 |
| | | M | 15.8594 | 13.66813 | 4 |
| | | Total | 14.7554 | 10.17776 | 8 |
| | Total | F | 18.8383 | 21.22217 | 9 |
| | | M | 13.7457 | 10.59016 | 9 |
| | | Total | 16.2920 | 16.47987 | 18 |

Note: Looking time variables: F12=familiar test trials 1 & 2, N12=novel test trials 1 & 2; Sex: F=Female, M=Male.

**Table 10. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli during the first 2 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12 | FAMILIAR FIRST | F | 7.7070 | 2.50861 | 5 |
| | | M | 6.3766 | 2.88778 | 5 |
| | | Total | 7.0418 | 2.64481 | 10 |
| | NOVEL FIRST | F | 7.1201 | 4.41836 | 4 |
| | | M | 5.1344 | 1.07709 | 6 |
| | | Total | 5.9287 | 2.86413 | 10 |
| | Total | F | 7.4462 | 3.25007 | 9 |
| | | M | 5.6990 | 2.08244 | 11 |
| | | Total | 6.4853 | 2.74322 | 20 |
| N12 | FAMILIAR FIRST | F | 12.8203 | 8.31045 | 5 |
| | | M | 5.0668 | 1.98719 | 5 |
| | | Total | 8.9436 | 7.01065 | 10 |
| | NOVEL FIRST | F | 15.8730 | 2.33629 | 4 |
| | | M | 7.1608 | 2.77903 | 6 |
| | | Total | 10.6457 | 5.13330 | 10 |
| | Total | F | 14.1771 | 6.25838 | 9 |
| | | M | 6.2090 | 2.57623 | 11 |
| | | Total | 9.7946 | 6.04364 | 20 |

Note: Looking time variables: F12=familiar test trials 1 & 2, N12=novel test trials 1 & 2; Sex: F=Female, M=Male.

**Table 11. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli during the first 3 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 | FAMILIAR FIRST | F | 11.1362 | 5.27856 | 5 |
| | | M | 15.5565 | 10.80012 | 5 |
| | | Total | 13.3464 | 8.34580 | 10 |
| | NOVEL FIRST | F | 11.7142 | 4.53109 | 4 |
| | | M | 11.8158 | 8.72892 | 4 |
| | | Total | 11.7650 | 6.43866 | 8 |
| | Total | F | 11.3931 | 4.66084 | 9 |
| | | M | 13.8940 | 9.52791 | 9 |
| | | Total | 12.6435 | 7.38910 | 18 |
| N123 | FAMILIAR FIRST | F | 19.8622 | 17.14441 | 5 |
| | | M | 11.6547 | 6.89163 | 5 |
| | | Total | 15.7585 | 13.05591 | 10 |
| | NOVEL FIRST | F | 12.0260 | 6.24765 | 4 |
| | | M | 12.1286 | 8.92117 | 4 |
| | | Total | 12.0773 | 7.13024 | 8 |
| | Total | F | 16.3795 | 13.36638 | 9 |
| | | M | 11.8653 | 7.32495 | 9 |
| | | Total | 14.1224 | 10.71069 | 18 |

Note: Looking time variables: F123=familiar test trials 1, 2 & 3, N122=novel test trials 1, 2 & 3; Sex: F=Female, M=Male.

**Table 12. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli during the first 3 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 | FAMILIAR FIRST | F | 6.8333 | 1.84103 | 5 |
| | | M | 6.3237 | 2.43449 | 5 |
| | | Total | 6.5785 | 2.05247 | 10 |
| | NOVEL FIRST | F | 6.3298 | 3.50937 | 4 |
| | | M | 4.9238 | 1.20620 | 6 |
| | | Total | 5.4862 | 2.33251 | 10 |
| | Total | F | 6.6095 | 2.52656 | 9 |
| | | M | 5.5601 | 1.90594 | 11 |
| | | Total | 6.0324 | 2.21056 | 20 |
| N123 | FAMILIAR FIRST | F | 12.8286 | 8.45272 | 5 |
| | | M | 5.8414 | 1.98010 | 5 |
| | | Total | 9.3350 | 6.85995 | 10 |
| | NOVEL FIRST | F | 12.7207 | 2.65500 | 4 |
| | | M | 6.3487 | 2.04665 | 6 |
| | | Total | 8.8975 | 3.93751 | 10 |
| | Total | F | 12.7807 | 6.19442 | 9 |
| | | M | 6.1181 | 1.93207 | 11 |
| | | Total | 9.1163 | 5.44843 | 20 |

Note: Looking time variables: F123=familiar test trials 1, 2 & 3, N123=novel test trials 1, 2 & 3; Sex: F=Female, M=Male.

**Table 13. Mean looking times (in seconds) of 4-month-olds to the familiar and novel stimuli during all 4 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234 | FAMILIAR FIRST | F | 9.7561 | 4.20375 | 5 |
| | | M | 14.8559 | 8.08637 | 5 |
| | | Total | 12.3060 | 6.64383 | 10 |
| | NOVEL FIRST | F | 12.0737 | 4.95412 | 4 |
| | | M | 12.6575 | 4.24310 | 4 |
| | | Total | 12.3656 | 4.28157 | 8 |
| | Total | F | 10.7861 | 4.41946 | 9 |
| | | M | 13.8788 | 6.38660 | 9 |
| | | Total | 12.3325 | 5.56038 | 18 |
| N1234 | FAMILIAR FIRST | F | 18.0002 | 15.26346 | 5 |
| | | M | 10.7795 | 5.08693 | 5 |
| | | Total | 14.3898 | 11.38101 | 10 |
| | NOVEL FIRST | F | 11.7830 | 6.23636 | 4 |
| | | M | 11.9556 | 8.31644 | 4 |
| | | Total | 11.8693 | 6.80573 | 8 |
| | Total | F | 15.2370 | 11.90834 | 9 |
| | | M | 11.3022 | 6.26569 | 9 |
| | | Total | 13.2696 | 9.45021 | 18 |

Note: Looking time variables: F1234=all 4 familiar test trials, N1234=all 4 novel test trials; Sex: F=Female, M=Male.

**Table 14. Mean Looking times (in seconds) of 10-month-olds to the familiar and novel stimuli during all 4 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234 | FAMILIAR FIRST | F | 6.9734 | 2.50938 | 5 |
| | | M | 6.6686 | 1.85277 | 5 |
| | | Total | 6.8210 | 2.08570 | 10 |
| | NOVEL FIRST | F | 6.3401 | 3.23948 | 4 |
| | | M | 5.7207 | 1.20127 | 6 |
| | | Total | 5.9685 | 2.09811 | 10 |
| | Total | F | 6.6919 | 2.68239 | 9 |
| | | M | 6.1515 | 1.52959 | 11 |
| | | Total | 6.3947 | 2.08256 | 20 |
| N1234 | FAMILIAR FIRST | F | 12.0955 | 6.38056 | 5 |
| | | M | 5.7508 | 1.75371 | 5 |
| | | Total | 8.9231 | 5.53561 | 10 |
| | NOVEL FIRST | F | 13.5544 | 5.75461 | 4 |
| | | M | 5.6027 | 1.48631 | 6 |
| | | Total | 8.7834 | 5.39696 | 10 |
| | Total | F | 12.7439 | 5.77627 | 9 |
| | | M | 5.6700 | 1.52995 | 11 |
| | | Total | 8.8533 | 5.32140 | 20 |

Note: Looking time variables: F1234=all 4 familiar test trials, N1234=all 4 novel test trials; Sex: F=Female, M=Male.

**Table 15. Log transformed looking scores of 4-month-olds to the familiar and novel stimuli during the first pair of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1LOG | FAMILIAR FIRST | F | 2.6498 | .52756 | 5 |
| | | M | 2.7324 | .96740 | 5 |
| | | Total | 2.6911 | .73589 | 10 |
| | NOVEL FIRST | F | 2.3196 | .71468 | 4 |
| | | M | 2.1891 | .65028 | 4 |
| | | Total | 2.2543 | .63639 | 8 |
| | Total | F | 2.5030 | .60082 | 9 |
| | | M | 2.4909 | .84172 | 9 |
| | | Total | 2.4970 | .70945 | 18 |
| N1LOG | FAMILIAR FIRST | F | 2.7091 | 1.39681 | 5 |
| | | M | 2.2475 | 1.22127 | 5 |
| | | Total | 2.4783 | 1.26064 | 10 |
| | NOVEL FIRST | F | 1.9969 | 1.28013 | 4 |
| | | M | 1.9421 | .08188 | 4 |
| | | Total | 1.9695 | .84027 | 8 |
| | Total | F | 2.3925 | 1.31566 | 9 |
| | | M | 2.1118 | .87988 | 9 |
| | | Total | 2.2522 | 1.09533 | 18 |

Note: Looking time variables: F1LOG= log scores of the first familiar trial, N1LOG=log scores of the first novel trial; Sex: F=Female, M=Male

**Table 16. Log transformed looking scores of 10-month-olds to the familiar and novel stimuli during the first pair of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1LOG | FAMILIAR FIRST | F | 1.8885 | .58105 | 5 |
| | | M | 1.9270 | .70947 | 5 |
| | | Total | 1.9078 | .61170 | 10 |
| | NOVEL FIRST | F | 1.9102 | .97631 | 4 |
| | | M | 1.6507 | .16714 | 6 |
| | | Total | 1.7545 | .59262 | 10 |
| | Total | F | 1.8982 | .72552 | 9 |
| | | M | 1.7763 | .48593 | 11 |
| | | Total | 1.8311 | .59142 | 20 |
| N1LOG | FAMILIAR FIRST | F | 2.3717 | .74414 | 5 |
| | | M | 1.6167 | .47039 | 5 |
| | | Total | 1.9942 | .70908 | 10 |
| | NOVEL FIRST | F | 3.1257 | .10748 | 4 |
| | | M | 1.6667 | .56899 | 6 |
| | | Total | 2.2503 | .86679 | 10 |
| | Total | F | 2.7068 | .66264 | 9 |
| | | M | 1.6440 | .50106 | 11 |
| | | Total | 2.1223 | .78186 | 20 |

Note: Looking time variables: F1LOG= log scores of the first familiar trial, N1LOG=log scores of the first novel trial; Sex: F=Female, M=Male.

**Table 17. Mean log transformed looking scores of 4-month-olds to the familiar and novel stimuli during the first 2 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12LOG | FAMILIAR FIRST | F | 2.3446 | .25458 | 5 |
| | | M | 2.4996 | .70823 | 5 |
| | | Total | 2.4221 | .50834 | 10 |
| | NOVEL FIRST | F | 2.3707 | .62400 | 4 |
| | | M | 2.0606 | 1.00621 | 4 |
| | | Total | 2.2156 | .79263 | 8 |
| | Total | F | 2.3562 | .42263 | 9 |
| | | M | 2.3045 | .82705 | 9 |
| | | Total | 2.3303 | .63769 | 18 |
| N12LOG | FAMILIAR FIRST | F | 2.4954 | .81627 | 5 |
| | | M | 2.1848 | .69281 | 5 |
| | | Total | 2.3401 | .73230 | 10 |
| | NOVEL FIRST | F | 2.1797 | .77172 | 4 |
| | | M | 2.3669 | .49229 | 4 |
| | | Total | 2.2733 | .60755 | 8 |
| | Total | F | 2.3551 | .76430 | 9 |
| | | M | 2.2657 | .58317 | 9 |
| | | Total | 2.3104 | .66110 | 18 |

Note: Looking time variables: F12LOG= mean log scores of first familiar trials 1 & 2, N12LOG=mean log scores of the first novel trials 1 & 2; Sex: F=Female, M=Male.

**Table 18. Mean log transformed looking scores of 10-month-olds to the familiar and novel stimuli during the first 2 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12LOG | FAMILIAR FIRST | F | 1.9461 | .36019 | 5 |
| | | M | 1.6874 | .35953 | 5 |
| | | Total | 1.8168 | .36566 | 10 |
| | NOVEL FIRST | F | 1.7473 | .60823 | 4 |
| | | M | 1.5610 | .32925 | 6 |
| | | Total | 1.6355 | .43907 | 10 |
| | Total | F | 1.8577 | .46323 | 9 |
| | | M | 1.6185 | .33205 | 11 |
| | | Total | 1.7261 | .40410 | 20 |
| N12LOG | FAMILIAR FIRST | F | 2.3299 | .73248 | 5 |
| | | M | 1.5613 | .31631 | 5 |
| | | Total | 1.9456 | .66860 | 10 |
| | NOVEL FIRST | F | 2.5867 | .27799 | 4 |
| | | M | 1.8454 | .38724 | 6 |
| | | Total | 2.1419 | .50556 | 10 |
| | Total | F | 2.4440 | .56174 | 9 |
| | | M | 1.7163 | .37016 | 11 |
| | | Total | 2.0438 | .58563 | 20 |

Note: Looking time variables: F12LOG= mean log scores of familiar trials 1 & 2, N12LOG=mean log scores of novel trials 1 & 2; Sex: F=Female, M=Male.

**Table 19. Mean log transformed looking scores of 4-month-olds to the familiar and novel stimuli during the first 3 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 LOG | FAMILIAR FIRST | F | 2.2258 | .39832 | 5 |
| | | M | 2.4443 | .60369 | 5 |
| | | Total | 2.3351 | .49574 | 10 |
| | NOVEL FIRST | F | 2.2459 | .46111 | 4 |
| | | M | 2.0291 | .80936 | 4 |
| | | Total | 2.1375 | .62072 | 8 |
| | Total | F | 2.2347 | .39897 | 9 |
| | | M | 2.2598 | .68976 | 9 |
| | | Total | 2.2472 | .54678 | 18 |
| N123LOG | FAMILIAR FIRST | F | 2.4720 | .35089 | 5 |
| | | M | 2.2290 | .57647 | 5 |
| | | Total | 2.3505 | .46778 | 10 |
| | NOVEL FIRST | F | 2.0589 | .72595 | 4 |
| | | M | 2.0808 | .32010 | 4 |
| | | Total | 2.0699 | .51953 | 8 |
| | Total | F | 2.2884 | .55370 | 9 |
| | | M | 2.1632 | .45900 | 9 |
| | | Total | 2.2258 | .49757 | 18 |

Note: Looking time variables: F123LOG= mean log scores of familiar trials 1, 2 & 3, N123LOG=mean log scores of novel trials 1, 2 & 3; Sex: F=Female, M=Male.

**Table 20. Mean log transformed looking scores of 10-month-olds to the familiar and novel stimuli during the first 3 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 LOG | FAMILIAR FIRST | F | 2.2258 | .39832 | 5 |
| | | M | 2.4443 | .60369 | 5 |
| | | Total | 2.3351 | .49574 | 10 |
| | NOVEL FIRST | F | 2.2459 | .46111 | 4 |
| | | M | 2.0291 | .80936 | 4 |
| | | Total | 2.1375 | .62072 | 8 |
| | Total | F | 2.2347 | .39897 | 9 |
| | | M | 2.2598 | .68976 | 9 |
| | | Total | 2.2472 | .54678 | 18 |
| N123LOG | FAMILIAR FIRST | F | 2.4720 | .35089 | 5 |
| | | M | 2.2290 | .57647 | 5 |
| | | Total | 2.3505 | .46778 | 10 |
| | NOVEL FIRST | F | 2.0589 | .72595 | 4 |
| | | M | 2.0808 | .32010 | 4 |
| | | Total | 2.0699 | .51953 | 8 |
| | Total | F | 2.2884 | .55370 | 9 |
| | | M | 2.1632 | .45900 | 9 |
| | | Total | 2.2258 | .49757 | 18 |

Note: Looking time variables: F123LOG= mean log scores of familiar trials 1, 2 & 3, N123LOG=mean log scores of novel trials 1, 2 & 3; Sex: F=Female, M=Male.

**Table 21. Mean log transformed looking scores of 4-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234LOG | FAMILIAR FIRST | F | 2.0463 | .38515 | 5 |
| | | M | 2.4242 | .51618 | 5 |
| | | Total | 2.2353 | .47331 | 10 |
| | NOVEL FIRST | F | 2.2808 | .47135 | 4 |
| | | M | 2.1573 | .43488 | 4 |
| | | Total | 2.2190 | .42500 | 8 |
| | Total | F | 2.1505 | .41564 | 9 |
| | | M | 2.3056 | .47322 | 9 |
| | | Total | 2.2281 | .43937 | 18 |
| N1234LOG | FAMILIAR FIRST | F | 2.4070 | .48292 | 5 |
| | | M | 2.1848 | .43145 | 5 |
| | | Total | 2.2959 | .44732 | 10 |
| | NOVEL FIRST | F | 2.0609 | .64315 | 4 |
| | | M | 2.1278 | .39314 | 4 |
| | | Total | 2.0944 | .49477 | 8 |
| | Total | F | 2.2532 | .55226 | 9 |
| | | M | 2.1595 | .38979 | 9 |
| | | Total | 2.2063 | .46620 | 18 |

Note: Looking time variables: F1234LOG= mean log scores of all 4 familiar trials, N1234LOG=mean log scores of all 4 novel trials; Sex: F=Female, M=Male.

**Table 22. Mean log transformed looking scores of 10-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 2.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234LOG | FAMILIAR FIRST | F | 1.8053 | .39384 | 5 |
| | | M | 1.7635 | .26554 | 5 |
| | | Total | 1.7844 | .31743 | 10 |
| | NOVEL FIRST | F | 1.6649 | .50671 | 4 |
| | | M | 1.6487 | .27867 | 6 |
| | | Total | 1.6552 | .35888 | 10 |
| | Total | F | 1.7429 | .42346 | 9 |
| | | M | 1.7009 | .26576 | 11 |
| | | Total | 1.7198 | .33636 | 20 |
| N1234LOG | FAMILIAR FIRST | F | 2.2567 | .59250 | 5 |
| | | M | 1.6124 | .24490 | 5 |
| | | Total | 1.9345 | .54588 | 10 |
| | NOVEL FIRST | F | 2.2561 | .34443 | 4 |
| | | M | 1.5875 | .25556 | 6 |
| | | Total | 1.8549 | .44164 | 10 |
| | Total | F | 2.2564 | .46906 | 9 |
| | | M | 1.5988 | .23836 | 11 |
| | | Total | 1.8947 | .48498 | 20 |

Note: Looking time variables: F1234LOG= mean log scores of all 4 familiar trials, N1234LOG=mean log scores of all 4 novel trials; Sex: F=Female, M=Male.

**Table 23. Raw looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over the first pair of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1 | F | F | 6.2900 | 2.79118 | 4 |
| | | M | 7.2256 | 3.00772 | 4 |
| | | Total | 6.7578 | 2.73239 | 8 |
| | N | F | 4.6357 | .71985 | 4 |
| | | M | 7.2119 | 6.60215 | 4 |
| | | Total | 5.9238 | 4.56059 | 8 |
| | Total | F | 5.4629 | 2.08395 | 8 |
| | | M | 7.2188 | 4.74951 | 8 |
| | | Total | 6.3408 | 3.65729 | 16 |
| N1 | F | F | 9.0732 | 4.81190 | 4 |
| | | M | 7.3057 | 2.78557 | 4 |
| | | Total | 8.1895 | 3.76051 | 8 |
| | N | F | 12.8760 | 8.84259 | 4 |
| | | M | 6.6865 | 1.60296 | 4 |
| | | Total | 9.7813 | 6.74962 | 8 |
| | Total | F | 10.9746 | 6.89678 | 8 |
| | | M | 6.9961 | 2.12983 | 8 |
| | | Total | 8.9854 | 5.34183 | 16 |

Note: Looking time variables: F1= looking time over the first familiar test trial, N1=looking time over the first novel test trial; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 24. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over the first 2 pairs of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12 | F | F | 5.0879 | 1.15615 | 4 |
| | | M | 6.1138 | 2.70210 | 4 |
| | | Total | 5.6008 | 2.00068 | 8 |
| | N | F | 4.8047 | 2.50514 | 4 |
| | | M | 8.3291 | 6.14155 | 4 |
| | | Total | 6.5669 | 4.73326 | 8 |
| | Total | F | 4.9463 | 1.81256 | 8 |
| | | M | 7.2214 | 4.54934 | 8 |
| | | Total | 6.0839 | 3.54568 | 16 |
| N12 | F | F | 7.0068 | 2.36168 | 4 |
| | | M | 5.6104 | 1.10079 | 4 |
| | | Total | 6.3086 | 1.86196 | 8 |
| | N | F | 8.5527 | 5.07530 | 4 |
| | | M | 6.1309 | 1.14053 | 4 |
| | | Total | 7.3418 | 3.64318 | 8 |
| | Total | F | 7.7798 | 3.75668 | 8 |
| | | M | 5.8706 | 1.07434 | 8 |
| | | Total | 6.8252 | 2.84544 | 16 |

Note: Looking time variables: F12= mean looking times over the first 2 pairs of familiar test trials, N12=mean looking times over the first 2 pairs of novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 25. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over the first 3 pairs of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 | F | F | 4.8333 | .93718 | 4 |
| | | M | 5.6491 | 2.66240 | 4 |
| | | Total | 5.2412 | 1.89853 | 8 |
| | N | F | 5.7796 | 2.80749 | 4 |
| | | M | 7.0163 | 4.34474 | 4 |
| | | Total | 6.3979 | 3.45036 | 8 |
| | Total | F | 5.3065 | 2.00257 | 8 |
| | | M | 6.3327 | 3.41497 | 8 |
| | | Total | 5.8196 | 2.75582 | 16 |
| N123 | F | F | 6.2555 | 1.68104 | 4 |
| | | M | 7.3818 | 3.09025 | 4 |
| | | Total | 6.8187 | 2.38039 | 8 |
| | N | F | 8.1325 | 2.96871 | 4 |
| | | M | 6.9993 | 2.85305 | 4 |
| | | Total | 7.5659 | 2.76270 | 8 |
| | Total | F | 7.1940 | 2.44842 | 8 |
| | | M | 7.1906 | 2.76099 | 8 |
| | | Total | 7.1923 | 2.52091 | 16 |

Note: Looking time variables: F123= mean looking times over the first 3 pairs of familiar test trials, N123=mean looking times over the first 3 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 26. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234 | F | F | 4.5286 | .56205 | 4 |
| | | M | 5.9910 | 2.56591 | 4 |
| | | Total | 5.2598 | 1.88894 | 8 |
| | N | F | 6.4114 | 2.00807 | 4 |
| | | M | 6.8792 | 3.99080 | 4 |
| | | Total | 6.6453 | 2.93536 | 8 |
| | Total | F | 5.4700 | 1.69599 | 8 |
| | | M | 6.4351 | 3.14209 | 8 |
| | | Total | 5.9525 | 2.48957 | 16 |
| N1234 | F | F | 5.9329 | 1.34564 | 4 |
| | | M | 6.6633 | 2.20554 | 4 |
| | | Total | 6.2981 | 1.73587 | 8 |
| | N | F | 7.3901 | 2.09071 | 4 |
| | | M | 9.0808 | 7.04955 | 4 |
| | | Total | 8.2355 | 4.89779 | 8 |
| | Total | F | 6.6615 | 1.80447 | 8 |
| | | M | 7.8721 | 5.00529 | 8 |
| | | Total | 7.2668 | 3.68804 | 16 |

Note: Looking time variables: F1234= mean looking times over all 4 familiar test trials, N1234=mean looking times over all 4 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 27. Log transformed looking scores10-month-olds to the familiar and novel stimuli over the first pair of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1LOG | F | F | 1.7768 | .38846 | 4 |
| | | M | 1.8861 | .53732 | 4 |
| | | Total | 1.8315 | .43797 | 8 |
| | N | F | 1.5237 | .16900 | 4 |
| | | M | 1.6909 | .85325 | 4 |
| | | Total | 1.6073 | .57641 | 8 |
| | Total | F | 1.6503 | .30859 | 8 |
| | | M | 1.7885 | .66831 | 8 |
| | | Total | 1.7194 | .50790 | 16 |
| N1LOG | F | F | 2.0407 | .74196 | 4 |
| | | M | 1.9260 | .42420 | 4 |
| | | Total | 1.9834 | .56286 | 8 |
| | N | F | 2.3625 | .73476 | 4 |
| | | M | 1.8764 | .25722 | 4 |
| | | Total | 2.1195 | .57204 | 8 |
| | Total | F | 2.2016 | .70490 | 8 |
| | | M | 1.9012 | .32585 | 8 |
| | | Total | 2.0514 | .55271 | 16 |

Note: Looking time variables: F1LOG= mean log scores of the first pair of familiar test trials, N1LOG=mean log scores of the first pair of novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 28. Mean log transformed looking scores10-month-olds to the familiar and novel stimuli over the first 2 pairs of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12LOG | F | F | 1.5456 | .16286 | 4 |
| | | M | 1.6454 | .60830 | 4 |
| | | Total | 1.5955 | .41568 | 8 |
| | N | F | 1.4197 | .47805 | 4 |
| | | M | 1.6403 | .70243 | 4 |
| | | Total | 1.5300 | .56860 | 8 |
| | Total | F | 1.4827 | .33740 | 8 |
| | | M | 1.6428 | .60832 | 8 |
| | | Total | 1.5628 | .48234 | 16 |
| N12LOG | F | F | 1.8012 | .38144 | 4 |
| | | M | 1.6388 | .13785 | 4 |
| | | Total | 1.7200 | .27934 | 8 |
| | N | F | 1.8792 | .49094 | 4 |
| | | M | 1.7713 | .20932 | 4 |
| | | Total | 1.8253 | .35412 | 8 |
| | Total | F | 1.8402 | .40913 | 8 |
| | | M | 1.7051 | .17872 | 8 |
| | | Total | 1.7727 | .31287 | 16 |

Note: Looking time variables: F12LOG= mean log scores of the first 2 pairs of familiar test trials, N12LOG=mean log scores of the first 2 pairs of novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 29. Mean log transformed looking scores10-month-olds to the familiar and novel stimuli over the first 3 pairs of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123LOG | F | F | 1.5069 | .17598 | 4 |
| | | M | 1.5613 | .59954 | 4 |
| | | Total | 1.5341 | .41008 | 8 |
| | N | F | 1.5806 | .50486 | 4 |
| | | M | 1.5302 | .56767 | 4 |
| | | Total | 1.5554 | .49807 | 8 |
| | Total | F | 1.5438 | .35222 | 8 |
| | | M | 1.5457 | .54077 | 8 |
| | | Total | 1.5448 | .44087 | 16 |
| N123LOG | F | F | 1.7108 | .25735 | 4 |
| | | M | 1.8357 | .29290 | 4 |
| | | Total | 1.7732 | .26383 | 8 |
| | N | F | 1.8624 | .32044 | 4 |
| | | M | 1.8239 | .40973 | 4 |
| | | Total | 1.8432 | .34115 | 8 |
| | Total | F | 1.7866 | .28100 | 8 |
| | | M | 1.8298 | .32978 | 8 |
| | | Total | 1.8082 | .29681 | 16 |

Note: Looking time variables: F123LOG= mean log scores of the first 3 pairs of familiar test trials, N123LOG=mean log scores of the first 3 pairs of novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 30. Mean log transformed looking scores10-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 3.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234LOG | F | F | 1.4452 | .12175 | 4 |
| | | M | 1.5949 | .49548 | 4 |
| | | Total | 1.5200 | .34346 | 8 |
| | N | F | 1.6926 | .37260 | 4 |
| | | M | 1.5672 | .56761 | 4 |
| | | Total | 1.6299 | .44952 | 8 |
| | Total | F | 1.5689 | .28868 | 8 |
| | | M | 1.5810 | .49347 | 8 |
| | | Total | 1.5749 | .39060 | 16 |
| N1234LOG | F | F | 1.6746 | .22558 | 4 |
| | | M | 1.7404 | .20636 | 4 |
| | | Total | 1.7075 | .20321 | 8 |
| | N | F | 1.7977 | .21933 | 4 |
| | | M | 1.9000 | .56818 | 4 |
| | | Total | 1.8488 | .40245 | 8 |
| | Total | F | 1.7361 | .21622 | 8 |
| | | M | 1.8202 | .40483 | 8 |
| | | Total | 1.7781 | .31652 | 16 |

Note: Looking time variables: F1234LOG= mean log scores of all 4 pairs of familiar test trials, N1234LOG=mean log scores of all 4 pairs of novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 31. Looking times (in seconds) of 4-month-olds to the familiar and novel stimuli over the first pair of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1 | F | F | 12.6641 | 9.78705 | 6 |
| | | M | 11.7437 | 6.25940 | 5 |
| | | Total | 12.2457 | 7.98725 | 11 |
| | N | F | 11.1377 | 5.66122 | 4 |
| | | M | 7.1156 | 5.94260 | 5 |
| | | Total | 8.9032 | 5.84546 | 9 |
| | Total | F | 12.0535 | 8.03238 | 10 |
| | | M | 9.4297 | 6.24968 | 10 |
| | | Total | 10.7416 | 7.13266 | 20 |
| N1 | F | F | 8.5299 | 6.53491 | 6 |
| | | M | 29.4484 | 39.44652 | 5 |
| | | Total | 18.0384 | 27.62435 | 11 |
| | N | F | 18.0195 | 23.29045 | 4 |
| | | M | 6.5555 | 2.76486 | 5 |
| | | Total | 11.6506 | 15.61237 | 9 |
| | Total | F | 12.3258 | 15.11800 | 10 |
| | | M | 18.0020 | 28.99216 | 10 |
| | | Total | 15.1639 | 22.69128 | 20 |

Note: Looking time variables: F1= looking time over the first familiar test trial, N1=looking time over the first novel test trial; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 32. Looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over the first pair of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1 | F | F | 5.8066 | 4.85286 | 4 |
| | | M | 8.1504 | 2.60986 | 4 |
| | | Total | 6.9785 | 3.81858 | 8 |
| | N | F | 4.1732 | .34407 | 3 |
| | | M | 6.6555 | 4.75723 | 5 |
| | | Total | 5.7246 | 3.82314 | 8 |
| | Total | F | 5.1066 | 3.54639 | 7 |
| | | M | 7.3199 | 3.80666 | 9 |
| | | Total | 6.3516 | 3.74767 | 16 |
| N1 | F | F | 4.5771 | 3.93514 | 4 |
| | | M | 8.4971 | 4.31255 | 4 |
| | | Total | 6.5371 | 4.35860 | 8 |
| | N | F | 2.3971 | 1.07854 | 3 |
| | | M | 9.0242 | 4.57247 | 5 |
| | | Total | 6.5391 | 4.90340 | 8 |
| | Total | F | 3.6429 | 3.08030 | 7 |
| | | M | 8.7899 | 4.18392 | 9 |
| | | Total | 6.5381 | 4.48170 | 16 |

Note: Looking time variables: F1= looking time over the first familiar test trial, N1=looking time over the first novel test trial; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 33. Mean looking times (in seconds) of 4-month-olds to the familiar and novel stimuli over the first 2 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12 | F | F | 8.7197 | 4.77418 | 6 |
| | | M | 10.7262 | 3.55395 | 5 |
| | | Total | 9.6317 | 4.18886 | 11 |
| | N | F | 9.7168 | 4.47233 | 4 |
| | | M | 6.7180 | 3.02924 | 5 |
| | | Total | 8.0508 | 3.81927 | 9 |
| | Total | F | 9.1186 | 4.42663 | 10 |
| | | M | 8.7221 | 3.76226 | 10 |
| | | Total | 8.9203 | 4.00350 | 20 |
| N12 | F | F | 7.0329 | 3.50223 | 6 |
| | | M | 24.0789 | 22.49242 | 5 |
| | | Total | 14.7811 | 16.96296 | 11 |
| | N | F | 11.2637 | 12.10433 | 4 |
| | | M | 7.2332 | 2.30978 | 5 |
| | | Total | 9.0245 | 7.88181 | 9 |
| | Total | F | 8.7252 | 7.77340 | 10 |
| | | M | 15.6561 | 17.49419 | 10 |
| | | Total | 12.1906 | 13.64674 | 20 |

Note: Looking time variables: F12= mean looking time over the first 2 familiar test trials, N12=mean looking time over the first 2 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 34. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over the first 2 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12 | F | F | 5.6294 | 4.22491 | 4 |
| | | M | 8.2358 | 4.02676 | 4 |
| | | Total | 6.9326 | 4.06696 | 8 |
| | N | F | 5.2910 | 1.60755 | 3 |
| | | M | 6.0031 | 2.60846 | 5 |
| | | Total | 5.7361 | 2.18225 | 8 |
| | Total | F | 5.4844 | 3.13354 | 7 |
| | | M | 6.9954 | 3.29656 | 9 |
| | | Total | 6.3344 | 3.21293 | 16 |
| N12 | F | F | 4.2861 | 1.92841 | 4 |
| | | M | 8.3926 | 3.08488 | 4 |
| | | Total | 6.3394 | 3.23886 | 8 |
| | N | F | 4.0104 | 1.27948 | 3 |
| | | M | 8.7086 | 2.44209 | 5 |
| | | Total | 6.9468 | 3.12858 | 8 |
| | Total | F | 4.1680 | 1.55782 | 7 |
| | | M | 8.5681 | 2.56482 | 9 |
| | | Total | 6.6431 | 3.09218 | 16 |

Note: Looking time variables: F12= mean looking time over the first 2 familiar test trials, N12=mean looking time over the first 2 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 35. Mean looking times (in seconds) of 4-month-olds to the familiar and novel stimuli over the first 3 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 | F | F | 7.5831 | 3.43161 | 6 |
| | | M | 11.6253 | 6.22891 | 5 |
| | | Total | 9.4205 | 5.08564 | 11 |
| | N | F | 11.1051 | 4.95419 | 4 |
| | | M | 6.4529 | 2.58778 | 5 |
| | | Total | 8.5205 | 4.30865 | 9 |
| | Total | F | 8.9919 | 4.24634 | 10 |
| | | M | 9.0391 | 5.25851 | 10 |
| | | Total | 9.0155 | 4.65189 | 20 |
| N123 | F | F | 7.8889 | 5.30116 | 6 |
| | | M | 20.5188 | 16.42019 | 5 |
| | | Total | 13.6297 | 12.86094 | 11 |
| | N | F | 8.8584 | 7.62377 | 4 |
| | | M | 8.5596 | 5.59807 | 5 |
| | | Total | 8.6924 | 6.12288 | 9 |
| | Total | F | 8.2767 | 5.93607 | 10 |
| | | M | 14.5392 | 13.17150 | 10 |
| | | Total | 11.4079 | 10.44943 | 20 |

Note: Looking time variables: F123= mean looking time (in seconds) over the first 3 familiar test trials, N123=mean looking time (in seconds) over the first 3 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 36. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over the first 3 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123 | F | F | 6.6647 | 3.48732 | 4 |
| | | M | 7.2025 | 2.51197 | 4 |
| | | Total | 6.9336 | 2.82824 | 8 |
| | N | F | 5.1254 | 1.27174 | 3 |
| | | M | 6.3813 | 2.26326 | 5 |
| | | Total | 5.9103 | 1.95233 | 8 |
| | Total | F | 6.0050 | 2.70125 | 7 |
| | | M | 6.7462 | 2.26158 | 9 |
| | | Total | 6.4220 | 2.40641 | 16 |
| N123 | F | F | 4.3903 | 1.61555 | 4 |
| | | M | 7.4945 | 2.52003 | 4 |
| | | Total | 5.9424 | 2.56775 | 8 |
| | N | F | 4.5833 | 2.16329 | 3 |
| | | M | 8.5815 | 1.34224 | 5 |
| | | Total | 7.0822 | 2.57845 | 8 |
| | Total | F | 4.4730 | 1.69576 | 7 |
| | | M | 8.0984 | 1.90013 | 9 |
| | | Total | 6.5123 | 2.55459 | 16 |

Note: Looking time variables: F123= mean looking times (in seconds) over the first 3 familiar test trials, N123=mean looking times (in seconds) over the first 3 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 37. Mean looking times (in seconds) of 4-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234 | F | F | 7.3464 | 2.78614 | 6 |
| | | M | 11.7813 | 6.00557 | 5 |
| | | Total | 9.3622 | 4.86540 | 11 |
| | N | F | 13.6091 | 7.43259 | 4 |
| | | M | 6.3668 | 2.44638 | 5 |
| | | Total | 9.5856 | 6.18696 | 9 |
| | Total | F | 9.8515 | 5.76076 | 10 |
| | | M | 9.0740 | 5.18006 | 10 |
| | | Total | 9.4627 | 5.34689 | 20 |
| N1234 | F | F | 7.2783 | 4.06877 | 6 |
| | | M | 20.3328 | 14.88296 | 5 |
| | | Total | 13.2122 | 11.97316 | 11 |
| | N | F | 10.4583 | 7.80693 | 4 |
| | | M | 7.8975 | 4.18642 | 5 |
| | | Total | 9.0356 | 5.78275 | 9 |
| | Total | F | 8.5503 | 5.67536 | 10 |
| | | M | 14.1151 | 12.21433 | 10 |
| | | Total | 11.3327 | 9.69925 | 20 |

Note: Looking time variables: F1234= mean looking time (in seconds) over all 4 familiar test trials, N1234=mean looking time (in seconds) over all 4 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 38. Mean looking times (in seconds) of 10-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234 | F | F | 5.7642 | 2.82841 | 4 |
| | | M | 6.7336 | 2.09742 | 4 |
| | | Total | 6.2489 | 2.36272 | 8 |
| | N | F | 4.7868 | .63882 | 3 |
| | | M | 7.3098 | 2.20380 | 5 |
| | | Total | 6.3636 | 2.14404 | 8 |
| | Total | F | 5.3453 | 2.09974 | 7 |
| | | M | 7.0537 | 2.04212 | 9 |
| | | Total | 6.3063 | 2.18034 | 16 |
| N1234 | F | F | 4.8921 | 2.71019 | 4 |
| | | M | 6.4478 | 1.78278 | 4 |
| | | Total | 5.6699 | 2.28068 | 8 |
| | N | F | 4.5762 | 2.11771 | 3 |
| | | M | 8.1008 | 1.32598 | 5 |
| | | Total | 6.7791 | 2.36930 | 8 |
| | Total | F | 4.7567 | 2.27947 | 7 |
| | | M | 7.3661 | 1.68226 | 9 |
| | | Total | 6.2245 | 2.31842 | 16 |

Note: Looking time variables: F1234= mean looking times (in seconds) over all 4 familiar test trials, N1234=mean looking times (in seconds) over all 4 novel test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 39. Log transformed looking scores of 4-month-olds to the familiar and novel stimuli over the first pair of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1LOG | F | F | 2.2860 | .79382 | 6 |
| | | M | 2.3518 | .53337 | 5 |
| | | Total | 2.3159 | .65578 | 11 |
| | N | F | 2.3083 | .53146 | 4 |
| | | M | 1.6269 | .99722 | 5 |
| | | Total | 1.9297 | .85565 | 9 |
| | Total | F | 2.2949 | .66661 | 10 |
| | | M | 1.9893 | .84523 | 10 |
| | | Total | 2.1421 | .75727 | 20 |
| N1LOG | F | F | 1.9653 | .60607 | 6 |
| | | M | 2.7183 | 1.27233 | 5 |
| | | Total | 2.3076 | .99289 | 11 |
| | N | F | 2.3676 | 1.08719 | 4 |
| | | M | 1.7985 | .46690 | 5 |
| | | Total | 2.0514 | .80138 | 9 |
| | Total | F | 2.1262 | .80077 | 10 |
| | | M | 2.2584 | 1.02537 | 10 |
| | | Total | 2.1923 | .89798 | 20 |

Note: Looking time variables: F1LOG= log transformed looking score of the first familiar test trial, N1log=log transformed looking score of the first test trial; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 40. Log transformed looking scores of 10-month-olds to the familiar and novel stimuli over the first pair of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1LOG | F | F | 1.5198 | .78473 | 4 |
| | | M | 2.0537 | .35653 | 4 |
| | | Total | 1.7867 | .63231 | 8 |
| | N | F | 1.4264 | .08406 | 3 |
| | | M | 1.7233 | .63245 | 5 |
| | | Total | 1.6119 | .50418 | 8 |
| | Total | F | 1.4798 | .55924 | 7 |
| | | M | 1.8701 | .52725 | 9 |
| | | Total | 1.6993 | .55978 | 16 |
| N1LOG | F | F | 1.2973 | .72243 | 4 |
| | | M | 2.0243 | .57823 | 4 |
| | | Total | 1.6608 | .71969 | 8 |
| | N | F | .7942 | .51100 | 3 |
| | | M | 2.1035 | .48798 | 5 |
| | | Total | 1.6125 | .81845 | 8 |
| | Total | F | 1.0817 | .64833 | 7 |
| | | M | 2.0683 | .49617 | 9 |
| | | Total | 1.6367 | .74494 | 16 |

Note: Looking time variables: F1LOG= log transformed looking score of the first familiar test trial, N1LOG=log transformed looking score of the first test trial; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 41. Mean log transformed looking scores of 4-month-olds to the familiar and novel stimuli over the first 2 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12LOG | F | F | 1.9114 | .40491 | 6 |
| | | M | 2.2663 | .38125 | 5 |
| | | Total | 2.0727 | .41768 | 11 |
| | N | F | 2.1462 | .43126 | 4 |
| | | M | 1.6923 | .56865 | 5 |
| | | Total | 1.8940 | .53726 | 9 |
| | Total | F | 2.0053 | .40960 | 10 |
| | | M | 1.9793 | .54757 | 10 |
| | | Total | 1.9923 | .47083 | 20 |
| N12LOG | F | F | 1.7919 | .38034 | 6 |
| | | M | 2.5964 | .87056 | 5 |
| | | Total | 2.1576 | .74295 | 11 |
| | N | F | 1.9239 | .65553 | 4 |
| | | M | 1.8860 | .36065 | 5 |
| | | Total | 1.9029 | .47600 | 9 |
| | Total | F | 1.8447 | .47776 | 10 |
| | | M | 2.2412 | .73131 | 10 |
| | | Total | 2.0430 | .63468 | 20 |

Note: Looking time variables: F12LOG= mean log transformed looking scores of the first 2 familiar test trials, N12LOG=mean log transformed looking scores of the first 2 test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 42. Mean log transformed looking scores of 10-month-olds to the familiar and novel stimuli over the first 2 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F12LOG | F | F | 1.5233 | .68195 | 4 |
| | | M | 1.9808 | .57044 | 4 |
| | | Total | 1.7521 | .63134 | 8 |
| | N | F | 1.5952 | .21547 | 3 |
| | | M | 1.6661 | .39804 | 5 |
| | | Total | 1.6395 | .32427 | 8 |
| | Total | F | 1.5541 | .49948 | 7 |
| | | M | 1.8060 | .47829 | 9 |
| | | Total | 1.6958 | .48832 | 16 |
| N12LOG | F | F | 1.2903 | .37486 | 4 |
| | | M | 2.0399 | .39936 | 4 |
| | | Total | 1.6651 | .53768 | 8 |
| | N | F | 1.2393 | .35993 | 3 |
| | | M | 2.0294 | .35950 | 5 |
| | | Total | 1.7331 | .52731 | 8 |
| | Total | F | 1.2685 | .33792 | 7 |
| | | M | 2.0341 | .35279 | 9 |
| | | Total | 1.6991 | .51566 | 16 |

Note: Looking time variables: F12LOG= mean log transformed looking scores of the first 2 familiar test trials, N12LOG=mean log transformed looking scores of the first 2 test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 43. Mean log transformed looking scores of 4-month-olds to the familiar and novel stimuli over the first 3 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123LOG | F | F | 1.8083 | .35758 | 6 |
| | | M | 2.2673 | .48907 | 5 |
| | | Total | 2.0170 | .46591 | 11 |
| | N | F | 2.1547 | .28331 | 4 |
| | | M | 1.6580 | .62028 | 5 |
| | | Total | 1.8788 | .53945 | 9 |
| | Total | F | 1.9469 | .36027 | 10 |
| | | M | 1.9627 | .61679 | 10 |
| | | Total | 1.9548 | .49168 | 20 |
| N123LOG | F | F | 1.8445 | .49104 | 6 |
| | | M | 2.5658 | .71630 | 5 |
| | | Total | 2.1724 | .68385 | 11 |
| | N | F | 1.7228 | .32206 | 4 |
| | | M | 1.9055 | .46287 | 5 |
| | | Total | 1.8243 | .39408 | 9 |
| | Total | F | 1.7958 | .41531 | 10 |
| | | M | 2.2357 | .66658 | 10 |
| | | Total | 2.0157 | .58573 | 20 |

Note: Looking time variables: F123LOG= mean log transformed looking scores of the first 3 familiar test trials, N123LOG=mean log transformed looking scores of the first 3 test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 44. Mean log transformed looking scores of 10-month-olds to the familiar and novel stimuli over the first 3 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F123LOG | F | F | 1.6498 | .55575 | 4 |
| | | M | 1.8621 | .35368 | 4 |
| | | Total | 1.7560 | .44594 | 8 |
| | N | F | 1.5504 | .23698 | 3 |
| | | M | 1.6899 | .39077 | 5 |
| | | Total | 1.6376 | .32941 | 8 |
| | Total | F | 1.6072 | .41949 | 7 |
| | | M | 1.7664 | .36263 | 9 |
| | | Total | 1.6968 | .38364 | 16 |
| N123LOG | F | F | 1.3456 | .32130 | 4 |
| | | M | 1.8965 | .33243 | 4 |
| | | Total | 1.6211 | .42226 | 8 |
| | N | F | 1.2803 | .62378 | 3 |
| | | M | 2.0518 | .21905 | 5 |
| | | Total | 1.7625 | .54591 | 8 |
| | Total | F | 1.3177 | .42724 | 7 |
| | | M | 1.9828 | .26857 | 9 |
| | | Total | 1.6918 | .47709 | 16 |

Note: Looking time variables: F123LOG= mean log transformed looking scores of the first 3 familiar test trials, N123LOG=mean log transformed looking scores of the first 3 test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 45. Mean log transformed looking scores of 4-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 4.**

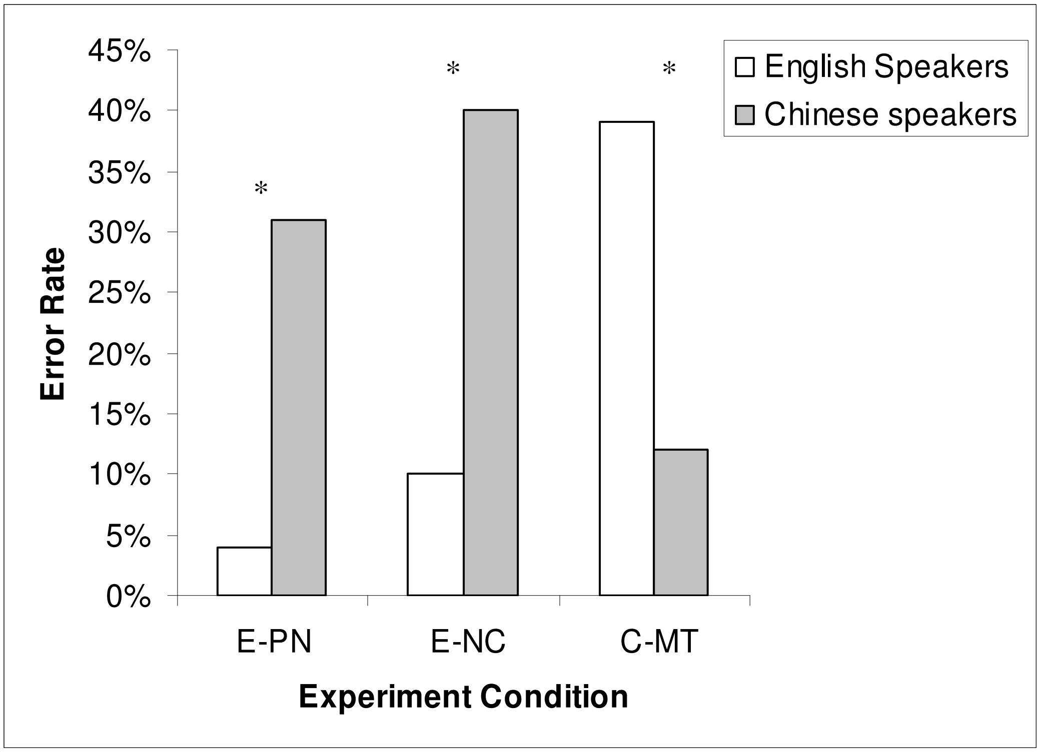
| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234LOG | F | F | 1.8066 | .30565 | 6 |
| | | M | 2.2829 | .46471 | 5 |
| | | Total | 2.0231 | .44155 | 11 |
| | N | F | 2.2716 | .34060 | 4 |
| | | M | 1.6684 | .51017 | 5 |
| | | Total | 1.9365 | .52414 | 9 |
| | Total | F | 1.9926 | .38500 | 10 |
| | | M | 1.9757 | .56265 | 10 |
| | | Total | 1.9841 | .46930 | 20 |
| N1234LOG | F | F | 1.7896 | .39404 | 6 |
| | | M | 2.5333 | .76618 | 5 |
| | | Total | 2.1277 | .68064 | 11 |
| | N | F | 1.8943 | .46138 | 4 |
| | | M | 1.8670 | .35629 | 5 |
| | | Total | 1.8791 | .37882 | 9 |
| | Total | F | 1.8315 | .40017 | 10 |
| | | M | 2.2001 | .66380 | 10 |
| | | Total | 2.0158 | .56599 | 20 |

Note: Looking time variables: F1234LOG= mean log transformed looking scores of all 4 familiar test trials, N1234LOG=mean log transformed looking scores of all 4 test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.

**Table 46. Mean log transformed looking scores of 10-month-olds to the familiar and novel stimuli over all 4 pairs of test trials by test trial order and sex in Study 4.**

| | TEST TRIAL ORDER | SEX | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| F1234LOG | F | F | 1.4986 | .49058 | 4 |
| | | M | 1.8002 | .30923 | 4 |
| | | Total | 1.6494 | .41247 | 8 |
| | N | F | 1.4744 | .09792 | 3 |
| | | M | 1.7996 | .31989 | 5 |
| | | Total | 1.6777 | .29923 | 8 |
| | Total | F | 1.4882 | .35171 | 7 |
| | | M | 1.7999 | .29500 | 9 |
| | | Total | 1.6635 | .34841 | 16 |
| N1234LOG | F | F | 1.3851 | .43167 | 4 |
| | | M | 1.7178 | .22360 | 4 |
| | | Total | 1.5515 | .36455 | 8 |
| | N | F | 1.3176 | .56153 | 3 |
| | | M | 1.9936 | .21782 | 5 |
| | | Total | 1.7401 | .48950 | 8 |
| | Total | F | 1.3562 | .44674 | 7 |
| | | M | 1.8710 | .25222 | 9 |
| | | Total | 1.6458 | .42817 | 16 |

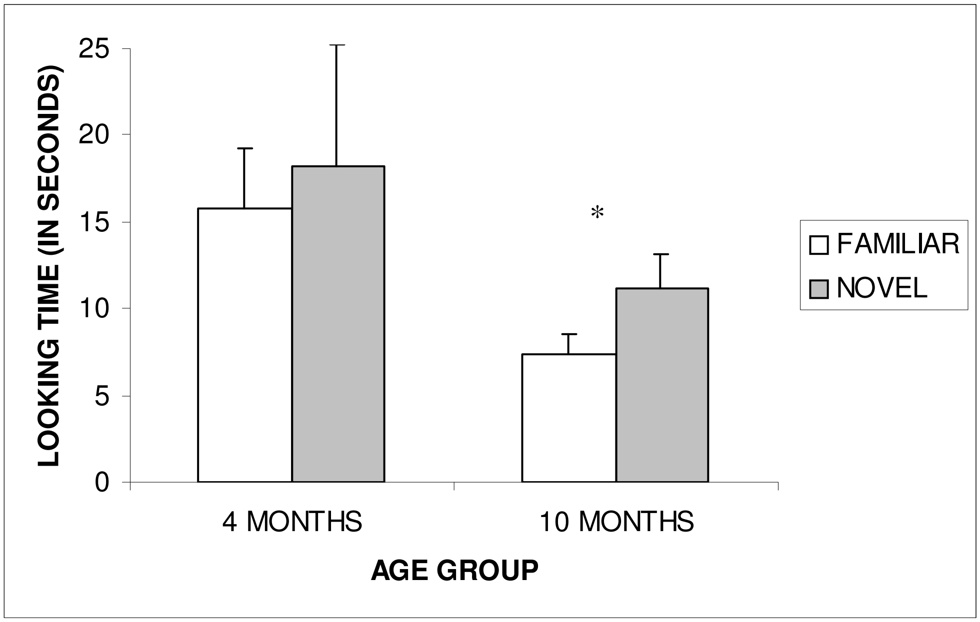
Note: Looking time variables: F1234LOG= mean log transformed looking scores of all 4 familiar test trials, N1234LOG=mean log transformed looking scores of all 4 test trials; Test Trial Order: F=familiar first, N=novel first; Sex: F=Female, M=Male.




Note: Ep-Eny: Pennsylvania vs. New York accent in English; Eny-Ec: New York vs. Chinese accent in Englih; Cm-Ct: Mainland China vs. Taiwan accent in Chinese.

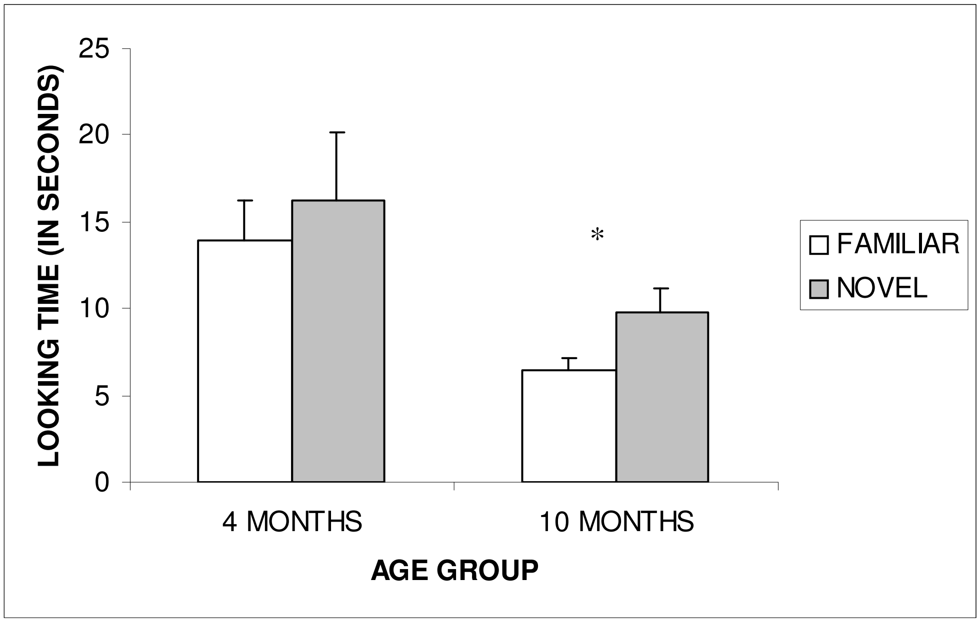
* p<.05

**Figure 1. Mean error rate of English speakers and Chinese speakers tested in Study 1.**



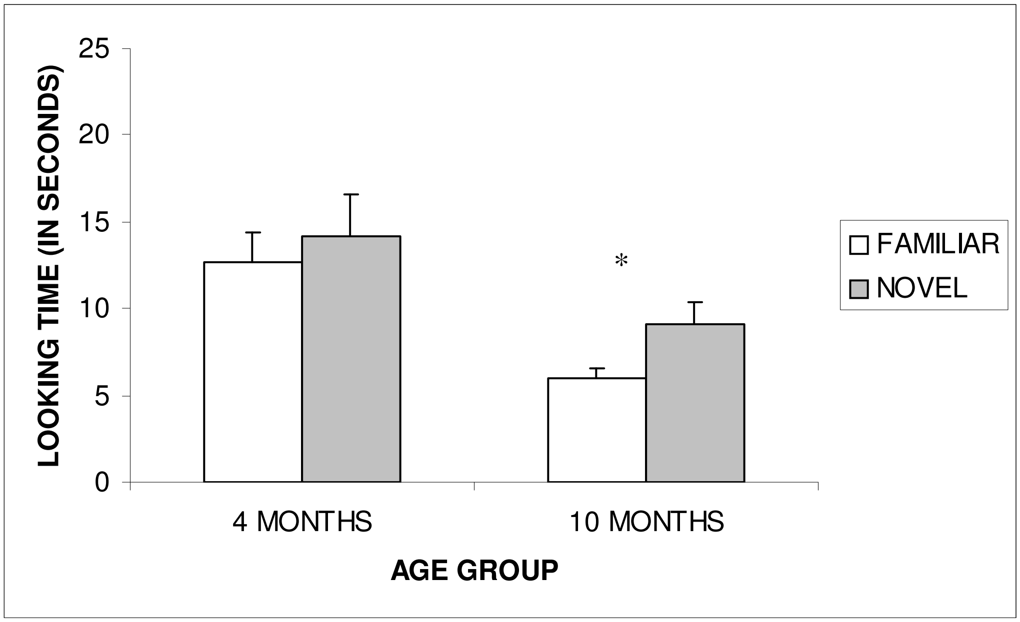

* p<.05

**Figure 2. Raw looking times (+SE) during the first pair of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**



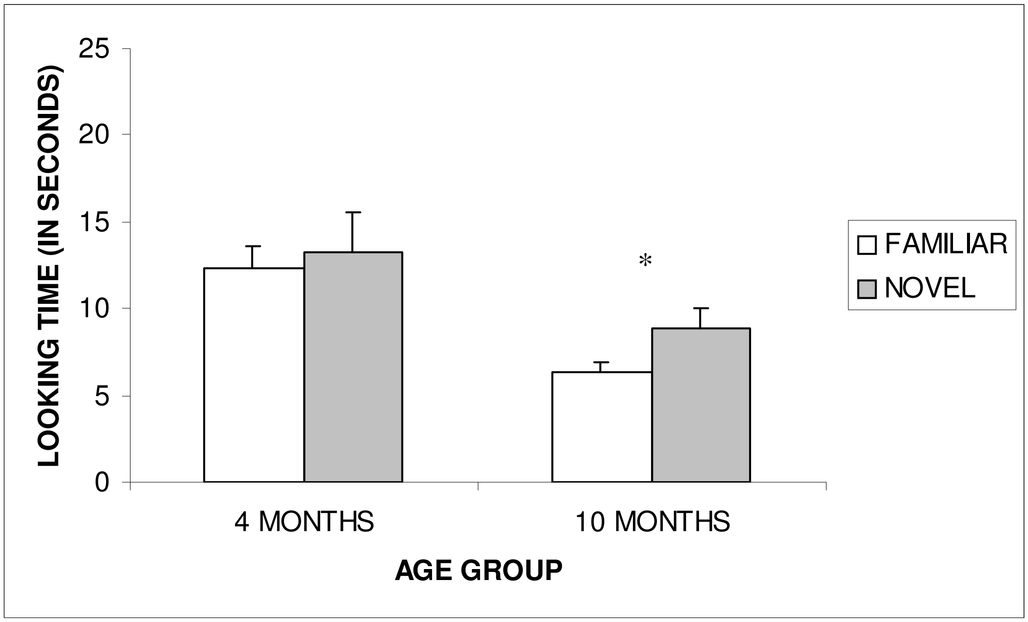

* p<.05

**Figure 3. Mean raw looking times (+SE) during the first 2 pairs of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**




* p<.05

**Figure 4. Mean raw looking times (+SE) during the first 3 pairs of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**




* p<.05

**Figure 5. Mean raw looking times (+SE) during all 4 pairs of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**

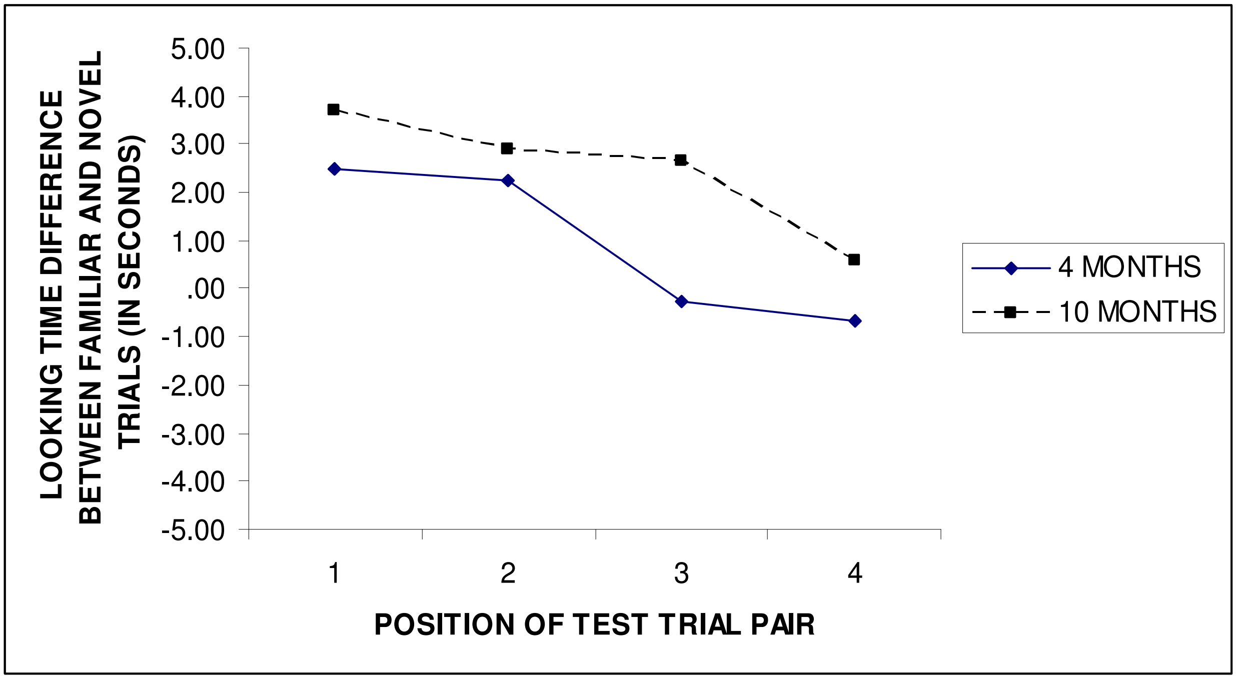
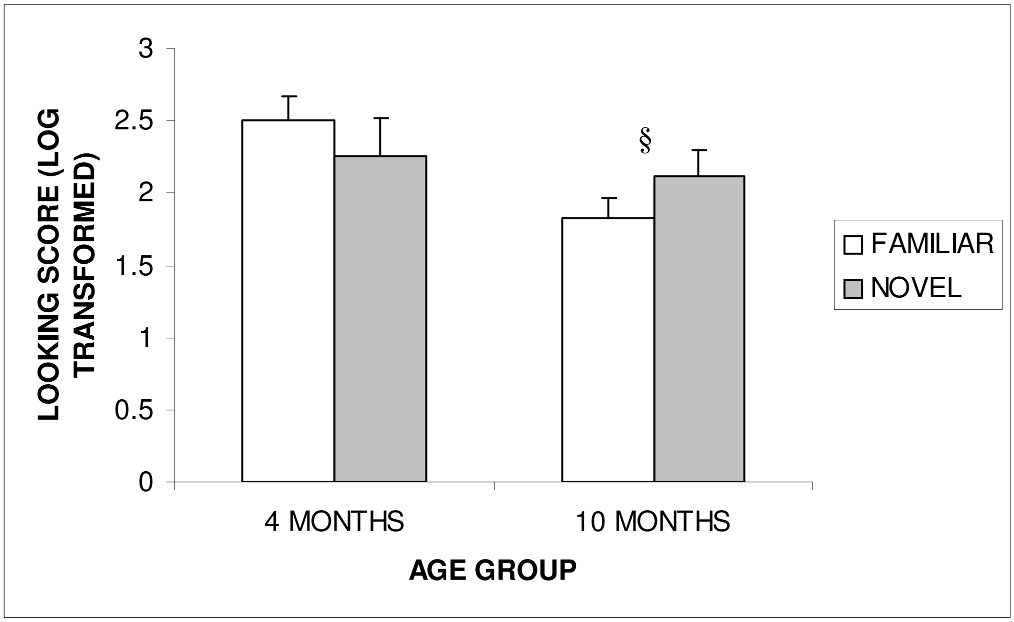


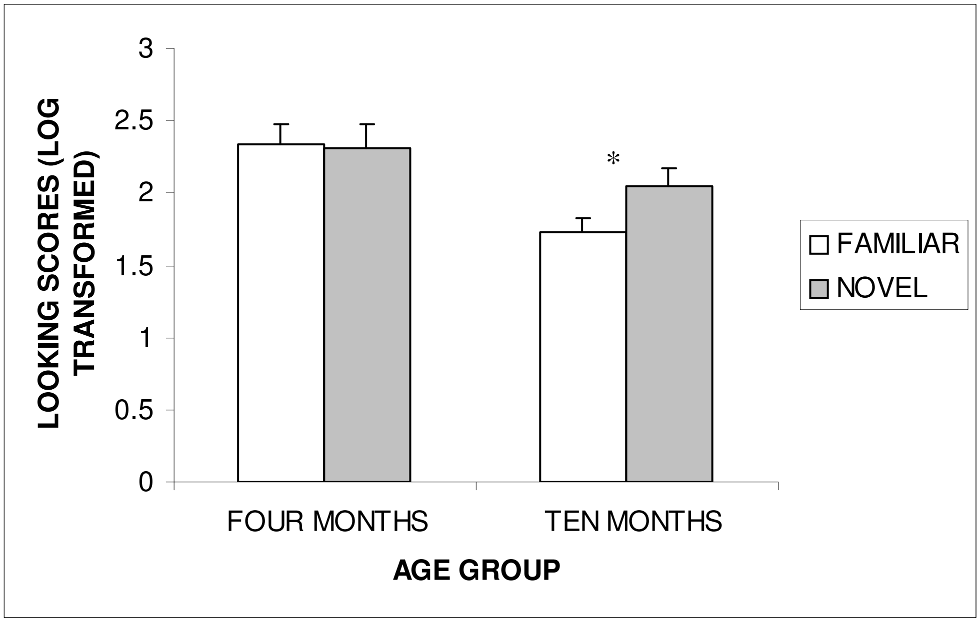

**Figure 6. Difference in looking time between the familiar and novel trials in the first, second, third and fourth pairs of test trials in 4- and 10-month-old infants in Study 2.**




§ p<.1

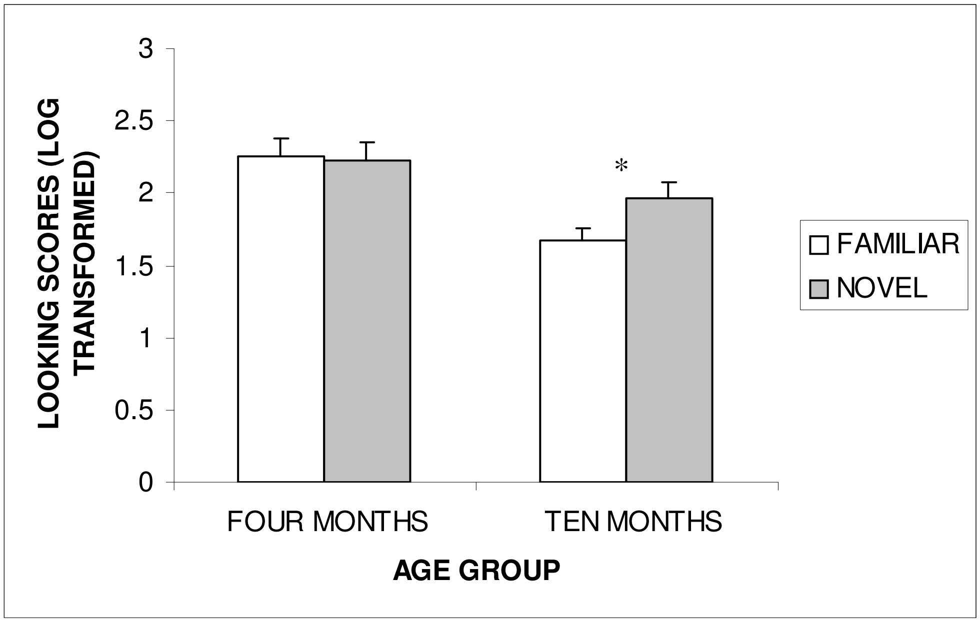
* p<.05

**Figure 7. Log transformed looking scores (+SE) during the first pair of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**



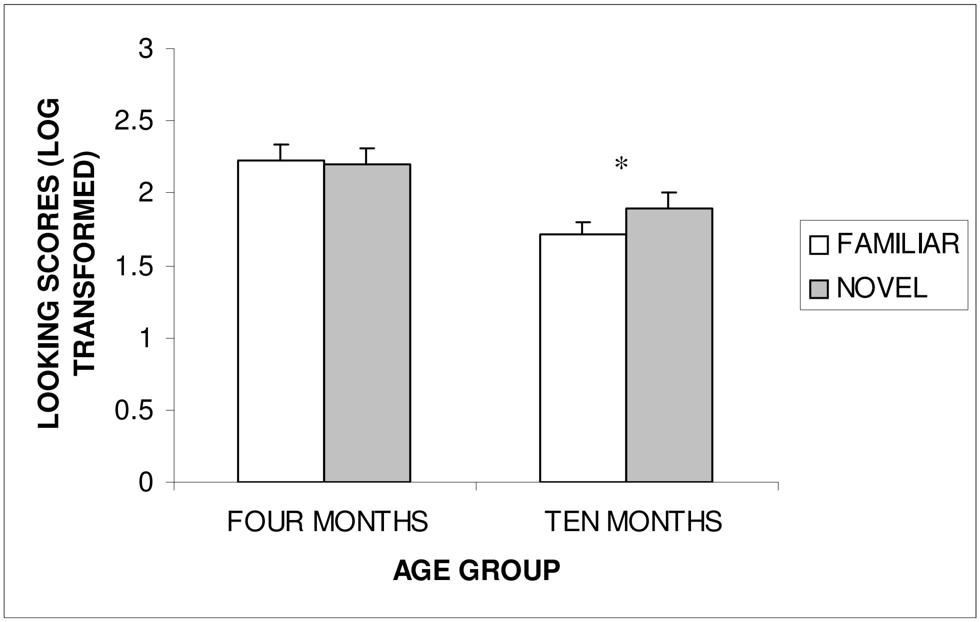

* p<.05

**Figure 8. Mean log transformed looking scores (+SE) over the first 2 pairs of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**




* p<.05

**Figure 9. Mean log transformed looking scores (+SE) over the first 3 pairs of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**




* p<.05

**Figure 10. Mean log transformed looking scores (+SE) over all 4 pairs of test trials of 4- and 10-month-old infants in Study 2 for the Pennsylvania and New York accents.**

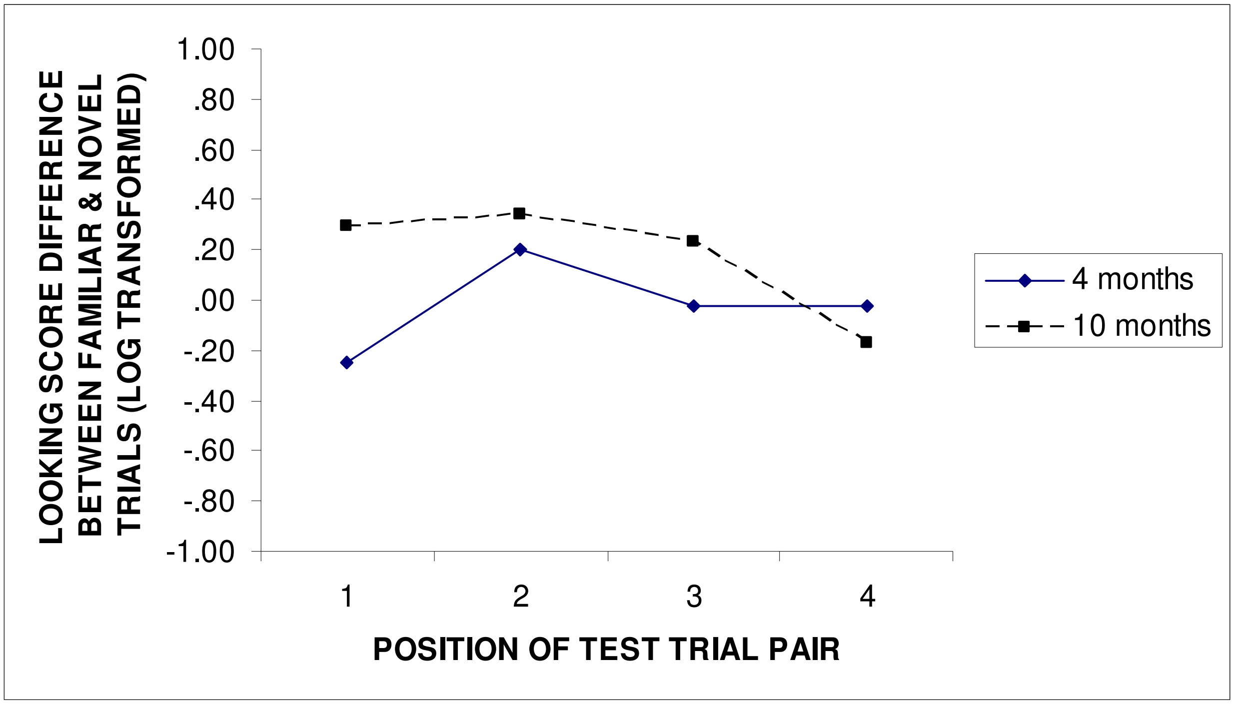
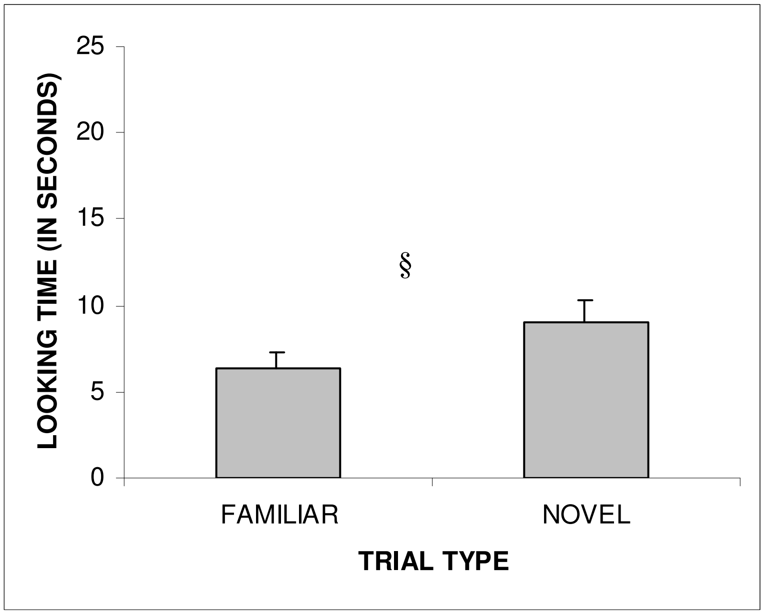


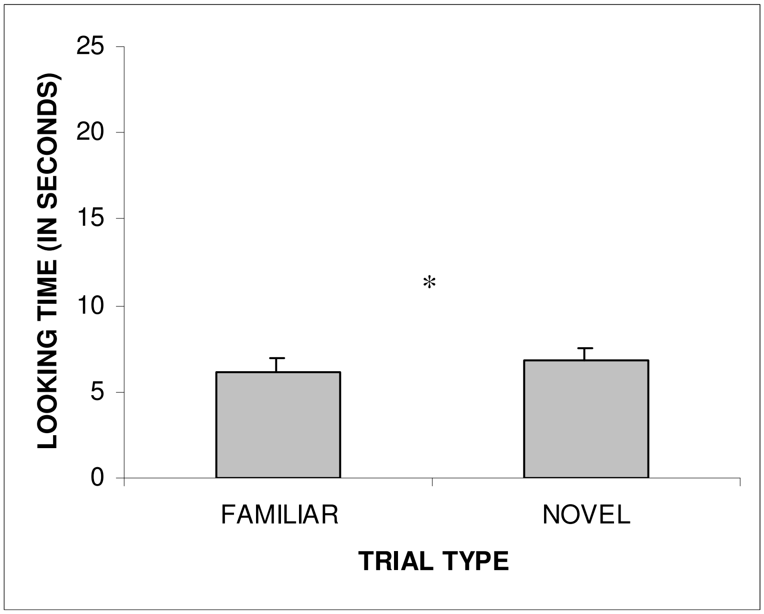

**Figure 11. Difference in log transformed looking score between the familiar and novel trials in the first, second, third and fourth pairs of test trials in 4- and 10-month-old infants in Study 2.**




§ p<.1

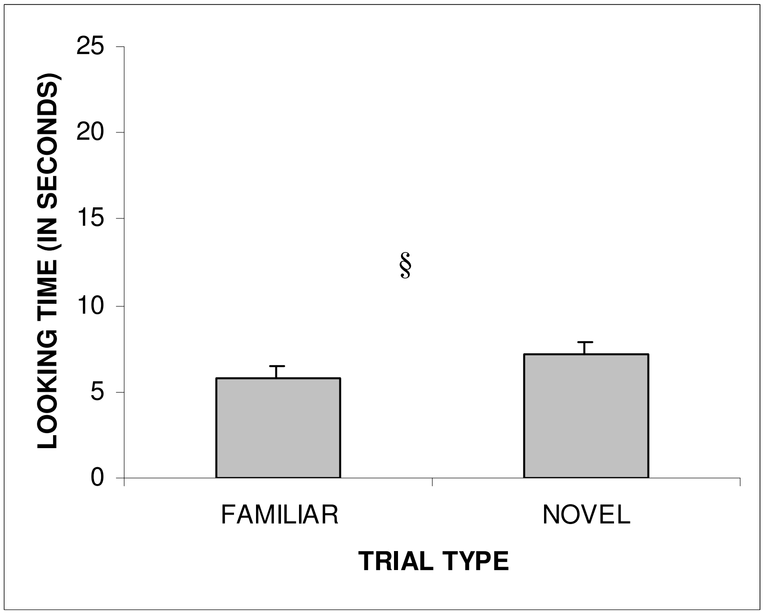
* p<.05

**Figure 12. Raw looking time (+SE) over the first pair of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**




* p<.05

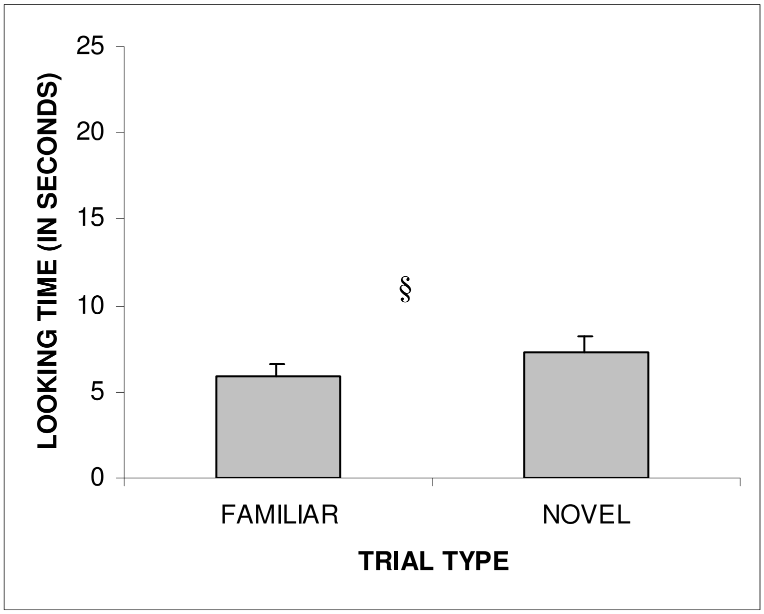
**Figure 13. Raw looking times (+SE) over the first 2 pairs of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**




§ p<.1

* p<.05

**Figure 14. Raw looking times (+SE) over the first 3 pairs of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**




§ p<.1

* p<.05

**Figure 15. Raw looking time over all 4 pairs of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**

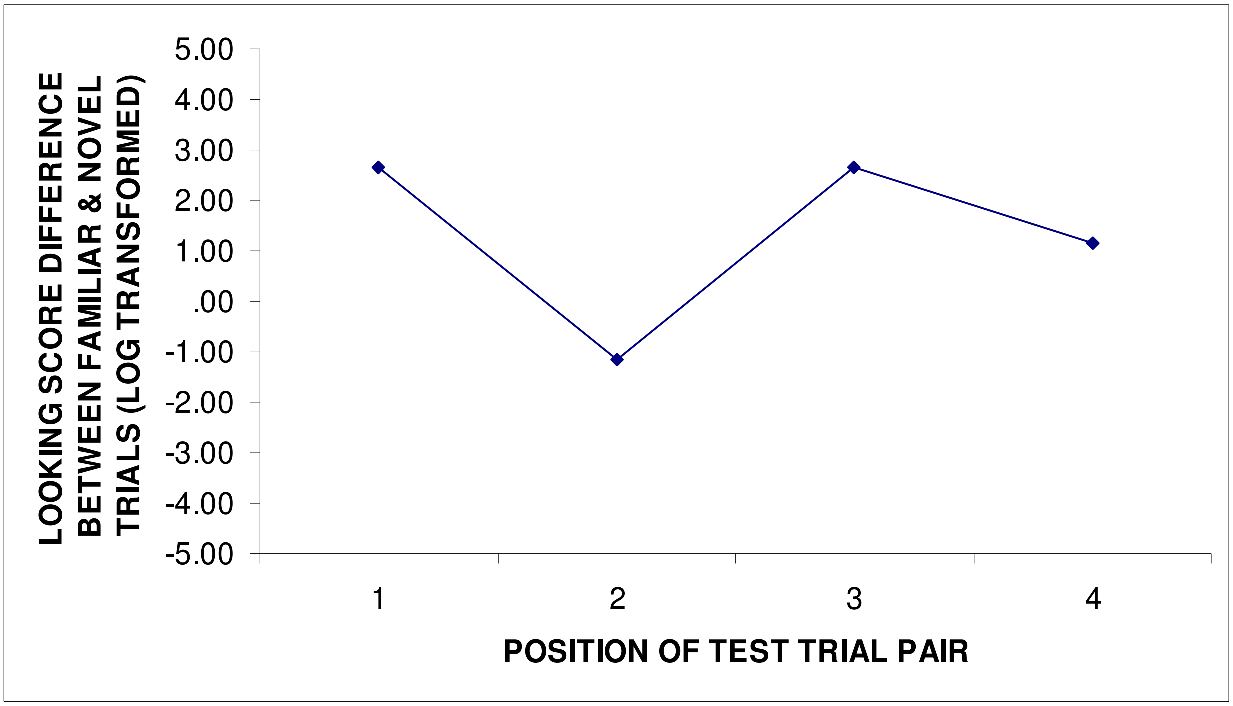
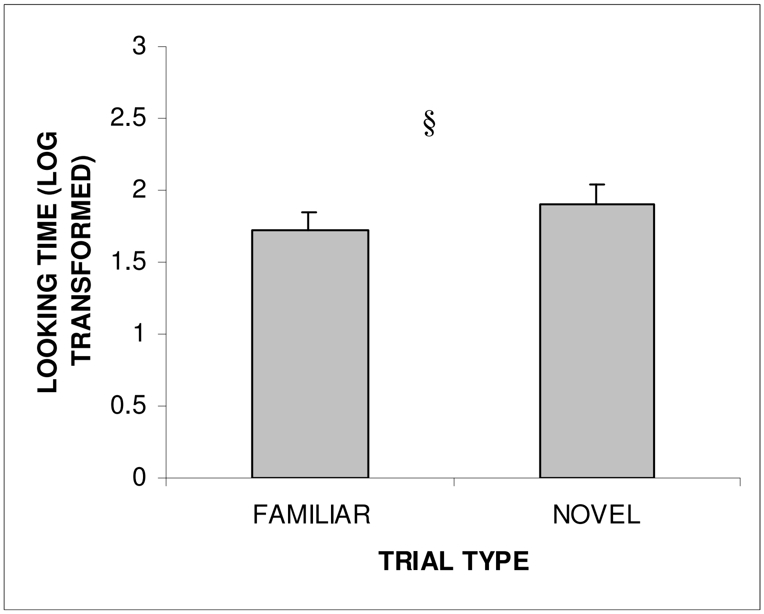


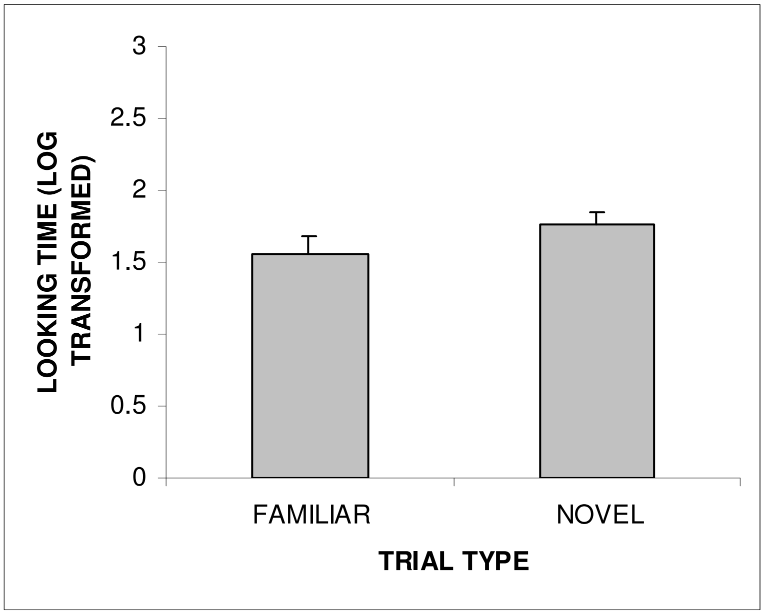

**Figure 16. Difference in looking time between the familiar and novel trials in the first, second, third and fourth pairs of test trials in 10-month-old infants in Study 3.**




§ p<.1

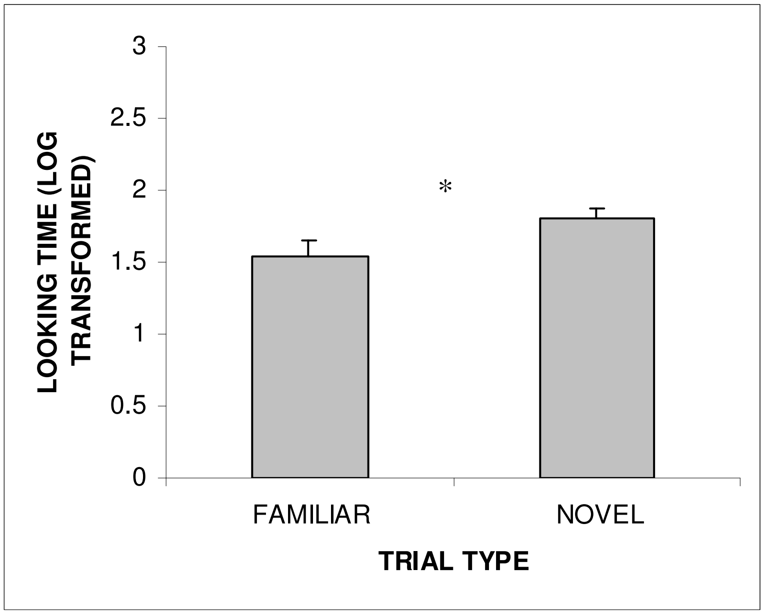
* p<.05

**Figure 17. Mean log transformed looking scores (+SE) over the first pair of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**



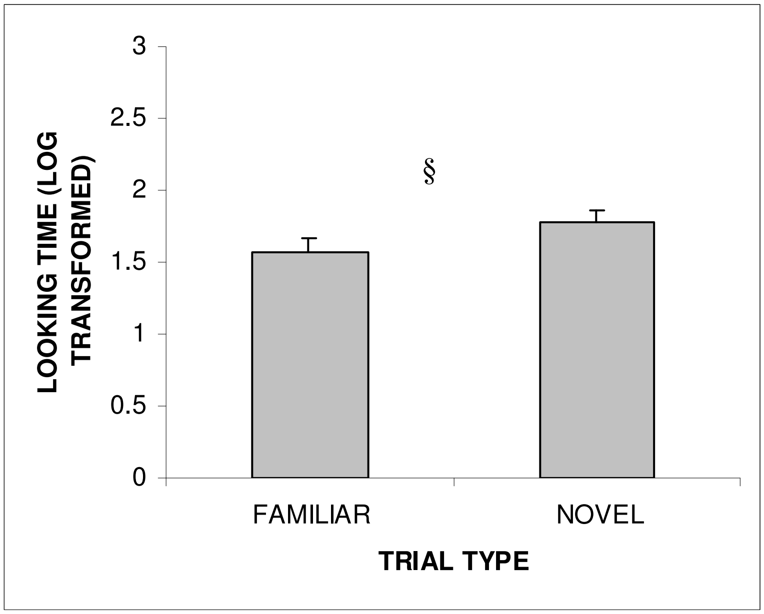

* p<.05

**Figure 18. Mean log transformed looking scores (+SE) over the first 2 pairs of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**




* p<.05

**Figure 19. Mean log transformed looking scores (+SE) over the first 3 pairs of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**




§ p<.1

* <.05

**Figure 20. Mean log transformed looking scores (+SE) over all 4 pairs of test trials of 10-month-old infants in Study 3 for the New York and Chinese accents.**

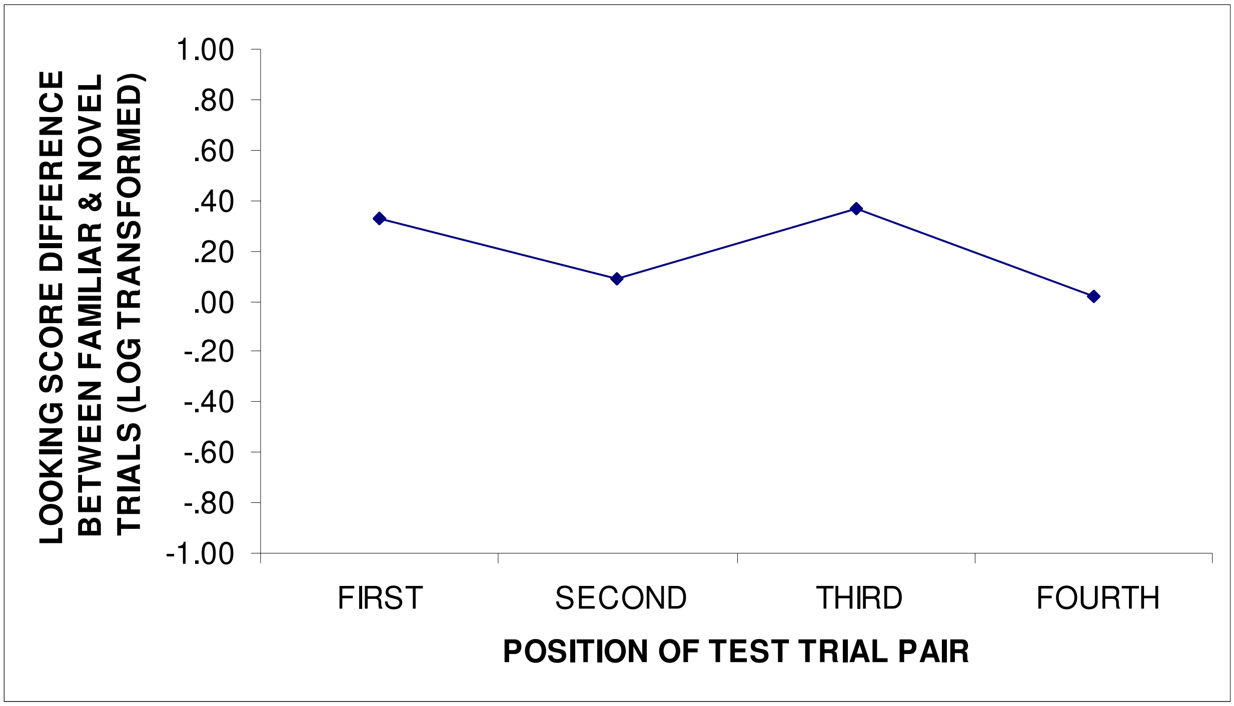
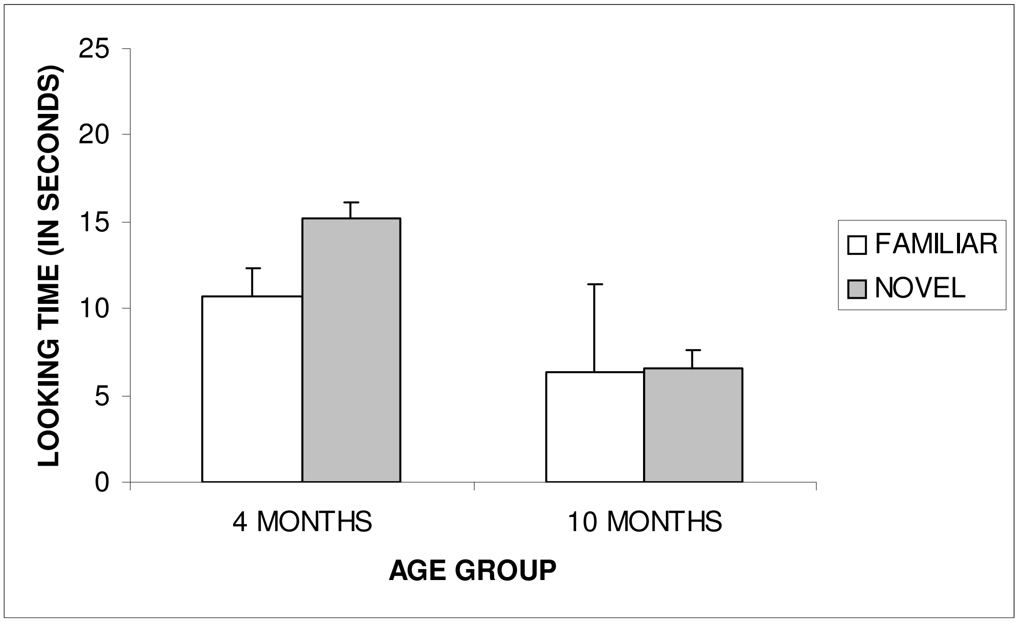
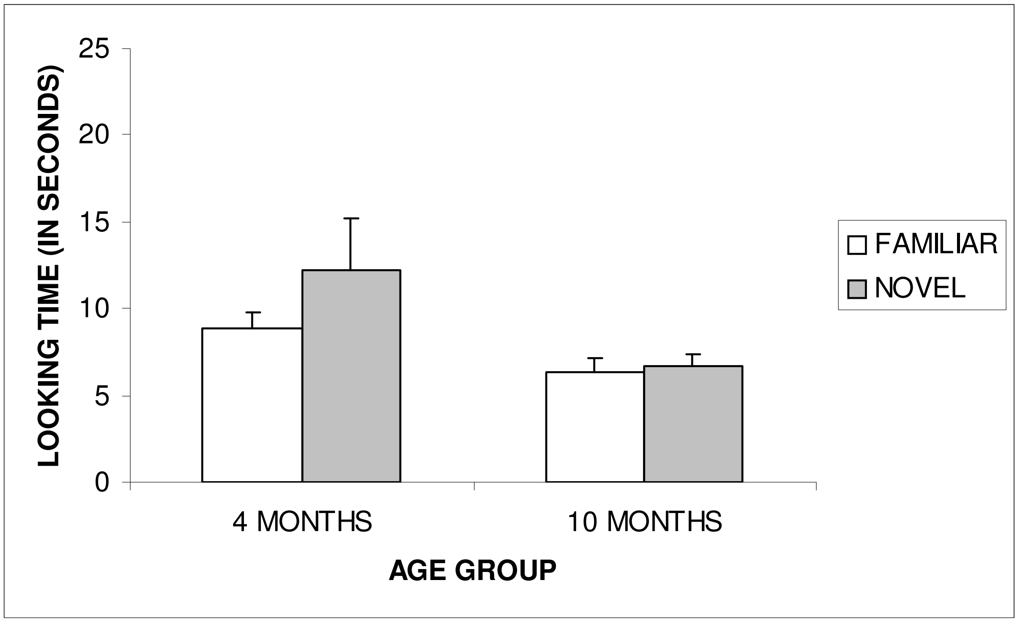



**Figure 21. Difference in log transformed looking score between the familiar and novel trials in the first, second, third and fourth pairs of test trials in 10-month-old infants in Study 3.**



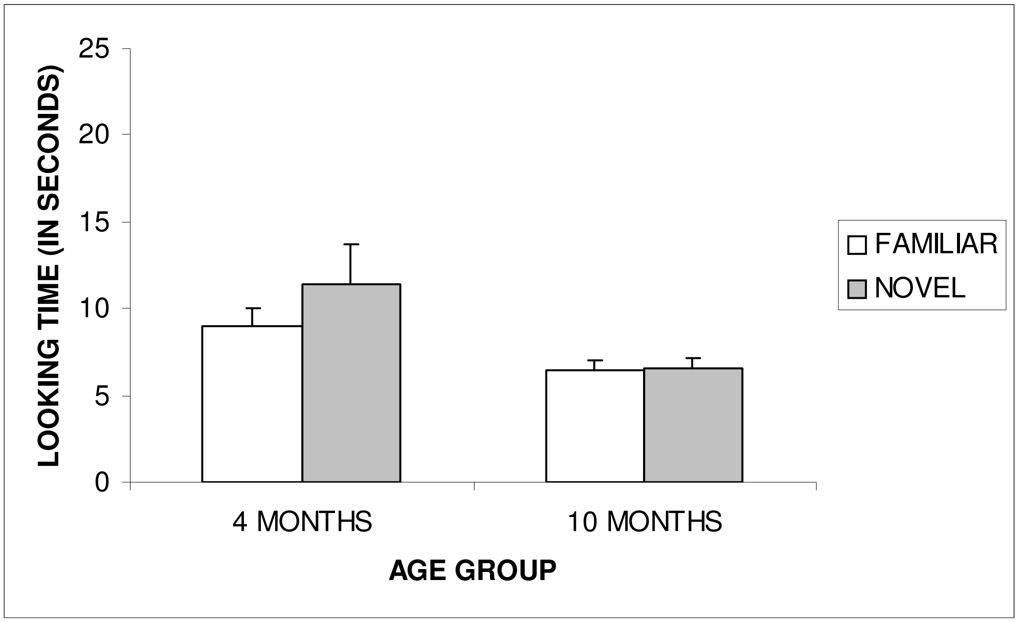

* <.05

**Figure 22. Looking times (+SE) over the first pair of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwan accents in the Chinese language.**



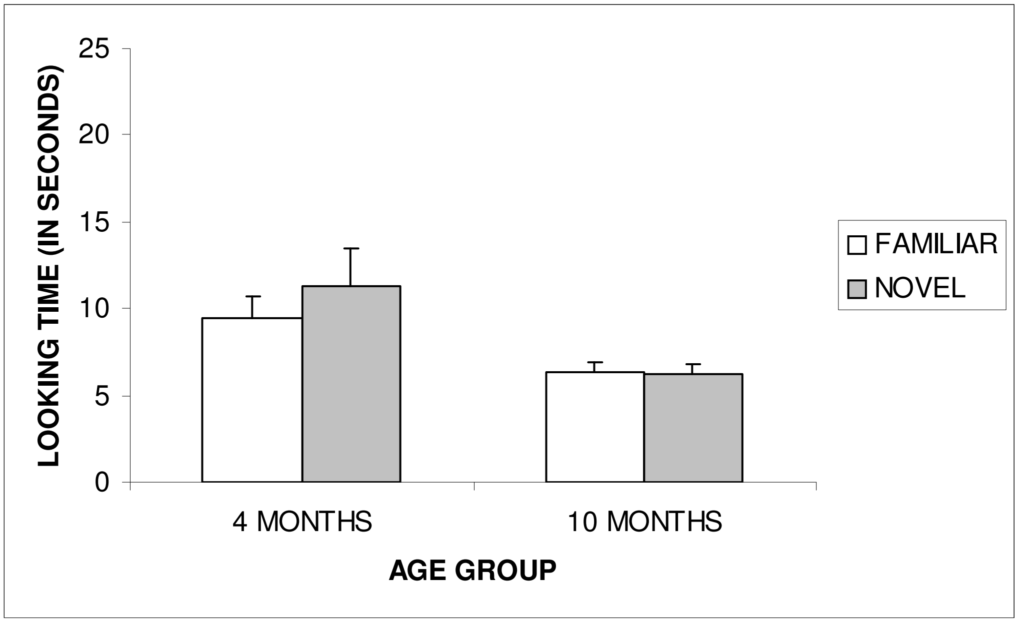

* <.05

**Figure 23. Mean looking times (+SE) over the first 2 pairs of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwan accents in the Chinese language.**




* <.05

**Figure 24. Mean looking times (+SE) over the first 3 pairs of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwan accents in the Chinese language.**




* <.05

**Figure 25. Mean looking times (+SE) over all 4 pairs of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwan accents in the Chinese language.**

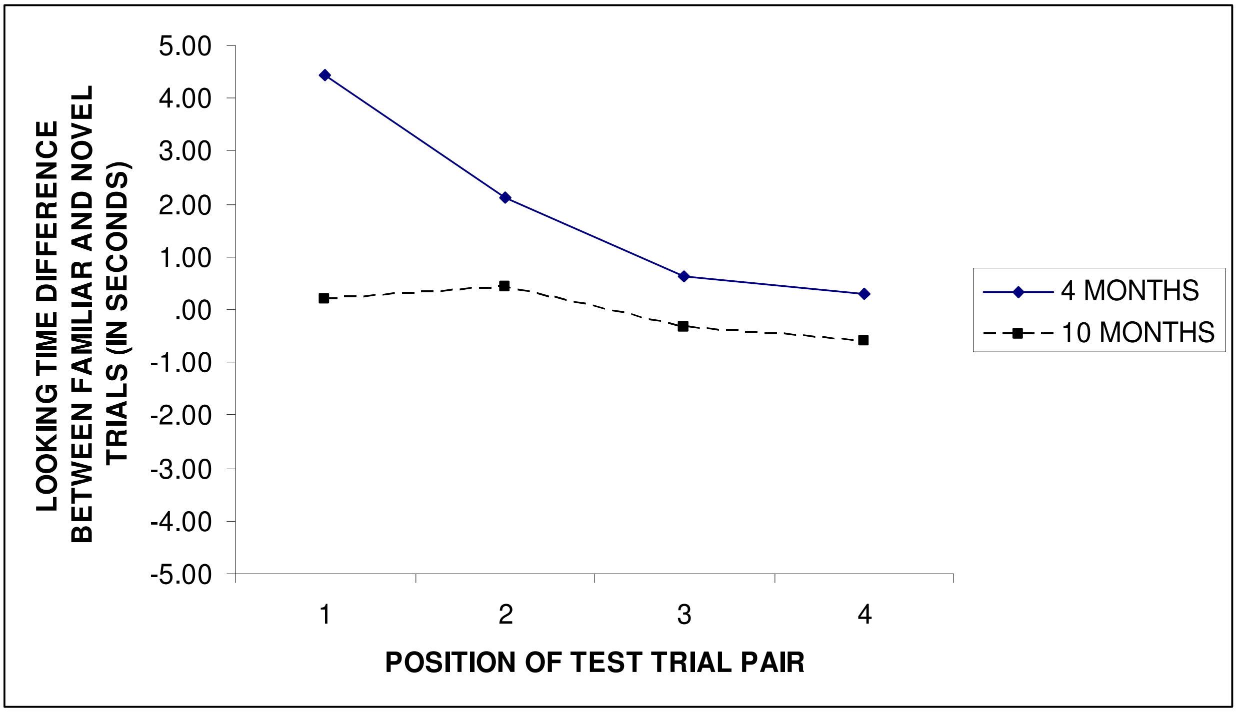
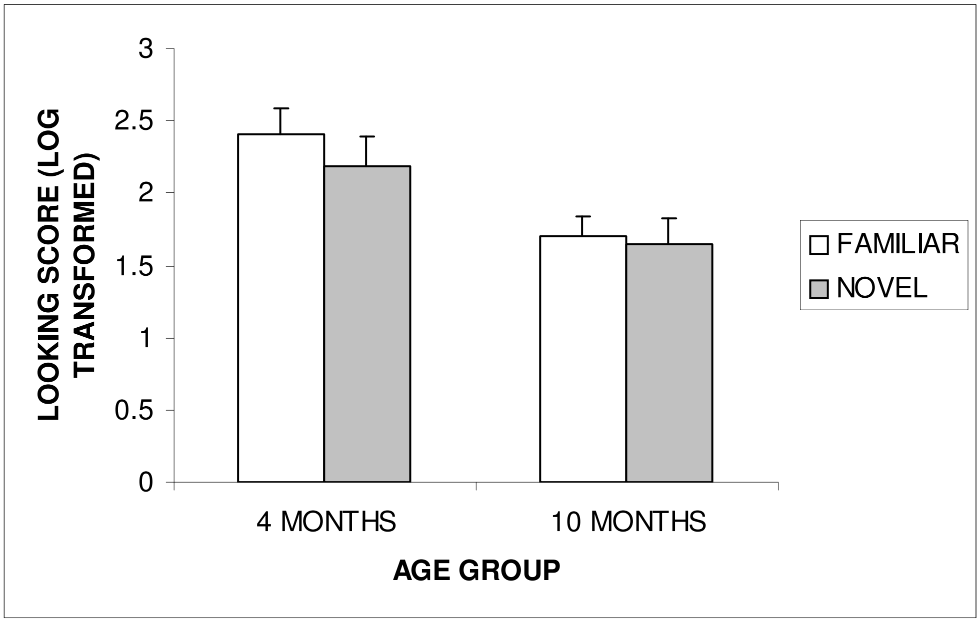
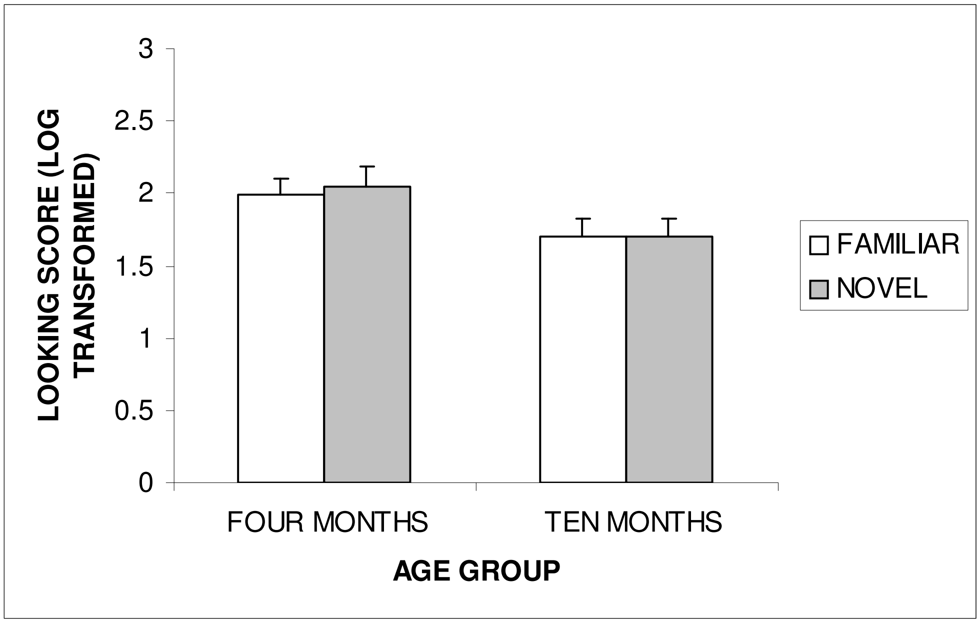



**Figure 26. Difference in looking time between the familiar and novel trials in the first, second, third and fourth pairs of test trials in 4- and 10-month-old infants in Study 4.**



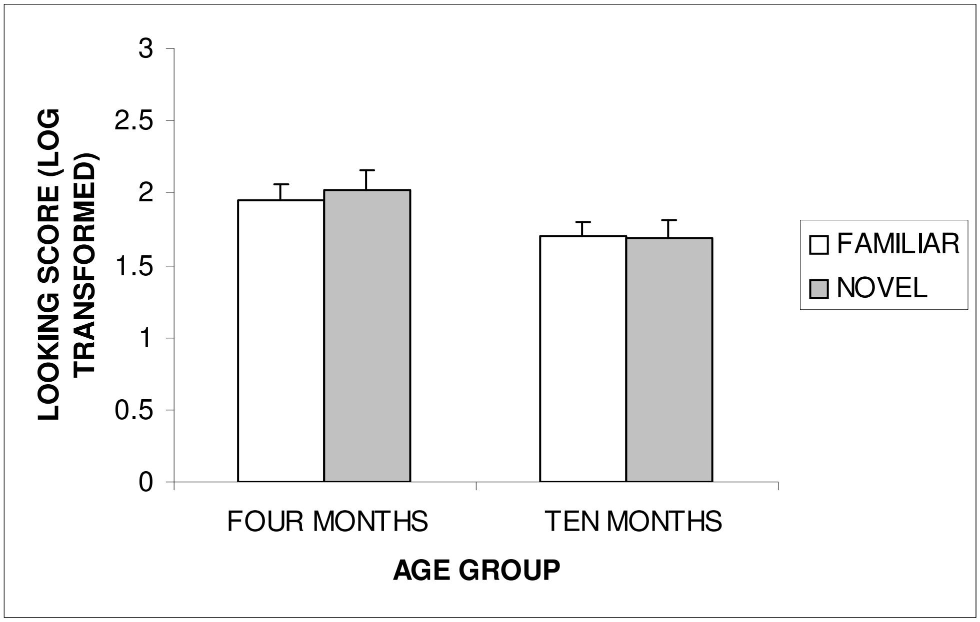

* <.05

**Figure 27. Log transformed looking scores (+SE) over the first pair of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwan accents in the Chinese language.**



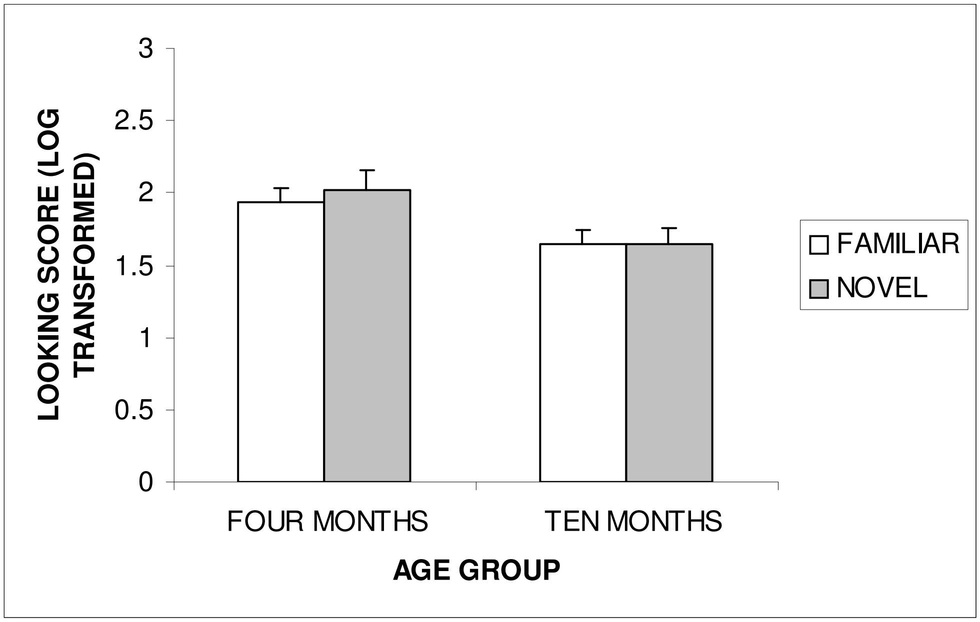

* p<.05

**Figure 28. Mean log transformed looking scores (+SE) over the first 2 pairs of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwanese accents in the Chinese language.**




* p<.05

**Figure 29. Mean log transformed looking scores (+SE) over the first 3 pairs of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwanese accents in the Chinese language.**




* p<.05

**Figure 30. Mean log transformed looking scores (+SE) over all 4 pairs of test trials of 4- and 10-month-old infants in Study 4 for the Mainland and Taiwanese accents in the Chinese language.**

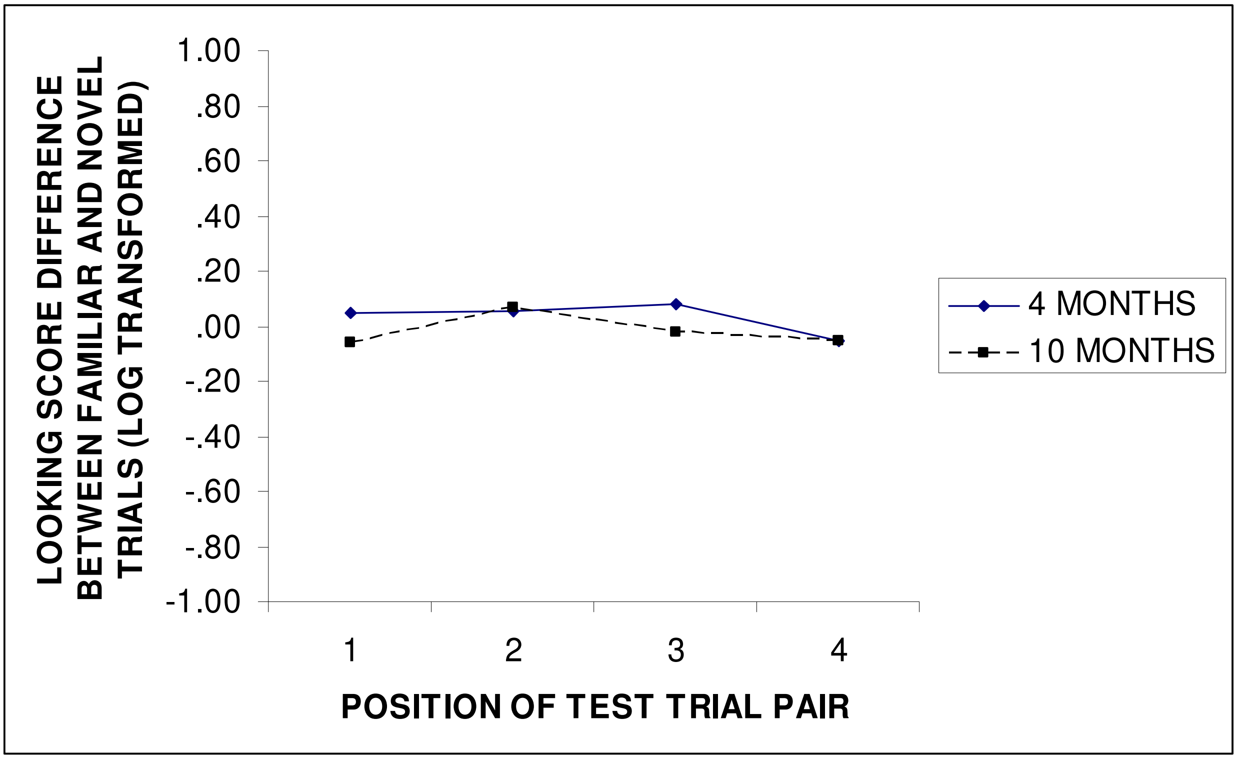



**Figure 31. Difference in log transformed looking score between the familiar and novel trials in the first, second, third and fourth pairs of test trials in 4- and 10-month-old infants in Study 4.**