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## Recognition Of Speech In Multi-Talker Babble By Individuals With Hearing Loss

Kyle J. Christensen  
Fort Hays State University, kjchristensen@mail.fhsu.edu

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RECOGNITION OF SPEECH IN MULTI-TALKER  
BABBLE BY INDIVIDUALS WITH  
HEARING LOSS

being

A Thesis Presented to the Graduate Faculty  
of the Fort Hays State University in  
Partial Fulfillment of the Requirements for  
the Degree of Master of Science

by

Kyle J. Christensen

B.A., Metropolitan State College of Denver

Date \_\_\_\_\_

Approved \_\_\_\_\_  
Major Professor

Approved \_\_\_\_\_  
Chair, Graduate Council

## Abstract

The purpose of this study was to determine the speech recognition abilities of individuals with hearing loss using multi-talker babble as a competing stimulus. Twenty-six young adults participated, 15 in the normal hearing group (mean age of 21.9 years) and 11 in the hearing loss group (mean age of 22.2 years). The participants with normal hearing (0-20 dB HL) had a high frequency pure tone average (HFPTA) of 5 dB HL in both ears, while the participants in the hearing loss group had an HFPTA of 13 dB HL in the right ear and 25 dB HL in the left ear. There was a significant difference in the hearing level of the two groups. Each group listened to words from an audio file and then repeated the words back to the researchers. Four-person multi-talker babble background noise was presented at signal-to-noise ratios of +15 dB, +5 dB, 0 dB and -5 dB. The results demonstrated that participants with normal hearing and participants with hearing loss had decreased speech recognition scores as the multi-talker babble interfered more with the target words; however, data revealed no statistical difference between the hearing loss group and the normal hearing group. In general, the results suggest that less favorable signal-to-noise ratios will affect an individual's ability to recognize speech in noise, but mild hearing loss does not affect word recognition to any greater degree. A qualitative analysis of the types of error trends demonstrated that phoneme voicing does not contribute to speech recognition. However, the type of speech errors (e.g., substitutions, omission), the phonemes in error and the manner-of-articulation errors made by the participants increased as background noise interfered more.

**Key Words:** Signal-to-noise ratios, hearing loss, high-frequency hearing loss, background noise, multi-talker babble.

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## **Introduction**

Noise exposure continues to escalate in the United States with 30 million people exposed to excessive noise levels and at least 26 million incidences of individuals with noise-induced hearing loss (Daniel, 2007). American leisure time involves activities such as listening to music and playing musical instruments, riding motorcycles, shooting guns, taking aerobic classes, which can be excessively loud. It was previously believed that the work place was the main source of unsafe noise exposure; however, the workplace is no longer the main suspect of unsafe noise exposure. Another popular opinion about hearing loss is that it affects only older individuals; however, younger individuals are frequently exposed to excessive noise levels, which is especially significant since hearing is an important part of effective communication. Often hearing loss may be a mild loss in the younger age groups (McCormick & Matusitz, 2010).

Sensorineural hearing loss occurs when there is damage to either the outer hair cells of the cochlea or the eighth cranial nerve pathway, resulting in the bone conduction and the air conduction thresholds exhibiting similar hearing levels with the absence of damage to the conductive hearing mechanism (Martin & Clark, 2012). At any point in a person's life, a sensorineural hearing loss can develop from a disease, injury, ototoxic drugs, tumors, natural aging, or damaging levels of noise exposure. The loss of hearing affects not only the hearing level of an individual but also the ability for an individual to discriminate and understand speech. It has been well documented that sensorineural hearing loss does affect the understanding of spoken messages (Cooper & Cutts, 1971; Kenyon, Leidenheim & Zwillenberg, 1998). However, when the hearing loss is isolated

to only high frequencies (3000-6000 Hz), as with noise-induced hearing loss, these individuals often do not notice the loss, but may exhibit difficulty comprehending speech when there is background noise (Roup & Noe, 2009).

The outer hair-cell damage in the high frequencies of the cochlea is directly related to the hearing thresholds of the individual. Any high frequency hearing thresholds below 60 dB HL is an indication of complete loss of the outer hair cells (Amos & Humes, 2007). Therefore, hearing thresholds below 60 dB HL reveal markedly reduced speech recognition. The research has also supported the importance of high frequencies for recognizing speech in the presence of background noise. Amos found further support that younger individuals with normal hearing are able to recognize speech significantly better in quiet and in noise as compared to older individuals with any degree of hearing loss. Even mild hearing loss affects the individual's ability to use high frequencies to aid in speech recognition. It does not matter if the individual has mild or severe high-frequency hearing loss when recognizing speech. The findings of Amos are in agreement with Turner and Cummings (1999) who also discovered that amplification of high-frequency thresholds below 55 dB HL were ineffective and required significant amounts of gain, causing more problems than benefits. This continues to highlight the impact of high-frequency hearing loss.

### **Definition of Selected Terms**

For the purposes of this study, two key terms need to be defined to ensure consistent understanding between the study and its readers: The terms "noise-induced hearing loss" and "signal-to-noise ratio."

**Noise-induced hearing loss.** Noise exposure at 85 decibel sound pressure level (dB SPL) or greater for prolonged periods of time or in sudden bursts, called acoustic trauma, can cause noise-induced hearing loss by damaging the cochlea, resulting in an audiometric examination with a notch or V-shape drop in the high frequencies at the 3000-6000 Hertz (Hz) level (McCormick & Matusitz, 2010). The frequencies located within the 3000-6000 Hz hearing frequencies drop below the normal hearing threshold of 20 dB hearing level (HL) with improved hearing at 8000 Hz and frequencies below 3000 Hz usually stay in the normal hearing range of 20 dB HL or better (Martin & Clark, 2012). Because many speech sounds, for example /k/, /s/, /f/, and /th/ fall within 3000-6000 Hz, persons with high frequency hearing loss are disposed to speech reception difficulty which is magnified in the presence of background noise. For the purpose of this study, background noise will be defined as any level of noise that competes with speech during communication.

**Signal-to-noise ratio.** Contrary to its name, a signal-to-noise ratio (SNR) is not displayed as a ratio, but is in fact a comparable difference of intensity between the signal and the noise. The signal consists of the desired stimuli, which is often speech, and the noise, which is the undesirable stimuli (Martin & Clark, 2012). Signal-to-noise ratios are always present when people attempt to listen to desired stimuli. If the background noise increases in amplitude in relation to the desired stimuli, the signal-to-noise ratio is less favorable. In other words, the background noise makes it harder to hear the desired stimuli. However, if the noise decreases amplitude relative to the desired stimuli, the signal-to-noise ratio is more favorable (Tye-Murray, 2009), in that the desired stimuli are

easier to hear. For example, in the average classroom, it is recommended that the SNR remain at +15 for an ideal learning environment. Therefore, the classroom teacher's voice should remain 15 dB SPL above the background noise (Bistafa & Bradley, 2000). When a teacher's voice is 50 dB HL and the classroom noise is 35 dB HL, the SNR is +15 dB. However, in reality the average classroom is closer to a SNR of +3.5 dB (Larson & Blair, 2008).

### **Word Recognition in Background Noise**

The effects of noise upon an individual's ability to comprehend speech have been well studied by researchers (Cooper & Cutts, 1971; Kenyon, Leidenheim & Zwillenberg, 1998; Lewis, Lilly, Hutter, Bourdette, Saunders & Fausti, 2006; Pittman & Wiley, 2001). Pittman and Wiley investigated the speech production ability and speech recognition ability of typical listeners in quiet and in two types of noise. The study was in two phases; part one used five women between the ages of 19 and 28, with typical hearing thresholds, who participated as the talkers in the speech production portion of the study. Researchers used the Speech in Noise (SPIN) Test that contained sentences with an embedded target word that the individual must recognize. The carrier sentences did not include semantic or grammatical clues for the participant to use to determine the target word. The female talkers were recorded saying 50 low-predictability (LP) sentences in a sound-treated room with no competing stimulus and then the female talkers were recorded again in multi-talker babble and wide band noise (white noise) at 80 dB SPL. Each of the talkers mean intensity increased by 14.5 dB SPL in the presence of noise. Talkers also increased the length of the target words by 65 milliseconds (ms) in multi-talker babble while

increasing the slope of the spectral graph, which displays the amplitude for octaves of average male and female voices.

In part two of the study, twenty-seven women and three men between the ages of 18 and 30 years, all with normal hearing, participated as listeners. The participants were asked to listen to the 50 LP sentences produced by the talkers in a sound-treated room. The talkers were recorded in quiet and in multi-talker babble. The listeners were required to write the final word (or target word) of the presented LP sentences. The listener's word recognition scores were much higher in multi-talker babble than in quiet (69% higher). The researchers hypothesized that this was due to the large improvement of the signal-to-noise ratio because of the natural voice adjustments of the speaker in noise. Because the innate voice adjustments improved the signal-to-noise ratio, it cannot be said that typical hearing individuals recognize speech more proficiently in background noise.

Gordon-Salant and Fitzgibbons (1997) reported that memory is a contributing factor in understanding speech since it includes recalling information while cognitively comprehending the message. A prime example of memory affecting speech recognition is retaining one sentence in working memory while receiving the preceding sentence. Elderly individuals are most inhibited by the memory challenges of speech recognition due to declines in auditory processing (Burk & Humes, 2007). However, single word recall is unimpeded by age in quiet and noisy conditions. This is important since the current study is interested in speech recognition and not memory capabilities.

Background noise is often accompanied by various amounts of reverberation in the environment (the amount of echoing). Walls, floors, and ceilings have the greatest

effect on reverberation within the average room. Reverberation in a room causes adjacent speech sounds to be overlapped or distorted while the listener attempts to understand the message (Helfer and Wilber, 1999). It also affects speech by interrupting the temporal sequence necessary for comprehension. This means that parts of the spoken words overlap due to echo.

### **Listening in Background Noise of Atypical Populations**

Cooper and Cutts (1971) evaluated the ability of individuals with sensorineural hearing loss (SNHL) to comprehend speech in background noise. The participants included a group of 16 individuals with normal hearing at or better than 10 dB HL and a group with a sensorineural hearing loss greater than 20 dB HL. A stimulus of spondaic words, spoken by a male with a standard American accent, was administered in the presence of noise from a recording of a cafeteria during the lunch hour. The results of the study demonstrated that individuals with sensorineural hearing loss have varied abilities of speech discrimination in background noise with 24-28% reduction of discrimination at +8, +6, and +4 signal-to-noise ratios, respectively. While the variability between the individuals was unpredictable, all the participants with a sensorineural hearing loss had greater difficulty discriminating speech as opposed to the normal hearing group.

Similarly to Cooper and Cutts' (1971) observations about atypical listeners, Findlay (1976) investigated the ability of individuals with typical hearing and noise-induced hearing loss to recognize speech from the CID W-22 word list in a competing noise stimulus composed of multi-talkers and presented with a -4 dB SNR. In a later study which helps explain Findlay's results, Hygge, Ronnberg and Arlinger (1992)

reported that with the addition of more talkers in the competing background noise, there was an increased amount of masking because it creates a steady state of masking rather than variable masking. In the Findlay study, administration of audiological measures identified the participant's hearing status and speech recognition ability in quiet, prior to participating in experimental testing. Participants with noise-induced hearing loss obtained a speech recognition score of 91% while typical listeners received a score of 95% accuracy prior to listening in background noise. The results of the experimental test then demonstrated that the mean scores of the two test groups within multi-talker background noise were decreased in both groups. Speech recognition was impeded in typical listeners by 20% accuracy and is significantly more impeding on an individual with noise-induced hearing loss, with a 35% accuracy reduction in speech reception.

Kenyon, Leidenheim and Zwillenberg (1998) evaluated speech discrimination abilities, with and without noise, in individuals with sensorineural hearing loss (SNHL). Sixty-seven adults (66 male, 1 female) were tested for speech reception thresholds so they could amplify the sound to simulate normal hearing during the speech discrimination test. All of the participants were required to have speech reception thresholds of 25 dB HL or better, discrimination scores of 80% or better in quiet and at least a SNHL of 50 dB HL in both ears. The results of the study demonstrated that the individuals with SNHL had a 33.1% speech discrimination loss in the presence of background noise even when the stimulus was amplified to simulate normal hearing.

Research about individuals of atypical populations other than individuals with deviant hearing levels was conducted by Lewis et al. (2006), who examined speech in the



presence of background noise and the speech perception abilities of individuals with and without multiple sclerosis (MS), in order to find a correlation between auditory processing deficits and MS. Multiple sclerosis affects the central nervous system and could result in auditory processing difficulties since auditory processing is a disorder of the central nervous system. A group of twenty-three participants diagnosed with multiple sclerosis were compared against a control group of thirty participants (15 males, 15 females), matched by age, gender, pure-tone averages and a mean age of 51 years. Besides MS, the participants could not have a diagnosis of any other disease or disorder, especially neurological disorders. Using the Sentence Intelligibility Test, the stimulus was presented at 65 dB SPL to the participants through loudspeakers in the acoustically-treated room while multi-talker babble was used as background noise at 55 dB SPL. The background noise was raised in 1 dB increments until the subject received a score of zero on the test. The results of each background noise interval were collected for analysis. In addition, each participant then completed a questionnaire concerning personal auditory symptoms and was asked to report any hearing difficulties. Hearing difficulties were reported for 33% of the control group while 70% of the test group reported having hearing difficulties despite having normal hearing. The results of the study demonstrated that the test group performed significantly poorer than the control group at all intervals of background noise. This is consistent with the subjects with MS reporting more cases of hearing difficulty. The researchers hypothesized that multiple sclerosis had a significant effect on auditory processing in multi-talker background noise.

All of the summarized research provides a well-rounded description of the detrimental effects of background noise on typical and atypical individuals. In the presence of background noise, hearing recognition is abated in typical individuals but is even more reduced in individuals with deviant hearing and certain neurological processing disorders.

### **Purpose**

The purpose of this study was to investigate the speech recognition abilities of individuals with hearing loss, using multi-talker babble as a competing stimulus. It was hypothesized that individuals with hearing loss, when presented a speech stimulus in the existence of background noise will perform with a reduced ability on a word discrimination test because of the attenuated high frequency sounds.

### **Justification**

The current study will add to the research concerning hearing loss and its effects on speech when the listener is in the presence of background noise. Further, it will gather data concerning what signal-to-noise level background noise most disrupts effective communication. Consonant phoneme frequencies which lie within a person's hearing loss are usually difficult to recognize in speech, but person's with hearing loss may not display significant difficulty recognizing speech. However, during certain situations of daily life and on numerous social occasions, background noise might further tax an individual's already-diminished hearing system to an extent of markedly reduced speech understanding. The negative effects of background noise on speech recognition is pertinent information for professionals working with clients, especially if the client has

atypical hearing. A qualitative analysis will provide the type of errors the participants make and how it will affect their speech recognition. The current study provides a range of observations about the effects of background noise on high frequency hearing loss when verbally communicating.

## **Methodology**

The purpose of this study was to determine the speech recognition abilities of individuals with hearing loss using multi-talker babble as a competing stimulus. An experimental design was implemented to obtain the results of this study. The dependent variable being observed was word recognition scores (WRS) from phonetically balanced word lists while the independent variables were: (1) the signal-to-noise ratios of the competing stimulus and (2) the status of the participant's hearing being typical or exhibiting hearing loss.

### **Research Approval**

To ensure the ethical treatment of all participants in the study, an Institutional Review Board (IRB) application (Appendix A) was submitted to the Human Subjects Review Committee in the Department of Communication Disorders. Following departmental approval, the IRB application was sent to the Fort Hays State University IRB. After Fort Hays State University IRB approved the study (Appendix B), participants were asked to read and sign an informed consent form (Appendix C) prior to participation in the study.

### **Participants**

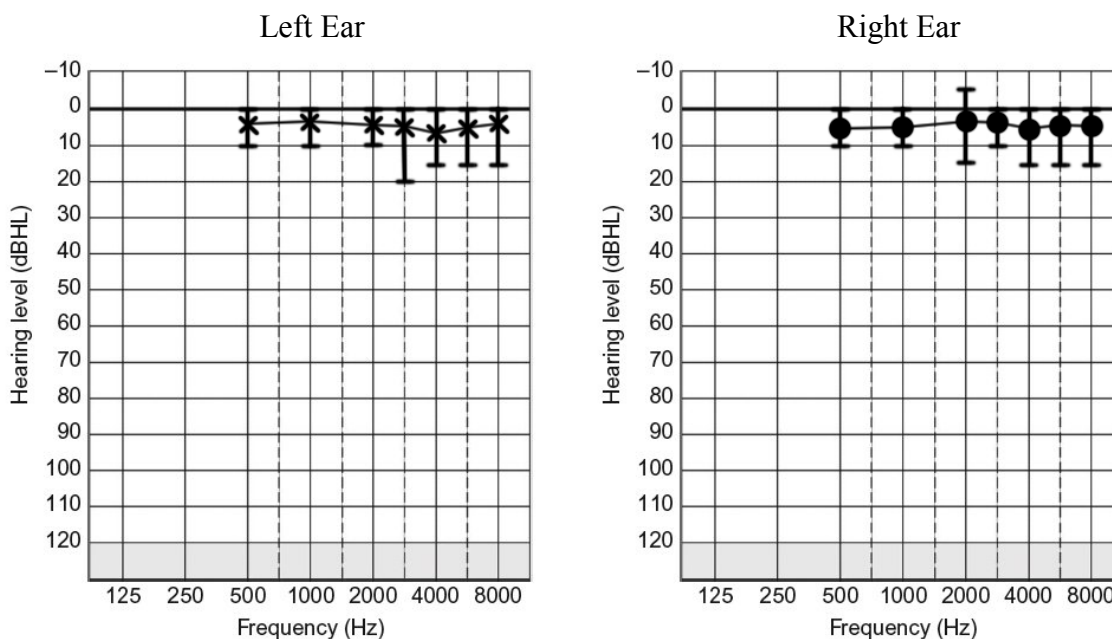
Recruitment of participants was accomplished by announcing the participation opportunity to students in several Fort Hays State University classrooms. All participants had to meet the following selection criteria: (1) be between the ages of 18 and 30, (2) do not currently wear hearing aids, (3) speak English as their primary language. Participants received a threshold screening to assess their hearing, tympanometry to evaluate middle ear function, otoacoustic emissions to determine cochlear function, and otoscopy to

visually inspect the outer ear. Based on these results, participants were placed in one of two groups, normal hearing (NH) or hearing loss (HL).

**Normal hearing group.** This group included 15 participants (5 males, 10 females) with a mean age of 21.9 years. To be assigned to this group, the participants had to have hearing within normal limits. Normal hearing for an adult is displayed on an audiogram as 20 dB HL or below. Figure 1 illustrates the average hearing levels for the normal hearing group. The high frequency pure tone average (HFPTA) for the group was 5 dB HL for both the right and left ears. The participants displayed normal functioning results for tympanometry and otoacoustic emissions screening assessments, thus further confirming normal hearing.

Figure 1.

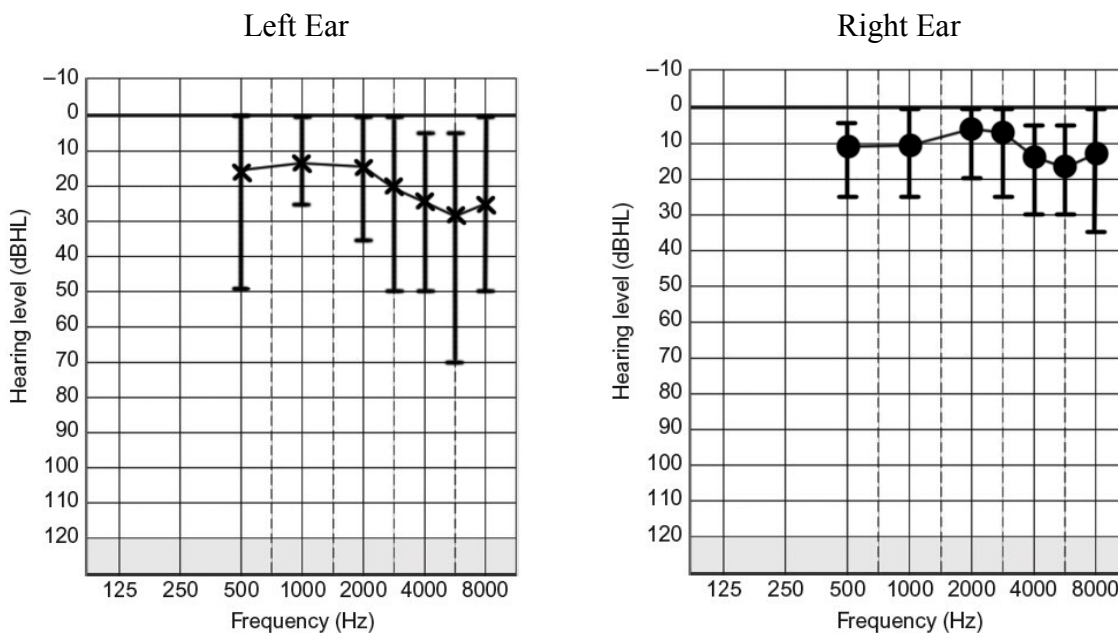
Audiogram of Average Hearing Threshold for NH Group



**Hearing loss group.** This group included 11 participants (8 males, 3 females) with a mean age of 22.2 years. To be assigned to this group, the participants had to demonstrate a hearing loss which is displayed on an audiogram of 20 dB HL or above. Figure 2 shows the average hearing levels for the hearing loss group in the right and left ear. The audiological testing determined the group’s high frequency pure tone average (HFPTA) to be 13 dB HL for the right and 25 dB HL for the left ear. The participants had normal functioning on the tympanometry screening and abnormal functioning on the otoacoustic emissions screening, confirming the presence of a hearing loss.

*Figure 2*

Audiogram of Average Hearing Threshold for HL Group



The hearing status of the two groups was analyzed to determine whether the pure tone averages were significantly different. Statistics showed a significant difference in the

hearing of each group. This would confirm that participants were assigned to the appropriate group. These findings are also reported in the results section.

### **Equipment and Procedure for Determining Auditory Function**

Several pieces of equipment were utilized for the collection of data and routine hearing evaluations and screenings. An otoscope was used to visually inspect the participant's external ear canal, prior to any collection of data. All equipment was current in electroacoustic calibration and met or exceeded standards of the American National Standards Institute.

**Hearing.** The stimuli for pure tone audiometry and speech audiometry were delivered through the Grason-Stadler GSI-61 clinical audiometer. Prior to each data collection session, a daily listening check was completed. Each participant entered the Tracoustic Acoustical Enclosure, where the hearing screening protocol was administered, to obtain a threshold screening of the participant's hearing at the frequencies 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz.

**Middle ear function.** All participants completed a tympanometry test to determine their middle ear function. The stimulus for testing the middle ear function was provided through a Grason-Stadler Tympanometer (GSI-38).

**Cochlear function.** Cochlear function was determined using otoacoustic emissions (OAE). This test was administered through the Biologic Audio Scout OAE instrument. Otoacoustic emissions tests were delivered with a 2000-6000 Hz screening protocol and a four-of-five pass criterion.

## **Materials**

Central Institute for the Deaf (CID) W-22 word lists and phonetically-balanced word lists containing 50 monosyllabic words were used utilized the word recognition assessments (Appendix D). These word lists are routinely used during standard audiological assessments and no alterations were made that could affect the word lists and their phonetic balance. “Phonetically-balanced” word lists refer to words in which the distribution of phonemes is consistent with the frequency of occurrence in typical speech. All word lists were professional audio recordings for increased inter-participant reliability. The competing noise stimulus was a professional audio recording produced by Auditec, which consisted of four-person multi-talker babble.

## **Procedures for Determining Word Recognition Scores**

Following the assessment of auditory function, the research protocol began with a visual inspection of the participant’s ears. Once completed, word recognition scores were obtained using phonetically balanced word lists from the CID W-22 word lists. The word recognition scores were determined at four different signal-to-noise ratios (SNR). The SNR was a comparison of the intensity between the intended talker and the multi-talker babble. The specified SNRs for this study were the following: +15 dB, +5 dB, 0 dB, and -5 dB (e.g., +15 dB indicates that the intensity of the intended talker is 15 dB above the intensity level of the multi-talker babble). A baseline score was acquired at +15 dB, which served as the quiet condition. The word recognition scores were procured from eight separate word lists counterbalanced to control for order effects (i.e., one for each listening condition). The CID W-22 word lists were presented to the participants at



50 dB HL because 50 dB HL is equivalent to 65 dB SPL. The average intensity for speech is 65 dB SPL (Boone et al, 2010). The multi-talker babble background noise was adjusted to create the various SNRs. The results of all testing procedures were recorded on a data collection sheet (Appendix E).

### **Data Analysis**

Descriptive statistics and inferential statistics were used to analyze the data collected from this study. In addition, reliability was established by having a research assistant verify the scoring on the word recognition tests and the accurate transfer of data into the data analysis program. Upon completion of the word recognition testing, a research assistant established 100% reliability for scoring and data transfer. A qualitative analysis of the data demonstrated the types of errors the participants made and the effect it had on understanding speech.

## Results

The purpose of this study was to determine the speech recognition abilities of individuals using multi-talker babble as a competing stimulus. Prior to data analysis, statistics were calculated to demonstrate that the two groups exhibited significant differences in their ability to hear pure tone signals. These results are displayed in Table 1, which clearly shows differences in the hearing between the two groups, with the hearing loss group having significantly poorer hearing.

Table 1

*Analysis of Average Hearing Threshold for the Normal Hearing (NH) Group and the Hearing Loss (HL) Group: Using HFPTA (N=26)*

Group	Right Ear			Left Ear		
	Mean HFPTA	SD	t	Mean HFPTA	SD	t
NH	5 dB HL	1.16	4.22***	5 dB HL	1.85	7.29***
HL	25 dB HL	2.37		13 dB HL	4.08	

\*\*\*p<.001

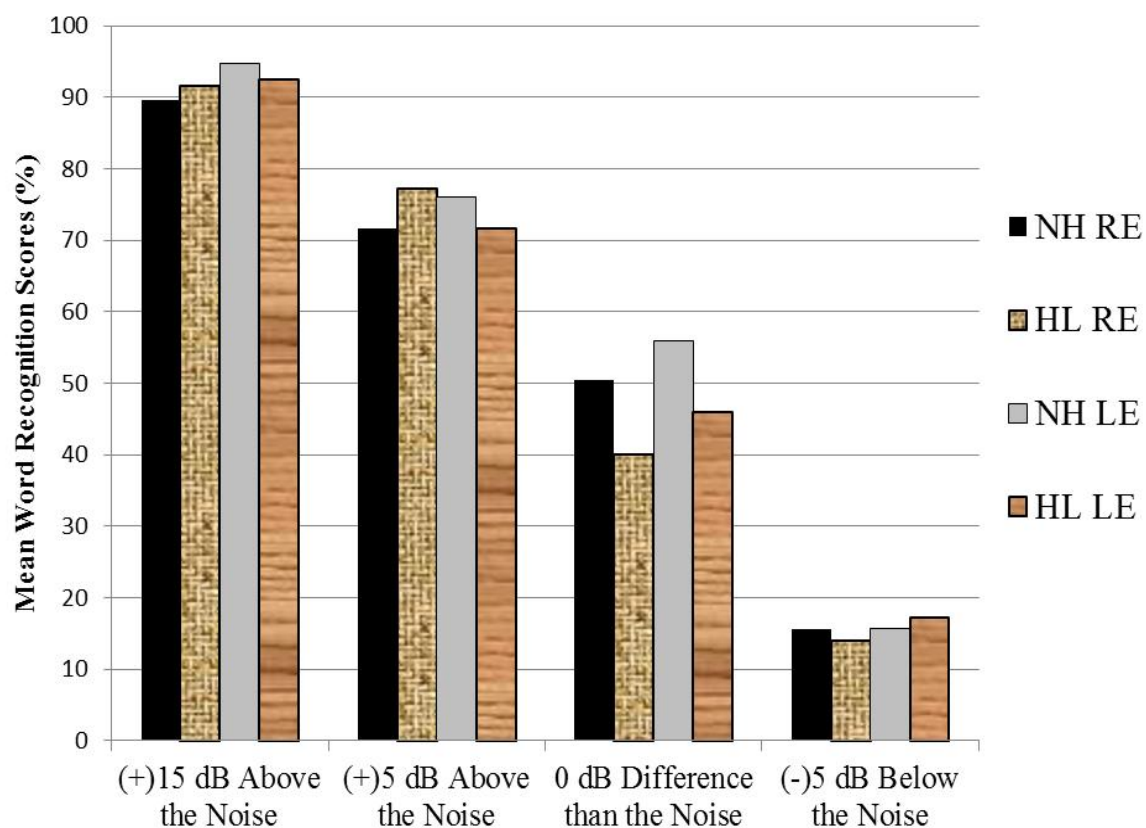
### Effects of Signal-to-Noise Ratio on Word Recognition Scores

Comparisons were made within groups using paired samples t-tests to determine whether less favorable signal-to-noise ratios (SNR) significantly impacted word recognition scores. Both groups were shown to perform significantly worse at all SNR (+5 dB, 0 dB, and -5 dB) when compared to the quiet condition of +15 dB. Then, an appraisal of significance was calculated between each adjacent SNR within the groups to determine any statistically significant reduction in word recognition scores. A paired samples t-test was utilized in order to assess significance.

Figure 3 depicts the reduction in word recognition scores of both groups as the SNR becomes less favorable. The word recognition scores are displayed as a percent, indicating the group accuracy with regard to the word lists. The left and right ear are represented separately for both groups, demonstrating slight variations; however, the trend in score reduction is consistent for both ears. There was no significant difference between the two groups.

*Figure 3*

Average WRS at Different SNR for Normal Hearing (NH) and Hearing Loss (HL) Groups (N= 26)



**Normal hearing group.** The effect of the SNR within the normal hearing group reveals a significant decrease in the right and left ears. Table 2 displays the significant change in word recognition scores as the SNR became less favorable in regards to the quiet condition. Word recognition score significantly decreased in the right ear at +5 dB by 16%,  $t(14)= 4.56, p < .000$ , 0 dB by 36%,  $t(14)= 8.70, p < .000$  and -5 dB by 72%,  $t(14)= 14.88, p < .000$ . The left ear significantly decreased at +5 dB by 20%  $t(14)= 5.70, p < .000$ , 0 dB by 40%  $t(14)= 11.97, p < .000$ , and -5 dB by 80%  $t(14)= 16.29, p < .000$ .

Table 2

*Summary of Statistical Analysis of Word Recognition Scores of Only the Normal Hearing Group When Each SNR is Compared to the Quiet Condition (N=15)*

<u>SNR</u>	<u>Right Ear</u>			<u>Left Ear</u>		
	<u>M</u>	<u>SD</u>	<u>t</u>	<u>M</u>	<u>SD</u>	<u>t</u>
+15 dB	22.40	1.16	4.56**	23.73	1.16	5.70**
+5 dB	17.93	3.39		19.00	2.83	
+15 dB	22.40	1.16	8.70**	23.73	1.16	11.97**
0 dB	12.60	3.76		14.00	2.95	
+15 dB	22.40	1.16	14.88**	23.73	1.16	16.29**
-5 dB	3.87	4.55		3.93	4.62	

\*\* $p < .001$

When analyzing whether there is a significant decrease in word recognition scores between any two adjacent SNR, a paired samples t-test revealed a significant reduction among all SNR. Table 3 represents the change in word recognition scores between each adjacent SNR. In the right ear the significant decrease at +15 dB to +5 dB by 16%,  $t(14)= 4.56, p < .000$ , then +5 dB to 0 dB by 21.4%,  $t(14)= 4.80, p < .000$ , and 0 dB to

-5 dB by 34.9%,  $t(14)= 6.96, p < .000$ . Within the left ear, there was a significant reduction at +15 dB to +5 dB by 20%  $t(14)= 5.70, p < .000$ , then +5 dB to 0 dB by 20%,  $t(14)= 5.62, p < .000$ , and 0 dB to -5 dB by 40.3%,  $t(14)= 13.61, p < .000$ . The most significant deterioration in word recognition scores occurred at the -5 dB, signal-to-noise ratio.

Table 3

*Summary of Statistical Analysis of Word Recognition Scores within the Normal Hearing Group Comparing Adjacent SNR (N=15)*

<u>SNR</u>	<u>Right Ear</u>			<u>Left Ear</u>		
	<u>M</u>	<u>SD</u>	<u>t</u>	<u>M</u>	<u>SD</u>	<u>t</u>
+15 dB	22.40	1.16	4.56**	23.73	1.16	5.70**
+5 dB	17.93	3.39		19.00	2.83	
+5 dB	17.93	3.39	4.80**	19.00	2.83	5.62**
0 dB	12.60	3.76		14.00	2.95	
0 dB	12.60	3.76	6.96**	14.00	2.95	13.61**
-5 dB	3.87	4.55		3.93	4.62	

\*\* $p < .001$

**Hearing loss group.** Similar to the normal hearing group, the hearing loss group exhibited significant decreases at each SNR when compared to a quiet condition. Table 4 demonstrates the effect SNR had on the word recognition scores of the hearing loss group as compared to the quiet condition. The significant reduction occurred in the right ear at +5 SNR by 16%,  $t(9)= 4.22, p < .002$ , 0 SNR by 52%  $t(9)= 9.58, p < .000$ , and -5 SNR by 80%  $t(9)= 14.42, p < .000$ , and then in the left ear at +5 SNR by 20%  $t(9)= 4.50, p < .001$ , 0 SNR by 44%  $t(9)= 7.76, p < .000$ , and -5 SNR by 76%  $t(9)= 11.8, p < .000$ .

Table 4

*Summary of Statistical Analysis of Word Recognition Scores of Only the Hearing Loss Group When Each SNR is Compared to the Quiet Condition (N=11)*

<u>SNR</u>	<u>Right Ear</u>			<u>Left Ear</u>		
	<u>M</u>	<u>SD</u>	<u>t</u>	<u>M</u>	<u>SD</u>	<u>t</u>
+15 dB	22.90	1.16	4.22*	23.10	1.85	4.47**
+5 dB	19.50	2.37		18.20	4.08	
+15 dB	22.90	1.16	9.58**	23.10	1.85	7.76**
0 dB	10.20	4.44		11.70	4.47	
+15 dB	22.90	1.16	14.42**	23.10	1.85	11.81**
-5 dB	3.30	4.67		4.80	5.35	

\*  $p < .05$ , \*\* $p < .001$

In the hearing impaired group, there was a significant decrease between every adjacent SNR. A paired samples t-test revealed a significant reduction in the right ear at +15 dB to +5 dB by 16%,  $t(10) = 4.22$ ,  $p < .002$ , then +5 dB to 0 dB by 38%,  $t(10) = 8.53$ ,  $p < .000$ , and 0 dB to -5 dB by 13.8%,  $t(10) = 90.12$ ,  $p < .000$ . Within the left ear, there was a significant reduction at +15 dB to +5 dB by 19.6%  $t(10) = 4.47$ ,  $p < .000$ , then +5 dB to 0 dB by 26.6%,  $t(10) = 4.64$ ,  $p < .000$ , and 0 dB to -5 dB by 28.8%,  $t(10) = 6.24$ ,  $p < .000$ . For the left and right ears, the most significant reduction of word recognition scores occurred at -5 dB, which was the least favorable listening condition in the study. The word recognition scores do not reflect any significant difference between the left and right ears within the groups.

Table 5

*Summary of Statistical Analysis of Word Recognition Scores within the Hearing Loss Group Comparing Adjacent SNR (N=11)*

<u>SNR</u>	<u>Right Ear</u>			<u>Left Ear</u>		
	<u>M</u>	<u>SD</u>	<u>t</u>	<u>M</u>	<u>SD</u>	<u>T</u>
+15 dB	22.90	1.16	4.22*	23.10	1.85	4.47**
+5 dB	19.50	2.37		18.20	4.08	
+5 dB	19.50	2.37	8.53**	18.20	4.08	4.64**
0 dB	10.00	4.27		11.55	4.27	
0 dB	10.00	4.27	9.12**	11.55	4.27	6.24**
-5 dB	3.45	4.46		4.36	5.28	

\*\*p<.001

### **Word Recognition Scores Between Groups**

In order to determine if there was any statistical significance between the two groups, independent samples t-tests were conducted at each SNR increment. The outcomes, indicated by the independent samples t-tests, revealed no statistical differences between the normal hearing and hearing loss groups, which was confirmed by the one way ANOVA analysis. Table 6 displays the results of the independent samples t-tests at each SNR and as can be seen no significant difference between the two groups. For the left ear, the most amount of change between groups occurred at 0 dB at  $t(24)= 1.74$ ,  $p < .096$ , while the least amount of change was at -5 dB,  $t(24)= -.22$ ,  $p < .827$ . In the right ear, the greatest amount of difference between groups developed at 0 dB,  $t(24)= 1.65$ ,  $p < .113$ , and the least change was obtained at -5 dB,  $t(24)= .23$ ,  $p < .820$ .

Table 6

*Summary of Statistics: Analysis of Word Recognition Scores Between the Normal Hearing and Hearing Loss groups at Each SNR (N=26)*

<u>SNR</u>	<u>Group</u>	<u>Right Ear</u>			<u>Left Ear</u>		
		<u>M</u>	<u>SD</u>	<u>t</u>	<u>M</u>	<u>SD</u>	<u>t</u>
+15 dB	NH	22.40	1.84	.73	23.73	1.16	1.05
	HL	22.90	1.37		23.10	1.85	
+5 dB	NH	17.93	3.39	1.21	19.00	2.83	.818
	HL	19.36	2.29		17.91	3.97	
0 dB	NH	12.60	3.76	1.65	14.00	2.95	1.74
	HL	10.00	4.27		11.55	4.27	
-5 dB	NH	3.87	4.55	.23	3.93	4.62	.22
	HL	3.45	4.46		4.36	5.28	

### **Qualitative Analysis of Speech Sound Errors**

The qualitative analysis was completed in order to explore beyond the established knowledge that an error occurred and reveal trends in the type of errors committed.

Table 7 shows the types of errors the participants made. The only characteristic void of any trends was voicing in that there was no difference in whether the phoneme was voiced or voiceless. For example, the phoneme “b” and “p” are only differentiated by activation of the voice for “b.” The types of errors produced were consistent between groups at each signal-to-noise ratio. At +15 dB and +5 dB, both groups produced phoneme substitution errors (e.g., “bun” became “fun”). Then at 0 dB both groups exhibited substitution and omission (e.g., “deer” becomes “ear”) phoneme errors. The



most types of errors were generated at -5 dB, which included phoneme substitutions, omissions, and additions (e.g., “tar” became “star”) at similar frequency.

The errors in manner-of-articulation yielded findings that were similar in trend between groups yet contained several variations at less favorable SNR. At +5 dB both groups generated fricative (e.g., the, thin, hat) and stop phoneme errors. Fricative phonemes are produced in the speech by a stricture of the airway, yet void of complete occlusion of the airway (e.g., “s” phoneme). Stop phonemes are produced in speech by briefly occluding the airway and rapidly releasing the air pressure (e.g., “k” phoneme). For 0 dB, the errors were similar to +5 dB; however, the normal hearing group also produced liquid phoneme errors (i.e., phonemes “l” and “r”). Liquid phonemes are generated in speech by elevating the tip of the tongue in the oral cavity and allowing air flow to escape around the lateral sides of the tongue. The hearing loss group did not use liquid errors, but instead, produced nasal phoneme errors (e.g., phonemes “m,” and “n”).

During the -5 dB testing, both groups produced all aforementioned manner-of-articulation errors with the inclusion of glide phoneme errors (i.e., phonemes “y” and “w”). Glide phonemes are produced in speech by a stricture in the oral cavity followed by a swift movement to a relatively open oral cavity. Table 7 displays the error trends from the qualitative analysis for both groups at each SNR with a comprised list of the most frequent phonemes in error. The most significant phoneme difference between the groups occurred a +15 dB with “h” in the HL group and not in the NH group.

Table 7

Analysis of the Error Trends Among the Normal Hearing (NH) Group and Hearing Loss (HL) Groups at Each Signal-to-Noise Ratios (SNR)

Characteristics	NH Group				HL Group			
	+15 SNR	+5 SNR	0 SNR	-5 SNR	+15 SNR	+5 SNR	0 SNR	-5 SNR
Type of Error	Substitutions	Substitutions	Substitutions Omissions	Substitutions Omissions Additions	Substitutions	Substitutions	Substitutions Omissions	Substitutions Omissions Additions
Errors in Manner of Articulation	Fricatives	Fricatives Stops	Fricatives Stops Liquids	Fricatives Stops Liquids Glides Nasals	Fricatives	Fricatives Stops	Fricatives Stops Nasals	Fricatives Stops Liquids Glides Nasals
Most Frequent Phonemes in Error	/ð, θ /	/h, d, t/	/d, t, ð, v, l, θ/	/n, ð, h, t, d, j, r, θ /	/h/	/d, h, v, t/	/n, h, f, d, t, z, θ /	/w, j, t, ð, m, v, l, z, r, θ /
Voicing Errors	No Trends	No Trends	No Trends	No Trends	No Trends	No Trends	No Trends	No Trends



## **Discussion and Conclusions**

The primary goal of this study was to examine the possible interactions between individuals with hearing loss and their ability to recognize speech in the presence of a multi-talker competing stimulus. Participants were asked to identify words from a phonetically-balanced list while listening to a competing background stimulus at various signal-to-noise ratios (SNR).

### **Signal-to-Noise Ratio**

The results of the study demonstrate that young adults with normal hearing and young adults with mild hearing loss have a reduced ability to recognize words in multi-talker background noise as the signal-to-noise ratio becomes less favorable. When the SNR was at +15 dB, the speech recognition scores were within normal limits and no difference between the two groups. In contrast, when the SNR became less favorable at +5 dB, 0 dB and -5 dB, the speech recognition scores diminished significantly. This suggests that individuals with normal hearing and those with hearing loss need a SNR of +15 dB or more favorable to adequately comprehend speech.

It is plausible that individuals listening to speech in multi-talker background noise can successfully understand speech when communication context is added to the situation. Knowing the topic of the conversation and having a view of the speaker's face are two ways to improve speech understanding with context. It is unlikely that individuals will be able to overcome the significant reduction of speech recognition at 0 dB and -5 dB even with context.

## **Word Recognition Scores**

The current study concurs with Cooper and Cutts (1971) that individuals with a hearing loss have reduced abilities to recognize speech in the presence of a competing stimulus. Even though the signal-to-noise ratios are not parallel between the two studies, there is an obvious relationship between less favorable SNR and the resulting diminished scores. Another similar trend among the studies is the score reduction between the interval SNR levels consisting of relatively equal amounts in listeners or, in other words, the speech recognition scores decrease at a consistent amount between equal SNR intervals.

In direct contrast with the current study, Pittman and Wiley (2001) found that individuals with normal hearing levels comprehend language better in the presence of a competing stimulus at less favorable SNRs. Conclusions are related to the speaker's ability to use innate compensatory strategies, such as elevating the voice and elongating word production to improve the SNR. Therefore, these findings cannot be directly related to the finding in the current study concerning SNR levels because the speakers in their study were able to innately increase the SNR to a more favorable status. That is, the current study upheld the integrity of the SNR by controlling for innate changes in human speech within background noise.

In answering the purpose of the study, the results showed no statistically significant difference between the normal hearing group and the hearing loss group. Therefore, it cannot be concluded that young adults with a mild hearing loss perform at a reduced ability in recognizing speech in multi-talker background noise. The results

appear counterintuitive with previous research, although there are several possible explanations for the findings.

One plausible reason for the results is the slight-to-mild hearing loss in the hearing loss group. There was a statistically significant difference in the hearing status between the two groups, but a slight-to-mild hearing loss may not be interfering enough with speech recognition to induce a significant reduction in scores. Another consideration is the young age of the participants in the hearing loss group. They could have the ability to overcome the slight-to-mild hearing loss with proficient auditory processing skills. This may not be the case in middle age and older adults.

Lastly, a potential explanation is that the study sample was not large enough to demonstrate statistically significant data. There was a trending development between the normal hearing group and hearing loss group at 0 dB and -5 dB. The normal hearing individuals had higher word recognition scores, which may have been statistically significant with an increased sample size in the hearing loss group.

A potential implication of the results is that individuals with a mild hearing loss are not significantly affected by the hearing loss and therefore unaware of their hearing loss. The people might not take precautions to protect their residual hearing from further loss, which would negatively impact their speech recognition. Impaired speech recognition scores can practically affect a person's life by hindering their ability to communicate at work, school, or socially.

### **Strengths and Limitations**

Strengths of this study involve many aspects with one being the significant amount of environmental control which intensifies the validity of the results. Also the

study was conducted with well established objective measurements from standard audiological assessments, further increasing the validity and reliability. All assessment procedures were counterbalanced to ensure no fatigue factors or learning factors contributed to the results. Another strength of the study was that the number of participants in the study allows it to be classified as a group study. That being the case, more confidence can be placed on the implications of the results. An important aspect of the study was age criterion being limited to young adults since less research has been conducted on hearing loss for this age group.

Another area of strength involves the control for several internal validity threats. Among those would be testing and history. The participants had not received extensive auditory tests in the past, thus controlling for history of the individual. Another internal validity threat controlled for was the instrumentation. All equipment was calibrated and in excellent working order and list materials were controlled for by using recorded stimuli.

Limitations of the study began with unavailability of individuals with greater hearing loss, leading to the hearing loss group having a slight-to-mild hearing loss. It can be hypothesized that more significant hearing loss would indeed demonstrate greater reduction in word recognition scores. The research conducted by Kenyon, Leidenheim and Zwillenberg (1998) and Lewis, Lilly, Hutter, Bourdette, Saunders, & Fausti (2006) contributed information about individuals with disorders and their ability to recognize speech in a competing stimulus. However, the current study attempted to add high frequency hearing loss but was unable to.

Another limitation was the sample size of the study that is, having only 11 participants in the hearing loss group. It can be classified as a group study; however, the results of the group study are relatively weak. In addition, the current study did not take into consideration typical people's innate ability to adapt to unfavorable signal-to-noise ratios.

### **Implications for Future Research**

The purpose of this study was to establish the relationship between hearing loss and a competing background stimulus; however, there are more types of hearing loss and reasons why people have hearing loss that can be explored for their effect on speech recognition in background noise. Another area of research could examine the ability of working professionals, such as teachers and speech-language pathologists, to recognize unfavorable signal-to-noise ratios and their corresponding techniques and strategies for enhancing the SNR to a more favorable level. Even more research could measure the possibility of training individuals to recognize language more proficiently in the presence of noise. Currently aural rehabilitation employs treatment of speech recognition which could be developed for individuals who require more competence to effectively recognize speech in noise.

### **Conclusions**

Speech-language pathologists, teachers, and other working professionals play an important role in the development of an individual's language, social abilities, and other acquired skills, but having knowledge about the effects of noise on an individual's recognition of language can be crucial for providing the best environment for learning. Whether the professional (such as a speech-language pathologist) is working in a



hospital, school, rehabilitation facility, or private practice setting, there is a need to be aware of noise in the environment because of the detrimental effects it has on speech recognition and the development of language. If any clients being served are put into a situation where the SNR is less than +15 dB, then there is concern for their ability to understand the clinician and others in the environment. It is important for speech-language pathologists to be aware of the student's classroom environment to ensure that the SNR does not interfere with the child's understanding of class material. Special care should be taken for students who have disorders that may place them at an extra disadvantage when listening in background noise. When the SNR is unfavorable, a possible solution is to ensure the teacher has a loud enough voice to improve the SNR. Furthermore, individuals who have disorders compounding the negative effects of noise on hearing, have an even greater need for professionals to provide the best signal-to-noise ratios as possible.

Hearing has a profound effect on language and the ability to communicate with others proficiently. Background noise can produce unfavorable SNRs and affect an individual's ability to communicate. The results of the study did not establish that a slight to mild hearing loss can negatively impact an individual's ability to communicate in noise. However, it is clear that multi-talker background noise has detrimental effects upon speech recognition.

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Appendix A  
IRB Application

**FORT HAYS STATE UNIVERSITY  
INSTITUTIONAL REVIEW BOARD  
FOR HUMAN SUBJECTS RESEARCH**

**APPLICATION**

Proposals for review by the IRB may be submitted at any time. With the exception of expedited reviews, complete proposals submitted no later than ten (10) business days prior to a scheduled meeting will be reviewed at that meeting. Late proposals will be reviewed at the next scheduled meeting. The IRB meeting schedule is posted on the website. Incomplete proposals will not be reviewed, and will be returned to the researcher for completion.

**Type of Request:**

**Full Review**

**Complete Application and Relevant Forms**

**Expedited Review**

**Complete Application and Expedited Review Attachment**

**Approved research proposal revision request (use revision /extension form)**

**Approved research proposal extension request (use revision /extension form)**

**Exempt from Review**

**Complete Application and Exempt Review Attachment**

### Application Information:

**1. Activity or Project Title:** Recognition of Speech in Multi-Talker Babble by Individuals with Normal Hearing and Individuals with High Frequency Hearing Loss.

**2. List all people involved in research project:**

Name & Title	Institution & Department	Phone	Email
*Kyle Christensen	FHSU- Communication Disorders	303-523-8032	Kjchristensen@ scatcat.fhsu.edu
**Frederick Britten	FHSU – Communication Disorders	785-628-4451	fbritten@fhsu.edu

\*Principal Investigator

\*\*Faculty Research Advisor (if student is Principal Investigator)

**Time period for activity:** From February 2011 to February 2012

\*If longer than 1 year, annual review will be needed

**3. Type of investigator and nature of the activity:** (Check all the appropriate categories)

A. Faculty/Staff at FHSU:

- Submitted for extramural funding to:
- Submitted for intramural funding to:
- Project unfunded
- Other (Please explain)

B. Student at FHSU:  Graduate  Undergraduate  Special

- Thesis  Graduate Research Paper
- Specialist Field Study  Independent Study
- Class Project (Course Number and Course Title):
- Other (Please Explain)

C. Investigator not from FHSU but using subjects obtained through FHSU

D. Other than faculty, staff, or student at FHSU:

○ Please identify each investigator and describe the research group:

#### 4. Certifications:

I am familiar with the policies and procedures of Fort Hays State University regarding human subjects in research. I subscribe to the university standards and applicable state and federal standards and will adhere to the policies and procedures of the Institutional Review Board for the Protection of Human Subjects. I will comply with all instructions from the IRB at the beginning and during the project or will stop the project.

AND

I am familiar with the published guidelines for the ethical treatment of human subjects associated with my particular field of study.

### **Statement of Agreement:**

By electronically signing this application package, I certify that I am willing to conduct and /or supervise these activities in accordance with the guidelines for human subjects in research. Further, I certify that any changes in procedures from those outlined above or in the attached proposal will be cleared through the IRB.

*If the Principal Investigator is a student, the electronic signature of the Faculty Advisor certifies: 1) Agreement to supervise the student research; and, 2) This application is ready for IRB review. The Student is the "Principal Investigator". The Faculty Research Advisor is the "Advisor". Designees may not sign the package. It is the student's responsibility to contact their Faculty Research Advisor when the study is ready for his/her signature.*

- I certify the information provided in this application is complete and correct
- I understand that I have ultimate responsibility for the conduct of the study, the ethical performance of the project, the protection of the rights and welfare of human subjects and strict adherence to any stipulations imposed by the IRB.
- I agree to comply with all FHSU policies, as well as all federal, state and local laws on the protection of human subjects in research, including:
  - Ensuring all study personnel satisfactorily complete human subjects in research training
  - Performing the study according to the approved protocol
  - Implementing no changes in the approved study without IRB approval
  - Obtaining informed consent from subjects using only the currently approved consent form



- Protecting identifiable health information in accordance with HIPAA Privacy rule
- Promptly reporting significant or untoward adverse effects to the IRB

## Description of Project

Completely describe the research project below. Provide sufficient information for effective review, and define abbreviations and technical terms. Do NOT simply attach a thesis, prospectus, grant proposal, etc.

### A. Project purpose(s):

The purpose of the study is to determine the word recognition abilities of individuals with normal hearing and individuals with high frequency hearing loss using a background noise recording of multiple people talking as a competing sound.

### B. Describe the proposed participants (number, age, gender, ethnicity, etc)

The participants are going to be a group of 12-18 students. They will be over the age of 18 and both male and female participants will be involved. The ethnicity will not be a controlled variable.

### C. What are the criteria for including or excluding subjects? Are any criteria based on age, gender, race, ethnicity, sexual orientation, or origin? If so, justify.

The participants must be over the age of 18 and a native speaker of English because the word recognition tasks will be presented in English. They need to have a history of excessive noise exposure. Typical language and cognitive skills are necessary completion of the study.

### D. Population from which the participants will be obtained:

#### General Populations:

- Adult students (18-65 years) on-campus  
 Adults (18-65 years) off-campus

- FHSU Students\*  
 FHSU Employees\*

- International Research Population \*

#### Protected Populations\*

- Children (Less than 18 Years)  
 Elderly (65+ Years)  
 Prisoners  
 Wards of the State  
 Pregnant Women  
 Fetuses

#### Vulnerable Population\*

*Vulnerable to coercion*  
*Vulnerable to influence*  
*Economically disadvantaged*  
*Educationally disadvantaged*  
*Mentally disabled*

\*APPROPRIATE ATTACHMENTS MUST BE INCLUDED IN THE APPLICATION PACKAGE

**E. Recruitment Procedures: Describe in detail steps used to recruit participants.** I am going to ask the professors of two departments to announce to their students that they can be part of my study and will receive a well rounded understanding of their hearing

status by participating in the study. A form will be posted in the student union to recruit students interested in participating (Attachment A).

**F. Describe the benefits to the participants, discipline/field, and/or society for completing the research project.**

The main benefit for the participant is the well rounded understanding of their hearing status. The study will also benefit the Communications disorders discipline by furthering knowledge about the speech recognition abilities of individuals with hearing loss.

**G. Describe the potential risks to participants for completing the research project.**

*A risk is a potential harm that a reasonable person would consider important in deciding whether to participate in research. Risk can be categorized as physical, psychological, social, economic and legal, and include pain, stress, invasion of privacy, embarrassment or exposure of sensitive or confidential information. All potential risks and discomforts must be minimized to the greatest extent possible by using appropriate monitoring, safety devices and withdrawal of a subject if there is evidence of a specific adverse event.*

All procedures are routinely use in audiological evaluation and there are minimal risks for the participants.

**H. Describe the follow up efforts that will be made to detect any harm to subjects, and how the IRB be kept informed. *Serious adverse or unexpected reactions or injuries must be reported to the IRB within 48 hours. Other adverse events should be reported within 10 days.***

The participants will asked to report any problems arising from the study and then those problems will be shared with the IRB immediately.

**I. Describe the procedures used in the research project (in detail, what will all participants experience during the research project):**

The results of all test protocols will be recorded on a data collection sheet, (Attachment B). Initially, each participant will enter the Tracoustic Acoustical Enclosure where the first protocol will be administered to attain a threshold screening of their hearing at the frequencies 500, 1000, 2000, 4000, 6000, and 8000 Hz. Then, a test of middle ear function using tympanometry will be conducted, followed by testing the participant's cochlear function using otoacoustic emissions (2000-6000 Hz screening protocol). A competent research assistant trained by an audiologist to deliver the tympanometry and otoacoustic emissions tests will ensure competent clinical skills for each test. Once these tests have been completed, word recognition scores will be obtained using the word lists from the CID W-22, which is a well researched word list routinely used in evaluation throughout the country (Attachment C). The first word recognition test will determine each participant's word recognition score in a quiet condition serving as a baseline score. Proceeding the quiet condition, a word recognition score will be attained from each participant using a CID W-22 word list in signal-to-noise ratios of -5, 0, and +5. To ensure the study controls for order effects, separate word lists will be incorporated at each signal-to-noise ratio (SNR)

condition and for each ear, totaling eight separate word lists. The speech stimulus word lists will be presented to the participants at 50 dB HL and for the competing stimulus, a recording of multi-talker babble will be used for each SNR.

**J. List all measures/instruments to be used in the project, include citations and permission to use (if measure/instrument is copyrighted) if needed or if it will be changed for this study. Attach copies of all measures:**

N/A

**K. Describe in detail how confidentiality will be protected before, during, and after information has been collected?**

The data will remain confidential before, during and after the study information is collected by using subject numbers rather than using any identifiable information. No personal information which could reveal the identity of a participant will be collected.

**L. Data: How will the data be stored? When will the data be destroyed? Who will have access to the data? If audio or video recordings are used, how will they be kept confidential?** The data will be stored in a locked file cabinet in a locked office. Upon closure of the research study, the data will be shredded and disposed.

**M. Informed Consent: Describe in detail the process for obtaining consent. *If non English speaking subjects are involved, describe how consent will be obtained.*** Consent will be obtained from the individual through written consent on the designated informed consent form.

**N. If informed consent is to be waived or altered, complete Supplemental: Consent Waiver Form**

N/A

**O. If written documentation of consent is to be waived, complete Supplemental: Documentation Waiver Form**

N/A

**N. Explain Debriefing procedures/end of study information that will be given to all participants.** Any data collected from the participants will be recorded onto a single page data collection sheet which will be discussed in detail with each participant following the study.

**O. Emergencies. How will emergencies or unanticipated adverse events related to the research be handled if they arise?** The primary researcher will call 911 for any emergencies.

**P. Will information about the research purpose and design be held from subjects? If yes, justify the deception.** No research purpose or design will be withheld from the participants.

**R. If the research involves protected health information, it must comply with the HIPAA Privacy Rule.**

Do you plan to use or disclose identifiable health information outside FHSU?

*If yes, the consent form must include a release of protected health information.*

The IRB may make a waiver of authorization for disclosure if criteria are met under the HIPAA Privacy Rule.

*If a waiver of authorization is being requested, the researcher must contact the IRB chair prior to submitting this application.*

Will the protected health information to be used or disclosed be de identified or will a limited data set be used or disclosed?

S. Each individual with a personal financial interest or relationship that in the individual's judgment **could reasonably appear to affect or be affected by the proposed study** involving human subjects should attach a Supplemental Form: Conflict of Interest. It is unnecessary to report any financial interests or relationships that do **not** reasonably appear to affect or be affected by the proposed study.

**Definitions:**

*"Conflict of interest"* occurs when an independent observer may reasonably question whether an individual's professional actions or decisions are influenced by considerations of the individual's private interests, financial or otherwise.

Conflicting financial interests do not include:

- Salary and benefits from Fort Hays State University;
- Income from seminars, lectures, teaching engagements, or publishing sponsored by federal, state, or local entities, or from non-profit academic institutions, when the funds do not originate from corporate sources;
- Income from service on advisory committees or review panels for governmental or non-profit entities;
- Investments in publicly-traded mutual funds;
- Gifts and promotional items of nominal value; and
- Meals and lodging for participation in professional meetings.

*"Principal investigator or other key personnel"* means the principal investigator and any other person, including students, who are responsible for the design, conduct, analysis, or reporting of research involving human subjects.

<p>An expedited review procedure consists of a review of research involving human subjects by the IRB chairperson or by one or more experienced reviewers designated by the chairperson from among members of the IRB in accordance with the requirements set forth in 45 CFR 46.110.</p>	<p style="text-align: center;"><b>Fort Hays State University Institutional Review Board Office for Scholarship and Sponsored Projects</b></p> <p style="text-align: right;">600 Park Street Hays, KS 67601 (785) 628-4349 E-mail: <a href="mailto:lpaige@fhsu.edu">lpaige@fhsu.edu</a></p>
<p>Request for Expedited Review</p>	

<b>Study Title</b>	The purpose of this study is to determine the speech recognition abilities of individuals with noise-induced hearing loss using multi-talker babble as a competing stimulus.
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**Name of Principal Investigator: Kyle Christensen**

	Departments with Human Subjects/Ethics Review Committees (Ethics Chair)	Departments without Human Subjects/Ethics Review
Departmental Representative	Dr. Finch, Vice Chair of the Department of Communication Disorders	
Date of	2-2-11	
Committee Members:	Dr. Wilhelm, Dr. Shaffer, Dr. Burnett, Dr. Britten, Dr. Finch	
Votes for:	5	
Votes Against:	0	

**EXPEDITED REVIEW CRITERIA**

Research must be "**minimal risk**" to qualify for an Expedited Review. Minimal risk means that the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.

**A. Risk Level:** Does this research pose more than minimal risk to participants?  Yes\*  No  
\* Greater than minimal risk research must be reviewed by the Full Board.

**B.** The categories in this list apply regardless of the age of subjects, unless they are protected (i.e., children, prisoners)

\* Research involving protected populations must be reviewed by the Full Board.

**C.** The expedited review procedure may not be used where identification of the subjects and/or their responses would reasonably place them at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, insurability, reputation, or be stigmatizing, unless reasonable and appropriate protections will be implemented so that risks related to invasion of privacy and breach of confidentiality are no greater than minimal.

**D.** The expedited review procedure may not be used for classified research involving human subjects.

**E.** The standard requirements for informed consent (or its waiver, alteration, or exception) apply regardless of the type of review--expedited or convened--utilized by the IRB.

**RESEARCH CATEGORIES** (Categories 1 through 7 pertain to both initial and continuing IRB review)

***Check Category that best describes the study:***

(1) Clinical studies of drugs and medical devices only when condition (a) or (b) is met.

(a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review.)

(b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

(2) Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows:

(a) from healthy, nonpregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or

(b) from other adults and children<sup>2</sup>, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml

per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

(3) Prospective collection of biological specimens for research purposes by noninvasive means.

*Examples: (a) hair and nail clippings in a nondisfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d) excreta and external secretions (including sweat); (e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.*

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)



*Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.*

(5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis). (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.)

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

(8) Continuing review of research previously approved by the convened IRB: Use Continuing Review process

**PROCESS:**

This form should be attached to the Application Package for Human Subjects Research. All components must be included:

- Application
- Informed Consent Process and Documentation (if needed)
- Recruitment materials
- Any research instruments that will be used for the study (interviews, questionnaires, advertisements) If the study is designed to develop instruments and test the instruments for validity, state this in the Research Summary. Provide a copy of the materials to the OHRPP once developed using an Amendment Form.

Departments with Human Subjects/Ethics Review Committees:

The Chair of the Committee provides the completed form to the Principal Investigator to upload.

Departments without Human Subjects/Ethics Review Committee:

The Department Chair provides the completed form to the Principal Investigator to upload, and recommends the study be considered for expedited review.

<b>ELECTRONIC SIGNATURES</b>
<b>PRINCIPAL INVESTIGATOR</b>
Your electronic signature means that the research described in the application and supporting materials will be conducted in full compliance with FHSU policies, as well as federal, state, and local laws on the protection of human subjects in research. You have the ultimate responsibility for the conduct of the study, the ethical performance of the project, and the protection of the rights and welfare of human subjects. In the case of student protocols, the faculty supervisor and the student share responsibility for adherence to policies.
<b>FACULTY RESEARCH ADVISOR- REQUIRED FOR STUDENT RESEARCH</b>
Your electronic signature certifies that you have read the research protocol submitted for IRB review, and agree to supervise these activities in accordance with the guidelines for human subjects in research. Although the Principal Investigator has ultimate responsibility for the conduct of the study, the ethical performance of the project, the protection of the rights and welfare of human subjects and strict adherence to any stipulations imposed by the IRB, faculty who are serving as the Principal Investigator's Faculty Advisor are responsible for providing appropriate supervision.
<b>DEPARTMENT HUMAN SUBJECTS/ETHICS REVIEW COMMITTEE CHAIR REQUIRED FOR FACULTY OR STUDENT RESEARCH FOR DEPARTMENTS WITH HUMAN SUBJECTS/ETHICS REVIEW COMMITTEES</b>
Your electronic signature certifies that the Committee has reviewed the application and all supporting documents pertaining to this research protocol. The Committee has determined that the proposed activity meets the criteria for exemption from IRB review.
<b>SIGNATURE OF DEPARTMENT CHAIR REQUIRED FOR FACULTY RESEARCH FOR DEPARTMENTS WITHOUT HUMAN SUBJECTS /ETHICS REVIEW COMMITTEES</b>
Your electronic signature affirms you have been informed of the research, and recommend that this study be considered for exemption.

Appendix B  
IRB Approval



# FORT HAYS STATE UNIVERSITY

*Forward thinking. World ready.*

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## OFFICE OF SCHOLARSHIP AND SPONSORED PROJECTS

DATE: February 21, 2011  
 TO: Kyle Christensen, B.A.  
 FROM: Fort Hays State University IRB

STUDY TITLE: [218186-2] Recognition of Speech in Multi-talker Babble by Individuals with Normal Hearing and Individuals With Hearing Loss

IRB REFERENCE #: 11-052  
 SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVED  
 APPROVAL DATE: 2/21/11  
 EXPIRATION DATE: 2/17/12  
 REVIEW TYPE: Administrative

Thank you for your submission of Amendment/Modification materials for this research study. Fort Hays State University IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Leslie Paige at 785-628-4349 or [lp Paige@fhsu.edu](mailto:lp Paige@fhsu.edu). Please include your study title and reference number in all correspondence with this office.



Appendix C  
Informed Consent

## Informed Consent

**Principle Investigator:** Kyle Christensen, Graduate Student

**Research Director:** C. Frederick Britten, Ph.D., Professor  
Department of Communication Disorders  
Fort Hays State University

**Research title: Recognition of Speech in Multi-Talker Babble By Individuals with Normal Hearing and Individuals with High Frequency Hearing Loss**

I have been asked to participate in a research study that investigates the ability of individuals with normal hearing and individuals with high frequency hearing loss to recognize speech in the presence of controlled background noise. Several standard hearing examinations will be performed to determine the status of my hearing for the purpose of the study. Once the status of my hearing has been determined, I will be asked to identify words from a word list in the presence of controlled background noise.

As a participant, I understand that:

1. Consent is given voluntarily without being coerced or forced.
2. Participants may withdraw from the study at any time without penalty.
3. There are minimal risks involved with this study and all procedures are routine non evasive and pose no health risks or danger.
4. The results of the study may be published, but any identifying information relating to the participants **will not** be disclosed.
5. Participants will be asked to spend 60 minutes completing the research study.
6. The benefits of this study include a well rounded understanding of your current hearing status.
7. Any questions concerning this study will be answered by Kyle Christensen at (303)-523-8032 or by Frederick Britten, Ph.D. at (785)-628-4451.
8. I will be provided a copy of this consent form.

---

Participant Signature

---

Date

Appendix D  
CID W-22 Word Lists



Appendix E  
Data Collection Sheet

### Data Collection Sheet

**Participant Number:** \_\_\_\_\_

**Gender:** M F

**Age:** \_\_\_\_\_

**Native Language:** \_\_\_\_\_

**Noise History:**

1. Do you have difficulty hearing? If yes, describe
2. Any situations when hearing is most difficult for you? If yes, describe
3. Do you have any history of noise exposure? If yes, describe
4. Do you have any ringing in your ears? If yes, describe
5. Do you use any form of hearing protection? If yes, describe

**Pure Tones**

	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz
Left ear							
Right ear							

**Tympanometry:** RE: \_\_\_\_\_ LE: \_\_\_\_\_ Pass: \_\_\_\_\_

**OAE:** RE: \_\_\_\_\_ LE: \_\_\_\_\_ Pass: \_\_\_\_\_

**Speech Recognition Scores**

SNR	Order	RE	List #		Order	LE	List #
Quiet							
+5							
0							
-5							



**List 1**

1. Mew \_\_\_\_\_
2. Deaf \_\_\_\_\_
3. Knees \_\_\_\_\_
4. Ache \_\_\_\_\_
5. Bathe \_\_\_\_\_
6. Ace \_\_\_\_\_
7. Chew \_\_\_\_\_
8. Bells \_\_\_\_\_
9. An \_\_\_\_\_
10. East \_\_\_\_\_
11. Thing \_\_\_\_\_
12. Jam \_\_\_\_\_
13. Carve \_\_\_\_\_
14. Owl \_\_\_\_\_
15. See \_\_\_\_\_
16. Twins \_\_\_\_\_
17. Stove \_\_\_\_\_
18. Them \_\_\_\_\_
19. High \_\_\_\_\_
20. She \_\_\_\_\_
21. Earn \_\_\_\_\_
22. wire \_\_\_\_\_
23. skin \_\_\_\_\_
24. ran \_\_\_\_\_
25. toe \_\_\_\_\_

**List 2**

1. felt \_\_\_\_\_
2. true \_\_\_\_\_
3. law \_\_\_\_\_
4. day \_\_\_\_\_
5. give \_\_\_\_\_
6. isle \_\_\_\_\_
7. as \_\_\_\_\_
8. not \_\_\_\_\_
9. could \_\_\_\_\_
10. low \_\_\_\_\_
11. wet \_\_\_\_\_
12. or \_\_\_\_\_
13. poor \_\_\_\_\_
14. me \_\_\_\_\_
15. there \_\_\_\_\_
16. dad \_\_\_\_\_
17. hunt \_\_\_\_\_
18. it \_\_\_\_\_
19. you \_\_\_\_\_
20. us \_\_\_\_\_
21. him \_\_\_\_\_
22. yard \_\_\_\_\_
23. what \_\_\_\_\_
24. none \_\_\_\_\_
25. up \_\_\_\_\_

**List 3**

1. knee \_\_\_\_\_
2. send \_\_\_\_\_
3. rooms \_\_\_\_\_
4. pew \_\_\_\_\_
5. key \_\_\_\_\_
6. ail \_\_\_\_\_
7. else \_\_\_\_\_
8. cap \_\_\_\_\_
9. move \_\_\_\_\_
10. gave \_\_\_\_\_
11. ease \_\_\_\_\_
12. chest \_\_\_\_\_
13. with \_\_\_\_\_
14. tare \_\_\_\_\_
15. thin \_\_\_\_\_
16. cars \_\_\_\_\_
17. show \_\_\_\_\_
18. ill \_\_\_\_\_
19. ham \_\_\_\_\_
20. hit \_\_\_\_\_
21. new \_\_\_\_\_
22. ice \_\_\_\_\_
23. bin \_\_\_\_\_
24. jaw \_\_\_\_\_
25. then \_\_\_\_\_

**List 4**

1. dumb \_\_\_\_\_
2. way \_\_\_\_\_
3. does \_\_\_\_\_
4. off \_\_\_\_\_
5. live \_\_\_\_\_
6. smart \_\_\_\_\_
7. and \_\_\_\_\_
8. oak \_\_\_\_\_
9. too \_\_\_\_\_
10. hurt \_\_\_\_\_
11. young \_\_\_\_\_
12. flat \_\_\_\_\_
13. die \_\_\_\_\_
14. own \_\_\_\_\_
15. star \_\_\_\_\_
16. tree \_\_\_\_\_
17. air \_\_\_\_\_
18. by \_\_\_\_\_
19. yore \_\_\_\_\_
20. odd \_\_\_\_\_
21. that \_\_\_\_\_
22. eat \_\_\_\_\_
23. one \_\_\_\_\_
24. well \_\_\_\_\_
25. now \_\_\_\_\_

**List 5**

1. nest \_\_\_\_\_
2. knit \_\_\_\_\_
3. west \_\_\_\_\_
4. tan \_\_\_\_\_
5. ears \_\_\_\_\_
6. owes \_\_\_\_\_
7. dull \_\_\_\_\_
8. start \_\_\_\_\_
9. aim \_\_\_\_\_
10. year \_\_\_\_\_
11. camp \_\_\_\_\_
12. wool \_\_\_\_\_
13. king \_\_\_\_\_
14. say \_\_\_\_\_
15. use \_\_\_\_\_
16. we \_\_\_\_\_
17. though \_\_\_\_\_
18. chair \_\_\_\_\_
19. ten \_\_\_\_\_
20. three \_\_\_\_\_
21. is \_\_\_\_\_
22. hand \_\_\_\_\_
23. tie \_\_\_\_\_
24. smooth \_\_\_\_\_
25. farm \_\_\_\_\_

**List 6**

1. end \_\_\_\_\_
2. lie \_\_\_\_\_
3. do \_\_\_\_\_
4. cute \_\_\_\_\_
5. bill \_\_\_\_\_
6. shove \_\_\_\_\_
7. raw \_\_\_\_\_
8. if \_\_\_\_\_
9. have \_\_\_\_\_
10. glove \_\_\_\_\_
11. may \_\_\_\_\_
12. add \_\_\_\_\_
13. jar \_\_\_\_\_
14. pie \_\_\_\_\_
15. he \_\_\_\_\_
16. this \_\_\_\_\_
17. done \_\_\_\_\_
18. ate \_\_\_\_\_
19. oil \_\_\_\_\_
20. are \_\_\_\_\_
21. no \_\_\_\_\_
22. book \_\_\_\_\_
23. on \_\_\_\_\_
24. when \_\_\_\_\_
25. out \_\_\_\_\_

**List 7**

1. if \_\_\_\_\_
2. teeth \_\_\_\_\_
3. stuck \_\_\_\_\_
4. fast \_\_\_\_\_
5. cost \_\_\_\_\_
6. cup \_\_\_\_\_
7. cat \_\_\_\_\_
8. at \_\_\_\_\_
9. peek \_\_\_\_\_
10. cot \_\_\_\_\_
11. feet \_\_\_\_\_
12. stuffed \_\_\_\_\_
13. pat \_\_\_\_\_
14. set \_\_\_\_\_
15. kicked \_\_\_\_\_
16. kissed \_\_\_\_\_
17. fist \_\_\_\_\_
18. eats \_\_\_\_\_
19. packed \_\_\_\_\_
20. pet \_\_\_\_\_
21. cats \_\_\_\_\_
22. tests \_\_\_\_\_
23. pops \_\_\_\_\_
24. kit \_\_\_\_\_
25. hats \_\_\_\_\_

**List 8**

1. soft \_\_\_\_\_
2. spot \_\_\_\_\_
3. stick \_\_\_\_\_
4. test \_\_\_\_\_
5. kick \_\_\_\_\_
6. hat \_\_\_\_\_
7. heat \_\_\_\_\_
8. fat \_\_\_\_\_
9. coast \_\_\_\_\_
10. task \_\_\_\_\_
11. sick \_\_\_\_\_
12. steep \_\_\_\_\_
13. stepped \_\_\_\_\_
14. hopes \_\_\_\_\_
15. fixed \_\_\_\_\_
16. pope \_\_\_\_\_
17. soaps \_\_\_\_\_
18. spits \_\_\_\_\_
19. asks \_\_\_\_\_
20. seeks \_\_\_\_\_
21. packs \_\_\_\_\_
22. soaped \_\_\_\_\_
23. sacks \_\_\_\_\_
24. pox \_\_\_\_\_
25. coasts \_\_\_\_\_