2005

Emotion perception in pre-kindergarten school children at Central Institute for the Deaf

Amanda Ruth Shinall

EMOTION PERCEPTION IN PRE-KINDERGARTEN SCHOOL CHILDREN AT CENTRAL INSTITUTE FOR THE DEAF

by

Amanda Ruth Shinall

An independent study
submitted in partial fulfillment of the
requirements for the degree of:

Master of Science in Deaf Education

Washington University School of Medicine
Program in Audiology and Communication Sciences

May 20, 2005

Approved by:
Dr. Rosalie M. Uchanski, Independent Study Advisor

PURPOSE:

The purpose of this study is to assess the ability of Pre-kindergarten (pre-k) students with both normal hearing (NH) and impaired hearing (HI) to identify emotion in speech through audition only. A secondary purpose is to assess whether a listener's familiarity with a speaker's voice has an effect on his/her ability to identify the emotion of the talker.

BACKGROUND:

Speech communication conveys two types of information; lexical and indexical information. The lexical information is the word sequence from the speech signal. The other type of information is the "indexical" or "personal" cues, meaning nonlinguistic aspects of the signals that provide information about the talker's gender, individual identity, dialect or accent, age and emotional state. Indexical cues are likely provided in nonlinguistic vocalizations, such as laughter, as well.

The idea that vocal acoustics are imbued with cues to talker emotional state has a long history in human inquiry. Emotion is defined by Merriam-Webster Online Dictionary as a state of feeling. The perception of emotion in the vocal expressions of others is vital for an accurate understanding of emotional messages (Banse and Scherer, 1996). Infant-directed speech captures infants' attention more effectively than does typical adult-directed speech (e.g., Cooper & Aslin, 1990; Fernald, 1985; Werker & McLeod, 1989; Morton & Trehub, 2001). Infants may be responding to the emotionality of this infant-directed speech, since this style of speech often conveys love and/or comfort (Trainor, Austin & Desjardins, 2000; Morton & Trehub, 2001). Infants also

respond in a more positive way (e.g., smile or gaze for a longer time) when presented with messages that convey positive emotions, and respond more negatively (e.g., crying, grimacing) to messages that convey negative emotions (Fernald, 1992; Morton & Trehub, 2001). This suggests that some aspects of speech are intrinsically meaningful (Fernald, 1992; Morton & Trehub, 2001). As children are developing, their understanding of emotion becomes important for their understanding of communicative intent, social competence and social adjustment (Holder & Kirkpatrick, 1991; Nowicki & Duke, 1994; Nowicki & Mitchell, 1998; Motley & Camden, 1988; Creusere, Alt & Plante, 2004).

There are different ways that emotion is conveyed in speech. Cicero and Aristotle suggested that each emotion is associated with a distinctive tone of voice (Bachorowski and Owren, 2003). Commonly analyzed acoustic parameters for emotion in speech have been pitch, duration at the phoneme or syllable level, inter-word silence duration and voiced/unvoiced duration ratio at the utterance level, energy related to the waveform envelope, the first three formant frequencies, and spectral moment or balance. These parameters reflect speech prosody, vowel articulation and spectral energy distribution (Yildirim et al., 2004). Data from Yildirim et al. (2004) show that happiness/anger and neutral/sadness share similar acoustic properties, at least for the speaker used for their study. Speech associated with anger and happiness was characterized by longer utterance duration, shorter inter-word silence, higher pitch and energy values with wider ranges, showing the characteristics of exaggerated or hyper-speech. Other researchers (House, 1994, Pereira, 2000 & Morton &Trehub 2001) have found some of these acoustic properties to be different. An example of this would be that they found happy to be shorter in duration than sad. In general (across studies of the acoustic properties of

emotional speech), there is much overlap in acoustic property values found for different emotions. Yildirim et al. also found that RMS energy, inter-word silence, and speaking rate are useful in distinguishing sadness from the other emotions they examined. These results were obtained from speech produced by an actress, and may or may not be generalized to other speakers (Yildirim et al., 2004). Bachorowski and Owren (2003) report that fundamental frequency and amplitude seem to be the most important acoustic aspects of emotional speech. The data concerning production and perception of emotion-related acoustic cues in speech are methodologically far from ideal, but they provide strong evidence that F_0- and amplitude-related features play a central role in conveying emotion (Bachorowski and Owren, 2003).

For adults listeners with hearing impairment, particularly those using cochlear implants, only a little is known about such listeners' ability to hear these important acoustic features for emotion perception (F_0- and amplitude-features). A study by Pereira (2000) showed that subjects who wore both hearing aids and cochlear implants consistently confused happiness with anger and sadness with neutrality. This suggested that intensity was being used as a primary cue for identifying emotion since higher intensities are common to both happiness and anger, while lower intensities are common to neutral and sadness (Pereira, 2000). A study by House (1994) also showed that adult cochlear implant users confused happiness with anger and sadness with neutrality. These confusions seem to reflect the use of intensity as a primary cue to detecting emotion in speech. House's results (1994) indicate that these CI users were also attending to fundamental frequency as a cue to emotion which was shown to be evident from responses of sadness and neutrality for anger as the intended mood. These three mood

types have more similar F_0-contours relative to the wide range in F_0-excursions found in happy speech (House 1994). While it seems that intensity and fundamental frequency play important roles in conveying emotion in speech for adults with hearing impairment, to date no similar studies have been conducted with children who use cochlear implants.

RATIONAL:

For young children with cochlear implants, it is important to know how well they perceive indexical information, such as emotion and talker-identity, because this ability may affect their ability to perceive the message of speech. Currently no one knows how well or poorly children with cochlear implants perceive emotion as compared to normal hearing children of the same age. And, the effect of familiarity with a voice on perception of emotion is unknown for children with cochlear implants. This study was done to find out how well children with cochlear implants are able to perceive emotion in speech in comparison to their same-age peers, as well as to asses whether familiarity with the talker's voice affects their ability to perceive emotion in speech.

PILOT EXPERIMENTS

Several pilot experiments were performed primarily to determine the selection of phrases/sentences for use with children, and the selection of a familiar and unfamiliar talker. House (1994) examined the ability of cochlear implant users to identify moods, and their ability to produce utterances using these moods. His test consisted of four moods: angry, happy, sad and neutral, and for each mood he recorded two utterances. One was a number (2510) and the other was "Now I'm going to move." (House 1994).

Using these utterances as a guide, four semantically neutral phrases, which could be said in each of four emotions (angry, fearful, happy, sad) were created (see below). The "neutral" emotion was intentionally omitted after discussions with the CID pre-k teaching staff. The staff felt that students in the CID pre-k program would not know what "neutral" meant. However, the teachers were confident that all CID students would know the emotion, "scared" or "fearful." Hence, for this study, scared is substituted for neutral. The vocabulary and syntax in the phrases and sentences are appropriate for pre-k children.

1. It's time to go.
2. Give me your hand.
3. 2510 (Two thousand five hundred ten)
4. Take what you want.

All teachers who have frequent contact with the CID pre-k children were interviewed to assess their regional accents, voice quality and willingness to make speech recordings. Ellie Rice, a teacher in the pre-k program, was selected (top choice) as she met all the requirements and was agreeable to participation. Five other female talkers were also recruited. These other talkers were from outside of the CID school faculty, and were unfamiliar to the CID children. These six talkers were then asked to record these four phrases/sentences. The talkers were asked to say the phrases in each emotional manner at least three times. Thus, each sentence was said at least twelve times. Though these talkers were not professional actors, they were coached on how to say each of these sentences so that they conveyed the four emotions. This coaching included giving the talker scenarios that would help them express the desired emotion. For example, for the

sentence “It’s time to go.” and for the happy tone, the talker was told to imagine that she and her family were about to leave for a fun vacation that they had been planning for a long time. A total of sixteen scenarios were generated for these phrases. Coaching also included allowing the talker to listen to just-recorded sentence productions and, after some discussion, to make real-time adjustments or modifications.

From informal listening to these recordings, two of the five unfamiliar talkers were chosen for subsequent pilot experiments. These two unfamiliar talkers were selected as most likely being able to convey emotion as effectively as the “familiar” talker. The recordings were then edited by separating and saving each phrase as its own wave file. Three “tokens” of each phrase for each emotion produced by each talker were edited. The overall intensity level of each waveform was then normalized to a constant value.

1: PILOT WITH NORMAL HEARING ADULTS

Purpose and Methods

The purpose for our pilot with normal hearing adults was to select one unfamiliar talker that expressed emotion in speech as closely as possible (in accuracy) to our familiar talker, and to select one or two sentences that were identified with the highest accuracy.

Five adults were recruited from the Washington University Program in Audiology and Communication Sciences student population. The testing lasted approximately one hour. The listeners were tested in an audiology booth. They were given a board with four pictures of a girl making different faces to convey the emotions, angry, fearful, happy and sad. They were asked to listen to the recordings of each talker while that

talker said every phrase in each of the four emotions three times ("All"; a total of 96 trials = 4 emotions x 4 phrases x 3 tokens x 2 repetitions). These recordings were played in a randomized order. After listening to each phrase, the listener responded by either pointing to the picture or saying the emotion they thought was being expressed. The listeners were then presented with blocks of trials in which each talker said only one particular phrase in each of the four emotions ("single"; a total of 24 trials for each phrase = 4 emotion x 1 phrase x 3 tokens x 2 repetitions), and again were asked to respond by either pointing to the picture or saying the emotion they thought was being expressed.

Results

The results in Table 1 indicate that the emotion identification scores of Unfamiliar Talker 1 are nearly identical to those of the Familiar Talker, particularly for sentences S2 and S4. The emotion identification scores for Unfamiliar Talker B's speech are generally lower than those from the other two talkers. The two sentences that the listeners identified most accurately were sentences #2 (S2) and #4 (S4). Consequently, for the subsequent pilot experiment with normal hearing children, the Familiar Talker and Unfamiliar Talker A were the two talkers used. And, only sentences #2 (S2) and #4 (S4) were selected for use in the next pilot experiment.

2: PILOT WITH NORMAL HEARING CHILDREN:

IDENTIFICATION EXPERIMENT

Purpose and Methods

The purpose of the pilot with normal hearing children was to asses their ability to identify the emotion of the talker, to select the sentence that would be used with the pre-k children at CID, and to determine the length of testing time that should be used when testing the CID pre-k children. In addition, this pilot experiment was performed to confirm that the familiar talker and unfamiliar talker A are similarly effective in conveying emotion, for young, normal-hearing listeners (who are unfamiliar with both talkers).

Three normal hearing children were recruited from the Washington University Program in Audiology and Communication Sciences and the CID staff. These were children either of staff members or of their friends. The children were between the ages of 3-6 years old. This age range was chosen to match the ages of the students in the CID pre-k program. The testing time was approximately thirty minutes. The children were asked to sit in an audiology booth and listen to the two talkers speak sentences 2 and 4. These sentences were presented one at a time. They were given a board with four pictures of a girl making different faces to convey the emotions, angry, fearful, happy and sad. The children were then asked to respond by either pointing to the picture or saying the emotion they thought was being expressed.

Results

The results of this pilot experiment (see Table 2) show that these children performed roughly at chance levels (25% correct) or at somewhat higher than chance levels, in identifying the emotion of these two talkers. The results do, however, show that the children were much more able to identify the correct emotion for sentence 4 than for sentence 2. We also observed that the children often became tired and fidgety after

approximately 15 minutes. This is why subject NH_1 completed only half of the experimental conditions.

Based on the generally low identification performance with normal hearing children of this age, we decided to perform both discrimination and identification experiments with the CID pre-k children. We also decided to use only Sentence 4 for these tests, as this sentence yielded higher scores than did Sentence 2. And, finally, we determined that two 15-minute test sessions should be scheduled for each CID child instead of one 30-minute test session.

EMOTION PERCEPTION EXPERIMENTS

Method

Subject Group A

Subject Group A consists of six pre-k students from CID. The ages of these students ranges from 3 years 6 months to 4 years 9 months. (There are sixteen students total in the CID pre-k program, 6 with normal hearing and 10 with impaired hearing. All were asked to participate, however, permission was received for only these six students.) Three of these students have normal hearing and the other three have impaired hearing. One of the three hearing impaired students wears bilateral, bone-conduction hearing aids and the other two wear Nucleus 24 cochlear implants with the ACE processing strategy. The student who has bone aids has worn them for 3 years and 2 months. One child with a CI has worn the implant for 4 years one month and the other child, for 2 years and 5 months. Table 3 shows demographic information for these six students. All of these six

students are familiar with one of the talkers (the CID teacher). Thus, the familiar vs. unfamiliar talker designations apply to these subjects in Group A.

Subject Group B

Group B is another group of pre-k-age children. These children were recruited from the Washington University Program in Audiology and Communication Sciences staff and their friends. This group consists of 5 children ranging in age from 3 years to 6 years one month. Table 3 shows demographic information for these five children. All of these children have normal hearing and were not from the CID student population. Hence, these children were not familiar with either of the talkers. Therefore, the familiar vs. unfamiliar talker designations do not apply to these subjects in Group B.

Subject Group C

This subject group consists of 8 students from CID's primary or middle school. They range in age from 6 years 5 months to 12 years 7 months. All of these students are hearing impaired. Four of the students wear bilateral hearing aids, one wears bilateral bone-conduction aids, two wear one hearing aid and a cochlear implant, and one wears just an implant. Table 3 shows demographic information for these eight students. These students are also unfamiliar with both talkers so the familiar vs. unfamiliar talker designations do not apply to these subjects in Group C.

Talkers

Two female talkers said one sentence in the four emotions (angry, fearful, happy, and sad). One of the female talkers was a teacher in the pre-k department at CID, and hence was familiar to only the pre-k children (Group A). The other female talker was

recruited from outside of the CID school faculty and was selected based on the results of pilot experiment 1 described earlier. This talker was unfamiliar to all the children, in subject Groups A, B and C. Though these talkers are not professional actors, they were coached on how to elicit emotions, and suggestions regarding production were taken from the methods section of House (1994).

Materials

Sentences were semantically neutral, and were appropriate in vocabulary and syntax for young children, with both normal and impaired hearing. Each talker spoke the sentence in the four emotions three times each (to produce three tokens). The sentence was:

Sentence 4: Take what you want.

All the sentences were digitized and normalized in level before presentation. Stimuli were presented using an Anchor AN-100 speaker, at a sound level of about 65 dB SPL. The speaker was located directly in front of the child, approximately 4 feet away. Testing was performed in an audiology test booth.

Identification Task

For the identification task, a board with pictures of a girl's face displaying the four emotions on it was placed in front of the subjects. The subjects then listened to each talker say the sentence "It's time to go," in one of the four emotions. The listeners responded by either pointing to the picture or saying the emotion they thought was being expressed.

Discrimination Task

For the discrimination task, a board with two pictures representing "same" feeling (two green squares) and "different" feeling (one red circle and a blue triangle) was placed in front of the subjects. The subjects were asked to listen to a talker say the sentence "It's time to go," two times. The two sentences were either of the "same" emotion (e.g., "happy" followed by "happy") or of "different" emotions (e.g., "angry" followed by "sad"). The listener then responded by either pointing to the picture representing "same" or "different," or by saying the word "same" or "different."

Results:

Subject Group A: Discrimination

For the discrimination task (see Figure 1) five of the six pre-k students were able to perform above chance (50%). This shows that these five students were able to discriminate these emotions through speech alone. The hearing impaired students did have more difficulty than the normal hearing children. Overall averages were 74% correct for the HI students and 94% correct for the NH students. The listener's age does seem to affect the results of the students' scores for this task. The one NH subject that is the youngest did less than perfect and the data for the HI students seems to improve with age. A t-test was run on these scores to see whether familiarity with a talker's voice had an effect on the students' responses. These results yield no significant difference in discrimination performance for speech from the familiar vs. unfamiliar talkers. These t-test results can be seen in the top half of Table 4.

Subject Group A: Identification

For both the NH and HI students (see Figure 2) the identification task was more difficult than the discrimination task. The NH students did better than chance (25% correct) with an average of 80% correct while the HI students overall average was near chance with an average of 46%. This shows that the NH students were much more able to identify emotion than were the HI students. Within each group of listeners (NH and HI), the students' scores appear to increase with the age of the student. However, this observation is based on only three listeners in each group. Morton & Trehub's (2001) results indicate clear age-related changes in the relative allocation of attention to prepositional (what the talker actually says) and paralinguistic (how the talker speaks) cues. Specifically, the majority of children 9 years old and younger judged a talker's emotion by what the talker said while adults judged emotion by how the talker spoke. The youngest children showed the greatest reliance on prepositional cues, i.e., what the talker said (Morton & Trehub, 2001). Thus, it is not surprising that this task was difficult for these young listeners, and that age might affect performance. As before, a two-sided t-test was performed to examine a difference, if any, between identification performance for the two talkers. These t-test results, shown in the bottom-half of Table 4, indicate there is no statistical difference in identification performance for the two different talkers' sentences.

Subject Group A: Identification Performance separated by Emotion

Angry: Some students were able to identify the emotion "angry" with 100% accuracy. Those students who did not identify "angry" with 100% accuracy performed

from 40% to 80%. Listener's age does not appear to be a factor in these students' results, shown in Figure 3.

Fearful: For all but one of the pre-k students, correct identification of the emotion "fearful" or "scared" was difficult. Two of the HI students got 0% correct on this task. One of the NH students was able to identify "fearful" with 100% accuracy for the unfamiliar talker. Age does not appear to be a factor in these students' results, shown in Figure 4.

Happy: Some students, for individual talkers, were able to identify the emotion "happy" perfectly. The other students' results were generally above chance (25%). For these data, it could be construed that when children are above the age of four and a half years old they do better on this task. These results are shown in Figure 5.

Sad: Four of the students achieved scores at or near 100% correct for the identification of the emotion "sad." The other two students' scores were near chance or at 0% correct. The NH listeners perceived sadness reliably while only one HI listener did. Listener's age also does not appear to have an effect on these scores as shown in Figure 6.

Subject Group B: Discrimination

The discrimination results from Subject Group B are shown in Figure 7. For this task and these subjects (with normal hearing, outside of the CID pre-k program), listener's age seems to have an effect on the performance. Two of the three listeners over the age of 5 were able to discriminate emotion fairly well (on average 90% correct), while both of the younger children (near 3 years old) performed poorly (on average 60%

correct). One child over 5 years of age performed near chance (50%) on this task. As done for the results from Subject Group A, a t-test was performed to see whether there was a difference in subjects' ability to identify emotion for speech from talker 1 vs. talker 2 (see top-half of Table 5). There was no significant difference in the students' emotion discrimination abilities for these two talkers.

Subject Group B: Identification

The identification results are shown in Figure 8. Identification of emotion by these normal hearing 3-6 year old children is above chance, but is far from perfect, even at 5-6 years old. As mentioned earlier, the results from Morton and Trehub (2001) indicate that children under the age of 9 judge "what" a talker said rather than "how" a talker spoke. This may explain why these children were unable to identify the emotions that were spoken – with this "fixed" sentence script. A t-test was run to see whether there was a difference in the subjects' ability to identify emotion from talker 1 vs. talker 2 (see bottom-half of Table 5). There was no significant difference in the students' abilities for these two talkers.

Subject Group C: Discrimination

These results are shown in Figure 9. Four of the five HI subjects over 9 years of age were able to reliably discriminate emotion. The younger subjects, 6-8 years old, were not able to discriminate emotion. Hence, it appears that age has an effect on emotion discrimination performance, at least for HI listeners of this age range (6-13 years). A t-test was run to see whether there was a difference in the subjects' ability to identify emotion for speech from talker 1 vs. talker 2 (see top-half of Table 6). There

was no significant difference in the students' emotion discrimination abilities' for these two talkers.

Subject Group C: Identification

These results are shown in Figure 10. In general, although the older subjects in this group could discriminate emotion (as shown in the previous figure), it appears they are not able to identify emotion reliably. Listener's age does not seem to affect ability to identify emotion. One HI student (age 11 years) was able to identify emotion. This particular student wears bilateral bone-conduction hearing aids, which may have a role in this listener's ability to identify emotion. A t-test was run to see whether there was a difference in the subjects' ability to identify emotion for speech from talker 1 vs. talker 2 (see bottom-half Table 6). There was no significant difference in the students' identification abilities for these two talkers.

Summary

For the emotion discrimination task, five out of the six CID pre-k students (Group A), two of five NH pre-k children (non-CID) ages 3-6 (Group B), and four of the eight CID primary/middle school children (Group C) were able to discriminate emotion for these stimuli. In the group of primary/middle school children, the listeners that were able to discriminate were over 9 years old. For the emotion identification task, it appears that only a few subjects achieved good performance. These few were NH CID pre-k students and one middle-school student with bone-conduction hearing aids.

Overall, talker does not seem to have an effect on either discrimination or identification. And, this result holds for data from the subjects (groups B & C) which

were unfamiliar with both talkers, and for the subjects (group A) which were familiar with one of the two talkers. Hence, neither talker had an effect on the subjects ability to do the discrimination or identification tasks.

Future

In future experiments a much larger group of subjects would be desirable. Also, it may be reasonable to restrict the age of children to 9 years or older (based on Morton & Trehub's report), to ensure that even NH children are able to identify emotion. To ensure that listeners attend to "tone" and not lexical information, foreign-language stimuli could be used, similar to methods in the study of Morton & Trehub (2001). In their study, native-English listeners heard speech from a talker who spoke in Italian. The purpose of Use of a foreign language obscures propositional cues (what the talker said) and forces listeners to respond solely on the emotional "tone" in the utterance (Morton & Trehub, 2001). Another consideration for future research, is the ability of an implant to transmit emotion information. This could be assessed by testing adults who were post-lingually deafened. The use of such subjects would eliminate issues related to learning emotions themselves, and to learning how emotions are associated with prosodic features of spoken English.

References

Bachorowski, J. and M. J. Owren (2003). "Sounds of Emotion; Production and Perception of Affect-Related Vocal Acoustics." *Annals of the New York Academy of Sciences 1000,* 244-265.

Banse, R. and K.R. Scherer (1996). "Acoustic Profiles in Vocal Emotion Expression." *Journal of Personality and Social Psychology 70*, 614-636.

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

Creusere, M, Alt, M., & Plante, E. (2004). Recognition of vocal and facial cues to affect in language-impaired and normally-developing preschoolers. *Journal of Communication Disorders, 37,* 5-20.

Fernald, A. (1985). Four-month-old infants prefer to listen to motherese. *Infant Behavior and Development, 8,* 181-195.

Fernald, A, (1992). Human maternal vocalizations to infants as biologically relevant signals: An evolutionary perspective. In J. H. Barkaw, L. Cosmides, & J. Tooby (Eds.), *The Adapted Mind: Evolutionary Psychology and the Generation of Culture* (pp. 391-428). New York: Oxford University Press.

Holder, H. B., & Kirkpatrick, S. W. (1991). Interpretation of emotion from facial expressions in children with and without learning disabilities. *Journal of Learning Disabilities, 24,* 170-177.

House, David (1994). *Perception and Production of Mood in Speech by Cochlear Implant Users*. International Conference on Spoken Language Processing (ICSLP)1994. Yokohama, Japan.

Morton, J. B. & Trehub, S. E., (2001). Children's understanding of emotion in speech. *Child Development, 72,* 834-843.

Motley, M. T., & Camden, C. T. (1988). Facial expression of emotion: A comparison of posed expressions versus spontaneous expressions in an interpersonal communication setting. *Western Journal of Speech Communications, 52,* 1-22.

Nowicki, S. & Duke, M. P. (1994). Individual difference in the nonverbal communication of affect: The diagnostic analysis of nonverbal accuracy scale. *Journal of Nonverbal Behavior, 18,* 9-35.

Nowicki, S. & Mitchell, J. (1998). Accuracy in identifying affect in child and adult faces and voices and social competence in preschool children. *Genetic, Social, and General Psychology Monographs, 124,* 39-59.

Pereira, Ceclie (2000). “The Perception of Vocal Affect by Cochlear Implantees.” *Cochlear Implants 16J,* 343-345.

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

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

Yildirim, S., M. Bulut, et al. (2004). *An acoustic study of emotions expressed in speech*. INTERSPEECH 2004 – ICSLP, Jeju, Korea.

Table 1

Pilot with Hearing Adults; average of 5 listeners
S1-S4 (sentence 1- sentence 4)
Familiar Talker, Unfamiliar Talker A, & Unfamiliar Talker B

Block/Condition	Familiar Talker				Sentence Average
All	S1	S2	S3	S4	
	99%	97%	96%	100%	98%
Single	S1	S2	S3	S4	
	100%	100%	100%	100%	100%

Block/Condition	Unfamiliar Talker A				Sentence Average
All	S1	S2	S3	S4	
	92%	97%	93%	99%	95%
Single	S1	S2	S3	S4	
	98%	100%	98%	100%	99%

Block/Condition	Unfamiliar Talker B				Sentence Average
All	S1	S2	S3	S4	
	91%	91%	87%	89%	89%
Single	S1	S2	S3	S4	
	98%	94%	94%	100%	96%

Table 2

Pilot with Normal Hearing Children

		Number correct out of 24 trials			
		Familiar Talker		Unfamiliar Talker A	
ID	**Age** (years.months)	S2	S4	S2	S4
NH_K1	4.5		9	11	
NH_K2	5.4	7	12	8	17
NH_K3	4.5	4	7	5	10
AVERAGE Number		5.5	9.3	8.0	13.5
Average %		23%	39%	33%	56%

Table 3

Identifier HI-hearing impaired NH-normal hearing	Age (yr.mo.)	Device	Left	Right	Age fitted	Time w/ Dev.
Subject Group A						
HI1	4.92	CI-nucleus		CI	9 mo. Old	4 yr. 1mo.
HI2	4.08	CI-nucleus		CI	2 yrs. Old	2yr. 5mo.
HI3	3.67	Bone aid	bone	bone	2 yrs.1 mo.	3yr. 2mo.
NH1	4.83	NA	NA	NA	NA	NA
NH2	4.42	NA	NA	NA	NA	NA
NH3	5.25	NA	NA	NA	NA	NA
Subject Group B						
Nha	3.17	NA	NA	NA	NA	NA
NHb	5.25	NA	NA	NA	NA	NA
NHc	3	NA	NA	NA	NA	NA
NHd	5.58	NA	NA	NA	NA	NA
Nhe	6.08	NA	NA	NA	NA	NA
Subject Group C						
PM1	9.42	Hearing aid	HA	HA		
PM2	11.5	HA & CI-Clarion	HA	CI		
PM3	10.92	Bone aid	bone	bone		
PM4	6.42	Hearing aid	HA	HA		
PM5	12.58	Hearing aid	HA	HA		
PM6	8.08	CI-Clarion		CI		
PM7	6.58	Hearing aid	HA	HA		
PM8	10	CI-nucleus	CI	HA		

Table 4

Subject Group A

t-Test: Two-Sample Assuming Unequal Variances
Discrimination

	Fam	UF
Mean	83.5	84
Variance	285.5	223.6
Observations	6	6
Hypothesized Mean Difference	0	
df	10	
t Stat	-0.054	
P(T<=t) one-tail	0.479	
t Critical one-tail	1.812	
P(T<=t) two-tail	0.958	
t Critical two-tail	2.228	

t-Test: Two-Sample Assuming Unequal Variances
Identification

	Fam	UF
Mean	62.5	63.2
Variance	545.1	765
Observations	6	6
Hypothesized Mean Difference	0	
df	10	
t Stat	-0.045	
P(T<=t) one-tail	0.482	
t Critical one-tail	1.812	
P(T<=t) two-tail	0.965	
t Critical two-tail	2.228	

Table 5

Subject Group B

t-Test: Two-Sample Assuming Unequal Variances

Discrimination

	Talker 1	Talker 2
Mean	71.6	67.6
Variance	590.8	328.3
Observations	5	5
Hypothesized Mean Difference	0	
df	7	
t Stat	0.295	
P(T<=t) one-tail	0.388	
t Critical one-tail	1.895	
P(T<=t) two-tail	0.777	
t Critical two-tail	2.365	

t-Test: Two-Sample Assuming Unequal Variances

Identification

	Talker 1	Talker 2
Mean	46.8	46.8
Variance	358.2	189.7
Observations	5	5
Hypothesized Mean Difference	0	
df	7	
t Stat	0	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.895	
P(T<=t) two-tail	1	
t Critical two-tail	2.365	

Table 6

Subject Group C

t-Test: Two-Sample Assuming Unequal Variances

Discrimination

	Talker 1	Talker 2
Mean	73	55.8
Variance	684.6	374.5
Observations	8	8
Hypothesized Mean Difference	0	
df	13	
t Stat	1.499	
P(T<=t) one-tail	0.0789	
t Critical one-tail	1.771	
P(T<=t) two-tail	0.158	
t Critical two-tail	2.160	

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	55.1	55.8
Variance	686.7	374.5
Observations	8	8
Hypothesized Mean Difference	0	
df	13	
t Stat	-0.054	
P(T<=t) one-tail	0.479	
t Critical one-tail	1.771	
P(T<=t) two-tail	0.958	
t Critical two-tail	2.160	

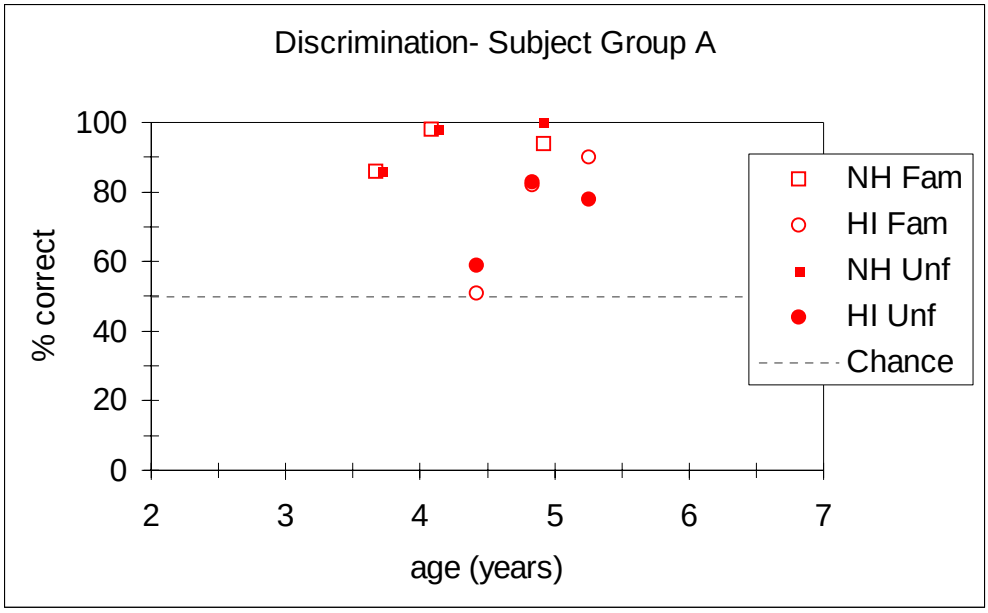
Discrimination- Subject Group A
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age (years)
NH Fam
HI Fam
NH Unf
HI Unf
Chance

Figure 1

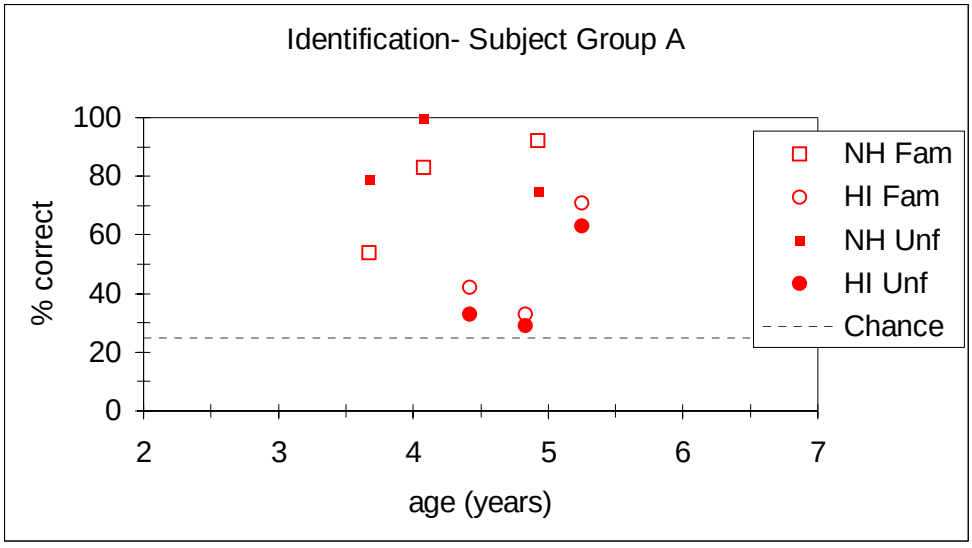
Identification- Subject Group A
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age (years)
NH Fam
HI Fam
NH Unf
HI Unf
Chance

Figure 2

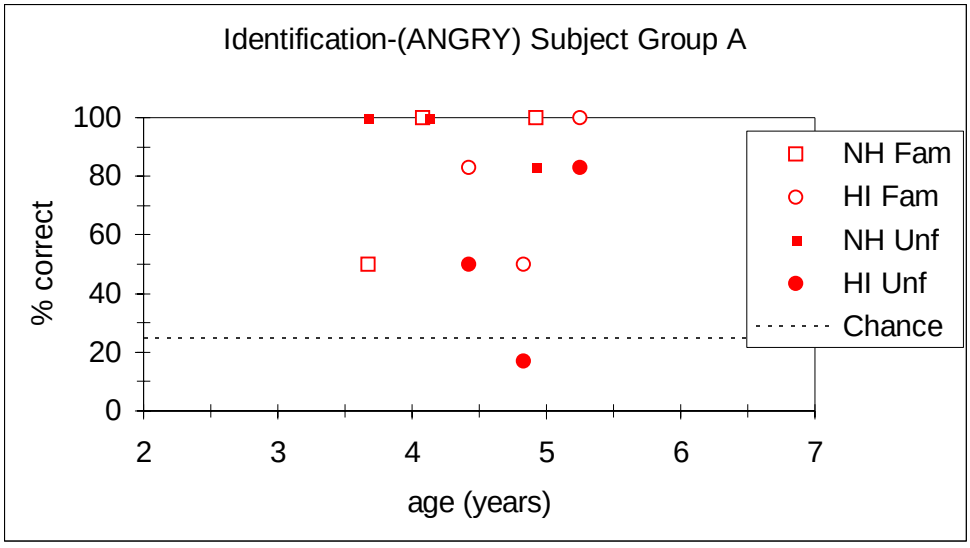
Identification-(ANGRY) Subject Group A
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age (years)
NH Fam
HI Fam
NH Unf
HI Unf
Chance

Figure 3

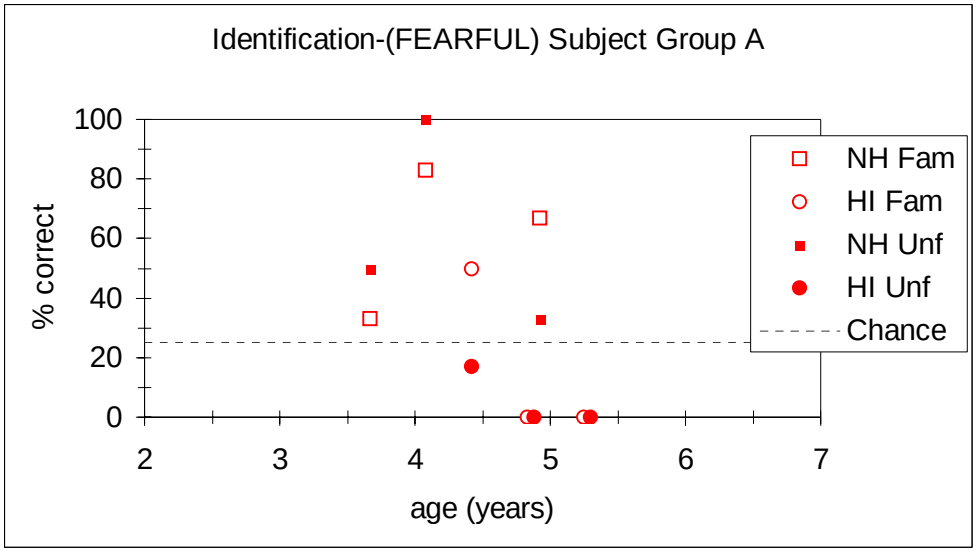
Identification-(FEARFUL) Subject Group A
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age (years)
NH Fam
HI Fam
NH Unf
HI Unf
Chance

Figure 4

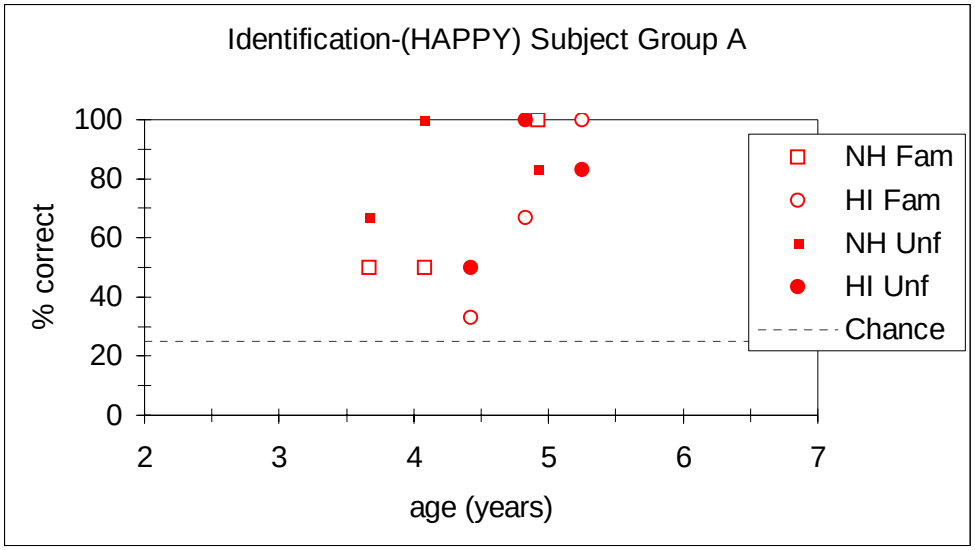
Identification-(HAPPY) Subject Group A
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age (years)
NH Fam
HI Fam
NH Unf
HI Unf
Chance

Figure 5

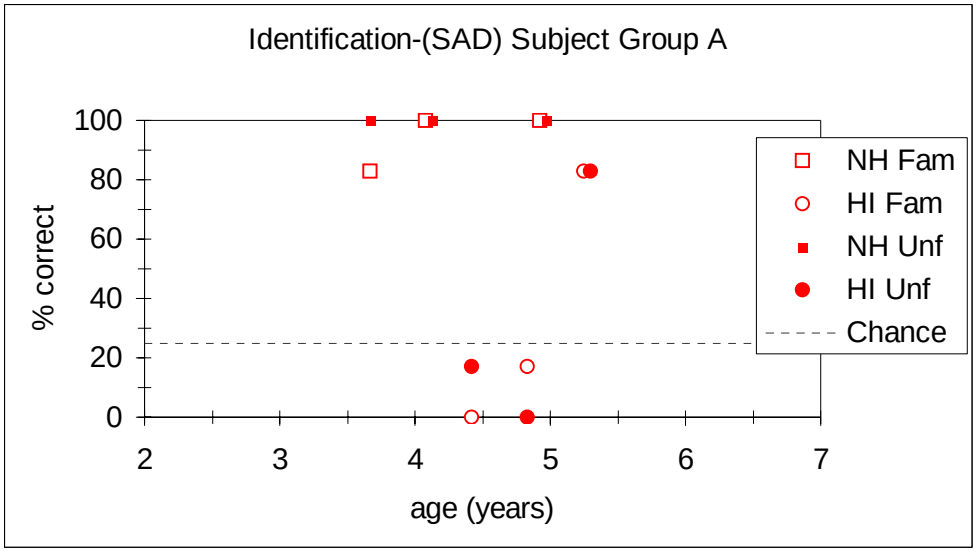
Identification-(SAD) Subject Group A
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age (years)
NH Fam
HI Fam
NH Unf
HI Unf
Chance

Figure 6

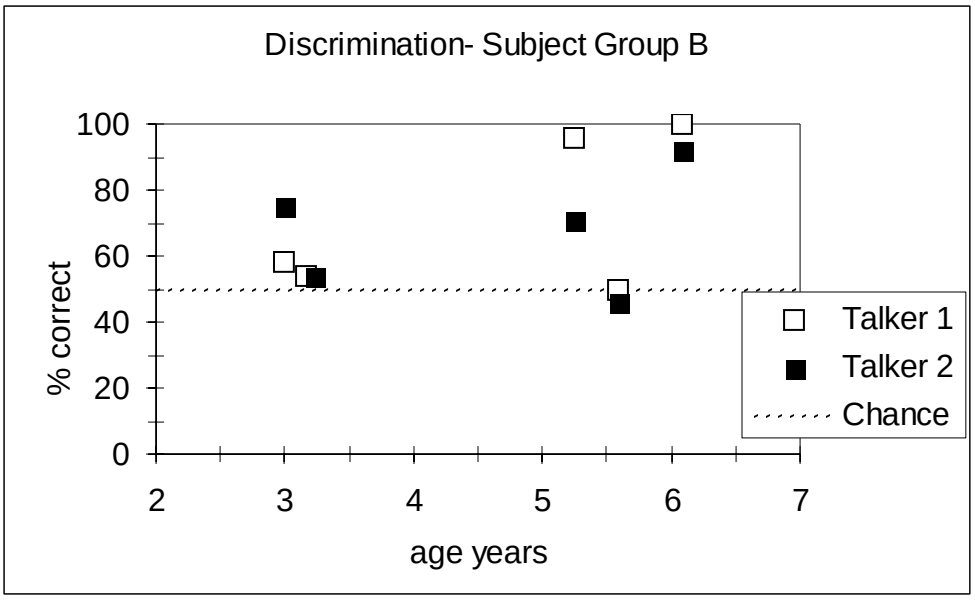
Discrimination- Subject Group B
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age years
Talker 1
Talker 2
Chance

Figure 7

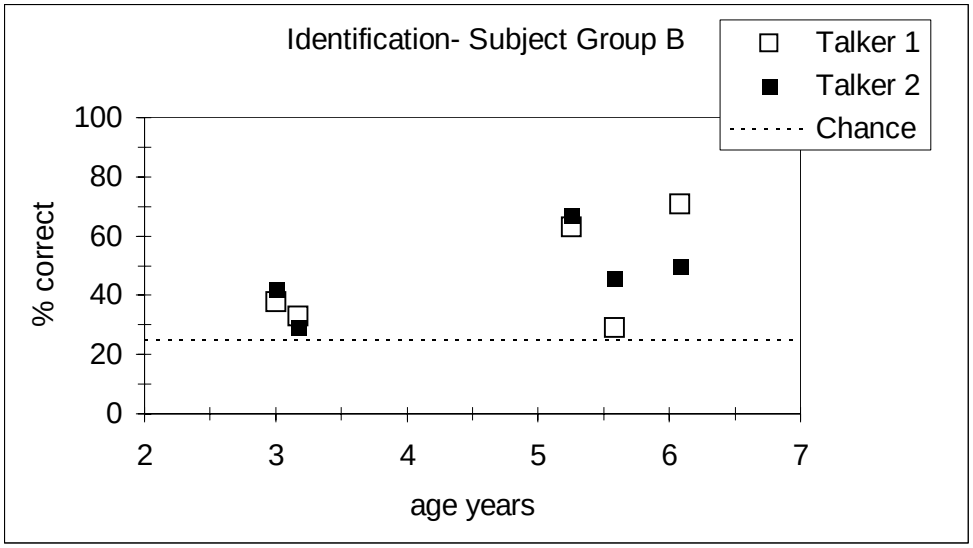
Identification- Subject Group B
Talker 1
Talker 2
Chance
100
80
60
40
20
0
% correct
2
3
4
5
6
7
age years

Figure 8

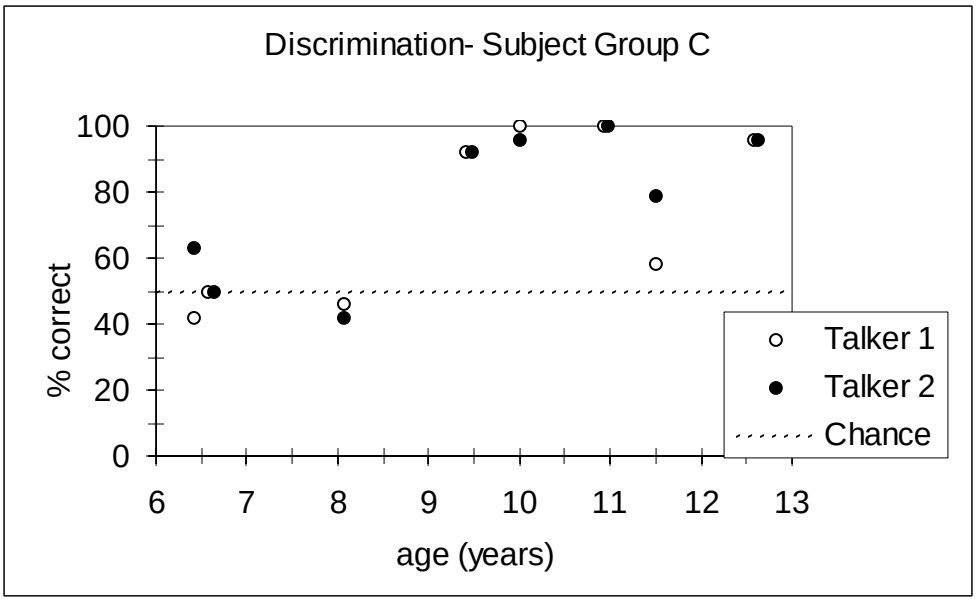
Discrimination- Subject Group C
100
80
60
40
20
0
% correct
6
7
8
9
10
11
12
13
age (years)
Talker 1
Talker 2
Chance

Figure 9

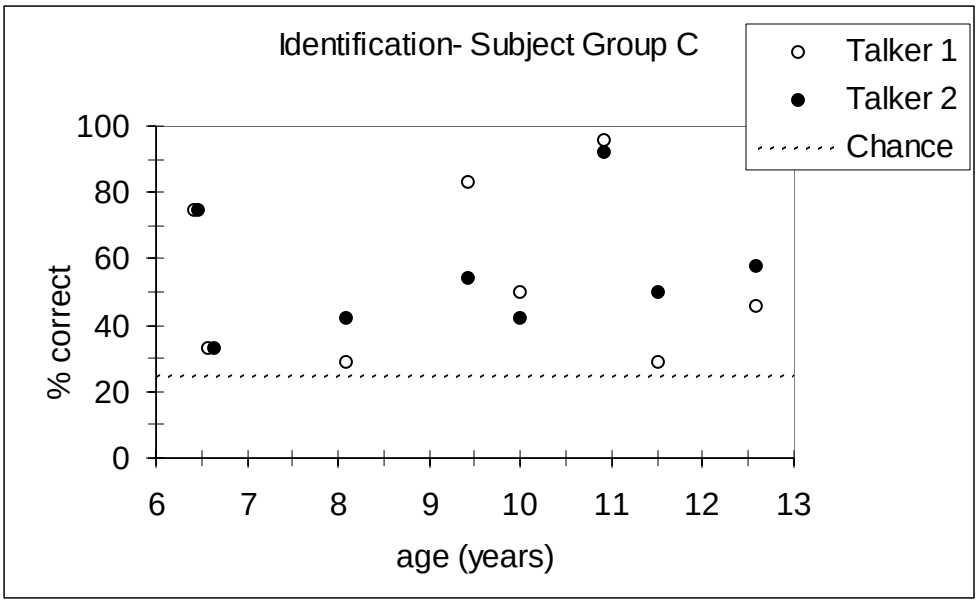
Identification- Subject Group C
Talker 1
Talker 2
Chance
% correct
100
80
60
40
20
0
6
7
8
9
10
11
12
13
age (years)

Figure 10