Gender of Speaker Influences Infants' Discrimination of Non-Native Phonemes in a Multimodal Context

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Abstract

Previous research has shown that infants can discriminate both native and non-native speech contrasts before the age of 10-12 months. After this age, infants' phoneme discrimination starts resembling adults', as they are able to discriminate native contrasts, but lose their sensitivity to non-native ones. However, the majority of these studies have been carried out in a testing context, which is dissimilar to the natural language-learning context experienced by infants. This study was designed to see the influence of speaker-gender and visual speech information on the ability of 11 month-old infants to discriminate the non-native contrasts. Previous research in our laboratory revealed that 11 month-old infants were able to discriminate retroflex and dental Hindi contrasts when the speech was infant-directed, the speaker was a female and visual speech information was available (i.e., infant watched digital movies of female speakers). A follow-up study showed that with an adult-directed *male* voice and absence of visual speech information, 11 month-old infants did not discriminate the same non-native contrasts. Hence the aim of the present study was to address the questions posed by these two studies. Does the gender of the speaker matter alone? Also, to what extent is the visual speech information helpful for the discriminatory abilities of the infants? Would the manner of speech help infants discriminate the non-native contrasts? The result of the current study show that 11 month-old infants were unable to discriminate between the phonemic Hindi contrasts. Hence gender seems to matter as the presence of male face and voice did not seem to aid discrimination.

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Chapter 1

Introduction & Literature Review

During the first postnatal year of their lives, human infants are able to discriminate a wide range of universal phoneme contrasts. Phonetic contrasts are the linguistic units of analysis in speech perception in which the phones are characterized mainly in terms of their articulatory properties. That is, phonemes are linguistic units (either spoken or written) that are used contrastively to construct a language. Cross language studies are responsible for labeling young infants as 'language-universal' perceivers because results have shown that they are able to discriminate both native as well as non-native contrasts. However, infants' sensitivity to non-native phoneme contrasts seems to decline toward the end of the first postnatal year as a result of specific linguistic experience (Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Lalonde, 1988).

This developmental decline in non-native sensitivity has been illustrated in a number of studies comparing certain phonetic contrasts in different languages. American English infants' discrimination of English (ba versus da), Hindi (retroflex ta versus dental <u>ta</u>) and Nthlakapmx (a Salish language of the Canadian Pacific region; ki versus qi) contrasts were compared at three ages; 6 to 8 months, 8 to 10 months, and 10 to 12 months (Werker & Tees, 1984). Around 6 to 8 months, all infants were able to clearly discriminate the contrasts in all the languages (native and non-native); by 8 to 10 months, some of the infants were able to distinguish the non-native sounds but others did not; and by 10 to 12 months of age, infants' sensitivity to the non-native contrasts significantly declined. Interestingly, monolingual adult English speakers were not able to discriminate these same non-native contrasts, although the infants could do so in the first 8 months of their lives. In a subsequent experiment, Werker and Tees (1984) tested infants who had Hindi and Nthlakapmx as their native language with the same contrasts. Like their American English infant counterparts, they were able to discriminate all of the contrasts at an early age, and continued to discriminate their own native contrasts as they approached 1 year of age, even though the English infants failed to discriminate these same contrasts (i.e., the Hindi and Nthlakapmx). This study by Werker and Tees demonstrated clearly the time period within which a language-general pattern of speech discrimination changed into a language-specific pattern in human infants.

In one respect, these studies of infants' perception of native and non-native speech sounds have highlighted the importance of early experience in shaping and tuning infants' sensitivities to their native language environment. However, most of the studies testing the ability of infants to discriminate between non-native speech contrasts have been carried out in a context which is not similar to the one encountered by infants in their everyday lives. Often synthetic and non-modulated sounds (Trainor & Desjardins, 2002) have been used because their spectral properties are easy to manipulate and hence easier to control. Sometimes multiple natural exemplars have also been used (e.g., Werker et al., 1981; Werker & Tees, 1984) but visual information is almost never provided to the infants in studies involving discrimination of non-native speech contrasts. Speech perception is a multi-sensory event and it involves other modalities besides the auditory one. The present investigation is an attempt to understand the effect of contextual variation in this arena of speech perception.

Different Models for Changes in Phoneme Discrimination

Ecological theory provides one view for the development of speech perception in infants. According to the ecological theory (Gibson, 1969) perception is largely context dependent with the perceiver gaining direct information from the world via integrated perceptual systems. There is no such thing as impoverished sensory input as the sensory organs are inextricably enmeshed with the integrated perceptual systems. So in speech perception, the articulatory gestures in the speech signals provide information directly to the perceiver. This gestural information is shaped by the structure of the vocal tract and dynamic articulatory transformations (e.g. glottal opening, alveolar closure; Best, 1995).

Based on an ecological theory of perception, Best (1993) has proposed the Perceptual Assimilation Model (PAM) in order to explain the differential rate of decline in sensitivity to non-native contrasts. In infant speech perception literature, the concept of ‘perceptual constancy’ has acquired an important position with regards to phonetic categorization. It is defined as the ability of infants to tolerate within-category variability along several acoustic dimensions. This results in infants’ ability to identify different members of the same phonetic category as similar to each other but distinct from the members of another phonetic category (Miller, 1983). Perceptual constancy has been seen in infants by at least 7 months of age (Kuhl, 1980). According to Best and colleagues (1988), infant listeners become familiar with the phonological system of their native language over time. Once infants are highly familiar with their native phonological system, they attempt to assimilate all speech sounds into existing phonemic categories. Thus, infants attempt to assimilate non-native contrasts to their own phonological categories based on phonetic similarities that such sounds share with their native language. So non-native contrasts (e.g., the Hindi retroflex vs. dental consonants) that map onto a single English phonemic category are difficult to discriminate because they are essentially perceived as two exemplars of one phoneme. In contrast, non-native phonemes that map onto two different phonemic categories of the native language *or* do not map onto any single language category (like Zulu clicks) are easily discriminated. Infants’ decline in non-native phoneme sensitivity has also been explained by the ‘use it or lose it’ principle. According to this account, perceptual capacities that do not receive sufficient environmental stimulation are bound to fade away (Jusczyk, 2000).

In evaluating these models, it is important to specify the nature of developmental loss (i.e. whether the loss of sensitivity to non-native contrasts is an irreversible reduction in sensory ability due to a lack of input or is it a loss of a particular mode of perceptual or attentional processing). There have been studies done in which adults could discriminate differences in non-native phoneme contrasts after some training when the contrasts were presented in isolation (Tees & Werker, 1984). Hence the loss seen in late infancy is probably not permanent and does not involve sensorineural loss. On the other hand, training with adults had no positive effect on discrimination when the contrasts were presented in the context of ongoing, continuous speech (Werker & Tees, 1984b). This weakens the possible explanation about relative phonetic experience shaping attention according to the phonetic properties of the most prevalent language in the environment. Adult listeners can discriminate non-native phonetic categories in testing conditions involving isolated cues but not under testing conditions that are similar to natural processing of language (Werker & Tees, 1984b). But at the same time, the training provided in the study by Werker and Tees may have been insufficient to carry the attentional focus of the participants from isolated cues to acoustically complex contexts (Best, McRoberts, LaFleur & Silver-Isenstadt, 1995). Hence the difficulty shown by adults in discrimination may be a consequence of an attentional deficit similar to the process of acquired equivalence, which involves learning to ignore distinctive differences between stimuli (Aslin & Pisoni, 1980).

Methodological Considerations in Infant Speech Perception Studies

As mentioned earlier, most of these studies testing the ability of infants to discriminate between non-native speech contrasts have used either a synthetic, non-modulated sound or a natural exemplar (which was not infant-directed) with no concomitant visual information. This kind of testing context may not accurately reflect the natural language environment to which the infant is exposed in their everyday life. In fact adults speak to infants in a distinct manner. This is known as infant directed speech (IDS). This speech register is characterized by higher pitch and wider pitch range than adult conversation (Fernald & Simon, 1984; Garnica, 1977; Menn & Boyce, 1982), fewer words (per utterance), more rhythmic, repetitious, and longer duration of the words as well (Garnica, 1977). Infants prefer IDS to adult directed speech (ADS) throughout the first year of life (Cooper et al., 1997, Cooper & Aslin, 1990, Werker & McLeod, 1989). Infant directed speech is believed to augment speech perception by engaging and maintaining attention and by facilitating learning and information processing (Fernald, 1984; Kaplan, et al, 1997; Papousek, Papousek, & Symmes, 1991). Exposure to a particular language influences perception early in life as it highlights the critical acoustic differences between the phonetic categories of the language and simultaneously ignores the phonetic units that are not relevant in the native language. So IDS, with its exaggerated acoustic characteristics could be aiding the infant in this process. A recent correlational study (Liu, Kuhl, & Tsao, 2003) showed a significant positive correlation between clarity of mother's ID speech and infants' (6-8 and 10-12 month-olds) vowel discrimination abilities.

Moreover, in the typical language environment of infants, they hear voices and see faces at the same time and subsequently learn to associate speech with visual information (Kuhl & Meltzoff, 1982; Locke, 1993). There is evidence that infants are better at discriminating vocal expressions when facial expressions accompany them (Walker-Andrews & Lennon, 1991). Visual speech information is also believed to accentuate the comprehension of clear speech signals containing complicated content or that are spoken with a heavy foreign accent (Reisberg, McLean & Goldfield, 1987). The ecological perspective that gestural information in speech is directly contributing to the development of speech perception is strengthened by the findings on cross-modal speech perception. The classic McGurk effect is a good example of this.

When conflicting consonants are presented simultaneously as audio plus visual syllables, listeners perceive a blended pattern as they use information from both auditory and visual modalities (McGurk & MacDonald, 1976). For example, when adults saw a video of a speaker articulating "ba", but heard a synchronized voice track articulating "ga", they reported hearing either "va" or "tha". In a preference study with 4 ½ month-old infants, Spelke, (1976) found that when two different visual events were presented side by side, and the sound track of only one of the events was presented centrally, infants paid more attention to the auditorally specified event. More recently, independent studies by Burnham & Dodd (2004), Desjardins and Werker (1996), and Johnson, Rosenblum, and Schmuckler (1995) have all found evidence of the influence of visual speech on infants' perceptions of phonemes.

Because factors such as language-specific facial information and IDS have not previously been included in studies of infants' phoneme discrimination, Ostroff and Cooper (2003) tested 11-month-olds' ability to discriminate non-native phonemic contrasts when viewing videos of female IDS. They tested American English infants' discrimination of two different phoneme contrasts: the English contrasts-bilabial /ba/ versus alveolar /da/ (as the control) and the Hindi non-native contrasts -- retroflex /da/ versus retroflex /t̲a/. The infants were presented with either a target or a face articulating the English and Hindi contrasts in both IDS and ADS conditions. Their results showed that, in general, infants discriminated both native and non-native contrasts as long as the concomitant facial information was available. Although only marginally significant, there was a trend toward better discrimination when infants also heard ID speech. This finding stands in contrast to past studies that have concluded that near 11 to 12 months of age, infants lose their ability to distinguish certain non-native contrasts (Werker & Tees, 1984, Werker & Lalonde, 1988). The most important thing to be noted here is that the result of the previous studies was actually replicated here, as there was no discrimination of the Hindi contrasts by infants in the target and AD speech condition. This is precisely the context in which most of the earlier studies were carried out when the researchers were unable to find discrimination of non-native contrasts among infants around 10 to 12 months of age.

There may be two possible influences on the discriminatory ability of 11 month-old infants for the non-native contrasts: (1) type of speech (ID or AD) and/or (2) visual information (face or target). ID speech seemed to assist the infants in both conditions of visual information as it was related to a trend toward better performance in infants than AD speech. At the same time, presence of a face resulted in better discrimination even with AD speech. The worst performance was in the target and AD speech condition and this is true even for discrimination of native (English) contrasts.

The fact that a female voice alone was used in Ostroff and Cooper's study in both infant-directed and adult directed speech may be indicative of the type of voice quality predicted to draw the attention of the infants especially for the discrimination of non-native contrasts. Most of the previous studies have used a male voice with the exception of Best et al (1988, 1995). Importantly, in Best's study, the non-native contrast (Zulu) was discriminate by infants and it is one of the only studies that have used a contrast spoken by a female. There are differences in the spectral properties of speech between male and female speakers. For example there is a significant difference in the height of the pitch of a female and a male voice. The average fundamental frequency of a woman's normal speaking voice is around 220 Hz and man's is around 120 Hz (Peterson & Barney, 1952). As ID speech involves higher pitch, a woman's ID speech is ranging from 300 to 600 Hz (Fernald & Simon, 1984). Thus, it may be premature to conclude from Ostroff and Cooper's (2003) study that adult faces (perhaps when coupled with IDS) are sufficient to induce infants' discrimination of non-native speech contrasts. If so, then changing the gender of the face + voice display should not impact discrimination.

Several studies have shown that males (fathers and non-fathers) also speak in a distinct manner while addressing infants and they tend to exaggerate their speech while doing so, though not to the same extent as females (Fernald et al, 1989). Also infants around 8 to 9 months of age have been found to prefer infant-directed speech to adult-directed when spoken either by a male or a female (Werker & McLeod, 1989). In spite of these data showing infants' attention to male speech, a subsequent experiment by Ostroff and Cooper (2003) found that when presented with the Hindi retroflex /da/ vs. retroflex /ta/ contrast, 11-month-old infants showed no discrimination under conditions of a male AD voice + geometric target. This failure in non-native discrimination could be due to a lack of facial information, a lack of ID speech, the presence of a male voice, or various combinations of these factors.

Goal of the Present Study

The study proposed here investigated the ability of 11 month-old American English infants to discriminate the non-native speech contrasts (Hindi- retroflex /da/ and dental /da/) in a slightly different context from Ostroff and Cooper's study (2003). These contrasts are those that have been used earlier (Werker & Lalonde, 1988). Male ID Hindi speech tokens were synchronized with a male face articulating the contrast in an infant-directed manner to examine whether American English infants can discriminate this non-native contrast. The primary hypothesis is that if facial information is critical for discrimination of non-native speech contrasts, 11-month-old infants should be able to discriminate between the Hindi contrasts. Besides visual information, exaggerated characteristics of ID speech may also aid discrimination of Hindi contrasts by infants. However, if characteristics of female speech are important for highlighting the available speech information, there should be no evidence of discrimination.

The procedure employed here was the infant-controlled visual habituation paradigm. The major assumption of this paradigm is that habituation of a particular stimulus by infants implies the formation of a memory for that stimulus (Miller, 1983). When the stimulus changes and the infant recognize the change, dishabituation is implied. If there is a failure to dishabituate, the infant is unable to notice the change in the stimulus. Most of the studies involving perception of non-native contrasts have used the head-turn procedure with the notable exception of Best et al. (1995). It may be more sensitive psychophysically and also less demanding than conditioned head turn procedure (Best, McRoberts, LaFleur & Silver- Isenstadt, 1995). Usually, the visual habituation procedure is employed in designs involving between-subjects comparison, as the degree of the stability of the individual performance in the habituation procedure across repeated measures in within-subject comparison is unknown (Polka, Jusczyk & Rvachew, 1995).

Chapter 2

Methods

Participants

Participating parents and infants were solicited by letter and a follow-up telephone call. Twenty-four healthy, full-term, 11-month-old (15 males and 9 females) infants were recruited for this experiment. Prenatal and postnatal health and monolinguicity (all native English) of the infants was confirmed from the parents. Information regarding the family structure (whether single parent homes or married homes), their order in the family (first born or not), diet (whether breast fed or bottle fed), average age of the mothers, average combined formal education of the parents and average combined annual household income of the parents was obtained directly from the parents (Appendix C).

The demographics of the final sample were as follows: 96 % were white/Caucasian while 4 % were American Asian; 96% were from married homes and 4% from divorced homes. The average age of the infants' mothers was $M = 31.217$, $SD = 3.41$.

Auditory/Visual stimuli

The phonemes that were used in this experiment are the ones that were originally used by Werker and Tees (1984). The Hindi contrasts were retroflex /da/ versus the dental /d̲a/. Speech samples were obtained by making audio-visual recordings of an East Indian, native male speaker of Hindi. He was first presented with a recording of Werker's original male phonemes, and asked to closely approximate these same phoneme contrasts several times in an infant-directed manner (he was the father of an infant). Five different adult native Hindi speakers then listened and rated the male speaker's tokens for their appropriateness as exemplars of both contrasts (i.e., retroflex and dental). The two phonemes rated as the best exemplars of each contrast were used in infant testing (2 retroflex; 2 dental). Then the audio-visual clips were edited and pieced together into a single movie file. The movies consisted of two tokens from each type of contrast alternating with each other.

The phonemes were analyzed acoustically. Independent samples t-test revealed no significant differences in the mean pitch, duration and amplitude of retroflex and dental contrasts. Also, independent samples t-test did not show any significant difference between the mean pitch, first formant and second formant frequency of the vowels in the retroflex and dental consonant-vowel contrasts (see Table 1).

Apparatus

Infants were seated on the parent's lap and they faced a color computer monitor, surrounded by black material so that the screen was prominent within the infant's visual field. Two small loud speakers were located directly adjacent to the right and left of the monitor, and a digital camcorder (Panasonic DV401) was also located behind the black panel, directly above the left-placed loud speaker. The infant and mother sat directly in line with the digital camcorder so that head/eye movements turned to the monitor (located slightly to the right of center) were clearly distinguishable to the observer. The observer watched the infant on a colored television, located in an adjacent, soundattenuated control room. The entire testing protocol was controlled by custom software written for a Macromedia Director platform on a Mac G4 computer.

Procedure

The infants were tested at the Infant Perception Lab of Virginia Polytechnic Institute and State University. The parents were asked to fill in the informed consent form and information regarding the infant and the family. When the infant was calm and alert, he or she was brought into the testing room with dimmed lights.

The parent holding the infant was deafened to the audio information being made available to the infant with the help of headphones playing continuous speech placed in their ears (in order to remove any unintentional influences or possible cues from them).

The observer viewed the infant via a video camcorder and recorded the looking time of the infant (duration of time the infant looked at the screen) by pushing the space bar of the computer, which activated a blinking red dot on a white background on the infant monitor. This served to draw the attention of the infant to the visual display. When the observer saw the corneal reflection in the infants' eyes, he or she pressed the space bar the second time, which activated the audio-visual display. This also signaled the start of the first trial. When the infant looked away from the screen for more than one second, the observer would press the space bar again signaling the end of the trial.

Infant-controlled habituation was first used by Horowitz (1974) when she demonstrated that infants showed a release from habituation (or dishabituation) of visual attention to an unchanged visual pattern when there was a change in the auditory stimulus In the present study, the tokens of the speech contrast and the face of the male articulating the contrasts were presented to the infant on every trial. The trial duration was under infant control. If the infant looked away from the screen for more than 1 second, the trial would end and the screen would go blank. An example of this technique- an infant would be habituated to the male face uttering the first Hindi phoneme (retroflex da) in an infant-directed manner and then be tested for the discrimination of the second Hindi sound token (dental d̲a). The order of presentation of the retroflex and dental contrasts was counterbalanced across the subjects.

Habituation criterion was expressed as a 50% reduction in the individual infant's looking time relative to the duration of the mean of the first two trials (called baseline trials) in the habituation phase. After the criterion for habituation was met during the pre-test phase, the audio-visual presentations were shifted to the contrasting syllable for the second phase (change phase). Before the change phase though, all of the infants received two no-change post-habituation trials (lag trials). This is a feature designed to assess the spontaneous attention shifts (Bertenthal, Haith & Campos, 1983). Spontaneous recovery has been observed in the habituation paradigm where infants' look duration increases after reaching the habituation criterion even when there is no change in the stimulus presented to the infants. Hence lag trials serve as an inbuilt control for assessing the spontaneous attention shifts. During the lag trials, the same stimulus is presented to infants as the one being presented during the pre-test phase. If their look durations increase, it can be attributed to spontaneous recovery. If there were no lag trials, this increase in look duration could be mistakenly attributed to discrimination of the phonemes. This may result in misleading inferences about the study.

The index of discrimination was the change in the looking times by the infants between the last two trials in the lag phase and the two trials in the test phase. The test phase consisted of two trials only. The look durations of the infants were calculated and updated to meet the habituation criterion on a trial-by-trial basis by a computer algorithm programmed into an application for the *Macromedia Director*.

Chapter 3

Results

Interobserver reliability

Interobserver reliability was assessed offline by two trained coders reviewing 25% of the videotapes from the sessions. Pearson's correlation coefficient was calculated on the duration of individual trials, as recorded by the coders (offline and online coder). The bivariate correlation was 0.99.

Adult discrimination

Twenty-nine adult English speakers (27 monolingual) were tested with the same phonemes used to test the 11 month-old infants in this study. The subjects were undergraduate students from a Psychology class. They were awarded extra credit for participation. They were tested in an AX (same/different) procedure. The subjects were first familiarized with native English phonemes in the training phase to make sure they were able to understand the requirements of the task. They were given a phoneme twice and then tested on another or the same phoneme and asked if it was same or different from the phoneme presented before. So if 'ba' was presented to them initially and then again, 'ba' was given, the correct answer would be 'same' and vice versa. Similarly, in the test phase, the subjects were presented with the retroflex and dental Hindi contrasts and asked whether two pairs of phonemes were same or different.

A chi square test was carried out to assess the ability of adult English speakers to discriminate between the retroflex and dental contrasts. The difference between the correct and incorrect responses by the subjects was significantly different from chance ($\chi^2 = 29.29$, $p < 0.001$). 73% of the subjects were unable to discriminate the change in Hindi contrasts.

Infant phoneme discrimination

Data obtained from 24 infants were included in the analyses. Analysis of Variance (ANOVA) was chosen for statistical analysis of the data. The average of the first two trials was considered the baseline measure. The average of the two lag trials was considered the pre-change measure and the average of the last two trials was considered the post-change measure. The three trial types (baseline, pre-change and post-change) were entered as within-subject variables, whereas gender (male, female) and order (retroflex first, dental first) were entered as the between-subject factors. There was a significant main effect of trials [F (1, 40) = 29.47 $p < 0.001$] but there was not a statistically significant main effect for gender [F (1, 20) =0.01, $p > 0.05$] or order [F (1, 20) = 0.02, $p > 0.05$]. The two-way and three-way interactions were not statistically significant.

Further analysis of trials with paired samples t-test showed a significant difference between baseline (M = 30.24, SD = 14.09) and pre-change phase (M = 12.05, SD = 7.04), t (23) = 7.45 $p<0.05$. This significant difference between baseline and lag phase is indicative of habituation. More importantly, there was no significant difference between pre-change phase (M = 12.05, SD = 7.04) and post-change phase (M = 10.98, SD = 6.22), t (23) = 0.64, $p > 0.05$. This implies lack of discrimination of non-native contrast by the infants. Also, there was a significant difference between baseline (M = 30.24, SD = 14.09) and post-change phase (M = 10.98, SD = 6.22), t (23) = 6.42, p <0.05.

Chapter 4

Discussion & Conclusion

The main goal of this study was to investigate the influence of gender of speaker on the ability of 11 month-old infants to discriminate non-native Hindi contrasts in a multi-modal context. The non-native contrasts used in this study were retroflex /da/ and dental /d̲a/ and previous research shows that American English infants before the age of 10-12 months can easily discriminate these same contrasts. However, infants around 10-12 month of age are unable to discriminate these contrasts (e.g. Werker & Lalonde, 1988, Werker & Tees, 1984). Importantly, most of the research done earlier did not employ visual speech information. The stimuli were presented in the auditory modality only and they possessed characteristics of male speech. The present experiment provided a comparison of discrimination of non-native contrasts in multi-modal context with a male speaker to a previous study in our lab with a female speaker. The previous study (Ostroff & Cooper, 2003) showed clear discrimination between non-native contrasts when a movie with a female speaker articulating the speech contrasts in an infant-directed manner was shown to the infants. This experiment was designed to assess whether the addition of visual ID speech would be sufficient to account for discrimination of the non-native contrasts. Hence the current study used male Hindi speech in an infant-directed manner to test the ability of 11 month-old infants to discriminate between retroflex and dental contrasts. Overall, the findings were consistent with our predictions. That is, the infants did not discriminate between the Hindi contrasts even when a male speaker was articulating the contrasts in an infant-directed manner. A major question, which arises here, is whether infants in this study were unable to discriminate between non-native speech contrasts due to inadequate allocation of attention or because it did not interest them enough. The baseline trials of the present experiment with male visual speech were compared with baseline trials of the previous experiment with female visual speech. There was no significant difference between them [$t(33) = 1.93$, $p > 0.05$]. So, the infants perhaps found the two different kinds of visual stimuli equally interesting but they probably obtained more information from the female speaker.

One possible explanation for these different results as a function of speaker gender may relate to there being distinct differences between the acoustic properties of the male recordings used in this study and the female recordings in the previous study (See Figure 1, Tables 1 and 2). These differences are expected because of the difference in gender of the speaker. As mentioned earlier, there are acoustic differences between male and female voices with females having higher pitch and greater pitch variability (Peterson & Barney, 1952). Studies on production differences between male and female voices reveal differences in fundamental frequency and formant structures (Fant, 1973). Formants are defined as concentration of acoustic energy within a particular energy band, especially in speech. They are the resonance frequencies of the vocal tract and are inversely related to the overall vocal tract length (Fant, 1973). Hence females with a shorter vocal tract length have a formant pattern with 20% higher frequencies than male formant pattern. First formant frequency F1 and second formant frequency F2 can be plotted against each other to get a vowel or a consonant-vowel map, which provides an idea about the acoustic quality of the voicing of the segments. Generally, the further apart the formant, the clearer is the enunciation of the speech unit. The F1/F2 plot comparing the male vowels in the current study with the female vowels in Ostroff and Cooper's study showed higher values for the first formant and second formant frequency for the female speech stimuli as compared to male speech stimuli (See Figure 1).

The main finding in the present study was consistent with the results from Werker and Tees (1984) with non-native contrasts, as infants did not discriminate the phonemic contrasts. The presence of a face and exaggerated contours of infant-directed speech did not appear to aid the infants because they still did not discriminate the Hindi phonemic contrasts. But in the presence of female face and infant-directed voice, infants in Ostroff and Cooper's study did discriminate the same contrasts. Hence the influence of auditory, visual, and auditory/visual information together needs to be probed further before reaching any conclusion.

Influences of auditory information on infant perception

The female voice has distinct acoustic characteristics, including higher pitch and exaggerated pitch contours. High pitch of infant-directed speech is believed to attract infants' attention or aid in communication of emotion and the exaggerated pitch contours assist infants in discriminating vowels better (Trainor & Desjardins, 2002). Mothers were seen to expand their f_0-range while addressing infants as compared to adult-directed speech. Fathers, on the other hand used the same mean f_0- range in both infant and adult-directed speech (Fernald, Taeschner, Dunn, Papousek, Boysson-Bardies & Fukui, 1989). So the quality of infant-directed speech used might influence the attention of infants. Greater f_0-range in female infant-directed speech might have helped the infants discriminate the phonemic contrasts in Ostroff & Cooper's study. Narrower f_0-range in male infant-directed speech, on the other hand might not have aided discrimination in the present study because it probably failed to focus infants' attention on the difference between the retroflex and dental contrasts in Hindi. An earlier study (Werker & McLeod, 1989) showed that female ID speech elicited more positive affective responsiveness from infants than male ID speech. In another study, infants looked longer when they heard female ID speech than when they heard male ID speech (Pegg, Werker & McLeod, 1992). Hence female ID speech may have resulted in greater recruitment of attention in Ostroff and Cooper's study.

Different aspects of female ID speech can be further investigated and compared with male ID speech. Changing the acoustic attributes of ID speech can help us identify the acoustic characteristics of speech influencing the infants' attention during discrimination of non-native contrasts. So, if the pitch of the female ID speech is lowered and the pitch of the male ID speech is raises and presented to the infants, which gender speaker will help in better discrimination? If the infants discriminate the contrasts with the higher pitch of the speaker even when it is a male, then pitch is playing a significant role in improved discrimination. Otherwise, there are some other characteristics of female speech responsible for discrimination of the non-native phonemic contrasts. Similarly, change in pitch variability in male and female speakers could also help address the issue of identifying acoustic characteristics responsible for garnering the attention of infants leading to better discrimination.

Influences of facial/visual information on infant perception

The face is a highly salient perceptual object for infants. It provides a lot of information about speech and its associated characteristics like pitch and voice intonation contours with the movements of the lips, tongue and cheeks and eyebrow placement (Lewkowicz, 1996). Even though, there were no significant differences in the pitch, intensity and duration between retroflex and dental contrasts used in the current experiment, the face might have influenced attention because the contrasts used provided information to the infants about specific place of articulation of these speech sounds. Place of articulation refers to the location of the mouth where the primary constriction of airflow results in phoneme production (Kuhl & Meltzoff, 1989). Retroflex/da/ and dental /d̲a/ phonemes used in this study had distinct places of articulation. The former sound was produced as a result of restriction of airflow with the tongue tip and the tongue bent slightly backward towards the hard palate. The dental phoneme is articulated as a result of pressing the tip of the tongue directly behind the front teeth. This was clearly visible from the movies of the male speaker. But still the absence of discrimination by the infants implies that facial information did not appear to help them. Importantly, this visual information did not seem to aid discrimination in adults either.

Perhaps the combination of male face and voice (even when it was infant-directed) could not capture the attention of 11 month-old infants. This could also be attributed to heightened interest of infants in female faces and voices probably due to their greater exposure to female caregivers during the first postnatal years of their lives. In one of the visual preference studies done to examine gender categorization, 3-4 month old infants preferred a female face to a novel male face, showing a spontaneous preference for female faces (Quinn, Yahr, Kuhn, Slater & Pascalis, 2002). Interestingly, all of these infants had female primary caregivers. However, infants with male primary caregivers showed a spontaneous preference for male faces. This study shows a direct influence of the environment on the infant's face preference. Greater exposure to a male presence in the environment may elicit more attention to a male face and voice and possibly aid the infants' ability to discriminate. The effect of male primary caregivers on the ability of infants to discriminate between non-native contrasts can be examined by testing only infants who have a male primary caregiver. This may not be practical in the current setting but may be possible in another suitable location or culture where fathers stay at home. If these infants discriminate the same phonemic contrasts, the crucial role of the caregiving environment would be exemplified.

One way to test whether the infants gleaned more information from female visual stimuli would be to compare the visual aspects of ID speech stimuli in these two studies using the same movies without any sound. Infants can be habituated to one of the non-native phonemes in the visual modality only and then presented with the phonemic contrast in the visual domain itself. Infants would either get to look at a male or a female speaker articulating the phonemes in the absence of sound. If the infants discriminate between the visual stimuli with a female speaker, it could be due to the exaggerated visual style of the ID speech in females as compared to male ID speech. This exaggerated style is prevalent in both visual and auditory domain.

Influence of auditory and visual information on infant perception

The importance of both auditory and visual information in speech perception is highlighted by the McGurk effect. McGurk effect involves presentation of auditory information (/ba/) concurrently with conflicting visual information (/ga/) to subjects. Most of the adults report hearing a fused syllable of the two (/da/). This effect has been observed in 4½ and 5 month-old infants (Burnham & Dodd, 2004; Rosenblaum, Schmuckler, & Johnson, 1997). In a recently published study (Desjardins & Werker, 2004) done in 4 month-old infants with McGurk effect employing the habituation paradigm, it was found that not all infants could integrate visual and auditory aspects of speech. This was in contrast to adults, who could easily do it. Also, children from 3 to 8 years of age were less likely to be influenced by the visual signal than adults, especially when the auditory and visual information were mismatched (McGurk & McDonald, 1976). Hence integration of auditory and visual properties could be an issue in the current study. But Ostroff and Cooper (2003) found the best discrimination between the non-native contrasts when both audio and visual information were available and the worst when no visual information was present. Apparently, the 11 month-old infants were integrating the audio-visual stimuli and getting additional information in both experiments.

ID speech has distinct acoustical properties, which distinguishes it from AD speech. Also, the facial characteristics of the speaker speaking in an infant-directed manner are different from those of adult-directed speech. There are more exaggerated expressions that are associated with the affective state of ID speech. It has been seen that ID speech and a face in the synchronous condition appear to aid in the discrimination of the audible aspects of bimodal speech in 6 month and 8 month-old infants. (Lewkowicz, 1996). An important thing to be noted here is that a female speaker used ID speech in this experiment with 6 and 8 month-old infants. Studies have shown that females show greater emotional expressiveness than males; not only is greater facial and gestural animation reported in females but also greater expression accuracy which refers to facial/gestural movements which convey emotion information (Hall, 1984). Also, adult female talkers have been rated to be more intelligible than male adult speakers (Bradlow, Torretta & Pisoni, 1996). The speakers' communicative intent in the prosodic contours of ID speech has been found to be more informative to adults than AD speech (Fernald, 1989). Hence, the exaggerated affective state in female ID speech might be related to greater intelligibility of the stimulus for infants in Ostroff and Cooper's study.

The information from the male face+infant-directed voice in the present study might have been insufficient to highlight the differences between the contrasts probably as a function of its emotional attenuation as compared to female face and ID speech. Ostroff and Cooper's study is being replicated in our lab with a movie of a different East Indian female speaker uttering a slightly different phonemic contrast (Hindi) in an infant-directed manner.

The visual and auditory aspects of infant-directed speech perception can be investigated further especially with relation to gender. Female face matched with male ID speech and male face matched with female ID speech can be presented to the infants and their ability to discriminate between the same phonemes can be tested. If the infants are able to discriminate between the phonemes if the female face is presented, no matter what the gender of the voice, it can be concluded that female face influences the ability of infants to discriminate to a greater extent. However, if the infants discriminate when they hear the female voice, no matter what the gender of the face is, then it can be said that the female ID speech is playing a key role in the discrimination of the non-native phonemes.

Summary

To summarize the current study, no discrimination was seen in 11 month-old infants when they were presented with retroflex and dental Hindi contrasts in the auditory and visual modality, with a male articulating the contrasts in an infant-directed manner. The presence of a male face and infant-directed voice together did not seem to aid the infants unlike the presence of a female face and infant-directed voice in Ostroff and Cooper's (2003) study. Future research needs to investigate the differences in characteristics of male and female speech in the auditory and visual domain, which could lead to discrimination of non-native contrasts.

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Table 1
<u>Acoustical analyses</u>

Phoneme	Mean pitch overall (Hz)		Independent samples t-test
	Mean	SD	
Retroflex da (Rda)	235.72	4.48	t(2) = -0.18, p > 0.05
Dental <u>d</u>a (D<u>d</u>a)	234.97	3.88	

Phoneme	Mean pitch of vowel (Hz)		Independent samples t-test
	Mean	SD	
Rda	245.62	10.6	t(2) = 0.78, p > 0.05
D<u>d</u>a	251.65	2.69	

Phoneme	Duration (per second)		Independent samples t-test
	Mean	SD	
Rda	0.8	2.82E-02	t(2) = 0.19, p > 0.05
D<u>d</u>a	0.82	0.106	

Phoneme	Intensity overall (dB)		Independent samples t-test
	Mean	SD	
Rda	66.99	0.38	t(2) = -1.47, p > 0.05
D<u>d</u>a	65.07	1.8	

Phoneme	Intensity of vowel (dB)		Independent samples t-test
	Mean	SD	
Rda	71.43	0.18	t(2) = -15.73, p > 0.05
D<u>d</u>a	65.92	0.46	

Phoneme	FI (Hz)		Independent samples t-test
	Mean	SD	
Rda	754.68	47	t(2) = 1.2, p > 0.05
D<u>d</u>a	799.94	24.8	

Phoneme	F2 (Hz)		Independent samples t-test
	Mean	SD	
Rda	1213.29	10.82	t(2) = 3.85, p > 0.05
D<u>d</u>a	1355.55	51.18	

Table 2

Acoustical Analyses from Ostroff and Cooper's study (2003)

Phoneme	Mean pitch (Hz) Mean	SD	Independent samples t-test
Hindi /ta/	270.33	17.07	t (6) = 1.17, p > 0.05
Hindi /t̲a/	249.65	31.13	

Phoneme	Phoneme duration (sec) Mean	SD	
Hindi /ta/	1.02	0.186	t (6) = -1.47, p > 0.05
Hindi /t̲a/	1.17	0.223	

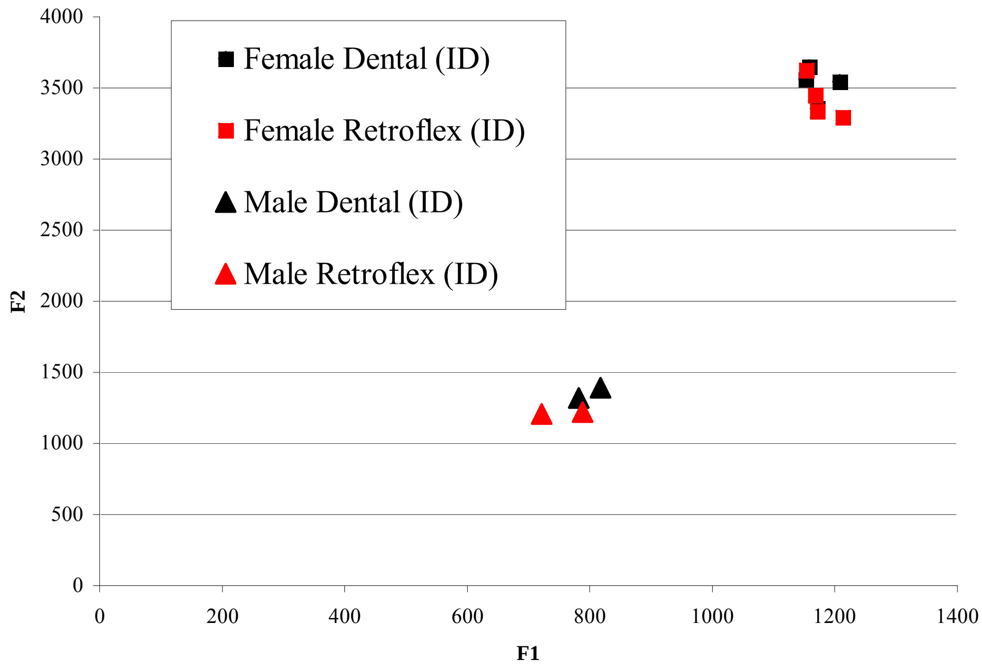

Figure 1. Comparison of the first formant frequency (F1) and second formant frequency (F2) plots of the ID speech contrasts spoken by a male and a female

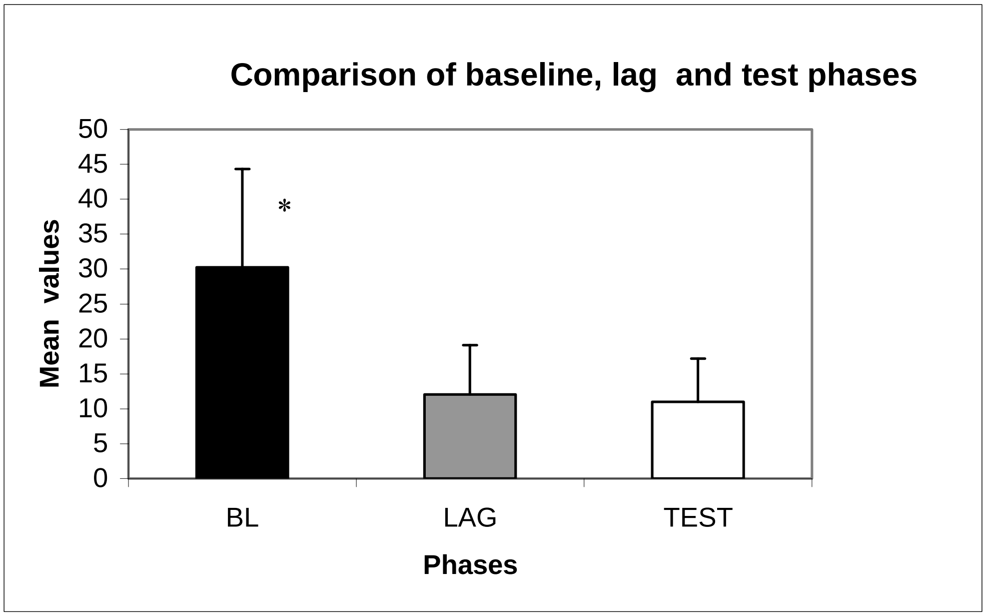

Figure 2. Comparison of fixation durations in the baseline, lag and test phases.

Appendix A

INFANT PERCEPTION LABORATORY

DEPARTMENT OF PSYCHOLOGY
VIRGINIA TECH

Dear Parent(s):

Our ***Infant Perception Laboratory*** in the Department of Psychology at Virginia Tech is currently interested in having **11-month-old infants** and their parent(s) participate in a new project!

We are interested in infants' abilities to hear the difference between two foreign speech sounds (these are language sounds from Hindi, that your baby probably has not heard before). Your baby will get to watch a movie and listen to one speech sound for a while, and after they start to lose attention, we will change to a new speech sound. Infants usually enjoy the change from an old to a new sound, and increase their attention. Your participation would involve one visit to the Infant Perception Lab, located on the 3rd floor of Williams Hall on the campus of Virginia Tech (we've enclosed a map). This visit will be scheduled at a time that is convenient for you (nights and weekends included). Our entire procedure lasts for approximately 15 minutes, but we schedule a full hour with you and your baby to give you time to get settled and not feel rushed. If there are older children in the family and you would like to bring them along, we offer free childcare. We also have convenient parking for you directly in front of our building.

If you are interested in scheduling an appointment for your infant or like to find out more about our work, please feel free to call us at 231-3972. We hope to see you and your baby very soon!

Sincerely,

Robin Panneton Cooper, Ph.D.
Associate Professor

Appendix B

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants of Investigative Projects

Title of project: The Influence of Gender and Facial Information on Infants' Discrimination of Non-Native Phonemes

Principle investigators: Dr Robin Panneton Cooper, Department of Psychology
Naureen Bhullar, Department of Psychology

I. Purpose of Research Project

You and your infant are invited to participate in our study on 11 month-old infants' discrimination of foreign speech sounds.

II. Procedure

Your infant will be tested for approximately 15 minutes, provided that he/she is awake, alert, and quiet. You will hold your baby on your lap, and face a colored monitor onto which a face or a geometric target will be projected. When your infant looks at this display, he/she will hear a speech sound uttered by a male native speaker of Hindi. Your infant will continue to hear this sound until, his/her attention begins to fade. At this point, he/she will be presented once again with the target, but now with a new speech sound. We are interested in whether your infant will increase attention to this novel speech sound.

We will videotape your infant during the session, so that we can watch the baby form an adjoining room in order to code his/her attention and also, so that we can have undergraduate assistants in our lab recode your baby's behavior and facial expressions at a later time (for reliability estimates). However, no identifying information about your baby will appear on these tapes. There are minimal risks associated with this research project.

III. Benefits of this study

Your baby's participation in this study will benefit the field of speech perception, and will help identify the factors necessary for infants' successful discrimination of foreign sounds.

IV. Extent of anonymity and confidentiality

All the information gathered in this study will be kept confidential and the results will not be released without your consent. The information that your baby provides will be identified by subject number only and not by names. Your informed consent will be kept separate from your infants' information. The results of this study may be presented at scientific meeting, and/or published in a scientific journal. If you would like, you will be sent a summary of this work when this project is completed. All tapes will be destroyed 5 years after completion of this study.

V. Freedom to withdraw

You have the right to terminate your involvement in this project at any time and for any reason, if you so choose.

VI. Approval of research

This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech.

VI. Subject's permission

I have read and understood the informed consent for this project. I have been given an opportunity to ask further questions about the procedures and I understand I have the right to end this session for any reason I so choose. If I have any questions regarding this research and its conduct, I should contact the persons named below. Given these procedures and conditions, I give my permission to be tested in the procedure described above.

Dr Robin Panneton Cooper, Principle Investigator	231-5938
Naureen Bhullar, Graduate Assistant	231-3972
Dr David Harrison, Human Subjects Committee	231-4422
Dr David Moore, Assistant Vice Provost for Research Compliance	231-4991

Signature of participant: ____

Date: ____

Appendix C

Infant #_______ Experiment #__

Infant Perception Laboratory

Family Information Sheet

(All information is strictly confidential)

Infant's Birthdate: ______________________ Mother's Age:___________ Father's Age:_____________

Mother's Occupation: _______________________ Father's Occupation: __________________________

Mother's Education: High School Partial College College Master's Ph.D.

Father's Education: High School Partial College College Master's Ph.D.

Annual Family Income: $10,000-$20,000 $20,000-$35,000 $35,000-$50,000 $50,000-$65,000

$65,000-$80,000 $80,000-$95,000 > $95,000

Marital Status: Married Separated Divorced Unmarried/Single Widowed

Mother's Race: White/Caucasian African American Hispanic Asian Native American

Other_____________________

Father's Race: White/Caucasian African American Hispanic Asian Native American

Other_____________________

Was your infant: Full Term (38-42 weeks) Premature (≤ 37 weeks) Postmature (>42 weeks)

Infant's Birthweight: ____________ lbs _____________ozs

Has your infant had any medical problems? Yes No Please List:___________________________________

Please list the birth date and gender of any older children:

_________________________________ M F
_________________________________ M F

_________________________________ M F
_________________________________ M F

What is the primary language spoken in your home?
____

Please list any other languages that are spoken in your home:
____

Does your infant watch any T.V.? Yes No Please list:____

How did you find out about our study? Letter Brochure Friend Lecture

Infant Questionnaire Appendix D

For the following questions, please circle the number that is most typical of your baby.

1. How easy is it for you to calm or soothe your baby when he/she is upset?

1	2	3	4	5	6	7
very easy			*about average*			*difficult*

2. How easy is it for you to predict when your baby will go to sleep?

1	2	3	4	5	6	7
very easy			*about average*			*difficult*

3. How easy is it for you to know what's bothering your baby when he/she cries or fusses?

1	2	3	4	5	6	7
very easy			*about average*			*difficult*

4. How many times per day, on the average, does your baby get fussy and irritable-for either short or long periods of time?

1	2	3	4	5	6	7
never	*1-2*	*3-4*	*5-6*	*7-8*	*10-14*	*over 15*

5. How much does your baby cry and fuss in general?

1	2	3	4	5	6	7
very little			*about average*			*quite often*

6. How easily does your infant get upset?

1	2	3	4	5	6	7
not easily			*about average*			*very easily*

7. When your baby gets upset, how vigorously or loudly does he/she cry?

1	2	3	4	5	6	7
very mildly			*about average*			*very loudly*

8. How much does your baby want to be held?

1	2	3	4	5	6	7
very often			sometimes			not very often

Appendix E

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants of Investigative Projects

Title of project: Adult speech discrimination of Male Hindi Phonemes
Principle investigators: Dr Robin Panneton Cooper, Department of Psychology
Naureen Bhullar, Department of Psychology

I. Purpose of Research Project

You are invited to participate in a study investigating adults' abilities to perceive differences in native and non-native speech contrasts.

II. Procedure

The discrimination task will take approximately 15 minutes of your time and will be conducted at the Infant Speech Perception Lab at Williams Hall on campus of Virginia Tech. You will be sitting on a chair facing a computer monitor and two loud speakers. You will be presented with a female face and concurrent repetitions of an English speech contrast. Subsequently you will be presented with a male face and concurrent repetitions of a non-native speech contrast. In each case, you will be asked whether you perceive a switch in the phonemes. There are no apparent risks to you resulting from this study.

III. Benefits of this study

Your participation in this study will benefit the field of speech perception. The results from this study will be compared with the results with our 11 month-old infants and this will help us understand the differences in the ability of infants and adults in perception of foreign languages.

IV. Extent of anonymity and confidentiality

All the information gathered in this study will be kept confidential and the results will not be released without your consent. The information you provide will be identified by subject number only and not your names. Your informed consent will be kept separate from your data. The results of this study may be presented at scientific meeting, and/or published in a scientific journal. If you would like, you will be sent a summary of this work when this project is completed.

V. Compensation

You will be given one extra credit point in your Psychology course for your participation in this study.

VI. Freedom to withdraw

You have the right to terminate your involvement in this project at any time and for any reason, if you so choose.

VII. Approval of research

This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech.

VII. Subject's permission

I have read and understood the informed consent for this project. I have been given an opportunity to ask further questions about the procedures and I understand I have the right to end this session for any reason I so choose. If I have any questions regarding this research and its conduct, I should contact the persons named below. Given these procedures and conditions, I give my permission to be tested in the procedure described above.

Dr Robin Panneton Cooper, Principle Investigator	231-5938
Naureen Bhullar, Graduate Assistant	231-3972
Dr David Harrison, Human Subjects Committee	231-4422
Dr David Moore, Assistant Vice Provost for Research Compliance	231-4991

Signature of participant: ______________________________________

Date: ____

Appendix F

Adult Discrimination of Non-native Phonemes

Date: ________________________

Experimenter: ________________________

Subject# ____: M F Native English Speaker? Yes No

If no, what is native language?_____________________

Do you speak other languages? Yes No Please list________________________

TRAINING

Phoneme	
Test	SAME DIFFERENT

Phoneme	
Test	SAME DIFFERENT

TEST

Phoneme	
Test	SAME DIFFERENT

Phoneme	
Test	SAME DIFFERENT

Phoneme	
Test	SAME DIFFERENT

Phoneme	
Test	SAME DIFFERENT

Phoneme	
Test	SAME DIFFERENT

Phoneme	
Test	SAME DIFFERENT