TOWSON UNIVERSITY COLLEGE OF GRADUATE STUDIES AND RESEARCH

THE EFFECT OF DIRECTION OF BACKGROUND NOISE, BACKGROUND NOISE TYPE, AND SIGNAL TYPE ON THE ACCEPTABLE NOISE LEVEL IN INDIVIUALS WITH NORMAL HEARING

by

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by Colleen Elizabeth Moore entitled: The Effect of Direction of Background Noise, Background Noise Type and Signal Type on the Acceptable Noise Level of Individuals with Normal Hearing has been approved by his or her committee as satisfactory completion of the thesis requirement for the degree Doctor of Audiology.

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ABSTRACT

Acceptable Noise Levels (ANLs) were examined for 19 participants with normal hearing using three types of stimuli (speech, music, phone ring) presented in the sound field at 0° and two types of noise (babble, white noise) presented in the sound field via three different direction conditions: 0° only, 180° only, and surround (0°, 90°, 180°, 270°). Results showed no significant differences in ANLs across noise type or stimulus type, but a significant difference for surround sound loudspeaker array compared with speakers from one direction, with a larger ANL associated with multiple loud speakers. The main conclusion was that an individual's tolerance for background noise is not affected by signal type or type of background noise but is affected by the direction of the noise source.

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Chapter 1

Introduction

Acceptable noise level (ANL), a phrase coined by Nabelek, (Nabelek, Tampas & Burchfield, 2004) refers to a method of quantifying the amount of background noise that is acceptable, or comfortable, while listening to speech. Various types of background noises have been used in ANL research including 12-talker babble, speech spectrum noise, traffic noise, music, and a pneumatic drill (Nabelek, Tucker & Letowski, 1991). Another way of defining ANL is the difference between a listener's most comfortable listening level (MCL) and background noise level (BNL). An equation of this scenario would be the following: ANL=MCL-BNL (Freyaldenhoven, Nabelek, Burchfield & Thelin, 2005). ANL was originally developed as a test to be administered in a clinical setting.

Research has shown that ANL is not related to age (Freyaldenhoven & Smiley, 2006; Nabelek et al.,1991; Nabelek, Freyaldenhoven, Tampas, Burchfield & Muenchen, 2006) gender (Rodgers, Harkrider, Burchfield & Nabelek, 2003), hearing sensitivity (Nabelek et al., 2006), type of background noise distraction (Crowley & Nabelek, 1996; Nabelek et al., 1991), characteristics of the middle ear (Harkrider & Smith, 2005), cochlear responses, efferent activity of the medial olivocochlear bundle pathway (Harkrider & Smith, 2005; Harkrider & Tampas, 2006), or speech perception in noise scores (Nabelek et al., 2004). Researchers have yet to investigate how different types of background noise affect ANL and if people are willing to accept different levels of background noise when listening to non-speech signals versus speech signals. This investigation was designed to determine the effect of the type of background noise and location of the noise source on ANL for speech and non-speech sounds (telephone ring and music),

Chapter 2

Review of Literature

MCL

Most comfortable listening level (MCL) is a phrase coined by Kopra and Blosser (1968) and it has been defined as the level at which speech or tones reach a person's most comfortable listening level or the level when speech or tones are "most comfortably loud" (Martin, 1994) while in an audiologic test setting. People who have normal hearing sensitivity often have an MCL of 40 dB HL to 55 dB HL (Martin, 1997). MCL is used in audiology because it is considered to be one way to estimate the intensity level at which a person is hearing at his or her optimal speech recognition ability (Brandy, 2002; Shapiro, 1975; Yantis, Millen & Shapiro, 1966).

MCL is frequently assessed during clinical audiologic testing. Martin, Champlin and Chambers (1999) found that 41% of audiologists measure MCL for every patient they see and 44% of audiologists measure MCL for their hearing aid patients. Commonly, an audiologist will determine MCL by presented running speech (continuously delivered speech) or spondees (two syllable words that carry equal stress on each syllable [Martin, 1997]) via prerecorded or monitored live voice. The audiologist adjusts the intensity until the patient states that he or she perceives the speech at a comfortable level. MCL is most often tested using speech stimuli; however, some audiologists prefer to use frequency specific tonal stimuli, especially when testing a patient who is a candidate for hearing aids (Punch, Rakerd & Joseph, 2004).

In clinical audiology, MCL is used for various reasons. One of the primary uses for MCL is to assist the audiologist when fitting a patient with hearing aids. The audiologist uses the MCL information for prescribing and programming hearing aids so that the acoustic gain results in a comfortably loud sound level for the patient when the patient is wearing the hearing aids. For similar reasons, MCL is used when fitting an individual with an assistive listening device such as an FM system or induction loop system. A patient's MCL can also be used during diagnostic testing, specifically to explore the patient's dynamic range. Dynamic range is the difference between the threshold of hearing and the uncomfortable loudness level (UCLs). The MCL occurs somewhere between these two points (Dillon, 2001). UCL has been defined as the sound pressure level at which speech becomes uncomfortably loud (Martin, 1997). A reduced dynamic range (e.g., an increased threshold which is not commensurate with an increased UCL) indicates the presence of loudness recruitment, which is as an abnormally steep growth of loudness as input level is increased (Keidser & Grant, 2001). Reduced dynamic range is attributed to damage to the outer hair cells in the cochlea. In the case of reduced dynamic range, MCL may be unusually close to a patient's hearing threshold and/or UCL. Newby and Popelka (1985) described the use of MCL as a test for reduced dynamic range. The test procedure they described involved obtaining a pure tone threshold and obtaining MCL and UCL using pure tones. In their protocol, a pure tone is presented to the patient and the patient is asked to indicate the level at which the tone is comfortably loud. If the patient reports that a tone is comfortably loud, and then with a slight increase of loudness the patient reports the tone is uncomfortable, this indicates recruitment. Because the general methods for testing are similar, MCL is often tested in conjunction with UCLs (Martin, Chaplin & Chambers, 1998). The audiologist uses this level when programming a hearing aid to make sure that the intensity level from the hearing aid will never exceed the patient's UCL levels.

There have been a number of attempts to develop a standard MCL protocol to obtain a clinically useful method of loudness scaling using various loudness categories. For example, Elberling and Nielsen (1993) developed the CAR procedure (CAR is not an abbreviation but the name of the procedure), in which pure tones are used to rate loudness in 7 categories using frequencies from 500 Hz to 2000 Hz. In that same year, Kiessling, Steffens and Wagner (1993) developed a procedure called the Direct Loudness Scaling Procedure to rate loudness in 13 categories using 1/3-octave band filtered noise stimuli with center frequencies of 500, 1000, 2000, and 4000 Hz. Further research in the 1990s included the Horfeldskalierung procedure developed by Hohmann and Kollmeier (1995). This procedure was used to rate loudness in 5 categories with a presentation of 1/3-octave filtered noise stimuli at the center frequencies of 250, 500, 1000, 2000, and 4000 Hz. Launer (1995) used a categorical scaling procedure to rate loudness in 7 categories with narrow band noise at 1370, 1600, 1850, 2150, 2500, and 2925 Hz. Ricketts and Bentler (1996) used a categorical scaling procedure to rate the loudness in 9 categories using 1/3 octave band noise stimuli centered at 500 and 3150 Hz.

Two methods that were created during the 1990s have become popular in today's clinical settings. These methods are the Loudness Growth in ½ Octave Bands method (LGOB) by Allen, Hall, and Jeng, developed at AT&T Laboratories (1990) and the Contour Test of Loudness Perception (Contour Test), (although the method of adjustments may have been a more precidce…)developed by Cox, Alexander, Taylor and Gray (1997). In the LGOB method, the person being tested is given a set of instructions that direct them to respond to different test signals according to the loudness of each signal (the method of instruction (written, oral) is not specified). The person is asked to judge the signal, choosing from 6 categories. The choices are: too loud, very loud, loud, OK, soft, and very soft. The listener is expected to indicate to the tester where on the scale each auditory signal is. The person being tested is presented randomly with one of five ½-octave bands of pure tones with frequencies ranging between 0.25, 0.5, 1.0, 2.0, and 4.0 K Hz and presented with 15 different intensities at each frequency.

The Contour Test is sometimes called the IHAFF test because it was created with other tests as part of a project by the Independent Hearing Aid Fitting Forum (IHAFF, 1997). IHAFF is a group of audiologists that formed in 1993 with the idea of providing collaborative guidance and data for the process of hearing aid evaluation and fitting. For the Contour Test instructions for the listener given to them in written form and also read aloud by the tester. The instructions for the Contour Test are as follows: "The purpose of this test is to find your judgments of the loudness of different sounds. You will hear sounds that increase and decrease in volume. You must make a judgment about how loud these sounds are. Pretend that you are listening to a radio at that volume. How loud would it be? After each sound, tell me which of these categories best describes the loudness. Keep in mind that an uncomfortably loud sound is louder than you would ever choose on your radio no matter what mood you are in." After the instructions are given, the patient is told that he or she should use any category that seems appropriate at any time and that it is OK to repeat or skip a category. The categories given to the person are numbered by loudness categories. The categories are as follows:

7. Uncomfortably Loud

6. Loud, but OK

5. Comfortable, but Slightly Loud

4. Comfortable

3. Comfortable, but Slightly Soft

2. Soft

1. Very Soft

Warble tones were chosen as the preferred stimulus for the Contour Test because they use a wider bandwidth than pure tones; however, research has shown that pure tones, warble tones, and 1/3 octave noise bands produce similar results in loudness tests (Byrne, 1986; Cox, 1989; Hawkins, 1980; Ricketts & Bentler, 1996). In the IHAFF procedure, warble tone pulses are presented monaurally at 250, 500, 1000, 2000, 3000, and 4000 Hz in four 200 msec pulses. The level of the tone is increased in 5 dB increments and the recommended starting level is just above threshold. The test is terminated when the listener indicates that an uncomfortably loud tone has been presented. The authors of the Contour Test stated that there had been no compelling data showing one single loudness test method to be superior. Because of this the authors of the Contour Test stated that is was designed with two specific goals in mind: to develop a scientifically defensible procedure and to develop a method that is practical to use in the clinical setting. Because the Contour Test met these goals, the test has become popular in both research and clinical settings (Beattie, Huynh, Ngo & Jones, 1997; Kiessling, Pfeimer & Dyrlund 1996; Punch, Rakerd & Joseph, 2004; Ruscetta & Palmer 2000). Although the Contour test is a popular test for MCL, there is still no standardized method used in the profession of audiology for establishing MCL. Several studies have investigated the reliability and practicality of different methods in an attempt to establish a standard.

MCL Reliability. The results of investigations into the reliability of MCL procedures are varied. Some studies have shown that when the same method of testing loudness levels is consistently used, the reliability of loudness scaling is similar to the reliability of pure tone threshold testing (e.g., Cox, 1989; Sammeth, Birman, & Hecox, 1989). Other investigations have shown that 95% of common MCL tests have test/re-test results that vary between 8 and 12 dB HL (Sammeth et al., 1989). Elberling (1999) conducted a meta analysis of seven research articles, each of which used a different loudness scaling procedure. Specifically, Elberling compared the LGOB (Allen et al., 1990), the CAR (Eberling et al., 1993), the Direct Loudness Scaling procedure (Kiessling et al., 1999) the Horfeldskalierung procedure (Hohmann & Kollmeier, 1995), a procedure developed by Launer (1995), a procedure developed by Ricketts and Bentler (1996), and the Contour Test of Loudness Perception (Cox et al., 1997). Elberling's goal was to find the most reliable and practical loudness scaling method to assist in the fitting of nonlinear hearing aids. The various investigations he studied provided data from individuals with normal hearing and data from individuals with sensorineural hearing loss. Elberling found that with normal hearing participants, loudness scaling results were quite different across methods. Specifically, participant ratings of "comfortable" on two different loudness tests were often associated with two very different sound pressure levels. In other words, normal hearing participants displayed a large variability in the sound level associated with a specific loudness category, and this varied about 35 dB HL for the “comfortable” level for this procedure. In spite of the large variability, researchers still found a statistically significant positive correlation between ratings across scales.

For individuals with hearing loss, Elberling’s research indicated that loudness scaling was not needed to get an accurate indication of loudness growth. With 70% of the studies he examined, the slope of loudness growth, as determined by loudness scaling, could be accurately predicted by the audiogram. Elberling concluded that the combination of the loudness growth function for people with hearing loss, coupled with the highly variable results at the “comfortable” rating for normal listeners indicates that even if loudness growth is obtained through scaling, fine tuning of a hearing aid program would most likely be required.

In 1978, Ventry and Johnson evaluated the reliability of the MCL of hearing levels (HL) for speech, which they called the Most Comfortable Level for Speech (MCL-S). The method involved introducing speech at the spondaic threshold minus 5 dB. The stimulus was increased in 5 dB steps until the listener indicated that his MCL-S was reached. They studied 100 male listeners with sensorineural hearing loss, ranging from mild to severe in degree, to determine the reliability of the MCL-S using an ascending presentation compared with a descending presentation protocol. Results from this study showed that test-retest reliability was excellent for both ascending and descending methods. When using the ascending method versus the descending method, the participant’s MCL-Ss were 20-23 dB higher and between subject variability was less. This suggests that the ascending approach should be used when finding an individual’s MCL for speech. Results also showed that MCL reliability was not affected by the severity of the hearing loss.

SNR

Signal to noise ratio (SNR) is a concept used in numerous fields including audiology, engineering, electronics, and acoustics. In its simplest definition, SNR is the ratio of the signal and noise sound intensity expressed in dB. SNR is calculated as the simple subtraction of the intensity level (in decibels) of the signal minus the intensity level of the noise. The higher the ratio, the less noise is present, resulting in less interference with the signal. High SNRs are desired for most listening tasks, e.g., a SNR of 20 dB is desired in school classrooms (ANSI S 12.60-2002), because it makes the message or signal easier to hear and understand.

SNR is important when considering speech intelligibility and enjoyment/comfort when listening to speech. The louder competing noise becomes, the more it will interfere or mask (cover) speech. SNR is also important for clinical purposes, as background noise is used for clinical masking to obtain accurate test results under certain testing conditions. In clinical audiology there are generally two types of maskers used, those for speech and those for pure tones. For pure tones, narrow band noise with a center frequency that matches the frequency of the pure tone is used. When masking for speech, a wider frequency band is used (Lass & Woodford, 2007). For example, speech spectrum noise is a commonly used masker in clinical audiology.

Noises in everyday life will also act as maskers. Anytime a signal is covered by a noise, that noise becomes a masker. This is problematic when listening to a speech signal in the presence of background noise because it causes a decrease in auditory discrimination and an increase in auditory fatigue (Cherry, 1954). One’s ability to decipher the speech signal can be influenced by a number of factors including the speaker's gender, dialect, rate of speech, clarity of speech, and spectral and temporal properties of noise (maskers) (Soli & Wong, 2008).

Speech Intelligibility

A patient's ability to understand speech is of great interest in audiology testing. Obtaining speech threshold levels and supra-threshold speech recognition scores in the sound booth can give the audiologist information about how well that patient is able to detect and understand speech in an ideal listening situation. A test that is widely used in audiology testing is speech recognition testing. It is a supra-threshold measure in which a score is determined by how many words are correctly repeated by the listener. Low scores indicate that the listener has trouble understanding speech when it is presented at a comfortable level, suggesting distortion within the auditory pathways when listening to a signal.

Background noise can affect speech understanding both for people with normal hearing sensitivity and people with hearing loss (Hygge, Ronnberg, Larsby, & Arlinger, 1992; Souza & Turner, 1994). The intelligibility of speech in the presence of background noise has often been considered important when fitting hearing aids. Several tests have been developed to look at speech understanding in the presence of background noise. Some of these tests include the Speech in Noise Test (Fikret-Pasa, 1993), the Speech Perception in Noise test (Kalikow, Stevens & Elliott, 1977), and the Hearing in Noise Test (Nilsson, Soli & Sullivan, 1993). Research has shown that individuals with very similar hearing thresholds may have very different speech recognition abilities in noise (Killion & Niquette, 2000; Laroche, Giguere, Vaillancourt & Soli, 2005; Smoorenburg, 1992; Soli & Vermiglio, 1999).

MCL and Background Noise: ANL

Signal to noise ratio can be a major influence on the ability of a listener to understand a speech signal comfortably (Soli & Wong, 2008). Thus, when assessing a most comfortable listening level, one has to consider whether background noise is present and how the addition of background noise may interfere with the signal that the person intends to hear. In the 1990s, several investigations were performed involving background noise and people's tolerance to background noise (e.g., Emanuel & Letowski, 1994; Nabelek et al., 1991; Nilsson, et al., 1994). These investigations were performed by testing a person's comfort level for speech with various background noises present. Nabelek called the level where speech is comfortable in the presence of background noise Acceptable Noise Level (ANL). ANL is defined as the difference between background noise level (BNL) and MCL. Nabelek first used babble as background noise; however, various background noises have since been used in ANL research. The main purpose of much of this research involving MCL for speech and background noise was to find out whether an individual's ability to tolerate noise has any effect on their personal acceptance of hearing aid use. This initial research precipitated more studies based on a person's tolerance of background noise (e.g. Freyaldenhoven, Smiley, Muenchen, & Konrad, 2006; Nabelek, Freyaldenhoven, Tampas, Burchfield, & Muenchen, 2006; Rogers, Harkrider, Burchfield, & Nabelek, 2003).

Nabelek and her colleagues first began their investigation of what came to be called ANL when they studied the tolerance of background noises by elderly persons, and if their tolerance or lack of tolerance to background noise would correlate with hearing aid use (Nabelek et al., 1991). They tested groups that consisted of normal hearing young people, older people with relatively good hearing, older people with hearing loss who were part-time hearing aid wearers, older people with hearing loss who were full time hearing aid wearers, and older people with hearing loss who didn't wear hearing aids. The method they developed to find a person's ANL consisted of first finding a person's MCL under headphones using a speech signal. For this portion of the study, the participant used the Method of Adjustment to adjust a dial to find his or her own MCL. Once MCL was established, a background noise, beginning at a SNR of 0 dB, was then added. The participant was again able to adjust the noise accordingly, by 2 dB steps, until he or she found a level of noise they considered to be tolerable while also listening to the speech at the established MCL. The tolerated levels were established with 5 different noises that included 12-talker babble, noise with the spectral envelope of average speech (speech spectrum noise), traffic noise, music, and a pneumatic drill. The results from this study indicated that full time hearing aid wearers tolerated significantly higher levels of music and traffic noise when compared with the other groups. The full time hearing aid user group was the only one, of the 5 groups analyzed, that was willing to listen in an average SNR of 7.5 dB. The other groups averaged a SNR of greater than 10 dB (the level that is considered to be a good listening environment [Kalikow et al., 1977]). These results were followed by further research related to tolerance of background noise.

In 1994, Emanuel and Letowski also investigated tolerance to noise in older listeners. These researchers looked at the noise tolerance difference in older adults for audio presentation and video/audio presentation while noise was presented. The researchers were specifically interested in whether gender, age, lifestyle and hearing loss were predictors of tolerance to background noise. The participants completed a demographic survey which provided age, gender, and lifestyle information. They were given a hearing test to determine hearing sensitivity. MCL was determined for the participant and then, while listening to the signal at MCL, one of three noises was introduced. The background noises used were speech spectrum noise, multi-talker babble, and traffic noise. The noise was increased in 2 dB steps until the participant indicated that the noise interfered with the understanding of the speech signal. Results from the investigation indicated that age and gender were not significant predictors of how well people tolerate noise and individuals with hearing loss generally do not tolerate noise as well as individuals with normal hearing sensitivity. Results also indicated that individuals who lead an active lifestyle tolerate noise better than other individuals.

Some studies have looked at the functional relationship between signal level and background noise level. Although these studies refer to this method as ANL testing, these studies actually involved a varying signal level and a varying background noise level while acceptable noise level testing involves a stationary signal level (MCL) and a varying level of background noise. This method could be referred to as acceptable signal to noise ratio rather than acceptable noise level. While these studies did not look specifically at ANL, they provide valuable data regarding acceptable signal to noise ratios, some of which can be compared with ANL data.

These studies looked at speech presentation level and tolerable background noise and whether this tolerable background noise level was affected by speech presentation level. The first of these studies investigated the functional relationship between background noise levels and speech presentation levels for listeners with normal hearing

(Franklin, Thelin, Nabelek & Burchfield, 2006). The procedure involved the participant finding his or her MCL by adjusting a dial (Method of Adjustment). Speech was randomly presented to the participants at the participants' MCL and at 20, 34, 48, 63 or 78 dB HL, with background noise. The participants were then instructed to notify the tester when the background noise reached the maximum level which they could "accept for a long time while following the words of the speech". The background noise was presented at an initial intensity level of 30 dB below the speech presentation level. It was then increased in steps of 10 dB until the participant indicated that he or she was no longer be able to comfortably listen to the speech. The results of this study indicated that as speech presentation levels were increased, background levels also increased.

Further research investigated speech presentation level with participants with hearing loss (Freyaldenhoven, Plyler, Thelin & Hedrick, 2007). The investigators examined overall acceptable signal to noise ratios for individuals with hearing loss and individuals with normal hearing, and compared the growth in acceptable signal to noise ratio levels between the two groups when the signal was increased. In this study, intensity levels were obtained through a loudspeaker with running speech as the signal and multi-talker babble as the noise. The participants were presented with speech at 8 different intensity levels and, for each level, they were instructed to adjust the background noise to an intensity level that they would be willing to "put up with" for a long time while listening to the signal. Results showed that for both acceptable signal to noise ratios and the growth of acceptable signal to noise in relation to the different speech levels presented, there was no significant difference between individuals with hearing loss and normal hearing listeners. This indicated that hearing sensitivity does not affect this acceptable signal to noise ratio or its growth in relation to speech levels.

Statement of Purpose

The majority of ANL research performed in the past has involved examining its use in hearing aid fitting protocols. Researchers of the previous studies have also investigated how well speech is understood while listening in noise (Kalikow et al, 1977; Nilsson et al, 1994; Smoorenburg, 1992; Soli & Wong, 2008; Souza & Turner, 1994).

Research has yet to be conducted to investigate a person's ANL while listening to non-speech signals, how the direction of background noise may affect ANL and how noises such as white noise and babble affect the ANL when using non-speech stimuli as signals. The purpose of this study was to investigate these issues.

Chapter 3

Methodology

Participants

Nineteen adults between the ages of 18 and 30 years (average 23.7 years old) with normal hearing sensitivity (pure-tone audiometric screening passed at 20 dB HL from 250 to 8,000 Hz [Goodman, 1965] tested in octave intervals) and normal middle ear function (normal middle ear admittance, peak pressure, ear canal volume, and gradient (American Speech-Language Hearing Association [ASHA], 1990; Margolis & Heller, 1987]) participated in this investigation. The group of listeners consisted of eighteen women and one man, sixteen of whom were graduate level audiology students. None of the participants were familiar with ANL testing.

Hearing screenings were conducted in a 9.5 ft. by 10.5 ft. double-walled sound treated booth with a Madsen Aurical diagnostic audiometer with ER-3A insert earphones using standard audiometric screening procedures (ASHA, 1994). Middle ear function was tested using a Zodiac 901 Madsen Electronic Middle Ear Analyzer.

Test Materials

Signals for the experimental testing consisted of running speech, music and a cell phone ring. The running speech (The Arizona Travelogue, Cosmos, Inc.) was from The Acceptability of Noise Level Test procedure (Nabelek et al., 2005) and can be described as a continuous discourse (a story) spoken by a radio announcer, at a rapid speaking rate (approximately 185 words per minute). The music used was classical-style piano piece composed by Dustin O'Halloran called Opus 36 (2006, Disc 2, Track 14 Marie Antoinette Soundtrack). The ring tone is called "phone05" and is offered as a basic ring tone by Nokia Corporation. All stimuli were downloaded into Adobe Audition 1.5 software and calibrated to a 1 kHz calibration warble tone provided on the ANL test CD. This was achieved by equating the root mean square (RMS) amplitude of the signals to the RMS amplitude of the calibration tone. The spectra of the speech shows the energy spread throughout the frequency range and spectrum of music shows most of the energy in the mid and low frequency range. The phone signal showed consistent and predictable frequency spikes with no sound energy in between these spikes. Spectrograms are shown to illustrate the temporal nature of the signals and noises. Spectrograms of the signals recorded directly from the CD are shown in Figure 1.

Two competing noises consisted of white noise obtained from Adobe Audition software and 12-talker babble obtained from the Acceptable Noise Level Test CD (www.cosmosdistributinginc.com). Spectrograms of the background noises were digitally recorded in the sound field through the 0˚ speaker (see Instrumentation Section). These spectrograms are shown in Figure 2. The spectra of the background noises in the sound field were recorded at lower amplitudes than on the CD to avoid peak clipping by the recording equipment. Specifically, the babble noise was recorded at a lower intensity than the white noise. The presentation order of the combinations of signals and noises was counterbalanced across the participants and the signals. This was achieved by rotating the order of signals and noises with the purpose of no two people having the same order of signals and noises introduced during testing. The spectra of the stimuli and noises are shown in Figures 3-7.

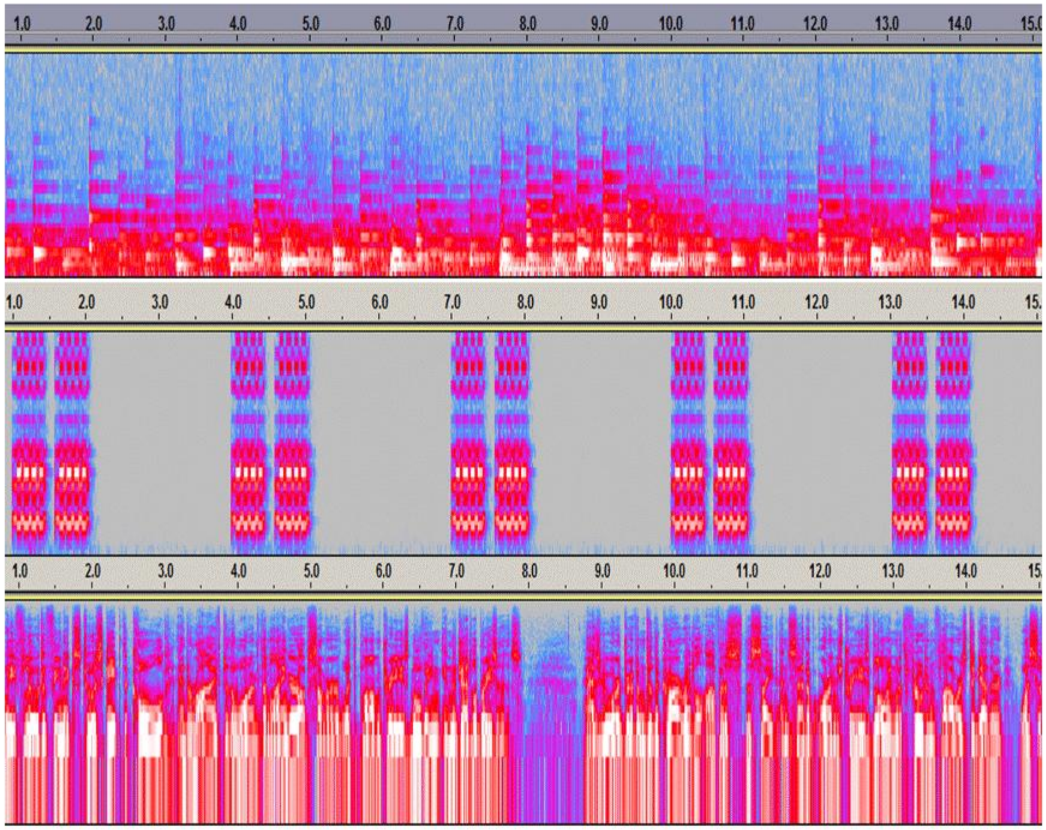

Figure 1. Spectrograms of music (top), phone (middle) and speech signal (bottom) recorded from CD.

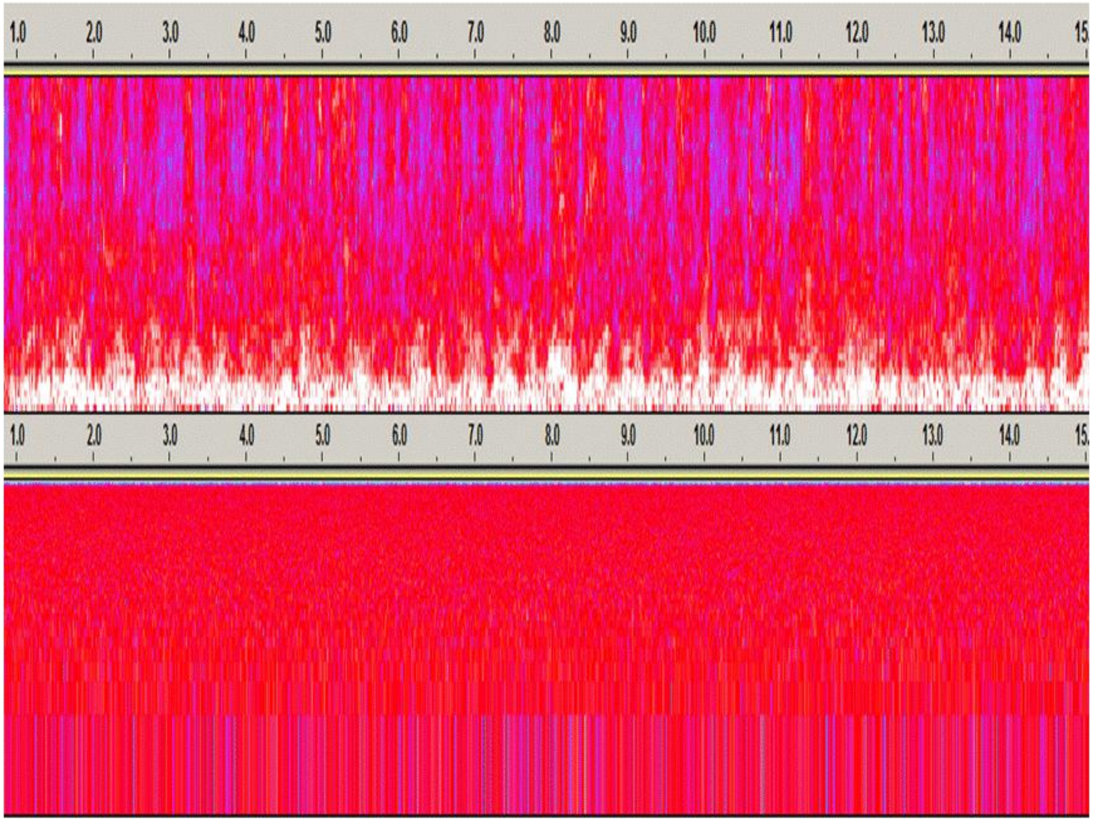

Figure 2. Spectrograms of babble (top) and white noise recorded from the sound field from 0˚.

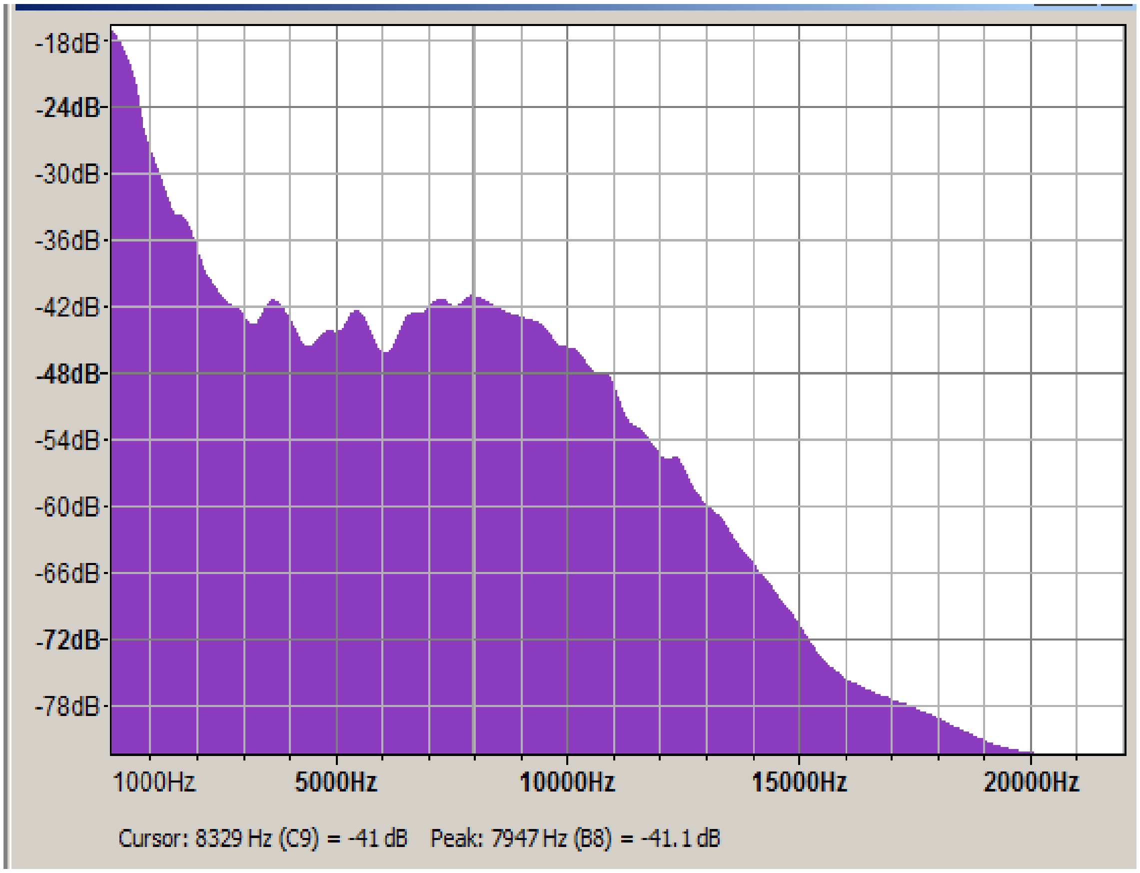

Figure 3. Spectrum of babble used in the study.

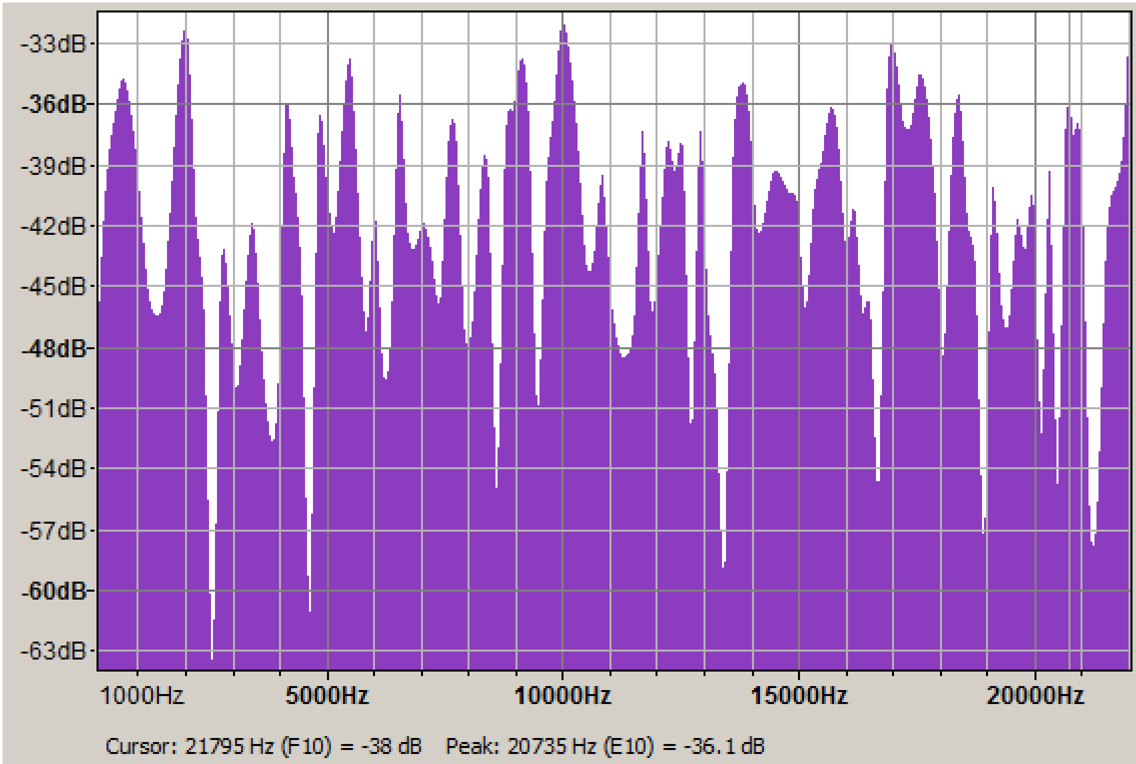

Figure 4. Spectrum of white noise used in the study.

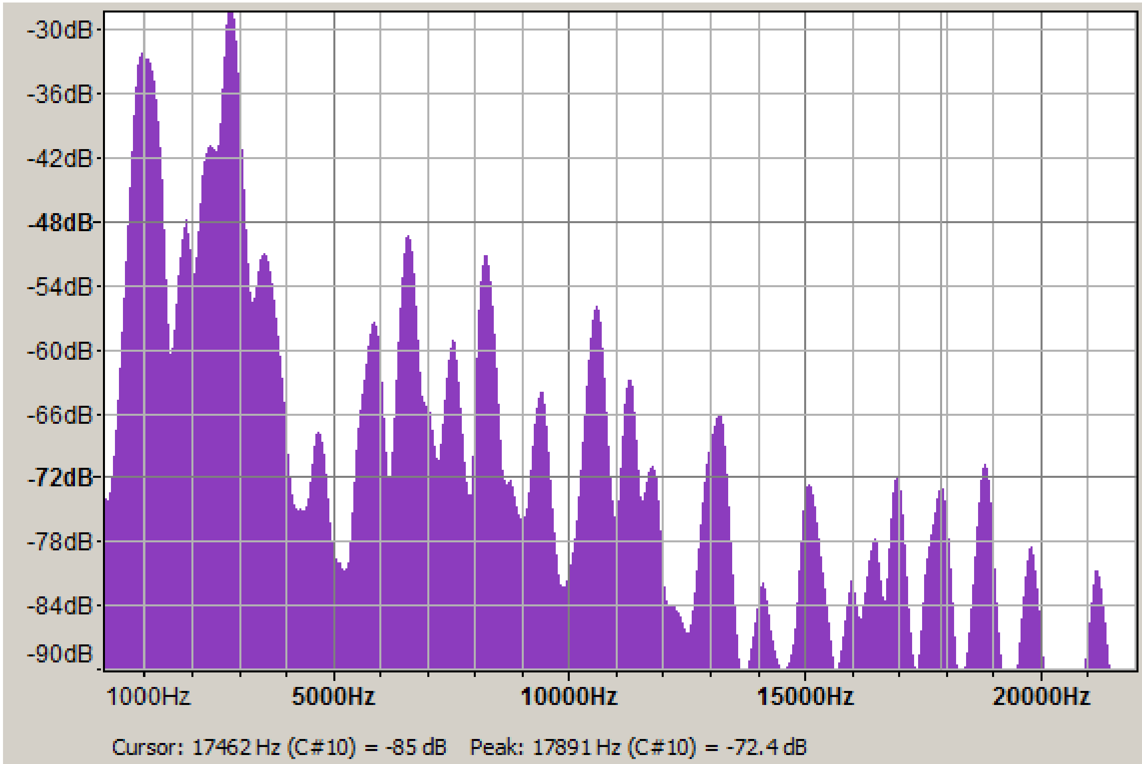

Figure 5. Spectrum of phone used in the study.

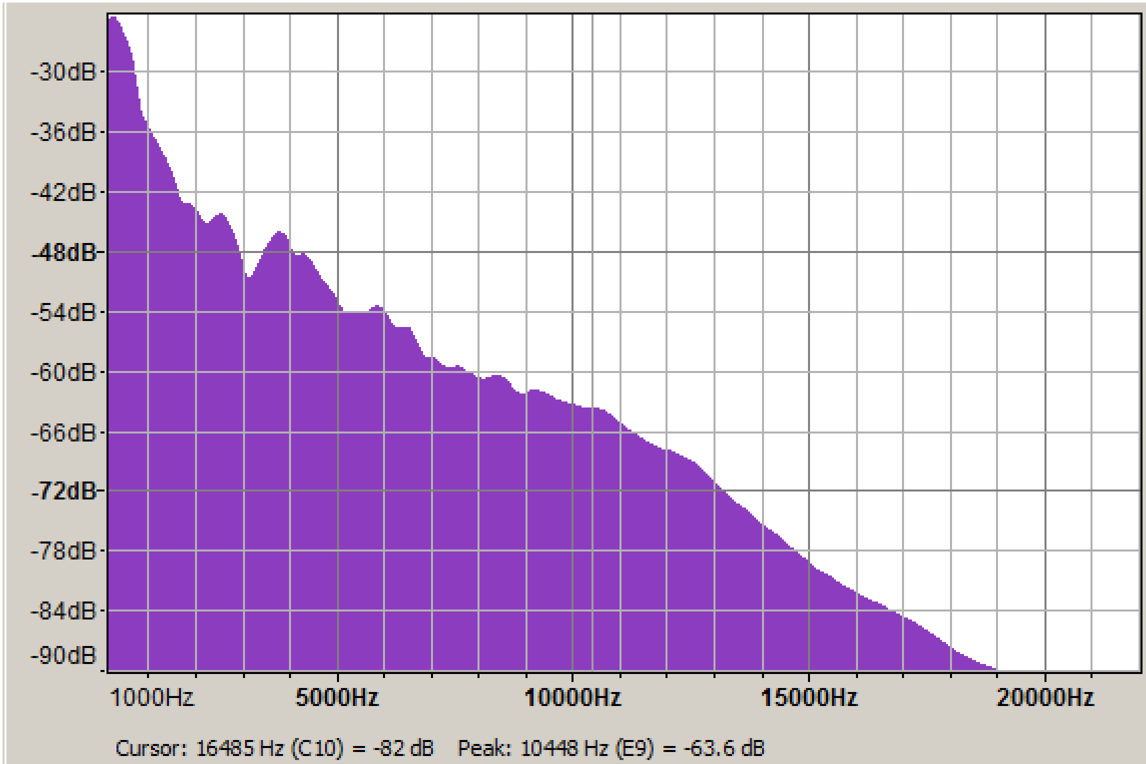

Figure 6. Spectrum of speech used in the study.

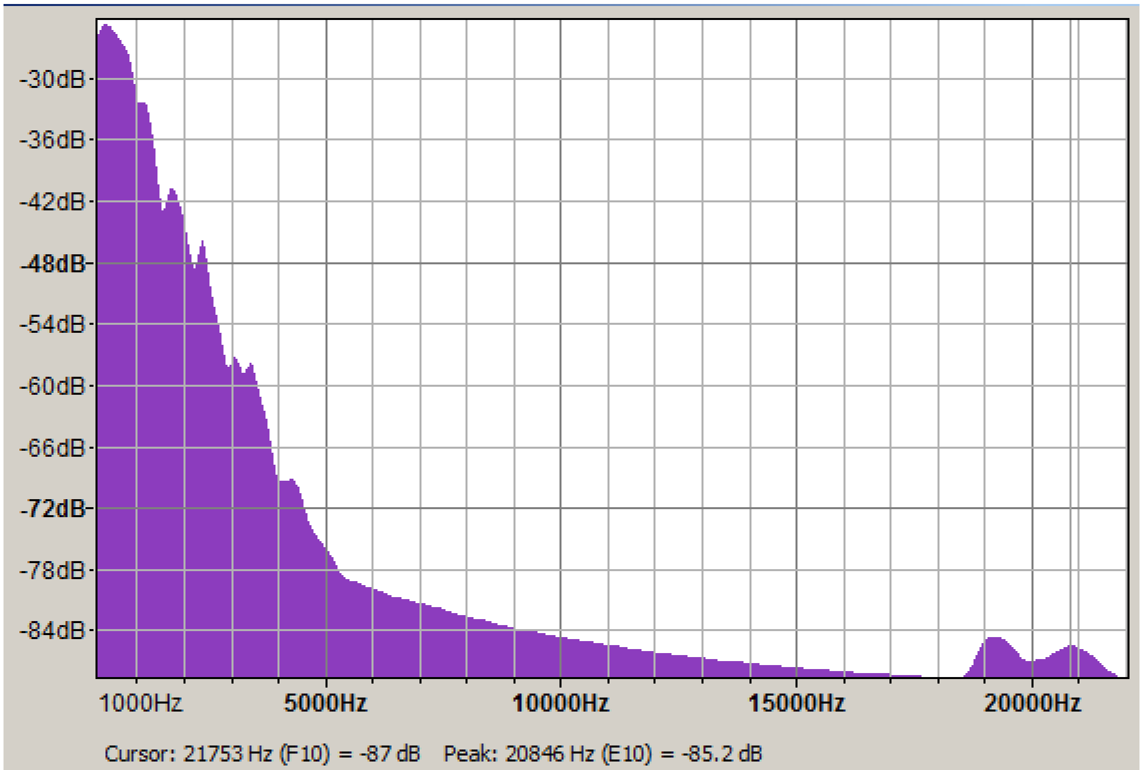

Figure 7. Spectrum of music used in the study.

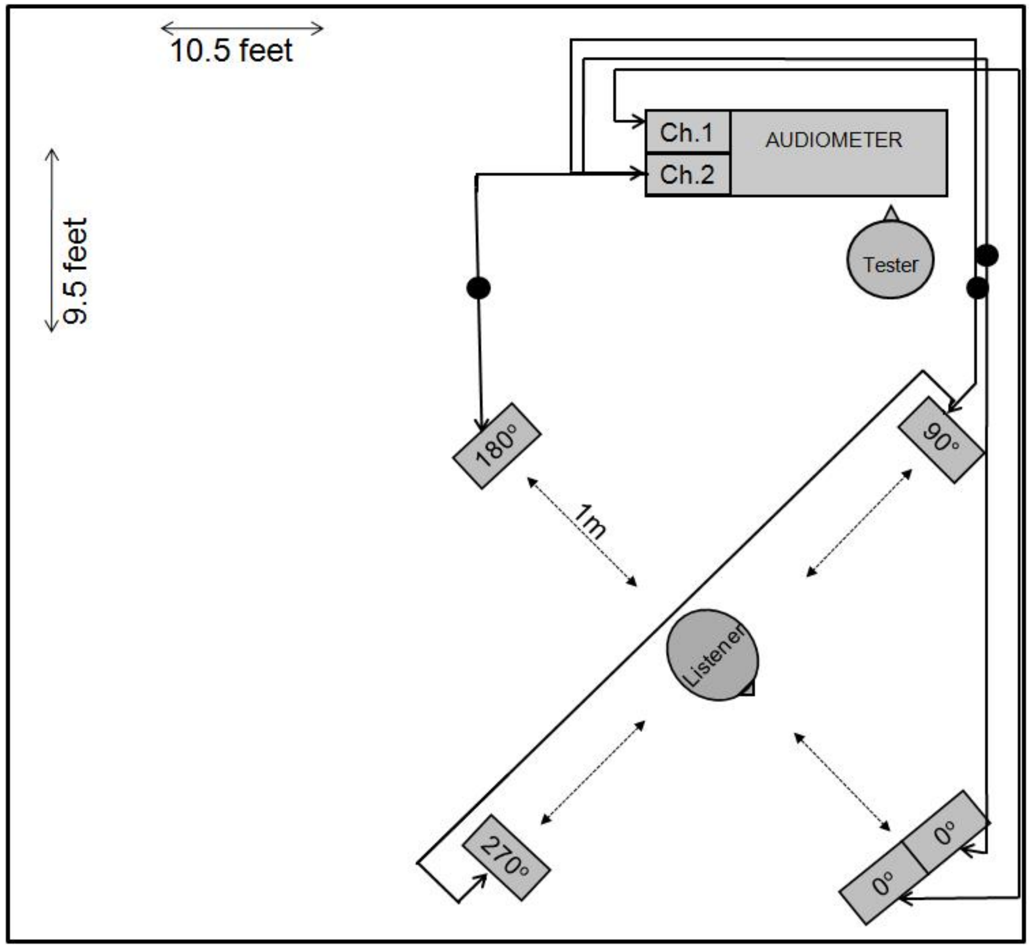

Figure 8. *Sound booth layout*
Note. Black lines represent wiring. Circles represent switches.

Instrumentation

Recorded signals for the experiment were presented via two Sony CDP-CE535 5-CD Players. Each was routed through a separate channel of the clinical audiometer. The output from each channel was sent to separate channels on a two-channel Crown amplifier (model D-75A). The output from the two channels of the amplifier was sent to Tannoy i5aw loudspeakers (with a nominal impedance level of 6 ohms) such that one channel (for the stimuli) was directed to a loudspeaker located close to 0° azimuth and placed 1 meter from the listener. The other channel (for the competing noise) was connected to a four additional loudspeakers located close to 0° azimuth and also at 90°, 180° and 270°, all of these loudspeakers were also 1 meter from the listener. Note that the two loudspeakers which were close to 0° azimuth were actually positioned side by side, one for the signal and one for the noise; thus, they were slightly to the right and left of 0°. The target stimuli were always directed to the speaker slightly to the right of 0° azimuth and the completing noise was directed to the speaker slightly to the left of 0°. Loudspeaker activation and deactivation was controlled by 3 switches that could turn the various loudspeakers off and on according to the test situation. All loudspeakers were placed at approximately the same level as the listener's head (45" from the floor).

The intensity level value recorded from each participant was read from the audiometer. The audiometer was calibrated using a Bruel & Kjaer Instruments digital frequency analyzer (type 2131) prior to testing each participant using a 1/3 octave band filter with a center frequency of 1,000 Hz to set the audiometer level to 70 when the frequency spectrum analyzer read 70 for the warble tone at the beginning of each CD. This calibration technique was used to ensure that the levels remained stable; however, they did not calibrate the audiometer in either dB SPL (because a 1/3 octave band would not indicate the overall level of a wide band stimulus) or dB HL (which would require calibration to a reference value referenced to normal hearing). The values recorded from the audiometer were subsequently converted to dB SPL values based on the measurement of the sound pressure level of all stimuli and noises in all of the loudspeaker conditions using an Ivie Technologies IE-35/Dell X51 handheld analyzer. It was subsequently found that there was additional attenuation in the circuit that was not accounted for by the calibration procedure, and a correction factor was generated and applied to the data. As mentioned previously, the listener was surrounded by a total of 5 loudspeakers: Two at 0˚ (one for the signal and one for the noise) and one each at 90˚, 180˚, and 270˚. Data collection involved a listener determining his or her most comfortable listening level (MCL) for signals presented solely from the speaker located at 0˚ azimuth. Next, Background Noise Level (BNL) was determined by presenting the signal at 0˚ and then simultaneously presenting noise via three different paradigms: (a) 0˚ (b) 180˚ and (c) 0˚, 90˚, 180˚, and 270. Finally, Acceptable Noise Level (ANL) was calculated by subtracting MCL from BNL (ANL=MCL-BNL) after the data had been converted to dB SPL. In summary, the listening paradigm required the use of either two (signal and noise from 0˚, signal from 0˚ and noise from 180˚) or five (signal from 0˚ and noise from 0˚, 90˚, 180˚, 270˚) loudspeakers.

Procedures

Most Comfortable Listening Level. Most comfortable listening levels (MCLs) were obtained for speech, music and cell phone ring stimuli in preparation for ANL testing. Once the listener was seated he or she was read the following instructions: “You will listen to either a story read by a male talker, music, or a telephone ring. After a few moments, select the loudness of the story that is most comfortable for you, as if listening to a radio. Please indicate whether you would like the story to be turned up or turned down until you reach the level that is most comfortable for you. You can tell me 'up', 'down', or 'stop' depending on if you want the level of the signal you are listening to be louder, softer, or 'stop' if it has reached a comfortable level. Remember, you will tell me 'stop' when the signal has reached the level you would like chose as if you were listening to a radio. Once this level has been found the test will be repeated three more times." The stimulus was introduced at 30 dB. The intensity of the stimulus was adjusted in 4 dB steps while the listener was exploring their listening range and 2 dB steps when the listener was selecting the final level. Final MCL was determined by calculating the median of the 4 runs, a method used with the Contour Test (Cox et al., 1995). This method was chosen because it is scientifically defensible procedure and it is commonly used in clinical settings.

Acceptable Background Noise Level. Once MCLs were established for all three signals, the maximum acceptable background noise levels (BNL) were measured using white noise and babble noise for the purpose of calculating ANL. The instructions were as follows: "Now you will be listening to two sounds at the same time coming from the loudspeakers in front of you. One of those will be one of the signals that you have been be either the sound of several people speaking at the same time or white noise. Pretend you are listening to music on a radio at work at a comfortable level and in the background your coworkers begin to speak. Their voices will become louder and louder. We are trying to establish the point when the background noise reaches the level when you would rather turn off the radio than continue listening to the radio with the competing noise present. In this scenario, the story, music or telephone ring is what you would want to coworkers speaking in the background. I will be adjusting the *noise* until you tell me it has reached a level that you would rather turn off the radio than continue to listen. You can tell me ‘up’ or ‘down’ until it has reached this level. Indicate that the level is at the point where you would rather turn off the radio then continue to listen with the competing noise present by saying the word ‘stop’. In this scenario it is not important that you understand everything that is being said on the radio but instead that the signal you are listening to is at a comfortable level with the competing noise also playing.” These instructions deviate from the instructions outlined for BNL in the Acceptable Noise Level Test procedure in order to clearly indicate to the listener that they are not listening for a level that interferes with speech recognition but rather a level that makes them want to turn off the signal. At this point in the test the established MCL for the signal was reintroduced and multi-talker babble or white noise was added at a beginning level of 25 dB SPL. The noise was adjusted in 4 dB/2dB steps in a manner similar to that used for determining the MCL in quiet. This was repeated 3 more times for a total of 4 runs. Final BNL was determined by averaging the 4 runs, a method used with the Contour Test (Cox et al., 1995).

Multi-talker babble and white noise were delivered from either one loudspeaker located at 0° azimuth or from 4 loudspeakers separated by 90° and surrounding the listener. The order of the signals, noises, and speaker conditions was randomized. Thus

12 ANLs were calculated for each participant (3 signals x 2 noises x 2 speaker array conditions).

Following the measurement of the 12 ANLs as described above, one additional test was conducted to further examine the effects of the spatial character of one of the background noises using one of the stimuli. Specifically, the ANL for multi-talker babble coming from directly behind (180°) the listener was measured using the male voice stimulus.

Data Analysis

This study used a randomized complete block design. Independent variables were signal type (recorded speech, music, telephone ring), noise type (babble, white noise) and loudspeaker configuration. The dependent variables were most comfortable listening level, established in quiet and in noise, and ANL. Descriptive analysis was used to examine MCL and ANL data. Repeated measures analysis of variance (ANOVA) was used to examine the main effects of signal type, noise, loudspeaker array and the interaction between these variables.

Chapter 4

Results

Most Comfortable Listening (MCL) Level

MCL levels for a phone ring, speech and music were obtained via sound field for each participant. The MCL values for each participant and the mean and standard deviation for speech, music and phone stimuli are shown in Table 1. Examination of Table 1 indicates average MCL varied from 47.8-49.3 dB SPL with the lowest for music and the highest for speech stimuli. A repeated measures analysis of variance test indicated no significant differences in MCL across stimuli, F (2, 36) = 0.879, p = .424.

ANLs for All Signals, All Noises, and All Loudspeaker Arrays

Acceptable Noise Level (ANL) ANLs for telephone ring and music stimuli were obtained using 12-talker babble noise and white noise via soundfield in two separate loudspeaker conditions. ANLs for speech were also obtained for these two conditions and one additional condition. The first two loudspeaker conditions are discussed below and the additional loudspeaker condition is discussed separately.

The first condition consisted of both the signal and noise presented at 0° only and the second condition was with the signal presented at 0° and noise presented at 0°, 90°, 180° and 270° (surround). Mean data for these conditions are shown in Figure 9 and listed in Table 2. Examination of Figure 9 and Table 3 indicates that the mean ANL differences between surround and 0° across stimuli conditions varied from 2.5 to 4.2 dB, For both 0° and surround noise, and in both white noise and babble noise, mean ANLs were greatest for speech and smallest for phone. Listeners were more tolerant of babble noise sound coming from all around them. Figure 10 shows these trends using a pseudo-3

Table 1. *MCL data reported in sound pressure level (dB SPL)*

	MCL		
Subject	Speech	Music	Phone
1	59.0	50.0	61.0
2	44.5	40.0	32.0
3	47.5	45.0	38.0
4	51.5	53.0	58.0
5	45.5	42.0	38.0
6	48.0	41.0	38.0
7	45.0	51.0	52.0
8	48.0	43.0	47.0
9	52.5	54.0	57.0
10	55.5	58.0	56.0
11	52.5	47.0	53.0
12	46.5	49.0	52.0
13	49.0	47.0	44.0
14	60.5	58.5	65.0
15	61.5	59.5	61.0
16	40.5	40.0	33.0
17	41.5	47.0	48.0
18	47.0	44.0	42.0
19	41.0	39.0	41.0
Mean	49.3	47.8	48.2
SD	6.3	6.5	10.0

dimensional figure. This figure clearly shows that participants were most tolerant of background noise with the telephone signal and least tolerate of background noise with the speech signal.

A 2x3x2 repeated measures analysis of variance was conducted to evaluate the effects of loudspeaker array (0°, surround), signal type (phone, speech, music), and noise type (babble, white) on ANL. The results indicated non-significant findings for signal type, F (2, 360) = 2.858, p =.070 and for noise type, F (1, 18) = 4.209, p = .055 and a significant finding for loudspeaker array, F (1, 18) = 19.48, p < .001. This indicates that listeners required a significantly greater ANL for the surround sound condition compared with the 0 degree condition, but the differences seen between noise and stimulus conditions did not reach significance. Note, however, that the differences approached significance, with p values at .07 and .055, indicating a slightly larger sample size may have shown significant differences between these main factors. None of the interactions was significant.

ANLs for 180º Babble Noise

ANLs were determined using speech stimuli at 0˚ and babble noise presented at 180°, and these data were compared with the previously discussed data collected for speech stimuli and babble noise in 0° and surround noise conditions. Mean ANLs for speech and babble for each loudspeaker array are illustrated in Table 2.

Table 2
Mean ANLs for Speech Stimuli

Mean ANLs for Speech Stimuli (MCL-BNL)				
	Babble		White Noise	
0°	180°	Surround	0°	Surround
4.8	3.8	7.5	4.8	9.0

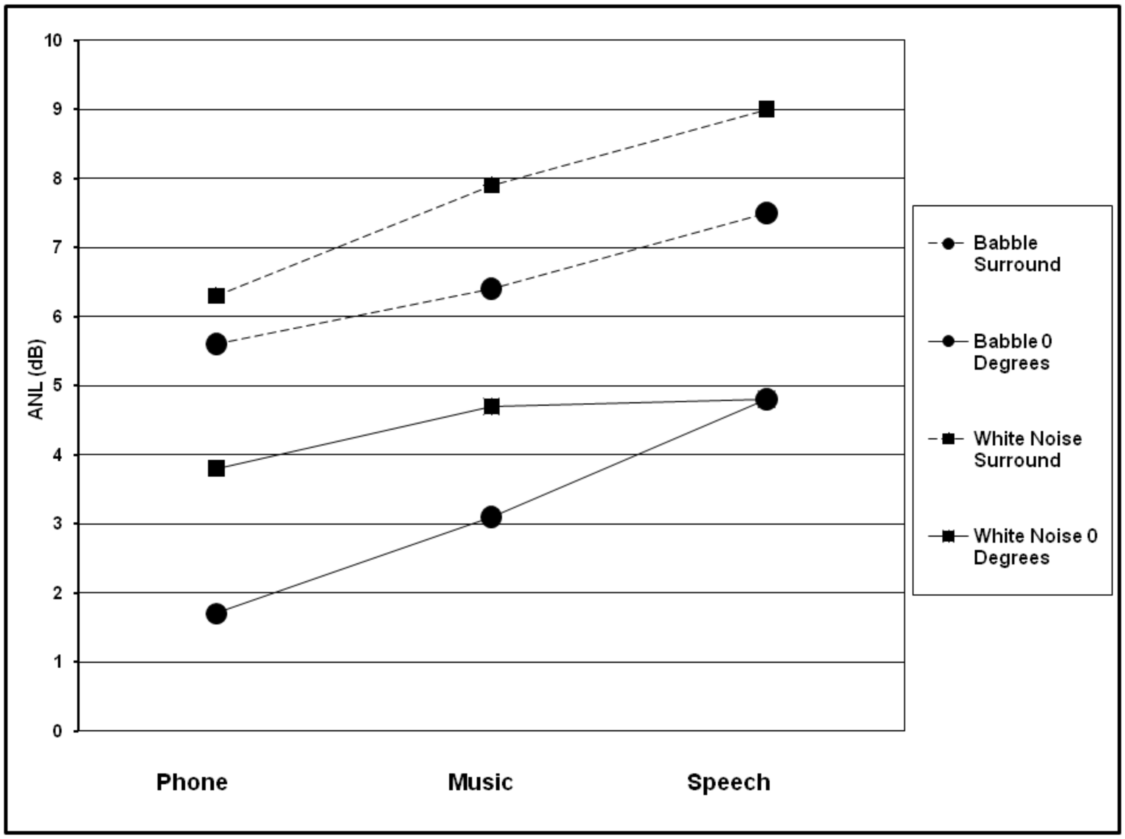

Figure 9 . Mean acceptable noise level (ANL) for phone, speech, and music signals obtained in white noise and multi-talker babble with noise at 0° azimuth and surround (see Table 3 for data). Circles represent babble noise condition, squares represent white noise condition, dashed lines represent surround condition, and solid lines represent front speaker condition.

Table 3

Data for Figure 9. Mean acceptable noise level (ANL; dB) for phone, speech, and music signals obtained in white noise and multi-talker babble with noise at 0° azimuth and surround noise

Test Condition	Phone Signal	Music Signal	Speech Signal
Babble Noise Surround	5.6	6.4	7.5
Babble Noise 0°	1.7	3.1	4.8
Difference (Surround 0°) for Babble Noise	3.9	3.4	2.7
White Noise Surround	6.3	7.9	9.0
White Noise 0°	3.8	4.7	4.8
Difference (Surround - 0°) for White Noise	2.5	3.2	4.2

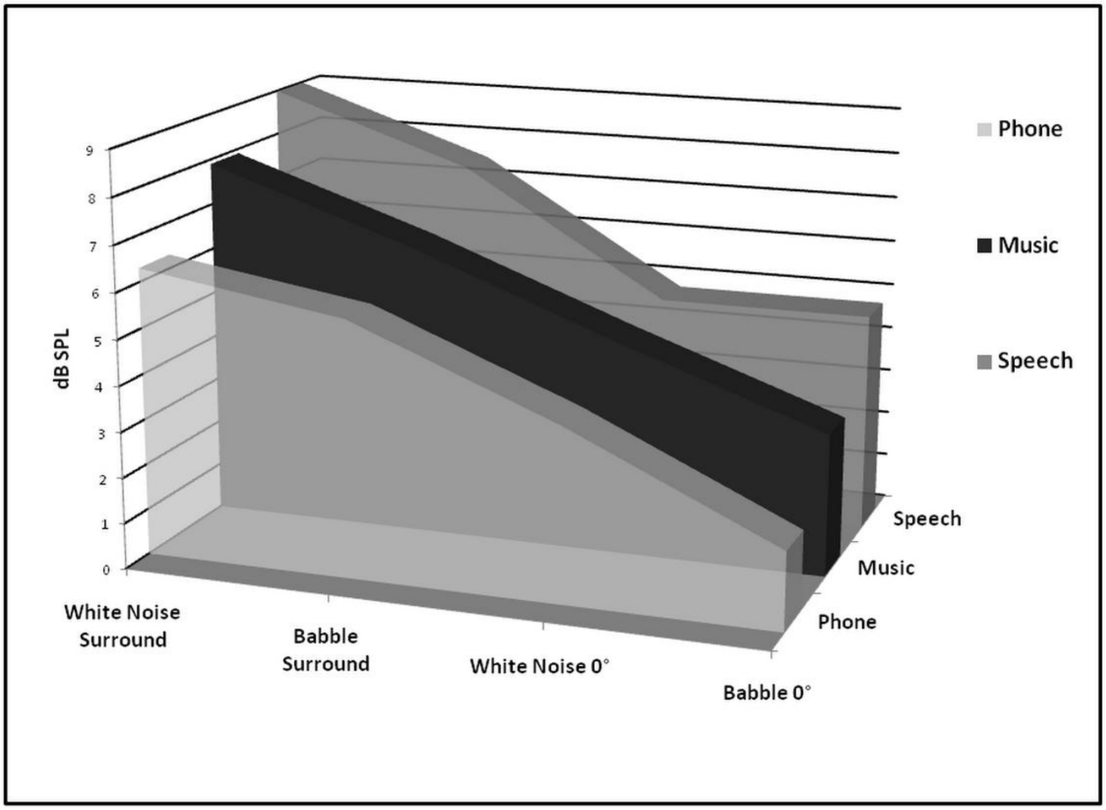

Figure 10. Mean acceptable noise level (ANL) for phone, speech, and music signals obtained in white noise and multi-talker babble with noise at 0° azimuth and surround noise.

Examination of this table indicates ANLs were greatest for the white noise surround condition (9.0 dB) and lowest for the 180° noise condition (3.8) with the 0° noise conditions in the middle (4.8), indicating a trend that listeners could most easily tolerate sound from the back (which is more removed from the sound source than sound from the front) and that sound surrounding the listener requires the largest ANL. A repeated measures analysis of variance indicated a significant main effect for loudspeaker array, $F(2, 36) = 11.219$, $p < .001$. Post-hoc analysis using the Bonferoni procedure indicated the surround condition was significantly different than the 0° and 180° conditions but the 0° and 180° conditions were not significantly different from each other.

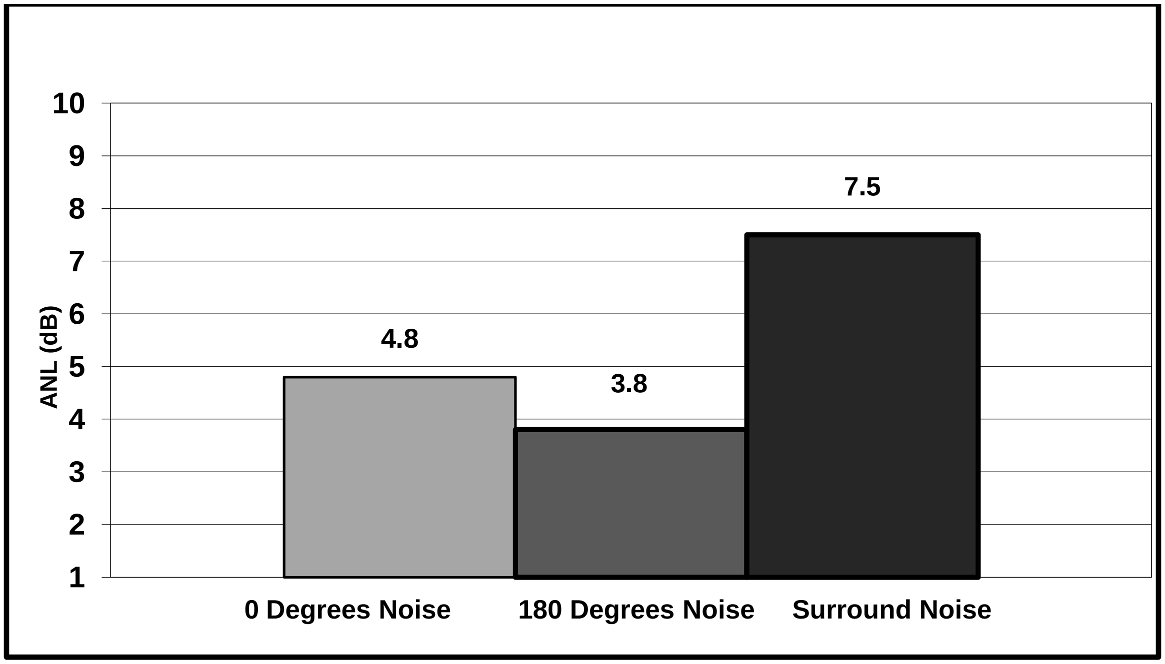

Figure 11. ANL means for speech in babble noise presented at 0° azimuth, 180° azimuth, and surround noise.

Chapter 5

Discussion

The purpose of this study was to determine if the direction of background noise, type of background noise and type of signal had an effect on ANLs for normal hearing listeners. Results showed no significant differences in ANLs across signal type and background noises; however, the results approached significance, with low *p* values (.07 for signal type and .055 for noise type). A significant difference was found for the direction of background noise, with surround sound associated with a significantly higher ANL compared with sound coming from just the front or just behind the listener.

MCLs

MCLs were recorded in the soundfield at 0° azimuth for speech, music and telephone ring stimuli. The mean MCL varied from 47.8-49.3 dB SPL across stimuli and was lowest for music and highest for speech. These MCL results are similar to or lower than other studies using speech stimuli. Specifically, in Rogers et al. (2003), the average MCL for female listeners recorded 1 meter from the listener at 0˚ azimuth using "running male speech" (unspecified source) was 36.2 dB HL (50.7 dB SPL), indicating results that were similar to the present study. This study used the same demographic of listeners (young [19 to 25 years old], normal hearing listeners) and speaker conditions (listener 1 meter from the meter away from a speaker placed 0˚ azimuth) as the present study and although it was not specified which speech stimuli was used, the author stated that it was male running speech. In 1971, Ventry, Woods, Rubin and Hill compared MCLs using various stimuli (pure tones, broad-and narrow-band noise, and connected speech) using Bekesy audiometry in young, normal hearing listeners. They found overall speech MCLs to be 49.3 dB SPL, noise MCLs to be 49.4 dB SPL and pure tone MCLs to be 51.7 dB SPL, consistent with the present study. Other studies showed higher overall MCLs. Franklin et al. (2006) found a mean MCL of 42.7 dB HL (57.2 SPL), which was 9-10 dB higher than the current values. The Franklin et al. (2006) study was the only prior study in which direct comparisons between the data can be made, since other studies that specifically stated that the Arizona Travelogue stimulus was used involved participants with hearing loss or the authors of the study did not discuss the MCLs in their results. However, studies using speech stimuli other than the Arizona Travelogue have also found MCL results that are higher than those found in the current study. For example, Punch et al. (2004) found typical MCLs for spondee words under headphones (using a 7-point loudness scale) to fall between 45 and 51 dB HL (59.5-65.5 SPL). It is unknown why the MCL values were approximately 10 dB lower than the values found in these prior studies; however, MCLs have not always been found to be reliable and investigations have shown that 95% of common MCL tests have test/re-test results that vary between 8 and 12 dB HL (Sammeth et al., 1989).

Individual MCLs varied more for the phone stimuli (SD = 10) compared with the music (SD= 6.5) and speech stimuli (SD = 6.3). The phone stimulus was associated with the lowest individual MCLs including 5 responses lower than 40 dB SPL (e.g., 32, 33, 38, 38, 38). In contrast only one individual MCL for music was less than 40 (e.g., 39 dB SPL), and none of the individual speech MCLs were lower than 40 dB (lowest speech MCL was 41.0 dB SPL). This is not surprising considering, as previously discussed, that the phone serves solely as an alerting device and the enjoyment of this signal is irrelevant. Furthermore, the listener’s were primarily college students, who would frequently be listening to a phone ring from a pocket, backpack, or purse, which would be expected to be at quite a low level. It is also possible that the ring tone was not the one the participants used, which may remind them of the phone ring for others, which would not be a sound level they would want to be at a loud intensity

Some factors that may contribute to inconsistent MCLs may be due to the fact that many of the participants were audiology students (which could have biased them towards lower levels due to their experience with threshold testing), that the MCL was obtained using an ascending approach, which has been shown in the psychophysical literature to result in lower levels (Ventry & Johnson, 1978), or that slight forward movements of the listener may have increased the actual level at the listener's ear, due to the close proximity of the listener to the speaker (e.g., a motion forward of 6" within a total distance of 3' from speaker to listener would result in an increase of 2 dB in the signal).

ANLs

Background Noise.

The trend seen in the data indicated that listeners found white noise to be more interfering than speech noise, possibly because of their familiarity with speech noise in their everyday lives; however, the differences did not reach statistical significance (p = .055). The trend seen in the data is consistent with previous research, which has indicated that larger ANLs are associated with noises such as white noise, speech spectrum noise, and pink noise compared with babble (e.g., Kattel et al., 2008; Nabelek et al., 1991). In Kattel et al., results showed that there was no significant difference for signal type when comparing the 45˚, 45˚ speech and 0˚ noise condition with the condition with speech at 90˚ and noise at 0˚ and 180˚; however, there was a significance difference in signal type when comparing the 45˚, 45˚ music and 0˚ noise condition with the 45˚, 45˚ speech and 0˚ noise condition. Although for the current sample, the type of background noise (babble, white noise) did not have a statistically significant effect on ANLs, a future study with a larger sample size and more carefully controlled methodology may yield data more consistent with that found in the literature

Signal Type

Mean ANLs were lowest for phone and highest for speech stimuli, with music falling between the two. The trend in the ANL data suggests that as signals become more important for the listener or a better ANL becomes critical for the task at hand, the ANL increases. This is logical, given that the task associated with speech is understanding, the task associated with music is enjoyment, and the task associated with the phone signal is simply detecting an alerting sound. When individuals listen to music and speech a "comfortable" level would be that in which the signal is loud enough to perceive and for the listener to be comfortable with the harmony and rhythm for music or to understand most of the words for speech. In contrast, the purpose of a telephone ring is detection of a signal (alerting device) and the understanding or enjoyment of the signal is irrelevant. Although ANLs were consistently greater when tested using speech stimuli compared to music and phone stimuli, the differences did not reach statistical significance (p = .07). As in the results for the background noise, it is possible that future research with a larger sample size and more carefully controlled methodology will yield a clearer picture of the effect of stimuli on MCL. Only one prior study, Kattel et al. (2008), examined ANLs using speech and music as signals for ANLs. In the Kattel study, ANLs were measured for music and speech in pink noise, babble and white noise. Music and speech were measured with the signal at 90˚ and noise at 0˚ and 180˚. Additionally, ANLs were measured with the signal at + 45˚ and -45˚ and the noise at 0˚. The Kattel study found a significant difference when using speech versus music for ANLs, supporting the trend seen in the present study. The differences in speaker position and the omission of phone stimuli precludes a true comparison between the studies.

Magnitude of ANL Values Compared with Previous Research.

The ANLs obtained in this study for the babble and speech at 0° azimuth condition were lower when compared to those obtained in previous studies which used similar testing conditions, although ANLs from past research are somewhat varied. Table 7 illustrates the descriptive statistics and compares methodologies of these and other studies. Examination of this table indicates the mean ANL for speech at 0° for the present study (4.8 dB) was considerably less than ANLs seen in previous research. Specifically, Franklin et al. (2006), Freyaldhoven et al. (2006) and Gordon-Hickey and Moore (2007) found mean ANLs to be 15.5, 12.9, 9.92 dB, respectively. Freyaldhoven et al. (2006) used a recording of a female talker (Auditec Audio) reading from a book, while the other two studies used the same male talker as in the present study; thus, the current data are about 5 dB to 11 dB less than those found in the two directly comparable studies. It is unknown why this occurred. A possible reason is because MCLs were lower in the present study compared other studies suggesting that the listeners may have used a different criteria overall to indicate both their comfort level and the level of background noise they would tolerate. Another possible reason is the specific instructions that were given to the listeners during testing. Specifically, when the examiner was determining ANL, listeners were told that it was not important that they understand the signal but that they choose a level that was comfortable. Although the overall trend showed greater ANLs for more "important" stimuli, it is possible that these instructions lead to the listener choosing a much lower ANL than has been seen in past literature. The ANLs from the current study continue to show the trend of the large range of differences in acceptable noise levels throughout the literature.

Table 4
ANL results from the current study and from five prior studies

Study	N	Signal Type	Loudspeaker Array		SD	Range	Mean ANL in dB
Present Study	19	Male Talker	0°	B	4.7	-4.5 to 13.0	4.8
Present Study	19	Male Talker	0°	W	6.0	-6.5 to 17.0	4.8
Present Study	19	Male Talker	Surround	B	5.6	-4.4 to 19.1	7.5
Present Study	19	Male Talker	Surround	W	7.1	-5.4 to 26.6	9.0
Present Study	19	Male Talker	180°	B	4.7	-5.9 to 10.1	3.8
Present Study	19	Male Talker	180°	W	N/A	N/A	N/A
Present Study	19	Music	0°	B	5.3	-9.0 to 12	3.1
Present Study	19	Music	0°	W	6.7	-6.0 to 18.0	4.7
Present Study	19	Music	Surround	B	7.7	-13.4 to 15.6	6.4
Present Study	19	Music	Surround	W	8.6	-11.9 to 24.0	7.9
Present Study	19	Music	180°	B	N/A	N/A	N/A
Present Study	19	Music	180°	W	N/A	N/A	N/A
Present Study	19	Telephone	0°	B	8.1	-15.0 to 15.0	1.7

				W	7.9	-11.0 to 16.0	3.8
			Surround	B	8.7	-12.9 to 20.1	5.6
				W	8.2	-12.9 to 17.6	6.3
			180°	B	N/A	N/A	N/A
				W	N/A	N/A	N/A
Freyaldhoven et al., 2005	40	Male Talker	0°/180°	B	2.9	-4 to 12	3.5
Freyaldhoven et al., 2006	30	Female Talker	0°	B	5.2	4 to 24	12.9
				SS	5.0	8 to 24	15.0
Gordon-Hickey and Moore 2007	24	Male Talker	0°	B	N/A	N/A	[b]9.92
				[a]M			6.25
Franklin et al., 2006	20	Male Talker	0°	B	7.3	N/A	15.5
Nabelek et al., 1991	15	Female Talker	Headphones	B	8.50	5 to 37	15.9
Kattel et al., 2008	20	Music and Male Taker	45°, 45°/0°, 180° Music	B	7.3	2.5 to 30.0	13.1
				W	11.6	5.5 to 32	21.1
				P N	7.8	3 to 30.5	14.8
			90°/0°, 180° Speech	B	6.8	3 to 29.5	13.6

		W	10.5	7.5 to 38.0	21.2
		PN	7.3	2-32.0	14.7
	45°, 45°/0°, 180° Speech	B	7.3	0.5 to 26.5	11.6
		W	9.1	7.5 to 37.5	19.0
		PN	7.2	2 to 29.5	12.2

Note. B=Babble, W=White Noise, S=Speech, P=Phone, M=Music, SS=Speech Spectrum Noise, PN=Pink Noise
[a]These levels were not tested.
[b]ANL was averaged across 7 means for ANL in music as averaged by Gordon-Hickey and Moore 2007. Standard Deviations and ranges for individuals were divided among 2 groups and with no total means were provided

Loudspeaker Array.

Results from this study showed that ANLs were significantly different for surround speaker condition compared with 0° and 180° conditions. For the comparison between 0° and surround for the phone, music, and speech stimuli, the use of a single loudspeaker was associated with mean ANLs that were 2.5-4.2 lower than for the surround speaker condition. ANLs in babble for speech were different by about 1 dB for the 0° and 180° conditions, which was not statistically significant. These results were not surprising because past research has shown when maskers are separated from a target (signal) by ± 15°, the average spatial release from masking was 8 dB (Marrone, Mason & Kidd, 2008). Although this research did not require the participant to understand the signal, it would be logical to propose that a smaller ANL would be found when the signal and noise were coming from the same direction.

Limitations and Future Research

Further research is needed to resolve several issues that occurred in the present study. First, merging the 0° signals from two separate speakers into one would be ideal. Because of limitations due to work space in the test laboratory, the speakers surrounding the listener were closer than ideal (3 feet). This may have caused the listener to be able to more clearly hear the two sounds from the front than in the surround sound condition and moving the head a small distance from one direction to another may have cause large changes in perception. If it had been possible to introduce the 0° signals from the same speaker, the ANLs may be different. In addition, several issues were discovered including attenuation due to wiring of the speakers, the use of a sound level meter that was especially sensitive to low frequencies and appeared to have been affected by the noise floor (mainly caused by the fan noise from the computer used to control the audiometer), and the use of an audiometer system that was not linear (this was accounted for with the calibration and correction procedures). Furthermore, a wider variety in the demographic of listeners should be used. In the present study, the listeners were overwhelmingly female audiology graduate students. An ideal study would include more male listeners and listeners who have less of an understanding of what was being investigated. In addition, further investigation of the effect of the type of signal and type of background noise should be conducted with a larger subject pool to further investigate the present studies results that bordered significance.

Summary

In summary, results showed a significant difference for surround sound loudspeaker array compared with speakers from one direction, with a larger ANL associated with multiple loud speakers but no significant differences in ANLs across noise type or stimulus type. ANLs showed a trend toward more "important" signals (speech and music versus telephone ring) having larger ANLs, however these results were not statistically significant. Though statistically not dependent on the type of signal used for testing, speech and music signals had the highest ANLs when compared with the telephone signal (i.e., the trend showed that listeners were willing to tolerate more background noise when listening to an alerting signal compared with listening to a more meaningful signal). The type of background noise presented also showed a trend that indicated listeners were able to accept more babble background noise compared to white noise, possibly because the speech babble is more familiar or because the white noise, which has a wider frequency spectrum, is more annoying overall; however, this trend was not statistically significant. The differences between the current study and the results reported in the literature and the limitations of the study (previously discussed) indicate that this study should be repeated with more carefully controlled methodology.

APPENDIX A

TOWSON UNIVERSITY

APPROVAL NUMBER: 10-A017

To: Colleen Moore
6122 Parkway Drive 2nd floor
Baltimore MD 21212

From: Institutional Review Board for the Protection of Human Subjects, Larry Wimmers

Date: Wednesday, September 23, 2009

RE: Application for Approval of Research Involving the Use of Human Participants

APPROVED SEP 23 2009 TOWSON IRB

Office of University Research Services
Towson University
8000 York Road
Towson, MD 21252-0001
t. 410 704-2336
f. 410 704-4494

Thank you for submitting an Application for Approval of Research Involving the Use of Human Participants to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University. The IRB hereby approves your proposal titled:

THE EFFECT OF TWO NOISES ON THE MOST COMFORTABLE LISTENING LEVEL OF SPEECH, MUSIC AND TELEPHONE SIGNALS

If you should encounter any new risks, reactions, or injuries while conducting your research, please notify the IRB. Should your research extend beyond one year in duration, or should there be substantive changes in your research protocol, you will need to submit another application for approval at that time.

We wish you every success in your research project. If you have any questions, please call me at (410) 704-2236.

CC: D. Emanuel
File

TOWSON UNIVERSITY
INFORMED CONSENT FORM

Title of Study: THE EFFECT OF TWO NOISES ON THE MOST COMFORTABLE LISTENING LEVEL OF SPEECH, MUSIC AND TELEPHONE SIGNALS

Principal Investigator: Colleen E. Moore
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Purpose of the Study:

To examine the effects of two noises on the comfortable listening level when listening to speech, music, and a telephone ring. Participants will be asked to identify the level when background noise reaches a level that begins to interfere with the signal that they are trying to listen to (speech, music and telephone ring).

Participants:

Adult volunteers (ages 18-30) with normal hearing and middle ear function will serve as participants for this investigation. All participants will meet the inclusion criteria for the study, including: 1); normal hearing sensitivity 2); cognitive skills and endurance to complete all testing 3) native speaker of English; and, 4) motivated to participate in this investigation.

Procedures:

Prior to participation in this investigation, you will undergo a complete audiological evaluation. You will listen to various tones under headphones and indicate when you hear them. A test of middle ear function will also be performed. These tests are routinely performed to determine if an individual has a hearing loss. All testing will be completed by a Towson University Doctor of Audiology (Au.D.) student who has completed 3 years of clinical and didactic training.

After the informed consent document is signed, testing will begin. All testing will take place in a sound treated booth with multiple speakers. You will be asked to listen to a story being read by a man, music and a telephone ring presented in random order. The three different sounds will first be presented by themselves and then with background noise present. When the signals are presented in quiet you will be asked to indicate to the investigator to turn up the signal until it reaches a level that is most comfortable to you. You will then be asked to listen to the signal at the comfortable level with background noise present. The background noise will be introduced at a very quiet level. You will be asked to signal to the investigator to turn the background noise up or down until it reaches a level that the noise begins to interfere with the signal in a way that would make you want to turn off the signal if it were your radio at home, and noise was present.

Overall, it is expected that you will participate in one visit, which will last for approximately 1.5 hours.

Benefits:

It is hoped that the results of this study will provide a greater understanding of how different types of background noise and the directions of those noises affects the most comfortable listening level when listening to a signal.

Risks:

There are no known risks associated with participation in this study. Standard audiological testing will be utilized. The sound intensity levels will be carefully monitored, and will be no louder than the level of normal or slightly above normal conversational speech. Should the assessment become distressing to you, testing will be terminated immediately.

Cost Compensation:

1. There will be no cost compensation for participation in this study.

Rights as a Participant:

1. Your participation in this study will remain strictly confidential. Only the Principal Investigator will have access to your identity and information associated with your identity. All participants' identifying information (name, audiometric information, and contact information) will appear only on a roster that will be stored in a cabinet in the Center for Amplification, Rehabilitation, and Listening (CARL) lab. This lab remains locked at all times. The CARL lab is located in Van Bokkelen, room 109B. Upon completion of the study, the master roster will be destroyed. All other tests will be kept locked in a cabinet in the CARL lab.

2. Participation in this study is voluntary. At any time prior to or during the study, you are free to discontinue participation. A decision not to participate or to withdraw from the study will have no effect on your status or any current or future services that you may be receiving at the Towson University Speech-Language-Hearing Center.

3. You are free to ask questions regarding the study and/or the test procedures. These questions will be answered to the best ability of the investigator.

4. If any questions should arise regarding the study, please contact the Principal Investigator, Colleen Moore, at (352) 371-8621, Dr. Diana Emanuel, research advisor, (410) 704-2417, or the Institutional Review Board Chairperson, Dr. Patricia Alt, Office of University Research Services, at (410) 704-2236.

Informed Consent:

_____ I have read and understood the information on this form.

_____ I have had the information on this form explained to me.

__________________________________ _______________
Subject's Signature Date

__________________________________ _______________
Witness to Consent Procedures* Date

__________________________________ _______________
Principal Investigator Date

*If investigator is not the person who will witness participant's signature, then the person administering the informed consent should write his/her name and title on the "witness" line.

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY.

IRB Approval Number: 10-A017

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