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A protocol for sound localization testing with young and aging normal hearing subjects

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A PROTOCOL FOR SOUND LOCALIZATION TESTING WITH YOUNG AND AGING NORMAL HEARING SUBJECTS

by

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A Dissertation Presented in Partial Fulfillment
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ABSTRACT

An important aspect of processing auditory stimulus is the ability to localize the source of a sound within the environment. Localization has been defined as the ability to determine the direction of sound (Tonning, 1975; Cranford, Boose, & Moore, 1990; Middlebrooks & Green, 1991; Cranford Andres, Piatz, & Reissig, 1993; Lorenzi Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000). Previous researchers have used a variety of test stimuli, test environments, loudspeaker arrays, and ages and numbers of subjects to measure the ability to localize sounds. Despite the obvious need for individuals to identify the specific location of a sound source, the variety of approaches suggests that there is no standard process for measuring localization abilities. As there is no gold standard for localization assessment, it is difficult to compare previous studies of localization. Therefore, a standardized protocol for measuring localization abilities would attenuate the need to vary testing procedures while determining an individual's ability to identify sound sources as part of a complete audiological assessment.

Forty male and 40 female adults, ages 21 to 60 years with normal hearing sensitivity and normal temporal processing abilities, will be used as subjects in this study. A protocol for localization testing developed by the primary investigator will be used to measure the subjects' localization abilities.

All testing will be completed in an IAC sound treated room, using eight sound field speakers. Each speaker will be arranged symmetrically on the wall, positioned within the horizontal plane with 45 degree intervals between each. The Central Institute for the Deaf Everyday Sentences (Alpiner & Schow, 2000; Healy & Montgomery, 2006) will be used as test stimuli. Five test conditions, one quiet and four noisy listening conditions, will be used to identify elicit localization. Of particular interest is the direction at which a subject can localize a speech stimulus accurately in the presence of background noise.

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CHAPTER I

INTRODUCTION, REVIEW OF LITERATURE, AND STATEMENT OF THE PROBLEM

Introduction

The ability to localize the source of a sound within an environment is an important aspect of processing auditory stimuli. There is general agreement that localization is the ability to determine the direction of sound (Tonning, 1975; Cranford, Boose, & Moore, 1990; Middlebrooks & Green, 1991; Cranford, Andres, Piatz, & Reissig, 1993; Lorenzi, Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000). However, the direction of sound can be variable and sounds do not always travel in a straight line.

Anatomical orientation and physiological processes contribute to the ability to localize sound. Localization is made possible through the use of two ears (binaural interaction). The physical placement of the ears, on each side of the head, contributes to localization by providing cues as to which ear is closest to the sound source if the source is not directly in front of a listener.

The anatomical location of the ears, used in conjunction with head turns and pinna traits, enhances localization. The ability of an individual to turn his or her head enhances localization by decreasing the distance between the ear nearest the source (near ear) which in turn can increase accurate perception of sound stimuli (Middlebrooks & Green, 1991).

However, head turns are initiated and preceded by cues generated as a result of the physical composition of the ear known as pinna traits. These traits include the shape of the ear and its composition of skin and cartilage. These pinna traits combine to produce shadowing effects. As Middlebrooks and Green suggested, these shadowing effects create complex echoes and perceptions of a sound source when sound stimuli originate from behind a listener. Sound stimuli differ in time of arrival (interaural time differences) and in intensity (interaural intensity differences).

The interaural time difference is the difference in time between the perception of sound by the ears. The ear closest to the source is known as the near ear while the ear furthest from the source is known as the far ear. However, interaural time differences are not always sufficient to accurately localize sound. For example, the wavelengths of sounds above 1500 Hz are not of sufficient length to bend around the head and thus be detected by the far ear within causing a reduction in time. Therefore, interaural time differences cues are used to accurately localize a low frequency sound wave below 1500 Hz.

Sounds above 1500 Hz require a different method of localization. The sounds are localized by differences in intensity, referred to as interaural intensity differences. Intensity differences are used for sounds above 1500 Hz because their decreased wavelength does not allow them to "bend" easily around the head to the far ear, thus eliminating any differences in time. For these high frequency sounds above 1500 Hz, a

35 dB difference in intensity may co-exist between the ears. The sound that reaches the far ear will be attenuated, therefore creating an interaural intensity difference between the two ears.

Localization of sound is also determined by the efficiency of temporal processing which has been defined by Chermak and Lee (2005) as a time-related aspect of processing auditory information. Temporal processing, as a central auditory function, will vary among individuals depending on hearing sensitivity and age. There tends to be agreement among authorities (Warren, Wagener & Herman, 1978; Cranford, Boose, & Moore, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Noble & Byrne, 1990; Lorenzi, Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000) that temporal processing abilities decline as a function of hearing loss and age.

Despite the importance of determining the specific location of a sound source, localization is rarely assessed during an audiometric evaluation. Nor does there appear to be a standard process or protocol to measure localization abilities. Researchers (Cranford, Boose, & Moore, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Noble & Byrne, 1990; Lorenzi, Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000) who have investigated localization procedures used a variety of test stimuli, test environments, and loudspeaker arrays to measure localization with individuals of different ages. A standardized method for assessing localization would not only encourage audiologists to assess this important function but would contribute to the usability of assessment data obtained about their clients.

Review of Literature

The ability to localize the source of a sound within an environment is an important contributor to one's success in processing auditory stimuli. Localization is used to determine the specific location of a sound source. Localization is made possible through the use of two important auditory cues, interaural time and intensity differences. Interaural time difference is the difference in time between the perception of sound stimuli between the ears. Interaural intensity difference is the difference in intensity between the perception of sound stimuli between the ears.

The following review of literature will focus on several anatomical and physiological processes that contribute to the ability to localize a sound source. In addition, information will be presented on localization in young and aging normal hearing subjects, localization in noise, lateralization within the auditory system, and localization within the vertical and horizontal planes.

Anatomy and Physiology of the Auditory System

The ability of an individual to use two ears improves perception and accuracy in sound localization. Within the brain, a sound may be detected and localized almost instantaneously. In order for this to occur, certain areas and components within the auditory anatomical system participate in localization functions.

The auditory system is divided into peripheral and central pathways. Anatomically, the peripheral system contains the outer, middle, and inner ears. The peripheral system is crucial to localization because of its ability to collect sound waves and funnel the waves to the central auditory system. Therefore, the detection of the sound stimulus is initially dependent upon the peripheral auditory system and the systems' abilities to transmit the sound stimulus to the central auditory system. The central pathways contain the eighth nerve, lower brainstem, and the auditory cortex. Therefore, when an individual perceives sound stimuli, the sound waves are detected by the peripheral system and then travel through the central auditory pathway to the auditory cortex, where processing of the stimuli occurs (Jerger, Chmiel, Wilson, & Luchi, 1995).

Outer Ear. The first component within the peripheral system is the outer ear which contains the pinna and the external auditory meatus. The pinna helps to provide localization cues as to the direction of a sound source, i.e., whether the sound originates from the front or back, side, vertical, or horizontal position to the individual. The pinna and the external auditory meatus (the ear canal) aid in the collection of a sound stimulus and funnel the waves to the middle ear system.

Middle Ear. After sound waves are collected by the outer ear, the waves travel through the external auditory meatus (ear canal) to the tympanic membrane (the eardrum). The sound waves subsequently strike the tympanic membrane, causing the ossicular chain to be set into vibration. The ossicular chain consists of three tiny bones, the malleus, incus, and stapes. When the ossicular chain is set into vibration, the sound waves are then transferred to the inner ear.

Inner Ear. The inner ear houses the cochlea which is the end organ of hearing and balance. The cochlea is a fluid-filled structure and contains hair cells. Sound waves that cause the ossicular chain to vibrate are then sent along the auditory pathway to the inner ear via the oval window. The fluid-filled cochlea is set into vibration by a traveling wave-like motion which in turn causes the basilar membrane to become stimulated. The sound stimulus acts as a pressure wave that travels along the basilar membrane from the base towards the apex. Due to the basilar membrane displacement, the outer hair cells become stimulated (Rappaport & Provencal, 2002). The result is the transmission of sound waves to the eighth cranial nerve.

Eighth Nerve. Jerger et al (1995) along with Martin and Clark (2003) described the eighth cranial nerve within the peripheral system as having two branches, the auditory branch which arises from the cochlea, and the vestibular branch, which arises from the semicircular canals, saccule, and utricle (the balance portion of the inner ear). The vestibular branch merges with the cochlear branch after it exits the cochlea. The auditory branch carries sound wave information to the brainstem while the vestibular branch facilitates function of equilibrium only. Arousal of the cochlea hair cells produces chemical changes that activate electrical impulses in the eighth nerve fibers. These electrical impulses then travel up the nerve fibers to the cochlear nucleus.

Lower Brainstem. The auditory brainstem contains structures and connections that are effective for binaural interaction of an auditory signal. Binaural interaction has been defined by Middlebrooks and Green (1991) as information from both ears that has been collected and processed within the brainstem. These auditory brainstem structures consist of the cochlear nucleus and its divisions, superior olivary complex and its divisions, lateral lemniscus and its divisions, and inferior colliculus and its divisions.

Cochlear Nucleus and its Divisions. The cochlear nucleus is the first component in the lower brainstem. Moore (1991) discussed the three major divisions of the cochlear nucleus. The first major division, the anterior ventral cochlear nucleus, transmits information to the medial superior olivary complex, lateral superior olivary complex, medial nucleus of the trapezoid body, and the inferior colliculus. As the second major division of the cochlear nucleus, the posterior ventral cochlear nucleus sends information to the lateral lemniscus and inferior colliculus. The third major division, the dorsal cochlear nucleus, sends information to the lateral lemniscus. The neurons of the cochlear nucleus branch out to innervate the superior olivary complex, the nuclei of the lateral lemniscus, and the inferior colliculus.

Superior Olivary Complex and its Divisions. The superior olivary complex is essential for accurate localization of a sound stimulus. Jerger et al (1995) identified each of the three major components of the superior olivary complex as the medial superior olivary complex, the lateral superior olivary complex, and the medial nucleus of the trapezoid body. Neurons in the medial superior olivary complex receive direct information from the anterior ventral cochlear nucleus. The medial superior olivary complex neurons are thought to initially process localization information for interaural time differences, thus aiding in the detection of low frequency sound stimuli.

The ipsilateral lateral superior olivary complex neurons are also found within the superior olivary complex and receive direct information from the anterior ventral cochlear nucleus. The lateral superior olivary complex neurons are thought to process information for interaural intensity differences, for high frequency sound stimuli. The medial nucleus of the trapezoid body receives input from the anterior ventral cochlear nucleus and sends the information to the lateral superior olivary complex.

Lateral Lemniscus and its Divisions. The nuclei of the lateral lemniscus has two important divisions, the dorsal nucleus and the ventral nucleus (Moore, 1991). The cochlear nucleus sends localization information to the contralateral ventral nucleus of the lateral lemniscus. The anterior ventral cochlear nucleus of the cochlear nucleus also sends direct information bilaterally to the dorsal nucleus of the lateral lemniscus. Binaural interaction occurs between the lateral superior olivary complex, sending information to the dorsal nucleus of the lateral lemniscus bilaterally. This is in cooperation with the medial superior olivary complex which sends information to the ipsilateral dorsal nucleus of the lateral lemniscus.

Inferior Colliculus and its Divisions. As described by Moore, the inferior colliculus has three components, the central nucleus, the pericentral nucleus, and the dorsal cortex. All three components of the cochlear nucleus send localization information to the contralateral central nucleus of the inferior colliculus. The pathways from the cochlear nucleus to each of these anatomical sites overlap extensively and as a result binaural interaction appears to occur almost simultaneously at several sites within the brainstem. As supported by Jerger et al (1995) and Moore (1991), several components within the peripheral and central system are needed for accurate localization of a sound stimulus. Localization of a sound stimulus has been studied in young and aging normal hearing subjects in quiet as well as noise simulated conditions.

Localization of a Sound Stimulus

An important aspect of processing auditory stimulus is the ability to localize the source of sound within the environment regardless of whether the sound is in the vertical or horizontal planes. Localization has been defined as the ability to determine the direction of sound (Tonning, 1975; Cranford, Boose, & Moore, 1990; Middlebrooks & Green, 1991; Cranford Andres, Piatz, & Reissig, 1993; Lorenzi Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000). Localization is made possible through anatomical orientation and physiological processes that contribute to one's ability to localize a sound source.

Localizing sound stimuli also relies upon interaural time and intensity differences. Interaural time difference is the difference in the perception of sound between the two ears which is used to accurately localize a low frequency sound wave below 1500 Hz. Interaural intensity differences are differences in intensity of the perceptions of sound between the ears. Intensity differences are used for sounds above 1500 Hz because their decreased wavelength does not allow them to "bend" easily around the head to the far ear, thus eliminating any differences in time. The sound that reaches the far ear will be attenuated, therefore creating an interaural intensity difference between the ears.

Localization within Normal Hearing Subjects

Normal hearing sensitivity can be determined by pure tone testing through air conduction and bone conduction at each octave frequency of 250 to 8000 Hz of 25 dB HL or better, bilaterally. Two significant factors allow an individual with normal hearing sensitivity bilaterally to localize a sound source. The first factor is the differences in intensity which are significant in detecting the source of a sound stimulus. Time differences as the second factor are significant for detecting the position of a sound stimulus.

Tonning (1975) investigated the clinical application of auditory localization abilities. Thirty subjects with normal hearing were positioned in the center of an anechoic room. Localization testing used one loudspeaker which was invisible to the subject and placed at subject ear level within the horizontal plane. Each speaker was positioned 0.9 meters from the subject's head. As depicted in Figure 1.1, the loudspeaker was randomly placed at 12 positions around the subject at 30-degree intervals. White noise was used as the test stimuli. Tonning found that all the subjects scored accurately on the localization task when the loudspeaker was placed in the front position between 90 and 270 degrees. However, more incorrect responses were recorded when the loudspeaker was positioned behind the subject, ranging from 120 to 240 degrees.

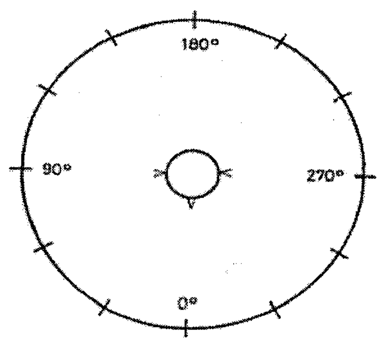


Figure 1.1. One Loudspeaker Array.

From Auditory Localization and its Clinical Application by F.M. Tonning, 1975, *Audiology*, 14, p. 371.

To address their interest in the influence of pinna-based spectral cues on sound localization within the horizontal plane, Musicant and Butler (1984) investigated localization abilities in normal hearing subjects. Eight subjects, five males and three females, with normal hearing sensitivity were used as subjects. For purposes of their study, Musicant and Butler defined normal hearing sensitivity as 15 dB HL or less at octave frequencies of 125 to 8000 Hz. The eight subjects were tested in a sound treated room with 13 loudspeakers, placed at 15-degree intervals. Based on the authors' description, the arrangement of the test environment can be conceptualized as shown in Figure 1.2. Each speaker was hung 1.5 meters from the subject's ear level within the horizontal plane. The subjects sat in the center of the 13 loudspeaker array, facing the #1 front loudspeaker. During sound presentation, the subjects were instructed to hold their head and eyes steady while facing forward. After the stimulus was presented, the subjects verbally identified the loudspeaker number from which they heard the sound.

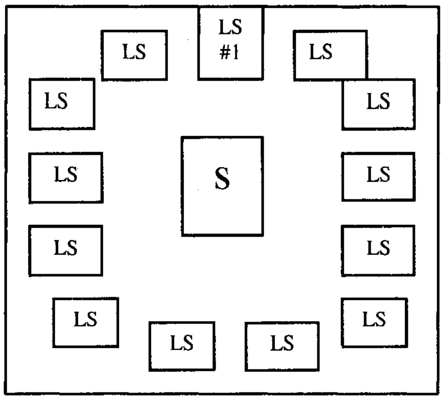


Figure 1.2. Thirteen Loudspeaker Array.

Musicant and Butler used broadband, a 4000 Hz high pass noise, a 1000 Hz low pass noise, and a 4000 Hz low pass noise as the noise stimuli for localization testing. Each noise stimulus consisted of 15 pulses, lasting approximately 30 msec in duration. A delay of 3 to 5 seconds separated each train pulse test trial. The noise stimuli were randomly presented through one of the 13 loudspeakers, one at a time. Each speaker emitted a sound stimulus 10 times at a level of 40 dB SL, for a total of 130 presentations to each subject. The 40 dB SL presentation setting was based on threshold measurements obtained from loudspeaker presentations before localization testing began.

Musicant and Butler found no significant difference between the broadband noise stimulus and the 4000 Hz high pass noise stimuli. However, the subjects scored significantly less ($p<0.01$) as compared to the 1000 Hz and 4000 Hz low pass noise stimuli. All subject scores were comparable for the 1000 and 4000 Hz low pass localization trials.

Musicant and Butler noted that front-rear reversals for the broadband and 4000 Hz high pass noise stimuli could have been due to pinna condition, i.e., the shape of the ear and its composition of skin and cartilage. Musicant and Butler concluded that the pinna can produce a head shadow effect which affects the accurate localization of a sound source from behind the listener. As supported by Middlebrooks and Green (1991), sounds above 1500 Hz do not have sufficiently long wavelengths to bend around the head and thus be accurately detected by the listener. Interaural intensity differences provide cues as to the origin of a sound stimulus.

Front-rear reversals occur because the interaural time and intensity differences are the same if the originating sound is in front or behind the listener. However, the listener is able to distinguish if the sound comes from in front or behind due to the spectral differences produced by the pinnae. If the pinnae is closest to the originating sound source, it can help to make a stronger contribution in front-rear localization (Gelfand, 1998).

Tonning (1975) and Musicant and Butler (1984) investigated localization testing in normal hearing subjects within the horizontal plane. Data from the two studies were in agreement that the subjects could accurately localize a sound source in the frontal position, but a break-down occurred when the sound was behind the subject. The inaccurate response could be due to pinna traits and the lack of interaural intensity cues. Localization testing has also been studied in quiet and noisy simulated environments.

Localization in Noise

In their investigation of sound localization in noise by normal hearing subjects, Lorenzi, Gatehouse, and Lever (1999) were particularly interested in determining the relationship between localization performance and the ability to detect a broadband signal. Lorenzi and her colleagues used four subjects, three males and one female ranging in age from 23 to 33 years who had normal hearing thresholds of 15 dB or better at octave frequencies of 250 to 8000 Hz.

Each subject sat in the center of a sound treated chamber as depicted in Figure1.3. Surrounding each subject were eleven loudspeakers, placed approximately 18 degrees apart within the horizontal plane, ranging from -90 degrees to +90 degrees. The subjects were positioned in the center of the test chamber and sat 1.25 meters away from each loud speaker and faced a loud speaker at 0 degrees azimuth and 0 degrees elevation.

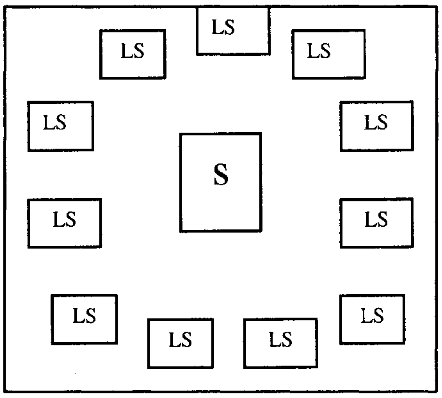


Figure 1.3. Eleven Loudspeaker Array.

The subjects listened to a signal train of 23 microseconds (us) pulses repeated at a rate of 100 Hz. Each pulse had a duration of 300 milliseconds (ms) and was presented at 70 dB SPL. The masking signal was a 900 ms white noise. Lorenzi, et al randomly presented 20 white noise samples. Six signal-to-noise ratios, consisting of -9 to +18 dB, were used. The pulsed train signal and the white noise masker were randomly switched to the presenting speakers.

After each signal was presented, the subjects identified the loudspeaker from which the pulse train was emitted. The subjects used a response box with an array of buttons arranged like the loudspeaker array to deliver their responses. Before each test trial, the subjects were instructed to keep their head and eyes steady while facing the front loud speaker positioned at 0 degrees azimuth and 0 degrees elevation.

Lorenzi and her associates found that both low frequency cues and high frequency cues were available to all normal hearing subjects in the detection of a sound stimulus during a localization task. When the white noise masker was at 0 degrees azimuth and the signal-to-noise ratio was greater than 0 dB, localization accuracy and consistency were relatively similar for all normal hearing subjects. When the noise was positioned at +90 degrees azimuth, localization and accuracy were also similar for all normal hearing subjects.

Walden, Surr, Cord, Edwards, and Olson (2000) also investigated localization abilities for normal hearing subjects. Walden et al recruited 20 (11 male, 9 female) normal hearing subjects, ages 46 to 73 years, from a military audiology and speech center. Normal hearing sensitivity for this study was defined as 20 dB HL or less at octave frequencies of 250 to 4000 Hz and 30 dB HL or less at 6000 to 8000 Hz bilaterally.

The Connected Speech Test (CST) was administered via sound field speakers. The Connected Speech Test, as described by Cox, Alexander, and Rivera (1991), is used to measure the intelligibility of everyday speech topics. The test has 48 passages of conversational speech, nine to ten words in length, each of which pertains to a familiar topic of conversation. Each listener is informed of the conversational topic in advance and is required to repeat the sentences one at a time. The multi-talker babble can be adjusted to simulate the signal-to-babble ratio encountered in everyday listening situations. Each passage is scored by the number of words correctly repeated by the listener.

Walden and his associates (2000) used varying presentation levels for the Connected Speech Test and speech babble signal-to-noise ratios to create everyday listening situations. The connected speech sentences were randomly emitted through one speaker while the remaining three speakers emitted the competing speech babble (Figure 1.4).

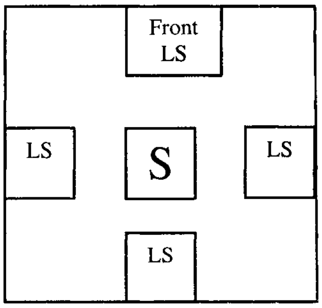


Figure 1.4. Four Loudspeaker Array.

The subjects were placed in the center of an audiometric test booth. Four loudspeakers were mounted to the booth walls, positioned at 90 degree intervals at ear level within the horizontal plane. The subjects sat facing the front loudspeaker and were directed to hold their head in a fixed position with the use of a headrest on the chair. Before the localization testing began, the subjects were given several practice sessions.

The subjects' responses were scored based on the accuracy of localizing the connected speech sentence. Walden et al found that all 20 normal hearing subjects scored 80 to 100% correct across all test conditions.

A comparison of the localization studies in noise with normal hearing subjects conducted by Lorenzi, Gatehouse, and Lever (1999) and Walden, Surr, Cord, Edwards, and Olsen (2000) revealed similar results. Results from these studies revealed that both low frequency cues and high frequency cues were available to all normal hearing subjects in the detection of a sound stimulus during a localization task. The knowledge base on sound localization in normal hearing subjects has been supplemented by localization studies with the aging population.

Localization in the Aging Population

Hearing loss in the aging population is a complex matter and may be due to structural changes within the peripheral auditory system. Thus, a reduction in the ability to process speech may be due to structural changes within the central auditory pathways. Investigating sound localization ability in the older population can be complicated by age-related changes within the auditory pathways which are often referred to as central presbycusis. Various authors (Nordlund, 1964; Stach, Spretnjak, & Jerger, 1990) have collectively defined central presbycusis as a central auditory processing disorder with no known cause other than the aging process. Aging individuals have demonstrated poor performance on various speech tasks that include the use of distorted speech stimulus or speech presented in the presence of background noise (Stach, Spretnjak, & Jerger, 1990). Therefore, any investigation of sound localization ability in the older population can be complicated by presbycusis.

Stach, Spretnjak, and Jerger examined the prevalence of central presbycusis by examining audiometric test results in a clinical population of older individuals. Stach and his colleagues used 700 individuals, males and females, who ranged in age from 50 to 93 years. One hundred subjects were placed in each of seven age groups: 50 to 54, 55 to 59, 60 to 64, 65 to 69, 70 to 74, 75 to 79, and 80 to 93 years. In order to be included in the study, the 700 individuals had to be free of middle ear, neurologic, and cognitive disorders or diseases nor could there be a diagnosis of dementia or Alzheimer's disease. The researchers did not control for hearing loss among the subjects even though they had documentation that hearing loss had increased as the subjects aged.

Stach, Spretnjak, and Jerger found that speech processing and understanding abilities tended to decline as the subjects aged. The researchers also documented that central presbycusis increased with age. Central presbycusis was prevalent in the older subjects as 95 percent of the subjects in the 80 to 93 age range showed signs of central presbycusis. However, 70 percent of all the subjects over the age of 60 years showed signs of difficulty with speech processing and understanding abilities.

As individuals age, their central auditory systems may not integrate competing sounds as efficiently, thereby creating differences in the way sounds are perceived and processed (Nordlund, 1964; Cranford, Boose, & Moore, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Walden, Surr, Cord, Edwards, & Olson, 2000; Abel, Giguere, Consoli, & Papsin, 2000). This time-related aspect of processing auditory information has been labeled by Chermak and Lee (2005) as temporal processing. Temporal processing can be associated with a decline in physical or mental status due to age-related changes throughout the auditory system. Temporal processing can be evaluated using a variety of different instruments, in particular, the Random Gap Detection Test (Chermak & Lee, 2005) a copy of which is found in Appendix A.

The Random Gap Detection Test has four subtests, two practice trials (Subtest 1 and Subtest 3) and two test trials (Subtest 2 and Subtest 4). Subtest 1 is a practice trial that uses nine pairs of 500 Hz tones as stimuli. Subtest 2, a test trial, uses nine pairs of randomly presented tones, ranging from 500 to 4000 Hz. Subtest 3 is another practice trial that uses nine pairs of click stimuli while Subtest 4 is a test trial that uses nine pairs of randomly presented click stimuli. Each subtest stimuli are presented binaurally through earphones at a comfortable listening level for the subject. The Random Gap Detection Test score is based on the consistency with which an individual identifies the smallest inter-pulse interval between two tones at a given frequency. The composite gap detection is an average of all frequencies tested and a gap detection threshold for clicks, which is reported separately. Individuals who have normal temporal processing abilities should have a score of 20 ms or less on the Random Gap Detection Test.

The central processes that contribute to localization are affected by aging (Warren, Wagener, & Herman, 1978; Cranford, Boose, & Moore, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Noble & Byrne, 1990; Lorenzi, Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000). One of the earliest studies focusing on sound localization within the horizontal plane and the aging population was that of Nordlund (1964) who investigated directional audiometry. Nordlund defined directional audiometry as the ability of a listener to localize a sound stimulus in a free-field listening environment and to use interaural time and intensity differences as cues for determining the origin of the sound stimulus. Fifty-one normal hearing subjects, ranging from 15 to

59 years of age, with normal pure tone audiograms, symmetrical hearing thresholds, and normal eardrums were selected as subjects.

Each subject was seated in the center of an anechoic chamber and faced a curved scale which was marked from 1 degree to 140 degrees (illustrated in Figure 1.5). Behind the curved scale, one hidden movable loudspeaker was placed approximately one meter from the subjects' head within the horizontal plane. During the presentation of a sound stimulus, Nordlund moved the loudspeaker from the control room with the use of a directional indicator between 1 degree and 140 degrees along the curved scale in random positions. The subject then indicated verbally where on the marked curved scale he or she determined the loudspeaker to be located. The subjects were given instructions about the testing process and procedures; testing time was approximately 45 minutes for each subject.

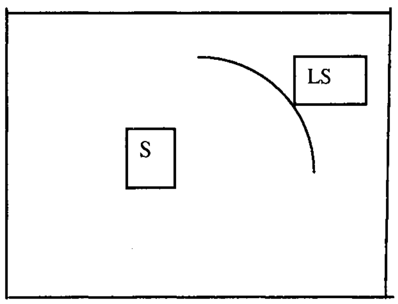


Figure 1.5. One Loudspeaker Array.

Two experimental conditions were presented. The first condition used four sound stimuli: a 500 Hz pure tone, a 2000 Hz pure tone, a 4000 Hz pure tone, and a low-pass filtered white noise. The speaker could be moved 1 to 140 degrees along the marked curved scale. During the first condition, the subject moved his or her head to trace the hidden sound stimulus along the curved scale.

The second experimental condition used only the low-pass filtered white noise while the subjects' head remained in a fixed position. A hidden loudspeaker was moved randomly but only at -30 degrees and +30 degrees along the curved scale.

During each experimental condition, each subject was given 20 listening trials for the pure tone sound stimulus at 500, 2000, and 4000 Hz. The subjects were given 10 listening trials for the low-pass filtered white noise sound stimulus. The intensity of the sound stimulus was set a comfortable listening level for each subject.

Nordlund found no significant difference among the various age groups for localizing a particular sound stimulus. The majority of the 51 normal hearing subjects had difficulty accurately localizing a 2000 Hz and a 4000 Hz pure tone sound stimulus but less difficulty localizing a low-pass filtered white noise sound stimulus. Nordlund suggested that these findings were influenced by the fact that localizing a 500 Hz pure tone sound stimulus and a low-pass filtered white noise stimulus are dependent upon interaural time differences which are the differences in time between the perception of sound between the ears.

However, localizing a 2000 Hz and a 4000 Hz pure tone sound stimulus is based on interaural intensity differences which are the differences in intensity between the perception of sound by the two ears. According to Hartmann (1999), head shadow can produce up to a 35 dB difference in intensity between the ears for high frequency sounds above 2000 Hz. The sound that reaches the far ear will be attenuated, therefore creating an interaural intensity difference between the two ears. Further, according to Hartmann, as well as Middlebrooks and Green (1991), low frequency sounds less than 1000 Hz are longer than the head and therefore a difference in interaural intensity would not exist. Accuracy of sound localization in the horizontal plane is achieved through interaural time and intensity differences.

Cranford, Boose, and Moore (1990) compared localization abilities in young normal hearing subjects and elderly hearing impaired subjects. Cranford, et al used 24 normal hearing subjects (mean age 29.6 years) and 24 elderly hearing impaired subjects (mean age 69.2 years). The elderly hearing impaired subjects had a high frequency sensorineural hearing loss and a high frequency pure tone average for 1000, 2000, and 4000 Hz that was no greater than 28.2 dB HL in each ear. The subjects had no history of neurological disease or head injury.

Cranford and his colleagues used the Precedence Effect, a task that presents identical sounds from sound field speakers positioned on opposite sides of an individual. The task becomes difficult because a tone is presented from each of two speakers but at a delayed time. Due to the interaural time differences, Cranford and his associates reported that the aging subjects tended to have difficulty with this task when the loudspeakers presented a delay of 0.7 ms and less.

The subjects were seated in the center of an audiometric test booth. One loud speaker was positioned directly in front of the subject (the "dummy" source), one was 45 degrees to the left, and the third 45 degrees to the right of the subject (Figure 1.6). Each loudspeaker was positioned approximately 150 centimeters from the subject's head. Due to the importance of head placement, all the subjects were instructed to keep their heads positioned in the specially designed bowl-shaped headrest attached to the chair and to continuously face the forward speaker. Subjects were required to verbally identify which speaker emitted the three pairs of clicks, whether the source originated from the front, right, or left loudspeaker.

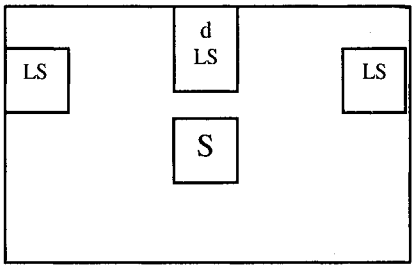


Figure 1.6. Three Loudspeaker Array.

The test stimuli, three pairs of clicks, lasted approximately 100 microseconds (us) in duration. The click stimuli were only emitted through the right and left loudspeakers, never through the front speaker which served as a “dummy source”. All stimuli were randomized trials, with a 0 ms to 8.0 ms delay between loudspeakers. Twenty trials were presented at each of 11 delays (0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 1.0, 2.0, 4.0, 6.0, or 8.0 ms), ten presentations to each speaker.

Cranford et al found that the young normal hearing subjects performed with 90% accuracy on all the localization tasks. For click stimuli with a 0 ms delay between loudspeakers, these subjects perceived stimuli from the front “dummy source” speaker. As the delay increased, the stimuli were perceived from the leading loudspeaker located 45 degrees to the right or left of the subject.

However as reported by Cranford, Boose, and Moore, the elderly subjects’ mean performance level was two or more standard deviations below that of the younger subjects on localization tasks with loudspeaker delays of 0.7 ms and shorter. The authors suggested that the sensorineural hearing loss influenced the performance of the elderly subjects. However, the difficulty may have been due to the interaural time differences. The decrease in auditory sensitivity due to the sensorineural hearing loss and the short duration of the sound stimulus (a pre-qualifier of temporal processing) seemed to be a disadvantage for the older subjects.

In a follow up-study, Cranford, Andres, Piatz, and Reissig (1993) used the same experimental conditions as did Cranford, Boose, and Moore (1990). However, the 1993 study used four test groups: 15 young normal hearing subjects (mean age of 37.7 years), 15 young hearing impaired subjects (mean age of 37.1 years), 15 older normal hearing subjects (mean age of 70.2 years), and 15 older hearing impaired subjects (a mean age of 72.3 years). All normal hearing subjects had a high frequency pure tone average at 1000, 2000, and 4000 Hz of 20 dB HL or better. However, all hearing impaired subjects had normal hearing sensitivity of 20 dB HL or better at 500 Hz, with a sloping high frequency pure tone average above 30 dB HL. Other criteria were the absence of a history of middle ear pathologies, neurological, or psychological problems.

Precedence Effect tasks were administered to all the subjects, and the listening tasks and test environment used in the Cranford et al, (1990) study were replicated (Figure 1.7). However Cranford et al (1993) found no significant relationship between age and hearing status. The elderly groups performed poorly compared to the younger subjects on the Precedence Effect tasks with loudspeaker delays of 0.7 ms or shorter.

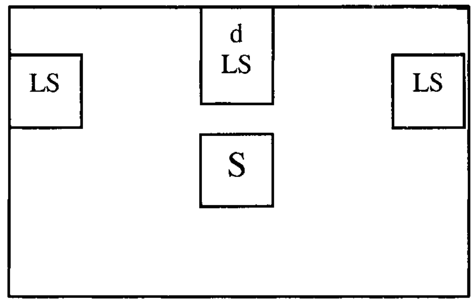


Figure 1.7. Three Loudspeaker Array.

Cranford and his associates interpreted the evidence of poor performance by the elderly subjects to be associated with sensory rather than cognitive factors. That is, the elderly subjects' performance was interpreted to be due to a breakdown in auditory temporal processing (either cochlear or cortical) rather than to cognitive factors (i.e., memory or attention). The authors also suggested that the presence of a sensorineural hearing loss could have had an effect on localization abilities due to the interaural time differences.

Russell (1976) studied individual differences on pure-tone localization tasks by examining tasking abilities for 85 subjects who completed a localization trial using a 1000 Hz tone within the horizontal plane. All the subjects had normal hearing thresholds and had not been test subjects for any other localization studies.

To complete the test trials, each subject was seated in the center of a semi-anechoic room with six loud speakers positioned approximately 30 degrees apart (Figure 1.8). A 1000 Hz pure tone was emitted from one of the six loud speakers at a time. Each signal was two seconds in duration and presented at 20 dB SL. The subject used a loudspeaker array diagram to verbally identify which speaker emitted the 1000 Hz pure tone. Five signals, a total of 30 signal presentations, were randomly presented from the loudspeakers.

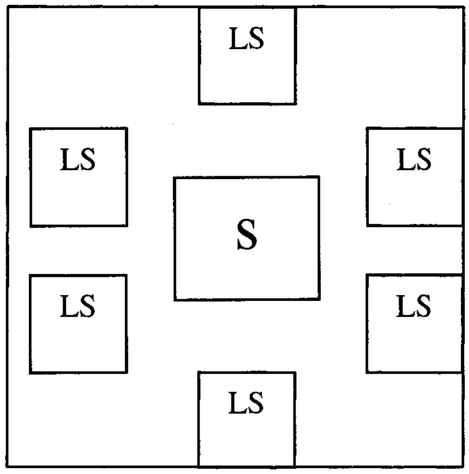


Figure 1.8. Six Loudspeaker Array.

Russell recorded subject responses as correct, contralateral, front-rear, adjacent, or no response. A contralateral response was defined as an incorrect response to a pure tone signal on the opposite side of the subject. A front-rear response was identified as an incorrect response to the pure tone signal from the presentation in front of or behind the subject. Lastly, the adjacent response was an incorrect response to the loud speaker on the same side as the actual presenting speaker.

Subject responses ranged from 25 to 85% accuracy. On the average, the subjects had greater incorrect responses to front-rear presentations and adjacent presentations than any other. Therefore, Russell's study demonstrated considerable variability within-subject responses to a 1000 Hz pure tone within the horizontal plane.

Sound localization abilities for aging subjects within the horizontal and vertical planes via sound field were investigated by Noble and Byrne (1990). Six normal hearing subjects, ages 60 to 75 years, were observed for accurate localization tasking.

Sound stimuli were emitted from one of 20 loudspeakers, ten of which were arranged along a vertical plane and the remaining ten along the horizontal plane (Figure 1.9). Noble and Byrne used an anechoic chamber and positioned the subjects' head at the same height as the horizontal speaker array. Sound stimuli consisted of pulsed pink noise that varied across the frequency range of 200 to 12,500 Hz. Each test trial consisted of four pulsed pink noise stimuli of approximately 0.9 seconds in duration. All test conditions were presented at the most comfortable level for each subject which was measured from loudspeaker #15, the speaker positioned directly in front of the subject within the horizontal plane.

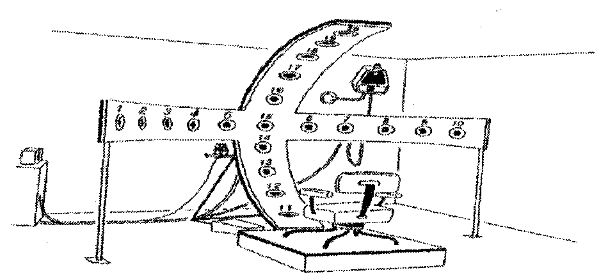


Figure 1.9. Twenty Loudspeaker Array.

From A comparison of different binaural hearing aid systems for sound localization in the horizontal and vertical planes by W. Noble and D. Byrne, 1990, *British Journal of Audiology*, 24, p. 338.

Each subject was given 20 randomly presented practice trials, (i.e., one trial per loudspeaker) to allow for familiarization with the localization testing procedures. For the localization test trials, all subjects were positioned directly in front of loudspeaker #15. The subjects were instructed to face forward prior to the presentation of each stimuli. After the stimuli were heard, the subject was able to move his or her head and torso to identify the appropriately numbered loudspeaker.

Noble and Byrne concluded that subjects with bilateral, normal hearing sensitivity scored approximately 100% correct on localization tasks when sound stimuli were presented within the horizontal plane. However, localization abilities within the vertical plane were severely disrupted. As supported by Middlebrooks and Green (1991) if hearing is symmetrical (less than a 10 dB difference between each ear), a sound stimulus that is presented at any location within the vertical plane should produce no interaural time or intensity differences.

Interaural time difference is the difference in time between the perception of sound between the ears while interaural intensity difference is the difference in intensity between the perception of sound from the near ear to the far ear. By producing no interaural differences, cues will not be provided as to where within the vertical plane a sound stimulus is presented. While Noble and Byrne (1990) focused on localization abilities for aging subjects within the horizontal and vertical planes, Abel, Giguere, Consoli, and Papsin (2000) investigated localization within the horizontal plane by older individuals.

In order to focus on the effects of aging on horizontal plane sound localization, Abel, et al, tested sound localization using an environment which simulated everyday listening situations. The subjects were given the task of detecting the direction of a continuous sound stimulus from a set of loudspeakers. Abel et al used six arrays of loudspeakers, two arrays of four (Figure 1.10) and four arrays of eight loudspeakers (Figure 1.11). The four loudspeakers were placed 50 degrees apart and the eight loudspeakers were placed 15 degrees apart. The loudspeakers were positioned to surround the subjects on a horizontal plane, at ear level.

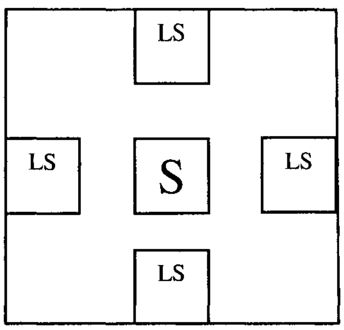


Figure 1.10. Four Loudspeaker Array.

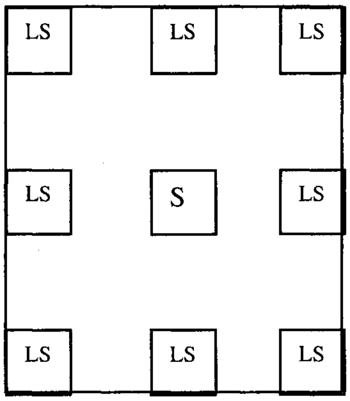


Figure 1.11. Eight Loudspeaker Array.

Forty males and 72 females, who had normal to moderate sensorineural hearing losses and ranged in ages of 10 to 81 years, were assigned to seven groups with 16 subjects per group. The subjects were asked to identify the direction of various sound stimuli of one-octave band noise at 500 and 4000 Hz, and broadband noise stimuli.

All sound stimuli were presented at a comfortable level of 75 dB SPL. The sound stimuli were sufficiently loud to be well above threshold for all the test subjects. Hearing threshold criteria allowed 25 dB SPL or less for subjects ranging between 10 and 29 years, 35 dB SPL or less for those subjects of 30 to 59 years of age, and 50 dB SPL or less for those 60 and 81 years. However, hearing thresholds had to be symmetrical. Each test stimulus was presented for 300 ms, which included a rise/fall time of 50 ms. The 500 Hz octave band stimulus was intended to facilitate the interaural time differences cues while the 4000 Hz octave band stimulus was intended to facilitate the interaural intensity differences cues.

Abel et al used the broadband noise stimuli to facilitate binaural and spectral cues, in combination. Upon presentation of the sound stimulus, the subject was instructed to press a button to signify when the stimulus was heard. The subjects used a touch screen keypad which depicted each loudspeaker situated on the surrounding horizontal array.

Abel and her colleagues suggested that sound localization abilities appeared to decline as subjects aged. The decline was noted for all three test stimuli: the one-octave band 500 Hz, 4000 Hz noise, and broadband noise. The subjects scored a higher percent correct when given the broadband noise stimulus than with the 500 Hz noise stimulus. This could be due to the subjects' having binaural and spectral cues, rather than only having interaural time difference cues.

Several studies have focused on various aspects of sound localization within the normal hearing aging population. Studies conducted by Nordlund (1964), Russell (1976), and Abel, Giguere, Consoli, and Papsin (2000) concluded similar results. These results revealed that subjects have difficulty accurately localizing a pure tone stimulus of 1000 Hz or greater, which is dependent upon interaural intensity differences. Interaural intensity difference cues are the differences in intensity between the perception of sound by the two ears. According to Hartmann (1999), head shadow can produce up to a 35 dB difference in intensity between the ears for high frequency sounds above 2000 Hz. The sound that reaches the far ear will be attenuated, therefore creating an interaural intensity difference between the two ears. Further, according to Hartmann, as well as Middlebrooks and Green (1991), low frequency sounds less than 1000 Hz are longer than the head and therefore a difference in interaural intensity would not exist.

Researchers such as Cranford, Boose, and Moore (1990) as well as Cranford, Andres, Piatz, and Reissig (1993) concluded as individuals aged, their mean performance on localization tasks decreased when compared to the younger subjects within the study. These authors suggested that the presence of a sensorineural hearing loss, decline in temporal processing abilities, and the lack of interaural time difference cues influenced the poor performance of the aging subjects.

Localization abilities in the aging population were also investigated by Noble and Byrne (1990). These researchers focused on sound localization within the horizontal and vertical planes. Results concluded that normal hearing subjects could accurately localize a sound stimulus when presented within the horizontal plane. However, localization abilities within the vertical plane were severely disrupted. As supported by Middlebrooks and Green (1991) if hearing is symmetrical (less than a 10 dB difference between each ear), a sound stimulus that is presented at any location within the vertical plane should produce no interaural time or intensity differences. By producing no interaural differences, cues will not be provided as to where within the vertical plane a sound stimulus is presented.

Lateralization within the Auditory System

Localization has been defined as the ability to determine the direction of sound (Tonning, 1975; Cranford, Boose, & Moore, 1990; Middlebrooks & Green, 1991; Cranford Andres, Piatz, & Reissig, 1993; Lorenzi Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000). Although localization of sound has been investigated somewhat extensively, less research has been devoted to sound lateralization within the auditory system.

In contrast to localization, lateralization occurs when a sound source is heard along the same plane between the two ears (Melnick & Bilger, 1965; Rosenhall, 1985; Gelfand, 1998). When earphones are placed over the ears, the listener will only use one ear at a time and the similar sound stimuli appear to be presented from within the head. The sounds that are being heard are lateralized. The Weber and the Stenger are examples of lateralization tests.

The Weber test (Rappaport & Provencal, 2002) can be used with a tuning fork or bone oscillator placed on the listener's forehead. The listener is instructed to indicate on which side of the head the sound stimuli are heard. This test lateralizes stimuli to the poorer ear if a conductive component is present (indicative of middle ear disorder/disease) or to the better ear if a sensorineural component is present (suggestive of inner ear/eighth nerve involvement).

The Stenger test (Martin, 2002) uses headphones to present two simultaneous tones at the same frequency to both ears. The "good" ear is presented a tone 10 dB above threshold and the "poor" ear is presented a tone 10 dB below threshold.

The Weber and Stenger are important for lateralizing sound stimuli via bone oscillator and headphones. Localization and lateralization both deal with detecting a sound source through different means. An important aspect of processing auditory stimuli is the ability to localize the source of sound within the environment, whether the sound is in the vertical or horizontal planes.

Vertical Planes

Vertical plane localization refers to a sound source on a path perpendicular to the ground. Within the vertical plane, if hearing is symmetrical (less than a 10 dB difference between each ear), a sound stimulus presented at any medial location within this plane should produce no interaural time or intensity difference. Interaural time difference is the difference in time between the perception of sound between the ears. For low frequency sounds (below 1500 Hz), the wavelengths are much longer than the diameter of the head and therefore, rely on interaural time differences. Interaural intensity difference is the difference in intensity between the perception of a sound stimuli between the near ear and far ear. High frequency sounds (above 1500 Hz) wavelengths are much shorter than the diameter of the head and must rely on interaural intensity differences. By not producing an interaural time or intensity difference, cues will not be provided as to where in the vertical plane a sound stimulus is presented. Any sound stimulus in the vertical plane may fall within the Cone of Confusion as shown in Figure 1.12 (Middlebrooks & Green, 1991).

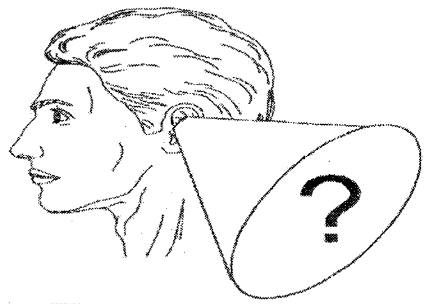


Figure 1.12. Cone of Confusion Model.

From Binaural Hearing by S.A. Gelfand, 1998, *Hearing: An Introduction to Psychological and Physiological Acoustics*, 3rd Edition, p. 381.

According to Middlebrooks and Green, the Cone of Confusion model contains all points within the vertical plane from which a sound source could possibly originate. The sound source is located on only one side of the head. The Cone of Confusion model explains the interaural time and intensity differences which remain constant over time. The listener can distinguish from which side of the head a sound source originates. However, the listener can not differentiate from where within the cone the sound originated.

A sound originating at any point within the Cone of Confusion will provide the same difference in stimuli at the two ears. These interaural time and intensity differences tend to be small but virtually identical, thereby producing no cues as to the origin of a sound stimulus. A sound arising at any location within the cone will provide the same interaural time and intensity differences at the two ears. If a listener is to localize a sound source based solely on these differences, a problem will arise because no cues as to the vertical location of sounds are provided based on these differences (Middlebrooks & Green, 1991; Gelfand, 1998; Shinn-Cunningham, Santarelli, & Kopco, 2000).

Shinn-Cunningham, Santarelli, and Kopco (2000) discussed the Cone of Confusion by defining interaural time difference as occurring due to differences in the distance from ear to ear in orientation to the sound location. The near ear perceives the sound stimuli first as opposed to the far ear which perceives it second. Fedderson, Sandel, Teas, and Jeffress (1957), suggested that this between-ear difference can result in a time delay of 660 microseconds for the sound to travel from the near to far ear which corresponds to a frequency of about 1500 Hertz (Hz).

Interaural intensity differences occur due to the listener's head acting as an obstacle to sounds, especially for high frequency wavelengths. High frequency sounds (above 1500 Hz) have shorter wavelengths than the diameter of the head. Therefore, the far ear from the sound source will receive less energy from the stimuli than the near ear. This was verified by Hartmann (1999) who suggested that high frequency sounds (above 2000 Hz) can produce a head shadow of 35 dB difference in intensity between the ears. The sound that reaches the far ear will be attenuated, therefore creating an interaural intensity difference between the two ears.

All sound sources within the Cone of Confusion are relatively constant at a given frequency. When listeners localize a sound source within the vertical plane, they often make incorrect responses as to the perceived origin of the sound source. The listener can localize the source but responds incorrectly due to the location of the source within the Cone of Confusion. Within the Cone of Confusion, accurate localization needs to incorporate binaural cues (hearing and perceiving with both ears) for source position and other cues, such as spectral cues and head rotation, for source location. It is noted that a large number of errors that occur within the Cone of Confusion are mirrored by the actual source location. For example, if a sound originates from behind the listener, the response may be the source originated in front of the listener and vice versa.

The advantage of using two ears simultaneously (binaural cues) can help resolve the position of the sound source within the Cone of Confusion. However, less noticeable cues such as spectral cues and head rotation must be used to detect the location within the cone. Spectral cues may be dependent upon the head, pinna, and torso. Localization of a sound stimulus can be measured within the vertical plane as well as the horizontal plane.

Horizontal Planes

Horizontal plane localization refers to a sound source that is on a path parallel to the ground. In traditional audiological experiments with localization, the horizontal plane is used (Russell, 1976; Musicant, 1984; Cranford, Boose, & Moore, 1990; Middlebrooks & Green, 1991; Cranford, Andres, Piatz, & Reissig, 1993; Gelfand, 1998; Lorenzi, Gatehouse, & Lever, 1999; Abel, Giguere, Consoli, & Papsin, 2000). The Duplex Theory has been used to explain horizontal localization. According to Gelfand (1998), this theory describes the interaural time difference between the ears that occurs at lower frequencies and the interaural intensity difference between the ears that occur at higher frequencies.

The Duplex Theory as discussed by Middlebrooks and Green (1991), Gelfand (1998), and Hartmann (1999) accounts for the extent of disturbance caused by head shadowing which is dependent on the frequency of the sound and the size of the listener's head. For low frequency sounds (below 1500 Hz), the wavelengths are much longer than the diameter of the head and therefore, rely on interaural time differences which provide cues for low frequency sounds. High frequency sound wavelengths (above 2000 Hz) are much shorter than the diameter of the head and must rely on interaural intensity differences cues.

A head shadow occurs when the head is positioned between the sound stimulus and the ear farthest from that stimulus which creates a reduction in intensity. For example, the sound stimulus coming from a right loudspeaker at 90 degrees azimuth will be reduced at the left ear because the head is blocking the path of the sound. Gelfand (1998) suggested that the head shadow is significant for high frequency sounds because these wavelengths do not bend around the head as easily as low frequency sounds whose wavelengths are longer the diameter of the head.

Gelfand explained the Duplex Theory and head shadow effect with the use of a model (Figure 1.13). The first image shows the relationship between the loudspeaker and the two ears. A sound stimulus is emitted from a loudspeaker, positioned within the horizontal plane. The illustration demonstrates the head shadow effect which occurs when the head is positioned between the sound stimulus and the ear farthest from that stimulus. This creates a reduction in intensity or time. The second image demonstrates low frequency stimuli bending around the head easily due to their large wavelengths. Low frequency stimuli have wavelengths that are much longer than the diameter of the head and are able to overcome the head shadow effect. The third image demonstrates high frequency stimuli not bending around the head as easily due to their shorter wavelengths. High frequencies have wavelengths that are shorter than head diameter resulting in a head shadow at the far ear, causing a reduction in intensity.

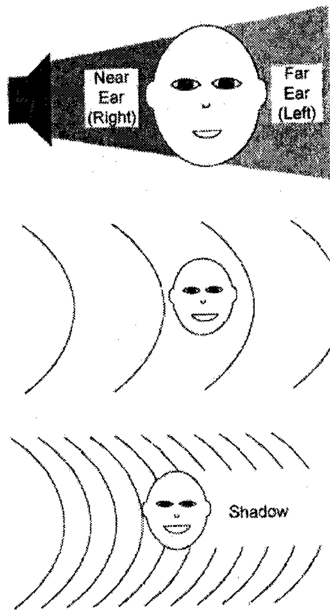


Figure 1.13. Duplex Theory Model.

From Binaural Hearing by S.A. Gelfand, 1998, *Hearing: An Introduction to Psychological and Physiological Acoustics*, 3rd edition, p. 375.

Hartmann (1999) suggested that high frequency sounds (above 2000 Hz) can produce a head shadow of 35 dB difference in intensity between the ears. The sound that reaches the far ear will be attenuated, therefore creating an interaural intensity difference between the two ears. Hartmann went on to explain that low frequency sounds (less than 1000 Hz) are longer than the head and therefore, a difference in interaural intensity will not exist. Accuracy of sound localization in the horizontal plane is achieved through interaural time and intensity differences.

Interaural time difference is another important cue for sound localization. The Woodworth Model (Gelfand, 1998) is used to explain interaural time difference and describes the arrival times of sound and the ability to be detected at each ear. This also addresses the head shadow effect and the physical distance between ears. The

Woodworth Model presents the head as an obstacle with the distance between each ear approximating 22 to 23 centimeters. Feddersen, Sandel, Teas, and Jeffress (1957) suggested that this between-ear difference can result in a time delay of 660 microseconds for the sound to travel from the near to far ear which corresponds to a frequency of about 1500 Hertz (Hz). If a high frequency sound stimulus is directly to the side of the listener (90 degrees azimuth), then an interaural time difference of 660 microseconds will occur. This interaural time difference will not occur for low frequency sounds due to its wavelengths overcoming the diameter of the head (Gelfand, 1998). Localizing a sound source within the horizontal plane can be explained by the Duplex Theory and the Woodworth Model. According to Gelfand, both concepts address interaural time and intensity differences, and its relation to the head shadow effect.

Statement of the Problem

A variety of test stimuli, test environments, loudspeaker arrays, and ages and numbers of subjects have been used to measure the ability to localize sounds. Despite the obvious need for individuals to identify the specific location of a sound source, the variety of approaches reported in the literature suggests that there is no standard process for measuring localization abilities. Therefore, a standardized protocol for measuring localization abilities would attenuate the need to vary testing procedures while determining an individual's ability to identify sources as part of a complete audiological assessment. The specific purpose of this capstone project is to develop a standardized protocol to measure localization abilities in young and older normal hearing adults.

CHAPTER II

A PROTOCOL FOR TESTING SOUND LOCALIZATION

Localization is the ability to determine the direction of a sound stimulus. The ability to localize a sound is made possible through different anatomical components as well as physiological processes. This incorporates binaural interaction and anatomical and physiological structures within the auditory system. In addition, the use of interaural time differences and interaural intensity differences provide cues as to where the sound stimulus may be located within the horizontal plane.

Previous studies of localization (Cranford, Boose, & Moore, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Abel, Giguere, Consoli, & Papsin, 2000) specifically focused on young normal hearing subjects and aging hearing impaired subjects. Other studies examined localization abilities for young normal hearing subjects as well as aging normal hearing subjects (Nordlund, 1964; Noble & Byrne, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Walden, 2000). In addition, localization studies used varying test stimuli and test booth set-ups (Tonning, 1975; Musicant & Butler, 1984; Russell, 1976; Lorenzi, Gatehouse, & Lever, 1999), suggesting that a gold standard for localization does not exist.

As reflected in the literature review provided in Chapter I, researchers of localization used a variety of test stimuli, test environments, loudspeaker arrays, and ages and numbers of subjects to measure the ability to localize sounds. Despite the obvious need for individuals to identify the specific location of a sound source, the variety of approaches suggests that there is no standard process for measuring localization abilities. Therefore, a standardized protocol for measuring localization abilities would attenuate the need to vary testing procedures during the process of determining an individual's ability to identify sound sources as part of a complete audiological assessment.

The specific purpose of this capstone project is to develop a standardized protocol for testing sound localization. This protocol will specify the technical components, calibration, stimulus items, test conditions, instructions, administration, and data forms that could be used by audiologists as part of a complete audiological assessment for individuals who range in age from 21 to 60 years.

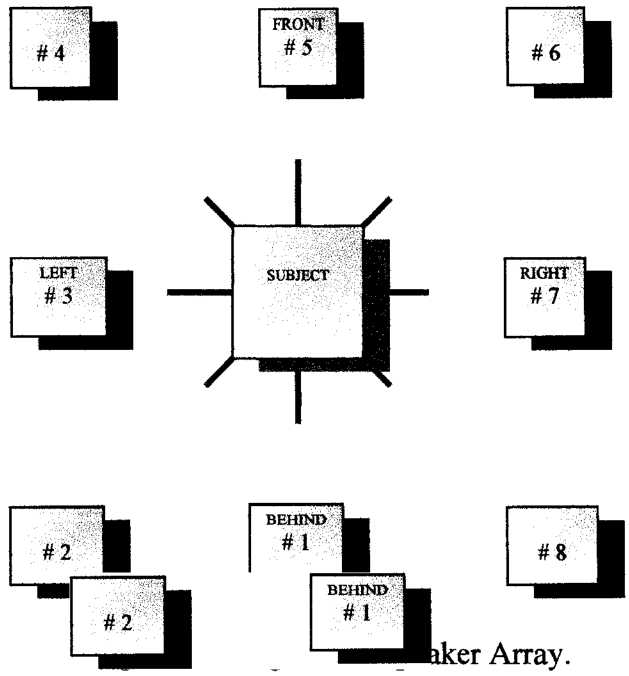
Technical Components

All experimental testing will be completed in an 8x8 foot double-walled IAC sound treated booth (ANSI S3.1 – 1991). In order to prevent standing waves (i.e., sound waves that may be reflected off the walls of the sound treated booth), the primary investigator will cover all internal surfaces within the sound-treated booth with four inch thick absorbent acoustic foam. Peabody Noise Control Company, Model TSF-P Acoustical Foam will be used. Also, the floor of the test booth will be covered with a one inch thick pile carpet.

To measure reverberation and standing waves within the sound-treated booth, the primary investigator will attach the sound level meter with a one inch pressure microphone to a tripod that will be placed in the center of the loudspeaker array approximately at head level of the subject. One Central Institute for the Deaf Everyday Sentence, presented at 50 dB HL and then 70 dB HL, will be emitted through one of the eight loudspeakers, at a time. These measurements will be recorded as verification that each loudspeaker is emitting a Central Institute for the Deaf Everyday Sentence at the appropriate level.

The test stimuli for audiological testing will be delivered via EAR Tone 3A insert earphones which will be routed through an Interacoustic AC 40 audiometer (ANSI S3.6 – 1996). The Random Gap Detection Test stimuli will be delivered by a Tascam CD-160 CD player via insert earphones which will also routed through the Interacoustic AC 40 audiometer. The test of localization stimuli will be delivered by a Tascam CD-160 CD player via LR2SA Line Radiator 20 watt loudspeakers (Figure 2.1) also routed through the Interacoustic AC 40 audiometer.

Eight sound field speakers (Figure 2.1) will be placed in the sound treated booth and arranged symmetrically within the horizontal plane with 45 degree intervals between each speaker (see Appendix B). The speakers will be LR2SA Line Radiator 20 watt loudspeakers. The Interacoustic AC 40 audiometer will be used to present 40 short speech sentences through the sound field speakers to each subject at 50 dB HL for one quiet test condition and 70 dB HL for four noisy test conditions. A conventional swivel chair with an attached headrest will be placed in the booth.



ker Array.

The subject will be positioned in the center of the IAC sound-treated booth and instructed to sit in the swivel chair with his or her head positioned against the attached headrest. The headrest will be used to help minimize head movement to keep the subjects' head continuously facing forward loudspeaker #5.

Eight LR2SA Line Radiator 20 watt loudspeakers will be arranged symmetrically within the horizontal plane with 45 degree intervals between each loudspeaker. The loudspeakers will be numbered 1 through 8, starting directly behind the subject and continuing clockwise. Loudspeaker #1 will be situated directly behind the subject, loudspeaker #3 will be 90 degrees to the left of the subject, loudspeaker #5 directly in front of the subject, and loudspeaker #7 will be 90 degrees to the right of the subject. Loudspeakers #2, #4, #6, and #8 will be positioned at 45 degrees to the other loudspeakers (Figure 2.1)

Calibration

An Interacoustic AC 40 audiometer (ANSI S3.6 – 1996) will be used. Nationally recognized calibration standards suggest that an individual with normal hearing can listen to sounds presented by an audiometer at varying frequencies and intensities to conduct the daily biological check. This primary investigator will serve as the listener for the biological checks. The daily check will cue the listener as to any distortion that may occur within the audiometer. In addition to the daily functional checks, the AC 40 audiometer will have been calibrated at least three months prior to the study by technicians trained in the maintenance and servicing of audiometric equipment.

In addition, a calibrated sound level meter will be used to verify the accurate functioning of the eight LR2SA Line Radiator 20 watt loudspeakers and the EAR Tone 3A insert earphones. The primary investigator will perform the daily biological check for each loudspeaker. The investigator will attach the sound level meter with a one inch pressure microphone to a tripod and place it three feet away from the loudspeaker at a 90 degree angle. Then, a 1000 Hz pure tone signal will be emitted from the audiometer through one speaker at a time. These measurements will be recorded as verification that each loudspeaker is emitting a 1000 Hz as displayed by the audiometer.

The primary investigator will also conduct the same daily checks for the EAR Tone 3A insert earphones. The same calibrated sound level meter will be used with the exception that a 2 cc coupler replaces the pressure microphone. The insert earphones will be patched to the IAC AC 40 audiometer to emit a 1000 Hz pure tone through each insert earphone. The insert earphone fits directly into the 2 cc coupler which is screwed onto the sound level meter. A 1000 Hz pure tone stimulus will be presented to the insert earphone which will be read by the sound level meter to verify a 1000 Hz signal is being emitted through the insert earphone. As already mentioned, the audiometric listening checks by a normal hearing individual (the primary investigator), loudspeaker measurements, and insert earphone measurements will be completed daily with the use of a calibrated sound level meter.

Stimulus Items

To assure that all test subjects have normal temporal processing abilities, the primary investigator will administer the Random Gap Detection Test. Temporal processing, as suggested by Chermak and Lee (2005), can be associated with a decline in physical or mental qualities due to age-related changes throughout the auditory system. Temporal processing can be assessed using a variety of different tests, in particular, the Random Gap Detection Test (see Appendix A).

Random Gap Detection Test. The Random Gap Detection Test has four subtests, two practice trials (Subtest 1 and Subtest 3) and two test trials (Subtest 2 and Subtest 4). Subtest 1 is a practice trial that uses nine pairs of 500 Hz tones as stimuli. Subtest 2, a test trial, uses nine pairs of randomly presented tones, ranging from 500 to 4000 Hz. Subtest 3 is another practice trial that uses nine pairs of click stimuli while Subtest 4 is a test trial that uses nine pairs of randomly presented click stimuli. Each subtest is presented binaurally through earphones at a comfortable listening level for the subject. The Random Gap Detection Test score is based on the consistency with which an individual identifies the smallest inter-pulse interval between two tones at a given frequency. The composite gap detection is an average of all frequencies tested and a gap detection threshold for clicks which is reported separately. Individuals who have normal temporal processing abilities should have a score of 20 ms or less on the Random Gap Detection Test.

Central Institute for the Deaf Everyday Sentences. This protocol for testing localization will use the Central Institute for the Deaf Everyday Sentences (Alpiner & Schow, 2000; Healy & Montgomery, 2006) as the test stimuli (see Appendix C). These sentences were chosen because they are designed to represent everyday American speech appropriate for all adults. A 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra for speech and noise to simulate a noisy listening condition. A varying signal-to-noise ratio will be used.

This Central Institute for the Deaf Everyday Sentences CD has 10 lists, labeled A through J with 10 sentences in each list. Using an Excel program (Microsoft Corporation, 2002), the primary investigator will randomly select 40 sentences from the 100 sentence list (see Appendix D). Each sentence will have a duration of approximately three seconds, with a three-second pause between each trial. The 40 sentences will be randomly presented five times through each loudspeaker for all five test conditions. Therefore, each subject will receive a total of 200 presentations, 40 presentations for one quiet listening condition and 160 presentations for the four noisy listening conditions. The Excel program will also be used to randomize the 40 phrases to be presented to all the subjects.

Test Conditions

The 40 short phrases will be randomized and presented in one of five test conditions. The test conditions are speech stimuli in quiet, speech stimuli in noise with a 5 dB signal-to-noise ratio, speech stimuli in noise with a 10 dB signal-to-noise ratio, speech stimuli in noise with a 15 dB signal-to-noise, and speech stimuli in noise with a 20 dB signal-to-noise ratio.

<u>Quiet Test Condition.</u> The speech stimuli in quiet were chosen to represent normal conservation at an intensity level of 50 dB HL with no presence of background noise. One of the test sentences will be presented to the subject through one loudspeaker randomly selected from the eight loudspeakers. An Excel program will be used for the random selection which will be accomplished before the localization testing begins. One of the eight loudspeakers will present one sentence at a time while the remaining seven speakers remain silent. The 40 Central Institute for the Deaf sentences will be randomly presented five times through each loudspeaker for this quiet test condition. Therefore, each subject will receive 40 presentations. The Excel program will also be used to randomize the 40 sentences to be presented to the subjects.

<u>Noisy Test Conditions</u>. The subjects' localization abilities in the presence of background noise will also be tested. Four different noisy test conditions will be presented to each subject. The first speech stimuli were chosen to represent speech in background noise with speech presented at 70 dB HL and noise presented at 65 dB HL. The second speech stimulus condition will represent speech in background noise with speech at an intensity level of 70 dB HL and noise at 60 dB HL. The third speech stimulus condition represents speech in background noise with speech presented at 70 dB HL and noise at 55 dB HL. The fourth test condition will represent speech in background noise with speech presented at 70 dB HL and noise at 50 dB HL.

The primary investigator will present one test sentence through one loudspeaker randomly selected from the eight possibilities. The Excel program will be used for the random selection before the localization testing begins. Only one of the eight loudspeakers will present one sentence at a time while the remaining seven speakers emit a 1000 Hz white noise stimulus. The 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra for speech and noise to simulate a noisy listening condition. The 40 phrases will be randomly presented five times through each loudspeaker for these four noisy test conditions. Therefore, each subject will receive 160 presentations. The Excel program will also be used to randomize the 40 phrases that will be presented to the subjects.

Instructions

Forty short phrases will be randomized and presented to the subjects in one of five test conditions: speech stimuli in quiet, speech stimuli in noise with a 5 dB signal-to-noise ratio, speech stimuli in noise with a 10 dB signal-to-noise ratio, speech stimuli in noise with a 15 dB signal-to-noise, and speech stimuli in noise with a 20 dB signal-to-noise ratio. For each test condition (one quiet and four noise), each subject will listen to the test directions. For purposes of validity and reliability, the same instructions will be read aloud to each subject. The instructions are as follows:

> *You are going to hear a short speech sentence. You will hear the sentence in quiet and with some noise in the background. Please listen carefully. As you listen to each sentence, face loudspeaker #5. As you listen to each sentence, please keep your eyes steady and hold your head against the headrest attached to the chair in which you are sitting. It is important that you not move your head as you listen.*
>
> *After you have heard a sentence, please swivel in the chair to point to the loudspeaker from which you heard the sentence. As you point, verbally identify the loudspeaker by number. Wait until you no longer hear any words before you point and identify the loudspeaker from which you heard the sentence. After you point to the appropriate loudspeaker, please sit back in the chair and face loudspeaker #5 with your head fixed against the headrest and your eyes steady.*

At times, it may be difficult for you to identify the loudspeaker from which you hear some of the sentences. If you are unsure, it is okay to take a guess at the direction from which you heard the sentence. Please remember to wait until the sentence has been presented, then point and verbally identify the number of the loudspeaker from which you heard the sentence. Do you have any questions?

Any questions posed by the subjects will be answered and, if necessary, the instructions will be repeated in their entirety. As further verification that the test procedures are understood, each subject will be asked to paraphrase the instructions for the examiner.

Administration of Test Protocol

Prior to administration of the localization test, each subject will be given a complete audiological test battery. This battery will consist of completion of a case history, otoscopic examination, tympanometry testing, speech discrimination testing, pure tone air conduction and bone conduction testing, and the Random Gap Detection test. After completion of the audiological test battery and verification that all test criteria have been met, the test of localization will be administered.

All experimental testing will be completed in an IAC sound treated booth (ANSI S3.1 – 1991). The test stimuli will be delivered via EAR Tone 3A insert earphones, which will be routed through an Interacoustic AC 40 audiometer (ANSI S3.6 – 1996) The Random Gap Detection Test stimuli will be delivered by a Tascam CD-160 CD player via insert earphones also routed through the Interacoustic AC 40 audiometer.

All of the audiological test procedures will be presented by the primary investigator. Testing time is estimated to be 90 minutes per subject with a 10-minute break between completion of the audiological battery and the testing of localization.

Approximately four weeks will be required to complete the audiological and localization testing for all the subjects to be used in the study.

Data Forms

Each subject's response will be recorded on the appropriate data sheets for the various testing measurements. The subject's history will be recorded on a case history form (see Appendix E) developed for the study. An audiometric data sheet (see Appendix F) will be used to record information obtained from each subjects' otoscopic examination, tympanometry testing, speech word discrimination testing, and pure tone air conduction and bone conduction testing. Also, each subject's response for the Random Gap Detection test (see Appendix A) will be recorded and scored based on how consistently the subjects identified two tones at a specific inter-pulse interval. The composite gap detection will be the average of all frequencies tested and a gap detection for clicks which is reported separately.

The localization test responses will be recorded (see Appendix G) based on whether the subject correctly identified the appropriately numbered loudspeaker from which the Central Institute for the Deaf Everyday Sentence was presented (see Appendix C). A correct response will be recorded with a check (√). An incorrect response will be recorded with an **X** to indicate an error and the number of the loudspeaker choice will be noted.

Expert Reviewers

In an attempt to establish some amount of validity and reliability for this proposed sound localization protocol, two individuals known to the primary investigator will be asked to participate in the study by serving as expert reviewers. These expert reviewers will be two doctoral-level audiologists whose primary area of employment is a private practice in audiology. The individuals will hold either a Ph.D. in Audiology or the Doctorate of Audiology (Au.D.) and will have been engaged in the private practice of audiology for at least five years prior to this study. Each will hold a current Certificate of Clinical Competence in Audiology (CCC-A) awarded by the American Speech-Language-Hearing Association and a valid state license for the practice of audiology and dispensing of hearing aids. The two reviewers will be judged to have the necessary knowledge and skills to provide the wide range of audiological services necessary to provide for the hearing service needs of individuals ages 21 years and upward. The individuals will also have the necessary instrumentation and physical space necessary to accommodate the methodology of the testing.

Each reviewer will be asked to use the localization protocol developed by the primary investigator with eight clients seen in his or her private practice who meet the pre-established eligibility criteria. Two clients will be used in each of the following age ranges: 21 to 30, 31 to 40, 41 to 50, and 51 to 60 years. Thus, the two reviewers will contribute test data for 16 individuals who represent each of the age ranges to be used by the primary investigator.

The complete protocol will be provided for each reviewer (see Appendix H). In addition, each reviewer will be asked to provide feedback by answering questions attached to the protocol. These questions are designed to examine the methodology used in the study and to elicit recommendations for changes that may be considered for further standardized of the sound localization protocol.

CHAPTER III

METHODS AND PROCEDURES

Sound localization studies have used young normal hearing subjects, aging hearing impaired subjects, and aging normal hearing subjects (Nordlund, 1964; Cranford, Boose, & Moore, 1990; Noble & Byrne, 1990; Cranford, Andres, Piatz, & Reissig, 1993; Abel, Giguere, Consoli, & Papsin, 2000; Walden, Surr, Cord, Edwards, & Olsen, 2000). In addition, a variety of test stimuli and loudspeaker array were used in these studies (Tonning, 1975; Russell, 1976; Musicant & Butler, 1984; Lorenzi, Gatehouse, & Lever, 1999). Interpretation of available literature suggests that a gold standard for sound localization testing has yet to be established. Chapter II of this capstone project proposed a standardized protocol for sound localization testing that would be feasible for use with younger and older adults. Chapter III will outline the methods and procedures for implementation of this protocol.

Methods

Subjects

This study will require the participation of 80 individuals, 40 males and 40 females, who range in age from 21 to 60 years. Based on their chronological age, the subjects will be assigned to one of four groups, 20 per group (10 males, 10 females). The age groupings are: 21 to 30 years, 31 to 40 years, 41 to 50 years, and 51 to 60 years.

In addition to the age requirement, subjects must meet the following criteria: normal audiological case history (see Appendix E), normal otoscopic examination (non-occluding ear canals, i.e. wax, debris, or external infections bilaterally), Type A tympanograms bilaterally, speech word discrimination of 85% correct or better bilaterally, pure tone testing through air conduction and bone conduction at each octave frequency of 250 to 8000 Hz of 25 dB HL or better bilaterally (see Appendix F), and a Random Gap Detection test threshold of 20 ms or less (see Appendix A).

<u>Subject Recruitment</u>

Subjects will be recruited through a variety of sources that include notices placed in church bulletins; university, junior, and technical college campus newspapers; senior citizens centers; and newsletters and bulletin boards in health, wellness, and recreational facilities within a 25 mile radius of the primary investigator's testing location. Permission for posting will be solicited from appropriate individuals in these facilities. The postings will read as follows:

> *My name is Alison V. Huff and I am a graduate student pursuing a doctoral degree in audiology at Louisiana Tech University. As part of my graduate program, I am working on a project that involves developing a standardized way to measure the ability of adults to localize sources of sound. If you are between 21 and 60 years of age and do not have a hearing loss, I am requesting that you consider participating in this project which is under the direction of faculty members in the Department of Speech at Louisiana Tech University.*
>
> *Your participation will require one visit to the local office of an audiologist. During this visit, which will last approximately one and one half hours, you will receive a free comprehensive hearing evaluation followed by asking you to listen to a series of short sentences and point to a loudspeaker from which you heard the sentence. There are no risks involved in your participation. While you will not be compensated for your participation, you will receive the results of your free hearing evaluation. If you are found to have a hearing loss, you will be given appropriate recommendations so that you may seek hearing health care services if you wish.*

If you are interested in participating in this project, please contact me at the telephone number or email address listed below. At that time, you will be asked to provide me your name, telephone number, email and mailing address. That is for the purpose of contacting you to schedule an appointment for you to come into the office. Please be assured that your personal information is only for the purpose of this project and will not be shared with any other individuals or agencies. Also, please feel free to contact me if you have any questions or if I can provide additional information. Thank you for your time and consideration, I look forward to hearing from you.

Please Contact:
Alison V. Huff
Telephone: (337) 856-0893
Email: aviator5@excite.com

Upon receipt of the contact information, potential subjects will be mailed an introduction letter (see Appendix I) with a more detailed explanation of the project and participation requirements. Those individuals who return the signed and dated introduction letter will be contacted by the primary investigator to make arrangements for testing. A two-week time period will be allowed for the potential subjects to return the introduction letter. If the introduction letter is not returned within two weeks, the primary investigator will contact the potential subjects, by telephone or email, to determine his or her intent to participate. If the introduction letter has not been received within two weeks of the first contact, a reminder letter (see Appendix J) will then be mailed to these potential subjects. No further attempts will be made to contact the potential subjects who have not returned the introduction letter within four weeks of the second follow-up contact.

As soon as the signed letter has been received, the primary investigator will contact the potential subject to schedule an appointment that is convenient for the testing to be completed. Test appointments will be scheduled in two hour blocks, Monday through Friday, beginning at 8:00 a.m. and ending at 5:00 p.m. with a one hour lunch break included for the primary investigator.

Instrumentation and Test Environment

All experimental testing will be completed in an 8x8 foot double-walled IAC sound treated booth (ANSI S3.1 – 1991). In order to prevent standing waves (i.e., sound waves that may be reflected off the walls of the sound treated booth), the primary investigator will cover all internal surfaces within the sound treated booth with four inch thick absorbent acoustic foam. Peabody Noise Control Company, Model TSF-P Acoustical Foam will be used. Also, the floor of the test booth will be covered with a one inch thick pile carpet.

To measure reverberation and standing waves within the sound treated booth, the primary investigator will attach the sound level meter with a one inch pressure microphone to a tripod that will be placed in the center of the loudspeaker array approximately at head level of the subject. One Central Institute for the Deaf Everyday Sentence, presented at 50 dB HL and then 70 dB HL, will be emitted through one of the eight loudspeakers, at a time. These measurements will be recorded as verification that each loudspeaker is emitting a Central Institute for the Deaf Everyday Sentence at the appropriate level.

The test stimuli for audiological testing will be delivered via EAR Tone 3A insert earphones which will be routed through an Interacoustic AC 40 audiometer (ANSI S3.6 – 1996). The Random Gap Detection Test stimuli will be delivered by a Tascam CD-160 CD player via insert earphones which will also routed through the Interacoustic AC 40 audiometer. The test of localization stimuli will be delivered by a Tascam CD-160 CD player via LR2SA Line Radiator 20 watt loudspeakers (Figure 3.1) also routed through the Interacoustic AC 40 audiometer.

Eight sound field speakers (Figure 3.1) will be placed in the sound treated booth and arranged symmetrically within the horizontal plane with 45 degree intervals between each speaker (see Appendix B). The speakers will be LR2SA Line Radiator 20 watt loudspeakers. The Interacoustic AC 40 audiometer will be used to present 40 short speech phrases through the sound field speakers to each subject at 50 dB HL for one quiet test condition and 70 dB HL for four noisy test conditions. A conventional swivel chair with an attached headrest will be placed in the booth.

All subjects will be positioned in the center of the IAC sound treated booth and instructed to sit in the swivel chair with his or her head positioned against the attached headrest. The headrest will be used to help minimize head movement, thus, keeping the subjects' head continuously facing forward loudspeaker #5.

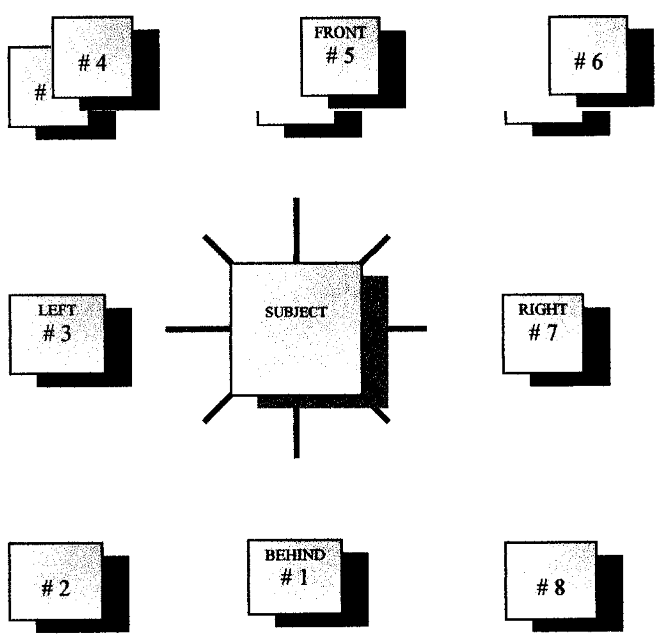


Figure 3.1. Eight Loudspeaker Array.

Eight LR2SA Line Radiator 20 watt loudspeakers will be arranged symmetrically within the horizontal plane with 45 degree intervals between each loudspeaker. The loudspeakers will be numbered 1 through 8, starting directly behind the subject and continuing clockwise. Loudspeaker #1 will be situated directly behind the subject, loudspeaker #3 will be 90 degrees to the left of the subject, loudspeaker #5 directly in front of the subject, and loudspeaker #7 will be 90 degrees to the right of the subject. Loudspeakers #2, #4, #6, and #8 are positioned at 45 degrees to the other loudspeakers (Figure 3.1)

Test Stimuli

The protocol for testing localization will use the Central Institute for the Deaf Everyday Sentences (Alpiner & Schow, 2000; Healy & Montgomery, 2006) as the test stimuli (see Appendix E). These sentences were chosen because they are designed to represent everyday American speech appropriate for all adults. A 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra for speech and noise to simulate a noisy listening condition. A varying signal-to-noise ratio will be used.

This Central Institute for the Deaf Everyday Sentences CD has 10 lists, labeled A through J with 10 sentences in each list. Using an Excel program (Microsoft Corporation, 2002), the primary investigator will randomly select 40 sentences from the 100 sentence list (see Appendix C). Each sentence will have a duration of approximately three seconds, with a three-second pause between each trial. The 40 sentences will be randomly presented five times through each loudspeaker for all five test conditions. Therefore, each subject will receive a total of 200 presentations, 40 presentations for one quiet listening condition and 160 presentations for the four noisy listening conditions. The Excel program will also be used to randomize the 40 phrases to be presented to all the subjects.

Test Conditions

The 40 short phrases will be randomized and presented in one of five test conditions. The test conditions are speech stimuli in quiet, speech stimuli in noise with a 5 dB signal-to-noise ratio, speech stimuli in noise with a 10 dB signal-to-noise ratio, speech stimuli in noise with a 15 dB signal-to-noise, and speech stimuli in noise with a 20 dB signal-to-noise ratio.

Quiet Test Condition. The speech stimuli in quiet were chosen to represent normal conservation at an intensity level of 50 dB HL with no presence of background noise. One of the test sentences will be presented to the subject through one loudspeaker randomly selected from the eight loudspeakers. The Excel program will be used for the random selection which will be accomplished before the localization testing begins. One of the eight loudspeakers will present one sentence at a time while the remaining seven speakers remain silent. The 40 Central Institute for the Deaf sentences will be randomly presented five times through each loudspeaker for this quiet test condition. Therefore, each subject will receive 40 presentations. The Excel program will also be used to randomize the 40 sentences to be presented to the subjects.

Noisy Test Conditions. The subjects' localization abilities in the presence of background noise will also be tested. Four different noisy test conditions will be presented to each subject. The first speech stimuli were chosen to represent speech in background noise with speech presented at 70 dB HL and noise presented at 65 dB HL.

The second speech stimulus condition will represent speech in background noise with speech at an intensity level of 70 dB HL and noise at 60 dB HL. The third speech stimulus condition represents speech in background noise with speech presented at 70 dB HL and noise at 55 dB HL. The fourth test condition will represent speech in background noise with speech presented at 70 dB HL and noise at 50 dB HL.

The primary investigator will present one test sentence through one loudspeaker randomly selected from the eight possibilities. The Excel program will be used for the random selection before the localization testing begins. Only one of the eight loudspeakers will present one sentence at a time while the remaining seven speakers emit a 1000 Hz white noise stimulus. The 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra for speech and noise to simulate a noisy listening condition. The 40 phrases will be randomly presented five times through each loudspeaker for these four noisy test conditions. Therefore, each subject will receive 160 presentations. The Excel program will also be used to randomize the 40 phrases that will be presented to the subjects.

Procedures

Prior to the localization testing, each subject will be administered an audiological battery that includes completion of an audiological case history (see Appendix E), an otoscopic examination, tympanometry testing, speech discrimination testing, pure tone testing through air and bone conduction (see Appendix F), and the Random Gap Detection test (see Appendix A). Once it has been determined that the subject has met the audiologic criteria for participation in the study, the localization testing (see Appendix G) will follow. If it is determined that there appears to be some hearing irregularities, that information will be discussed with the individual and recommendations made for appropriate hearing health care services. That individual would not then be used in the sound localization testing part of the study.

All the audiological procedures will be presented by the primary investigator. Testing time is estimated to be 90 minutes per subject with a 10-minute break between completion of the audiological testing and the test of localization. It is projected that four weeks will be required to administer the audiological test battery and the test of localization to the 80 subjects being recruited for the study.

In order to control for experimental consistency, the primary investigator will read the instructions aloud to all the subjects. Each subject will be seated in the center of the IAC sound treated booth (ANSI S3.3 – 1991) on a swivel chair positioned in the center of the booth.

As a first step in the process, each subject will complete an audiological case history (Appendix E). After completion, the primary investigator will review the document to verify completeness and seek responses to any unanswered questions. The subject will then be asked to sit quietly with his or her mouth closed while an otoscopic examination is performed. The subject will then be given directions for his or her participation in tympanometry testing.

Next, speech discrimination testing along with pure tone testing through air conduction and bone conduction via EAR Tone 3A insert earphones will be administered. The primary investigator will read aloud the test instructions to each subject as follows:

> *You will hear speech words in one ear and then the other ear. Please repeat the words that you hear. Some of the words will be loud and some of the words will be soft. Repeat all the words that you can; you may guess if you need to.*

Following the speech words, you will hear a series of beeps. Please press the button every time that you hear the beeps. Once again, the beeps may be loud or soft. Press the button even if you barely hear the beeps.

The last thing we will do is called the Random Gap Detection test. You will hear one beep or you may hear two beeps. If you hear one beep, raise one finger. If you hear two beeps, raise two fingers. Do you have any questions?

After the subject has been read the instructions, the audiological test battery will begin. At the beginning of each component of the testing, the instructions will be re-read to the subject. For example, instructions for the speech discrimination test will be read again and the speech discrimination testing will be completed. Next, only the instructions for the pure tone testing will be read followed by administration of the pure tone testing through air conduction and bone conduction. Lastly, only the instructions for the Random Gap Detection test will be read. The Random Gap Detection test will then be administered to the subject.

After all audiological testing has been completed, the primary investigator will review all test results with each subject. If a subject meets all of the audiological criteria, the subject will be given a 10-minute break before completing the localization test which will be administered by the primary investigator. In the event that a subject did not meet the audiological criteria, the primary investigator will review all test results and make the appropriate recommendations for follow-up hearing services that the individual may pursue if he or she chooses.

The primary investigator will then administer the test of localization which has five test conditions. The primary investigator will provide the informed consent to each subject which he or she will read, sign, and date (see Appendix K). Each subject will be seated in a swivel chair situated in the center of an IAC sound treated booth (ANSI S3.1 –

1991) and required to listen to the speech sentences being presented. Subjects are to be seated, facing loud speaker #5. The test stimuli will be transmitted to the appropriate speaker via a "router". The test stimuli will be randomly presented through one of the eight speakers at a time, both in quiet and noisy listening situations.

After the stimulus is presented from one of the eight speakers, the subject will be allowed to swivel in the test chair to point and verbally identify the appropriately numbered loud speaker. After pointing to the appropriate loudspeaker, the subject will resume the testing position, facing loudspeaker #5. The subject will be further instructed to hold his or her head and eyes steady during stimulus presentation. The responses will be recorded by the primary experimenter.

For the quiet and noisy listening conditions, each subject will listen to the testing directions that will be read aloud by the primary investigator. The instructions are as follows:

> *You are going to hear a short speech sentence. You will hear the sentence in quiet and with some noise in the background. Please listen carefully. As you listen to each sentence, face loudspeaker #5. As you listen to each sentence, please keep your eyes steady and hold your head against the headrest attached to the chair in which you are sitting. It is important that you not move your head as you listen.*
>
> *After you have heard a sentence, please swivel in the chair to point to the loudspeaker from which you heard the sentence. As you point, verbally identify the loudspeaker by number. Wait until you no longer hear any words before you point and identify the loudspeaker from which you heard the sentence. After you point to the appropriate loudspeaker, please sit back in the chair and face loudspeaker #5 with your head fixed against the headrest and your eyes steady.*
>
> *At times, it may be difficult for you to identify the loudspeaker from which you hear some of the sentences. If you are unsure, it is okay to take a guess at the direction from which you heard the sentence. Please remember to wait until the sentence has been presented, then point and verbally identify the number of the loudspeaker from which you heard the sentence. Do you have any questions?*

Any questions posed by the subject will be answered and, if necessary, the instructions will be repeated in their entirety. As further verification that the test procedures are understood, each subject will then be asked to paraphrase the instructions for the examiner.

The localization test responses will be recorded by the primary investigator on an answer sheet (see Appendix G). The test of localization is based on whether the subject correctly identified the appropriately numbered loudspeaker from which the Central Institute for the Deaf Everyday Sentence is presented (see Appendix C). If a subject responds correctly, the primary investigator will indicate the mark with a check (√). However, if the subject responds incorrectly, the primary investigator will indicate the error with an **X** and include the number of the subject's loudspeaker response.

After all audiological and localization testing has been completed, the subject will be thanked by the primary investigator and released from the study. The primary investigator will remind the subject that all personal information will remain confidential.

Data Analysis

Analysis of variance will be used with the factors being age group and test conditions. There will be five test conditions and four age groups. The dependent variable is the test response. The analysis of variance will have three degrees of freedom for age, four degrees of freedom for test condition, and 12 degrees of freedom for the interaction between age and test condition. This analysis will reveal whether the test condition has an effect on the response, whether age has an effect on the response, and whether there is an interaction of test condition with the response depending on age.

Regression analysis will also be used with age as the independent variable and the response as the dependent variable. In addition to age, test conditions will be entered as the independent variables. These will be entered as dummy variables. Because there are five different test conditions, there will be four dummy variables in the regression model. Each variable will be coded as a 0 or 1 value within the model. A second model for regression analysis will be used to analyze the data from the expert reviewers which will provide information about the experimental protocol for sound localization. These too will be coded as dummy variables.

APPENDIXES

APPENDIX A

RANDOM GAP DETECTION TEST

Subject Number_______________
Date_______________

AUDITEC

RGDT

RANDOM GAP DETECTION TEST (RGDT)
(Revised AFT-R)

Name________________________________ Age____Sex____Date__________

Interstimulus Interval (Gap) in msec.
(In order of presentation)

TONES

Subtest 1: Screening/Pratice

	0	2	5	10	15	20	25	30	40	Lowest Gap_____ msec.

Subtest 2: Standard

500 Hz	10	40	15	5	0	25	20	2	30	Lowest Gap_____ msec.
1000 Hz	30	10	15	2	0	40	5	20	25	Lowest Gap_____ msec.
2000 Hz	20	2	40	5	10	25	15	0	30	Lowest Gap_____ msec.
4000 Hz	5	10	40	15	20	2	30	0	25	Lowest Gap_____ msec.

CLICKS

Subtest 3: Screening/Practice, Clicks

	0	2	5	10	15	20	25	30	40	Lowest Gap_____ msec.

Subtest 4: Clicks

	30	5	20	40	2	0	15	10	25	Lowest Gap_____ msec.

Date: Thu May 25 22:44:43 2006 **From:** Bill Carver <billcarver@auditec.com>
[Add to Address Book | Block Address | Report **as Spam]**
To: <aviator5@excite.com>
Subject: RE: SPAM LOW:
graduate student dissertation

Alison V. Viator, you have our permission to include the Random Gap Detection Test and the CID Everyday Speech test produced and marketed by AUDiTEC in your dissertation at Louisiana Tech University. These tests are not to be sold by you. Signed:

William F. Carver, Ph.D., FASHA, FAAA
President,
AUDiTEC
-----Original Message-----
From: aviator5@excite.com [mailto:aviator5@excite.com]
Sent: Thursday, May 25, 2006 6:52 PM
To: billcarver@auditec.com
Cc: aviator5@excite.com
Subject: SPAM LOW: graduate student dissertation

Hello Dr. Carver, I spoke with you on the phone earlier this week. I am sending this as a reminder of the information that I would like to receive permission for to include these specific tests in my dissertation. The tests are the Random Gap Detection Test and the Central Institute for the Deaf (CID) Everyday Speech Sentences Test. I spoke with my dissertation chair and he states that permission has to be received from the authors/publishers to include these tests into my dissertation. Thank you for your time. It is greatly appreciated.

Sincerely,

Alison V. Viator, B.A.

3rd year audiology graduate

Louisiana Tech University

APPENDIX B

LOUDSPEAKER ARRAY

Speaker Array

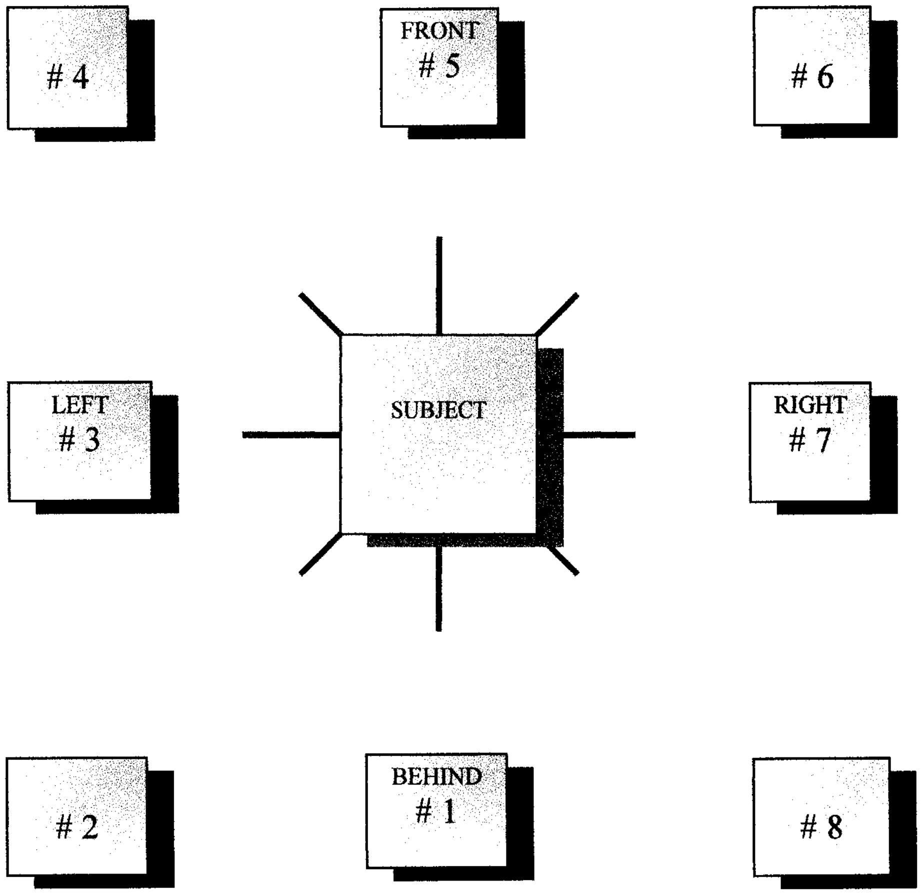


Figure B.1. Eight Loudspeaker Array.

The loudspeakers are numbered 1 through 8, starting directly behind the subject, and continuing clockwise. Loudspeaker 1 will be situated directly behind the subject, loudspeaker 3 will be 90 degrees to the left of the subject, loudspeaker 5 directly in front of the subject, and loudspeaker 7 will be 90 degrees to the right of the subject. Loudspeakers 2, 4, 6, and 8 will be positioned at 45 degrees to the other loudspeakers.

APPENDIX C

CENTRAL INSTITUTE FOR THE DEAF EVERYDAY SENTENCES

Central Institute for the Deaf Everyday Sentences

List A

1. Walking's my favorite exercise.
2. Here's a nice quiet place to rest.
3. Our janitor sweeps the floors every night.
4. It would be much easier is everyone would help.
5. Good morning.
6. Open your window before you go to bed.
7. Do you think that she should stay out so late?
8. How do you feel about changing the time when we begin to work?
9. Here we go.
10. Move out of the way.

List B

11. The water's too cold for swimming.
12. Why should I get up so early in the morning?
13. Here are your shoes.
14. It's raining.
15. Where are you going?
16. Come here when I call you!
17. Don't try to get out of it this time!
18. Should we let little children go to the movies by themselves?
19. There isn't enough paint to finish the room.
20. Do you want an egg for breakfast?

List C

21. Everybody should brush his teeth after meals.
22. Everything's all right.
23. Don't use up all the paper when you write your letter.
24. That's right.
25. People ought to see a doctor once a year.
26. Those windows are so dirty I can't see anything outside.
27. Pass the bread and butter please!
28. Don't forget to pay your bill before the first of the month.
29. Don't let the dog out of the house!
30. There's a good ballgame this afternoon.

List D

31. It's time to go.
32. If you don't want these old magazines, throw them out.
33. Do you want to wash up?

34. It's a real dark night so watch your driving.
35. I'll carry the package for you.
36. Did you forget to shut off the water?
37. Fishing in a mountain stream is my idea of a good time.
38. Fathers spend more time with their children than they used to.
39. Be careful not to break your glasses!
40. I'm sorry.

List E

41. You can catch the bus across the street.
42. Call her on the phone and tell her the news.
43. I'll catch up with you later.
44. I'll think it over.
45. I don't want to go to the movies tonight.
46. If your tooth hurts that much you ought to see a dentist.
47. Put that cookie back in the box!
48. Stop fooling around!
49. Time's up.
50. How do you spell your name?

List F

51. Music always cheers me up.
52. My brother's in town for a short while on business.
53. We live a few miles from the main road.
54. This suit needs to go to the cleaners.
55. They ate enough green apples to make them sick for a week.
56. Where have you been all this time?
57. Have you been working hard lately?
58. There's not enough room in the kitchen for a new table.
59. Where is he?
60. Look out!

List G

61. I'll see you right after lunch.
62. See you later.
63. White shoes are awful to keep clean.
64. Stand there and don't move until I tell you!
65. There's a big piece of cake left over from dinner.
66. Wait for me at the corner in front of the drugstore.
67. It's no trouble at all.
68. Hurry up!
69. The morning paper didn't say anything about rain this afternoon or tonight.
70. The phone call's for you.

List H

71. Believe me!
72. Let's get a cup of coffee.
73. Let's get out of here before it's too late.
74. I hate driving at night.
75. There was water in the cellar after the heavy rain yesterday.
76. She'll only be gone for a few minutes.
77. How do you know?
78. Children like candy.
79. If we don't get rain soon, we'll have no grass.
80. They're not listed in the new phone book.

List I

81. Where can I find a place to park?
82. I like those big red apples we always get in the fall.
83. You'll get fat eating candy.
84. The show's over.
85. Why don't they paint their walls some other color?
86. What's new?
87. What are you hiding under your coat?
88. How come I should always be the one to go first?
89. I'll take sugar and cream in my coffee.
90. Wait just a minute!

List J

91. Breakfast is ready.
92. I don't know what's wrong with the car, but it won't start.
93. It sure takes a sharp knife to cut this meat.
94. I haven't read a newspaper since we bought a television set.
95. Weeds are spoiling the yard.
96. Call me a little later!
97. Do you have change for a five-dollar bill?
98. How are you?
99. I'd like some ice cream with my pie.
100. I don't think I'll have any dessert.

Permission to reprint received from Dr. Bill Carver (May 25, 2006) – Auditec

APPENDIX D

FORTY CENTRAL INSTITUTE FOR THE DEAF EVERYDAY SENTENCES

Central Institute for the Deaf Everyday Sentences

Excel (Microsoft Corporation, 2002) was used to randomly select the following 40 Central Institute for the Deaf Everyday Sentences that will be used as the localization stimuli for the study.

1. It's a real dark night so watch your driving.
2. Let's get out of here before it's too late.
3. I like those big red apples we always get in the fall.
4. If your tooth hurts that much you ought to see a dentist.
5. There was water in the cellar after the heavy rain yesterday.
6. Let's get a cup of coffee.
7. Our janitor sweeps the floors every night.
8. They ate enough green apples to make them sick for a week.
9. See you later.
10. Open your window before you go to bed.
11. I'll catch up with you later.
12. Time's up.
13. Don't try to get out of it this time!
14. Here are your shoes.
15. You can catch the bus across the street.
16. Music always cheers me up.
17. Call me a little later!
18. Everybody should brush his teeth after meals.
19. Wait just a minute!
20. Breakfast is ready
21. Where are you going?
22. My brother's in town for a short while on business.
23. Stand there and don't move until I tell you!
24. Don't use up all the paper when you write your letter.
25. I don't want to go to the movies tonight.
26. There's a big piece of cake left over from dinner
27. The phone call's for you.
28. Look out!
29. Don't forget to pay your bill before the first of the month.
30. How come I should always be the one to go first?
31. Pass the bread and butter please!
32. I'm sorry.
33. Should we let little children go to the movies by themselves?
34. Do you think that she should stay out so late?
35. The water's too cold for swimming.
36. There isn't enough paint to finish the room.
37. Wait for me at the corner in front of the drugstore.
38. There's not enough room in the kitchen for a new table.
39. How do you know?
40. I haven't read a newspaper since we bought a television set.

APPENDIX E

SUBJECT CASE HISTORY

Alison V. Huff, B.A.
Primary Investigator
(337) 856-0893

Case History

Name_________________________ DOB_________________ Subject #__________

Address_____________________________ Telephone___________________________
_____________________________ Occupation___________________________

Hearing Difficulty: Onset________________ Progression___________________
Cause________________ Other_________________________

Difficulty Understanding Speech: In Quiet ____yes ____no
In Background Noise ____yes ____no

Head or Neck Surgery? _____yes ____no
If so, when and what part of the head or neck?__________________________________

List any medications that you are taking at this time:_____________________________

Ringing in the ears? _____yes _____no
If yes, ______right ear _____left ear _______both ears

Serious Illnesses (Please List):____

Family History of Hearing Loss (Please describe)_________________________________
Relation to You________________ Age of Onset_________ Cause_________________

Trauma: Noise Exposure______________________ Type of Noise__________________
Number of Hours____________________ Ear Protection Used____yes_____no
Head Injury or Accident____

Do you now wear a hearing aid? ____yes ____right ear ____left ear ____both _____none
Hearing Aid Type?______________ Hearing Test Results__________________________

Diagnosed with any type of Developmental Disorder? ____________________________
If so, when and what type?____

Have you ever had your hearing tested? _____yes _____no
If so, when and where?____
Results____

APPENDIX F

AUDIOGRAM

Subject Number ______________
Date ______________

Alison V. Huff, B.A.
Primary Investigator
(337) 856-0893

	Notes
Otoscopic Evaluation Right Ear	
Otoscopic Evaluation Left Ear	

	Type
Tympanometry Right Ear	
Tympanometry Left Ear	

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
AC Right Ear						
BC Right Ear						
AC Left Ear						
BC Left Ear						

	Percent Correct
Word Discrimination Right Ear	
Word Discrimination Left Ear	

APPENDIX G

LOCALIZATION TEST DATA SHEET

Localization Test Data Subject Number ____________

(PS) – Presenting Speaker Date____________

Quiet (PS) Condition	Response	Noise (PS) 70/65 dB	Response	Noise (PS) 70/60 dB	Response
6		7		2	
7		8		2	
8		4		8	
4		1		4	
4		4		1	
5		7		6	
7		5		2	
5		6		2	
2		4		4	
3		5		7	
6		5		5	
2		5		7	
1		3		7	
1		1		3	
4		4		5	
4		2		8	
6		7		5	
4		4		4	
5		2		4	
4		3		7	
8		4		8	
2		6		5	
1		4		7	
8		1		6	
3		5		4	
3		3		2	
4		5		8	
6		3		7	
5		2		2	
7		3		5	
6		5		7	
4		1		7	
4		2		1	
1		2		1	
6		1		3	
6		4		3	
7		1		2	
6		6		8	
4		4		3	
4		4		6	

Localization Test Data Subject Number_____________

(PS) – Presenting Speaker Date_____________

Noise 70/55 dB (PS)	Response	Noise 70/50 dB (PS)	Response
3		4	
3		4	
6		3	
8		3	
5		2	
2		3	
1		4	
5		2	
1		2	
4		4	
4		1	
2		8	
4		4	
4		5	
4		8	
6		4	
8		8	
2		5	
3		8	
2		6	
6		6	
1		6	
8		6	
4		3	
4		1	
4		1	
1		8	
5		2	
4		7	
7		3	
4		3	
6		2	
5		2	
4		7	
1		2	
3		8	
1		2	
3		8	
6		8	
3		1	

APPENDIX H

SOUND LOCALIZATION PROTOCOL

Dr. Xxxxxxxx Date:
Address
Telephone Number
Email address

Dear Dr. Xxxxxxxx:

Thank you for agreeing to participate in my doctoral dissertation project to develop a standardized test of sound localization. As I discussed with you, the purpose of this study is to develop a standardized protocol to determine how adults with normal hearing sensitivity and normal temporal processing perform on localization tasks.

Reported investigations of sound localization have used a variety of test stimuli, test environments, loudspeaker arrays, and ages and numbers of subjects to measure the ability to localize sounds. Despite the obvious need for individuals to identify the specific location of a sound source, the variety of approaches suggests that there is no standard process for measuring localization abilities. Therefore, a standardized protocol for measuring localization abilities would attenuate the need to vary testing procedures while determining an individual's ability to identify sources as part of a complete audiological assessment.

The specific purpose of this capstone project is to develop a protocol for testing sound localization. This protocol will specify the test environment, instrumentation, loudspeaker array, test stimuli, test conditions, and instructions that could be used by audiologists as part of a complete audiological assessment for individuals who range in age from 21 to 60 years.

As we also discussed, you are being asked to choose eight individuals from your audiology private practice to serve as subjects for this study. Please choose two individuals, male or female, in each of the following age ranges: 20 to 30, 31 to 40, 41 to 50, and 51 to 60 years. In addition, these eight individuals should have a normal audiological case history, normal otoscopic examination, Type A tympanograms bilaterally, speech word discrimination of 85% correct or better bilaterally, pure tone testing through air and bone conduction at each octave frequency of 250 to 8000 Hz of 25 dB HL or better bilaterally, and Random Gap Detection test thresholds of 20 ms or less.

The attached protocol contains all the instructions, test stimuli, instrumentation descriptions, data forms, etc. that you will need to complete the audiological and localization testing. In addition, you will find a questionnaire to complete that provides your feedback regarding the methodology used to develop this standardized test of sound localization. Your candid responses are requested.

Within one week of your receipt of this protocol, I will contact you to schedule an appointment to discuss implementation of the study and to respond to any questions you may have. I am requesting that you complete the testing on your eight clients within four weeks of that meeting.

Your assistance with this project is sincerely appreciated and I look forward to working with you. Please do not hesitate to contact me with any questions or concerns that you may have regarding this study.

Sincerely,

Alison V. Huff, B.A.
Doctoral Student
Au.D. Program
Department of Speech
Louisiana Tech University

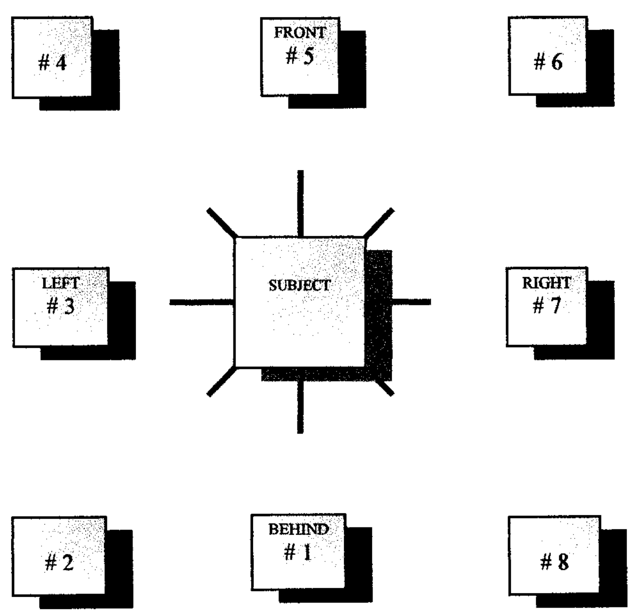
Enclosure: Standardized Protocol

Sound Localization Protocol

Test Environment / Instrumentation / Loudspeaker Array

All experimental testing will be completed in an 8x8 foot double-walled IAC sound treated booth (ANSI S3.1 – 1991). The test stimuli for audiological testing will be delivered via EAR Tone 3A insert earphones which will be routed through an Interacoustic AC 40 audiometer (ANSI S3.6 – 1996) The Random Gap Detection Test stimuli will be delivered by a Tascam CD-160 CD player via insert earphones which will also be routed through the Interacoustic AC 40 audiometer. The test of localization stimuli will be delivered by a Tascam CD-160 CD player via LR2SA Line Radiator 20 watt loudspeakers also routed through the Interacoustic AC 40 audiometer.

Eight sound field speakers will be placed in the sound-treated booth and arranged symmetrically within the horizontal plane with 45 degree intervals between each speaker. The speakers are LR2SA Line Radiator 20 watt loudspeakers. The Interacoustic AC 40 audiometer will be used to present 40 short speech sentences through the sound field speakers to each subject at 50 dB HL for one quiet test condition and 70 dB HL for four noisy test conditions. A conventional swivel chair with an attached headrest will be placed in the booth.



Eight Loudspeaker Array

The subjects will be positioned in the center of the IAC sound-treated booth (ANSI S3.1 – 1991) and instructed to sit in the swivel chair with their head positioned against the attached headrest. The headrest will be used to help minimize head movement, therefore, keeping the subjects head continuously facing the forward loudspeaker #5.

Eight LR2SA Line Radiator 20 watt loudspeakers will be arranged symmetrically within the horizontal plane with 45 degree intervals between each loudspeaker. The loudspeakers are numbered 1 through 8, starting directly behind the subject, and continuing clockwise. Loudspeaker #1 will be situated directly behind the subject, loudspeaker #3 will be 90 degrees to the left of the subject, loudspeaker #5 directly in front of the subject, and loudspeaker #7 will be 90 degrees to the right of the subject. Loudspeakers #2, #4, #6, and #8 will be positioned at 45 degrees to the other loudspeakers.

Test Stimuli

To assure that all test subjects have normal temporal processing abilities, the Random Gap Detection Test will be administered. Temporal processing, as suggested by Chermak and Lee (2005), can be associated with a decline in physical or mental qualities due to age related changes throughout the auditory system. Temporal processing can be assessed using a variety of different tests, in particular, the Random Gap Detection Test.

Random Gap Detection Test. The Random Gap Detection Test has four subtests, two practice trials (Subtest 1 and Subtest 3) and two test trials (Subtest 2 and Subtest 4). Subtest 1 is a practice trial that uses nine pairs of 500 Hz tones as stimuli. Subtest 2, a test trial, uses nine pairs of randomly presented tones, ranging from 500 to 4000 Hz. Subtest 3 is another practice trial that uses nine pairs of click stimuli while Subtest 4 is a test trial that uses nine pairs of randomly presented click stimuli. Each subtest is presented binaurally through earphones at a comfortable listening level for the subject. The Random Gap Detection Test score is based the consistency with which an individual identifies the smallest inter-pulse interval between two tones at a given frequency. The composite gap detection is an average of all frequencies tested and a gap detection threshold for clicks, which is reported separately. Individuals who have normal temporal processing abilities should have a score of 20 ms or less on the Random Gap Detection Test.

Central Institute for the Deaf Everyday Sentences. This protocol for testing localization will use the Central Institute for the Deaf Everyday Sentences (Alpiner & Schow, 2000; Healy & Montgomery, 2006) as the test stimuli. These sentences were chosen because they are designed to represent everyday American speech appropriate for all adults. A 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra for speech and noise to stimulate a noisy listening condition. A varying signal-to-noise ratio will be used.

This Central Institute for the Deaf Everyday Sentences CD has 10 lists, labeled A through J with 10 sentences in each list. Using an Excel program, the primary investigator will randomly select 40 sentences from the 100 sentence list. Each sentence will have a duration of approximately three seconds, with a three-second pause between each trial. The 40 sentences will be randomly presented five times through each loudspeaker for all five test conditions. Therefore, each subject will receive a total of 200 presentations, 40 presentations for one quiet listening condition and 160 presentations for the four noisy listening conditions. An Excel program will also be used to randomize the 40 phrases that will be presented to all the subjects.

Test Conditions

The 40 short phrases will be randomized and presented in one of five test conditions. The test conditions are speech stimuli in quiet, speech stimuli in noise with a 5 dB signal-to-noise ratio, speech stimuli in noise with a 10 dB signal-to-noise ratio, speech stimuli in noise with a 15 dB signal-to-noise, and speech stimuli in noise with a 20 dB signal-to-noise ratio.

Quiet Test Condition. The speech stimuli in quiet are chosen to represent normal conservation at an intensity level of 50 dB HL with no presence of background noise. One of the test sentences will be presented to the subject through one loudspeaker randomly selected from the eight loudspeakers. An Excel program will be used for the random selection which will be accomplished before the localization testing begins. Only one of the eight loudspeakers will present one sentence at a time, while the remaining seven speakers remain silent. The 40 Central Institute for the Deaf sentences will be randomly presented five times through each loudspeaker for this quiet test condition. Therefore, each subject will receive 40 presentations. An Excel program will also be used to randomize the 40 sentences to be presented to the subjects.

Noisy Test Conditions. The subjects' localization abilities in the presence of background noise will also be tested. Four different noisy test conditions will be presented to each subject. The first speech stimuli were chosen to represent speech in background noise with speech presented at 70 dB HL and noise presented at 65 dB HL. The second speech stimulus condition will represent speech in background noise with speech at an intensity level of 70 dB HL and noise at 60 dB HL. The third speech stimulus condition represents speech in background noise with speech presented at 70 dB HL and noise at 55 dB HL. The fourth test condition will represent speech in background noise with speech presented at 70 dB HL and noise at 50 dB HL.

One test sentence will be presented through one randomly selected loudspeaker from the eight possibilities. An Excel program will be used for the random selection before the localization testing begins. Only one of the eight loudspeakers will present one sentence at a time, while the remaining seven speakers emit a 1000 Hz white noise stimulus. The 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra for speech and noise to simulate a noisy listening condition. The 40 phrases will be randomly presented five times through each loudspeaker for these four noisy test conditions. Therefore, each subject will receive 160 presentations. An Excel program will also be used to randomize the 40 phrases that will be presented to the subjects.

Instructions

Forty short phrases will be randomized and presented to the subjects in one of five test conditions: speech stimuli in quiet, speech stimuli in noise with a 5 dB signal-to-noise ratio, speech stimuli in noise with a 10 dB signal-to-noise ratio, speech stimuli in noise with a 15 dB signal-to-noise, and speech stimuli in noise with a 20 dB signal-to-noise ratio. For each test condition (one quiet and four noise), each subject will listen to the test directions. For purposes of validity and reliability, the same instructions will be read aloud to each subject. The instructions are as follows:

You are going to hear a short speech sentence. You will hear the sentence in quiet and with some noise in the background. Please listen carefully. As you listen to each sentence, face loudspeaker #5. As you listen to each sentence, please keep your eyes steady and hold your head against the headrest attached to the chair in which you are sitting. It is important that you not move your head as you listen.

After you have heard a sentence, please swivel in the chair and point to the loudspeaker from which you heard the sentence. As you point, verbally identify the loudspeaker by number. Wait until you no longer hear any words before you point and identify the loudspeaker from which you heard the sentence. After you point to the appropriate loudspeaker, please sit back in the chair and face loudspeaker #5 with your head fixed against the headrest and your eyes steady.

At times, it may be difficult for you to identify the loudspeaker from which you hear some of the sentences. If you are unsure, it is okay to take a guess at the direction from which you heard the sentence. Please remember to wait until the sentence has been presented, then point and verbally identify the number of the loudspeaker from which you heard the sentence. Do you have any questions?

Any questions posed by the subject will be answered and, if necessary, the instructions will be repeated in their entirety. As further verification that the test procedures are understood, each subject will be asked to paraphrase the instructions for the examiner.

Subjects

This capstone study will require the participation of 80 individuals, 40 males and 40 females, who range in age from 21 to 60 years. Based on their chronological age, the subjects will be assigned to one of four groups, 20 per group (10 males, 10 females). The age groupings are: 21 to 30 years, 31 to 40 years, 41 to 50 years, and 51 to 60 years.

In addition to the age requirement, subjects must meet the following criteria: normal audiological case history, normal otoscopic examination (non-occluding ear canals, i.e. wax, debris, or external infections bilaterally), Type A tympanograms bilaterally, speech word discrimination of 85% correct or better bilaterally, pure tone testing through air conduction and bone conduction at each octave frequency of 250 to 8000 Hz of 25 dB HL or better bilaterally and a Random Gap Detection test threshold of 20 ms or less.

As we discussed, you are being asked to choose eight individuals from your audiology private practice to serve as subjects for this study. Please choose two individuals, male or female, in each of the following age ranges: 20 to 30, 31 to 40, 41 to 50, and 51 to 60 years. In addition, these eight individuals should meet the established audiological criteria.

Procedures

Prior to the localization testing, each subject will be administered an audiological battery that includes completion of an audiological case history, an otoscopic examination, tympanometry testing, speech discrimination testing, pure tone testing through air and bone conduction, and the Random Gap Detection test. Once it has been determined that the subject has met the audiologic criteria for participation in the study, the localization testing will follow. If it is determined that there appears to be some hearing irregularities, that information will be discussed with the individual and recommendations made for appropriate hearing health care services.

All the audiological procedures will be provided by the primary investigator. Testing time is estimated to be 90 minutes per subject with a 10-minute break between the audiological testing and the test of localization. It is projected that four weeks will be required to administer the audiological test battery and the test of localization to the 80 subjects being recruited for the study.

In order to control for experimental consistency, the primary investigator will read the instructions aloud to all the subjects. Each subject will be seated in the center of the IAC sound treated booth (ANSI S3.3 – 1991) on a swivel chair positioned in the center of the booth.

As a first step in the process, each subject will complete an audiologic case history. After completion, the primary investigator will review the document to verify completeness and seek responses to any unanswered questions. The subject will then be asked to sit quietly with his or her mouth closed while an otoscopic examination is performed. The subject will then be given directions for his or her participation in tympanometry testing.

Next, speech discrimination testing along with pure tone testing through air conduction and bone conduction via EAR Tone 3A insert earphones will be administered. The primary investigator will read aloud the test instructions to each subject as follows:

You will hear speech words in one ear and then the other ear. Please repeat the words that you hear. Some of the words will be loud and some of the words will be soft. Repeat all the words that you can; you may guess if you need to.

Following the speech words, you will hear a series of beeps. Please press the button every time that you hear the beeps. Once again, the beeps may be loud or soft. Press the button even if you barely hear the beeps.

The last thing we will do is called the Random Gap Detection test. You will hear one beep or you may hear two beeps. If you hear one beep, raise one finger. If you hear two beeps, raise two fingers. Do you have any questions?

After the subject has been read the instructions, the audiological test battery will begin. At the beginning of each component of the testing, the instructions will be re-read to the subject. For example, instructions for the speech discrimination test will be read again and the speech discrimination testing will be completed. Next, only the instructions for the pure tone testing will be read followed by administration of the pure tone testing through air conduction and bone conduction. Lastly, only the instructions for the Random Gap Detection test will be read. The Random Gap Detection test will be administered to the subject.

After all audiological testing has been completed, the primary investigator will review all test results with each subject. If a subject meets all of the audiological criteria, the subject will be provided a 10-minute break before completing the localization test which will be administered by the primary investigator. In the event that a subject did not meet the audiological criteria, the primary investigator will review all test results and make the appropriate recommendations for follow-up hearing services that the individual may pursue if he or she chooses.

The primary investigator will then administer the test of localization which has five different test conditions. The primary experimenter will provide the informed consent to each subject which they will read, sign, and date. Each subject will be seated in a swivel chair situated in the center of an IAC sound treated booth (ANSI S3.1 – 1991) and required to listen to the speech sentences being presented. Subjects are to be seated, facing loud speaker #5. The test stimuli will be transmitted to the appropriate speaker via a "router". The test stimuli will be randomly presented through one of the eight speakers at a time, both in quiet and noisy listening situations.

After the stimulus is presented from one of the eight speakers, the subject will be allowed to swivel in the test chair to point and verbally identify the appropriately numbered loud speaker. After pointing to the appropriate loudspeaker, the subject must resume testing position, facing loudspeaker #5. The subject will be further instructed to hold his or her head and eyes steady during stimulus presentation. The responses will be recorded by the primary experimenter.

For the quiet and noisy listening conditions, each subject will listen to the testing directions that will be read aloud by the primary experimenter. The instructions are as follows:

You are going to hear a short speech sentence. You will hear the sentence in quiet and with some noise in the background. Please listen carefully. As you listen to each sentence, face loudspeaker #5. As you listen to each sentence, please keep your eyes steady and hold your head against the headrest attached to the chair in which you are sitting. It is important that you not move your head as you listen.

After you have heard a sentence, please swivel in the chair to point to the loudspeaker from which you heard the sentence. As you point, verbally identify the loudspeaker by number. Wait until you no longer hear any words before you point and identify the loudspeaker from which you heard the sentence. After you point to the appropriate loudspeaker, please sit back in the chair and face loudspeaker #5 with your head fixed against the headrest and your eyes steady.

At times, it may be difficult for you to identify the loudspeaker from which you hear some of the sentences. If you are unsure, it is okay to take a guess at the direction from which you heard the sentence. Please remember to wait until the sentence has been presented, then point and verbally identify the number of the loudspeaker from which you heard the sentence. Do you have any questions?

Any questions posed by the subject will be answered and, if necessary, the instructions will be repeated in their entirety. As further verification that the test procedures are understood, each subject will be asked to paraphrase the instructions for the examiner.

The localization test responses will be recorded by the primary investigator on an answer sheet. The test of localization is based on whether the subject correctly identifies the appropriately numbered loudspeaker from which the Central Institute for the Deaf Everyday Sentence is presented. If a subject responds correctly, the primary investigator will indicate the mark with a check (√). However, if the subject responds incorrectly, the primary investigator will indicate the error with an **X** and include the number of the subject's loudspeaker response.

After all audiological and localization testing has been completed, the subject will be thanked by the primary investigator and released from the study. The primary investigator will remind the subject that all personal information will remain confidential.

Case History

Name__________________________ DOB___________________ Subject #___________

Address________________________________ Telephone_________________________
________________________________Occupation_________________________

Hearing Difficulty: Onset_________________ Progression of Hearing Loss___________
Cause_________________ Other__________________________

Difficulty Understanding Speech: In Quiet ____yes ____no
In Background Noise ____yes ____no

Head or Neck Surgery? _____yes ____no
If so, when and what part of the head or neck?____________________________________

List any medications you are taking at this time_____________________________________

Ringing in the ears?_____yes _____no
If yes, ______right ear _____left ear _______both ears

Serious Illnesses (Please list)____

Family History of Hearing Loss (Please describe)________________________________
Relation to You_________________ Age of Onset_________ Cause__________________

Trauma: Noise Exposure_______________________ Type of Noise__________________
Number of Hours______________________ Ear Protection Used___yes _____no
Head Injury or Accident____

Do you now wear a hearing aid?____yes ____right ear ____left ear ____both _____none
Hearing Aid Type?_______________ Hearing Test Results?__________________________

Diagnosed with any type of Developmental Disorder? _____________________________
If so, when and what type?____

Have you ever had your hearing tested? _____yes _____no
If so, when and where?____
Results____

Subject Number _______________
Date _______________

Audiogram

	Notes
Otoscopic Evaluation Right Ear	
Otoscopic Evaluation Left Ear	

	Type
Tympanometry Right Ear	
Tympanometry Left Ear	

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
AC Right Ear						
BC Right Ear						
AC Left Ear						
BC Left Ear						

	Percent Correct
Word Discrimination Right Ear	
Word Discrimination Left Ear	

HUMAN SUBJECTS CONSENT

The following is a brief summary of the project in which you are asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT: A Protocol for Sound Localization Testing with Young and Aging Normal Hearing Subjects.

PURPOSE OF STUDY/PROJECT: To develop a standardized test of localization to compare localization abilities for young and aging normal hearing subjects.

PROCEDURE: Subjects will be administered an audiological evaluation including otoscopy, tympanometry, pure tone testing by air conduction and bone conduction via inserts, and word discrimination test via inserts. Subjects will also complete the Random Gap Detection test via inserts and the investigator-developed test of localization via loudspeakers.

INSTRUMENTS: This study will use an IAC sound treated booth, Eight LR2SA Line Radiator 20 watt loudspeakers, Tascam CD-160 CD player, Interacoustics AC 40 audiometer, EAR Tone 3A insert earphones, router, otoscope, Madsen Zodiac 901 tympanometry machine, Performance Intensity function for Phonetically Balanced (PI-PB) word list, Random Gap Detection test and score sheet, the investigator-developed Localization test and score sheet, and Forty Central Institute for the Deaf (CID) Everyday Speech Sentences.

RISKS/ALTERNATIVE TREATMENTS: There are no risks involved in the study.

BENEFITS/COMPENSATION: No compensation is given to the participants for participating in this study.

I,________________________, attest with my signature that I have read and understood the following description of the study, "A Protocol for Sound Localization Testing with Young and Aging Normal Hearing Subjects", and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University. Further, I understand that I may withdraw at anytime or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my tests will be confidential, accessible only to the primary investigator, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

______________________________ ____________

Signature of Participant Date

CONTACT INFORMATION: The primary investigator listed below may be reached to answer questions about the research, subjects' rights, or related matters.

Alison V. Huff, B.A. (337) 856-0893

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the investigator:

Dr. Les Guice (318) 257-3056
Dr. Mary M. Livingston (318) 257-2292

Subject Number______________
Date______________

Random Gap Detection Test Form

AUDITEC

RGDT

RANDOM GAP DETECTION TEST (RGDT)
(Revised AFT-R)

Name______________________________ Age____ Sex____ Date__________

Interstimulus Interval (Gap) in msec.
(In order of presentation)

TONES

Subtest 1: Screening/Pratice

	0	2	5	10	15	20	25	30	40	Lowest Gap____ msec.

Subtest 2: Standard

500 Hz	10	40	15	5	0	25	20	2	30	Lowest Gap____ msec.
1000 Hz	30	10	15	2	0	40	5	20	25	Lowest Gap____ msec.
2000 Hz	20	2	40	5	10	25	15	0	30	Lowest Gap____ msec.
4000 Hz	5	10	40	15	20	2	30	0	25	Lowest Gap____ msec.

CLICKS

Subtest 3: Screening/Practice, Clicks

	0	2	5	10	15	20	25	30	40	Lowest Gap____ msec.

Subtest 4: Clicks

	30	5	20	40	2	0	15	10	25	Lowest Gap____ msec.

Central Institute for the Deaf Everyday Sentences

List A

1. Walking's my favorite exercise.
2. Here's a nice quiet place to rest.
3. Our janitor sweeps the floors every night.
4. It would be much easier is everyone would help.
5. Good morning.
6. Open your window before you go to bed.
7. Do you think that she should stay out so late?
8. How do you feel about changing the time when we begin to work?
9. Here we go.
10. Move out of the way.

List B

11. The water's too cold for swimming.
12. Why should I get up so early in the morning?
13. Here are your shoes.
14. It's raining.
15. Where are you going?
16. Come here when I call you!
17. Don't try to get out of it this time!
18. Should we let little children go to the movies by themselves?
19. There isn't enough paint to finish the room.
20. Do you want an egg for breakfast?

List C

21. Everybody should brush his teeth after meals.
22. Everything's all right.
23. Don't use up all the paper when you write your letter.
24. That's right.
25. People ought to see a doctor once a year.
26. Those windows are so dirty I can't see anything outside.
27. Pass the bread and butter please!
28. Don't forget to pay your bill before the first of the month.
29. Don't let the dog out of the house!
30. There's a good ballgame this afternoon.

List D

31. It's time to go.
32. If you don't want these old magazines, throw them out.
33. Do you want to wash up?

34. It’s a real dark night so watch your driving.
35. I’ll carry the package for you.
36. Did you forget to shut off the water?
37. Fishing in a mountain stream is my idea of a good time.
38. Fathers spend more time with their children than they used to.
39. Be careful not to break your glasses!
40. I’m sorry.

List E

41. You can catch the bus across the street.
42. Call her on the phone and tell her the news.
43. I’ll catch up with you later.
44. I’ll think it over.
45. I don’t want to go to the movies tonight.
46. If your tooth hurts that much you ought to see a dentist.
47. Put that cookie back in the box!
48. Stop fooling around!
49. Time’s up.
50. How do you spell your name?

List F

51. Music always cheers me up.
52. My brother’s in town for a short while on business.
53. We live a few miles from the main road.
54. This suit needs to go to the cleaners.
55. They ate enough green apples to make them sick for a week.
56. Where have you been all this time?
57. Have you been working hard lately?
58. There’s not enough room in the kitchen for a new table.
59. Where is he?
60. Look out!

List G

61. I’ll see you right after lunch.
62. See you later.
63. White shoes are awful to keep clean.
64. Stand there and don’t move until I tell you!
65. There’s a big piece of cake left over from dinner.
66. Wait for me at the corner in front of the drugstore.
67. It’s no trouble at all.
68. Hurry up!
69. The morning paper didn’t say anything about rain this afternoon or tonight.
70. The phone call’s for you.

List H

71. Believe me!
72. Let's get a cup of coffee.
73. Let's get out of here before it's too late.
74. I hate driving at night.
75. There was water in the cellar after the heavy rain yesterday.
76. She'll only be gone for a few minutes.
77. How do you know?
78. Children like candy.
79. If we don't get rain soon, we'll have no grass.
80. They're not listed in the new phone book.

List I

81. Where can I find a place to park?
82. I like those big red apples we always get in the fall.
83. You'll get fat eating candy.
84. The show's over.
85. Why don't they paint their walls some other color?
86. What's new?
87. What are you hiding under your coat?
88. How come I should always be the one to go first?
89. I'll take sugar and cream in my coffee.
90. Wait just a minute!

List J

91. Breakfast is ready.
92. I don't know what's wrong with the car, but it won't start.
93. It sure takes a sharp knife to cut this meat.
94. I haven't read a newspaper since we bought a television set.
95. Weeds are spoiling the yard.
96. Call me a little later!
97. Do you have change for a five-dollar bill?
98. How are you?
99. I'd like some ice cream with my pie.
100. I don't think I'll have any dessert.

Central Institute for the Deaf Everyday Sentences

Excel was used to randomly select the following 40 Central Institute for the Deaf Everyday Sentences that will be used as the localization stimuli for the study.

1. It's a real dark night so watch your driving.
2. Let's get out of here before it's too late.
3. I like those big red apples we always get in the fall.
4. If your tooth hurts that much you ought to see a dentist.
5. There was water in the cellar after the heavy rain yesterday.
6. Let's get a cup of coffee.
7. Our janitor sweeps the floors every night.
8. They ate enough green apples to make them sick for a week.
9. See you later.
10. Open your window before you go to bed.
11. I'll catch up with you later.
12. Time's up.
13. Don't try to get out of it this time!
14. Here are your shoes.
15. You can catch the bus across the street.
16. Music always cheers me up.
17. Call me a little later!
18. Everybody should brush his teeth after meals.
19. Wait just a minute!
20. Breakfast is ready
21. Where are you going?
22. My brother's in town for a short while on business.
23. Stand there and don't move until I tell you!
24. Don't use up all the paper when you write your letter.
25. I don't want to go to the movies tonight.
26. There's a big piece of cake left over from dinner
27. The phone call's for you.
28. Look out!
29. Don't forget to pay your bill before the first of the month.
30. How come I should always be the one to go first?
31. Pass the bread and butter please!
32. I'm sorry.
33. Should we let little children go to the movies by themselves?
34. Do you think that she should stay out so late?
35. The water's too cold for swimming.
36. There isn't enough paint to finish the room.
37. Wait for me at the corner in front of the drugstore.
38. There's not enough room in the kitchen for a new table.
39. How do you know?
40. I haven't read a newspaper since we bought a television set.

Developed Test of Localization Data Sheet

(PS) – Presenting Speaker Subject Number__________

Quiet (PS) Condition	Response	Noise (PS) 70/65 dB	Response	Noise (PS) 70/60 dB	Response
6		7		2	
7		8		2	
8		4		8	
4		1		4	
4		4		1	
5		7		6	
7		5		2	
5		6		2	
2		4		4	
3		5		7	
6		5		5	
2		5		7	
1		3		7	
1		1		3	
4		4		5	
4		2		8	
6		7		5	
4		4		4	
5		2		4	
4		3		7	
8		4		8	
2		6		5	
1		4		7	
8		1		6	
3		5		4	
3		3		2	
4		5		8	
6		3		7	
5		2		2	
7		3		5	
6		5		7	
4		1		7	
4		2		1	
1		2		1	
6		1		3	
6		4		3	
7		1		2	
6		6		8	
4		4		3	
4		4		6	

Developed Test of Localization Data Sheet

(PS) – Presenting Speaker Subject Number__________

Noise 70/55 dB (PS)	Response	Noise 70/50 dB (PS)	Response
3		4	
3		4	
6		3	
8		3	
5		2	
2		3	
1		4	
5		2	
1		2	
4		4	
4		1	
2		8	
4		4	
4		5	
4		8	
6		4	
8		8	
2		5	
3		8	
2		6	
6		6	
1		6	
8		6	
4		3	
4		1	
4		1	
1		8	
5		2	
4		7	
7		3	
4		3	
6		2	
5		2	
4		7	
1		2	
3		8	
1		2	
3		8	
6		8	
3		1	

Expert Reviewers Comments

Please answer the following questions after reviewing the protocol for Test of Localization.

I. Please provide pros and cons for each of the following by writing your comments below each of the components, 1 through 6.

(1) **Test Environment** – an 8x8 foot double-walled IAC sound treated room

(2) **Test Stimuli** – The protocol for testing localization will use the Central Institute for the Deaf Everyday Sentences as the test stimuli. A 1000 Hz white noise stimulus will be synthesized from the speech material to form the same average spectra and noise to simulate a noisy listening condition.

(3) **Loudspeaker Array** – Eight sound field speakers will be placed in the sound treated booth and arranged symmetrically within the horizontal plane with 45 degree intervals between each speaker.

(4) **Subjects** – The study will require the participation of 80 individuals, 40 males and 40 females, who range in age from 21 to 60 years. Based on their chronological age, the subjects will be assigned to one of four groups, 20 per group (10 males, 10 females). The age groupings are 21 to 30 years, 31 to 40 years, 41 to 50 years, and 51 to 60 years.

(5) **Subject Placement** – Subjects will be positioned in the center of the IAC sound treated booth and instructed to sit in the swivel chair with his or her head positioned against the attached headrest. The headrest will be used to help minimize head movement, therefore, keeping the subjects' head continuously facing the forward loudspeaker.

(6) **Test Conditions** – 40 Central Institute for the Deaf Everyday Sentences will be randomized and presented in one of five test conditions. The test conditions are speech stimuli in quiet, which will be presented at 50 dB HL. The second speech stimuli were chosen to represent speech in background noise with speech presented at 70 dB HL and noise presented at 65 dB HL. The third speech stimuli condition will represent speech in background noise with speech at an intensity level of 70 dB HL and noise at 60 dB HL. The fourth speech stimuli condition represents speech in background noise with speech presented at 70 dB HL and noise at 55 dB HL. The fifth test condition will represent speech in background noise with speech presented at 70 dB HL and noise at 50 dB HL.

II. As a practicing audiologist, would you add or omit any of the test characteristics? If so, what would you add or omit? Why?

III. What recommendations would you make about this proposed Test of Localization?

IV. Please comment on the organization of the test.

V. What problems do your foresee during this project?

VI. Would you modify or change any portion of the Test of Localization? If so, what changes would you make?

VII. What are your professional credentials?

VIII. How many years have you worked as a clinical audiologist?

IX. What is your primary work setting?

X. On the average, how many clients do you see in your practice per week?

XI. What is the age range of these clients?

XII. Do you administer a test of localization as part of your audiological evaluation? Why or why not?

XIII. How many audiologists work in your primary setting?

XIV. What type of audiological equipment do you have in your primary work setting?

APPENDIX I

INTRODUCTION LETTER

Alison V. Huff, B.A.
Primary Investigator
(337) 856-0893

Letter to Subjects and Participation Form

To: Interested Participant
Address

From: Alison V. Huff, Doctoral Student in Audiology
Department of Speech
Louisiana Tech University

Date: June 25, 2006

Subject: Capstone Project

My name is Alison V. Huff and I am a graduate student pursuing a doctoral degree in audiology at Louisiana Tech University. As part of my graduate program, I am working on a project that involves developing a standardized way to measure the ability of adults to localize sources of sound. If you are between 21 and 60 years of age and do not have a hearing loss, I am requesting that you consider participating in this project which is under the direction of faculty members in the Department of Speech at Louisiana Tech University.

Your participation will require one visit to the local office of an audiologist. During this visit, which will last approximately one and one half hours, you will receive a free comprehensive hearing evaluation followed by asking you to listen to a series of short sentences and point to a loudspeaker from which you heard the sentence. There are no risks involved in your participation. While you will not be compensated for your participation, you will receive the results of your free hearing evaluation. If you are found to have a hearing loss, you will be given appropriate recommendations so that you may seek hearing health care services if you wish.

If you are interested in participating in this project, please contact me at the telephone number or email address listed below. At that time, you will be asked to provide me your name, telephone number, email and mailing address. That is for the purpose of contacting you to schedule an appointment for you to come into the office. Please be assured that your personal information is only for the purpose of this project and will not be shared with any other individuals or agencies. Also, please feel free to contact me if you have any questions or if I can provide additional information. Thank you for your time and consideration, I look forward to hearing from you.

I, ______________________ would like to participate in the project entitled: A Protocol for Sound Localization Testing with Young and Aging Normal Hearing Subjects.

________________________ Signature	________________________ Date
________________________ Date of Birth	________________________ Telephone Number
________________________ Home Address	________________________ Email Address

Please return the participation form signed and dated to me at the address listed below:

Alison V. Huff, B.A.
110 Exchange Place, Suite 100
Lafayette, LA 70503
Email: aviator5@excite.com

APPENDIX J

FOLLOW-UP LETTER

Dear Mr. Xxxxxxxxx
Address
Email Address

Date:

I am writing to you today in regards to your interest in participating in the dissertation study for developing a standardized test of localization. As mentioned in the introduction letter and the follow-up telephone call, I am requesting your participation in this project which is under the direction of faculty members in the Department of Speech at Louisiana Tech University. All personal information will be kept confidential.

Once again, if you are interested in participating in this study, please complete the attached Introduction letter and return it me at the address below.

Thank you for your time, it is greatly appreciated. Please feel free to contact me at (337) 856-0893 if you have any questions or if I can provide additional information.

Sincerely,

Alison V. Huff, B.A.
Doctoral Student
Au.D. Program
Department of Speech
Louisiana Tech University

Please return the participation form signed and dated to me at the address listed below:

Alison V. Huff, B.A.
110 Exchange Place, Suite 100
Lafayette, LA 70503
Email: aviator5@excite.com

APPENDIX K

HUMAN SUBJECTS CONSENT

HUMAN SUBJECTS CONSENT

The following is a brief summary of the project in which you are asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT: A Protocol for Sound Localization Testing with Young and Aging Normal Hearing Subjects

PURPOSE OF STUDY/PROJECT: To develop a standardized test of localization to compare localization abilities for young and aging normal hearing subjects.

PROCEDURE: Subjects will be administered an audiological evaluation including otoscopy, tympanometry, pure tone testing by air conduction and bone conduction via inserts, and word discrimination test via inserts. Subjects will also complete the Random Gap Detection test via inserts and the investigator-developed test of localization via loudspeakers.

INSTRUMENTS: This study will use an IAC sound treated booth, Eight LR2SA Line Radiator 20 watt loudspeakers, Tascam CD-160 CD player, Interacoustics AC 40 audiometer, EAR Tone 3A insert earphones, router, otoscope, Madsen Zodiac 901 tympanometry machine, Performance Intensity function for Phonetically Balanced (PI-PB) word list, Random Gap Detection test and score sheet, the investigator-developed Localization test and score sheet, and Forty Central Institute for the Deaf (CID) Everyday Speech Sentences.

RISKS/ALTERNATIVE TREATMENTS: There are no risks involved in the study.

BENEFITS/COMPENSATION: No compensation is given to the participants for participating in this study.

I,______________________, attest with my signature that I have read and understood the following description of the study, "A Protocol for Sound Localization Testing with Young and Aging Normal Hearing Subjects", and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University. Further, I understand that I may withdraw at anytime or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my tests will be confidential, accessible only to the primary investigator, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

______________________________ ____________

Signature of Participant Date

CONTACT INFORMATION: The primary investigator listed below may be reached to answer questions about the research, subjects' rights, or related matters.

Alison V. Huff, B.A. (337) 856-0893

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the investigator:

Dr. Les Guice (318) 257-3056
Dr. Mary M. Livingston (318) 257-2292

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