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Sound localization accuracy in the blind population

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SOUND LOCALIZATION ACCURACY IN THE BLIND POPULATION

by

Mary Arrington DeLoach, B.A.

A Dissertation Presented in Partial Fulfillment
Of the Requirements for the Degree
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by Mary Arrington DeLoach

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ABSTRACT

The ability to accurately locate a sound source is crucial in the blind population to orient and mobilize independently in the environment. Sound localization is accomplished by the detection of binaural differences in intensity and time of incoming sound waves along with phase differences and spectral cues. It is dependent on auditory sensitivity and processing. However, localization ability can not be predicted from the audiogram or an auditory processing evaluation.

Auditory information is not received only from objects making sound, but also from objects reflecting sound. Auditory information used in this manner is called echolocation. Echolocation significantly enhances localization in the absence of vision. Research has shown that echolocation is an important form of localization used by the blind to facilitate independent mobility. However, the ability to localize sound is not evaluated in the blind population.

Due to the importance of localization and echolocation for independent mobility in the blind, it would seem appropriate to evaluate the accuracy of this skill set. Echolocation is dependent upon the same auditory processes as localization. More specifically, localization is a precursor to echolocation. Therefore, localization ability will be evaluated in two normal hearing groups, a young normal vision population and young blind population. Both groups will have normal hearing and auditory processing verified by an audiological evaluation that includes a central auditory screening. The localization assessment will be performed using a 24-speaker array in a sound treated chamber with four different testing conditions 1) low-pass broadband stimuli in quiet, 2) low-pass broadband stimuli in noise, 3) high-pass broadband stimuli in quiet, and 4) high-pass broadband speech stimuli in noise.

It is hypothesized that blind individuals may exhibit keener localization skills than their normal vision counterparts, particularly if they are experienced, independent travelers. Results of this study may lead to future research in localization assessment, and possibly localization training for blind individuals.

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Author Mary DeFoach

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GS Form 14
(5/03)

TABLE OF CONTENTS

Page

LIST OF FIGURES

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CHAPTER 1

INTRODUCTION, REVIEW OF LITERATURE, AND STATEMENT OF THE PROBLEM

Introduction

Localization is the ability to identify the source of a sound in space (Hebrank & Wright, 1974). Localization allows for the approximation of a sound of interest, the ability to track the direction and distance of a moving sound source, and to locate and attend to a speaker. Accurate localization abilities are dependent upon symmetrical normal hearing and a degree of central auditory processing.

Localization is a binaural processing event that relies on the ability of both ears simultaneously processing subtle differences in intensity and time, as well as phase and frequency spectrum. This ability to binaurally process information is important for daily listening tasks that involve speech, as well as other environmental sounds. In listeners with normal vision, the localization of people or objects can be compensated for and established with visual confirmation. The cooperation between the visual and auditory systems in localization is an efficient and natural process which also provides a degree of safety. However, this sensory cooperation is not possible for blind listeners. The blind must rely solely on audibility for localizing sound sources. This reliance is particularly evidenced in the blind for independent travel and mobility.

Independent travel and mobility for the blind in unfamiliar surroundings presents significant challenges. In addition to potentially limiting their range of travel, the ability to survey and monitor their surroundings is restrictive. This can lead to feelings of anxiety and fear (Barlow, Bentzen, and Bond, 2005).

In spite of this, it is quite common for the blind to enjoy independent travel and mobility. Independent travel and mobility of the blind is possible through more than one method. Assistive electronic devices, use of guide dogs, and use of the white cane are methods which may be used by the blind for travel. There are advantages and disadvantages to each method and each blind individual must consider their own personal situation to determine which method is best for them.

With the baby boom generation in America fast approaching their retirement years and living longer into those years, it is expected that there will be a significant increase in the number of Americans who are blind (National Center of Health Statistics, 1998). The most common causes of vision impairment in American adults are: diabetic retinopathy, age-related macular degeneration, cataracts, and glaucoma. It is anticipated by the year 2015 that there will be a 50% growth in the population of blind Americans (National Center of Health Statistics, 1998). Due to these projected trends, and given the importance of localization for independent mobility in the blind, data from localization-focused research will become more essential.

It is important for the blind traveler to localize accurately in their independent travel. To facilitate this, blind individuals may undergo orientation and mobility training as provided by a certified orientation and mobility specialist. Orientation and mobility specialists teach individuals with vision impairement the techniques to move about safely, comfortably and confidently in the environment. The goal of orientation and mobility training is to teach blind individuals the skills necessary for independent travel within any given situation.

Localization plays a critical role in this training. However, localization ability is not objectively assessed during any portion of the training. Furthermore, there is no standard clinical assessment of localization. Given the importance of localization for independent travel in the blind, it appears that the ability to assess and monitor localization efficiency would be of significant value. The traditional audiological evaluation assesses hearing only for sensitivity and intelligibility and cannot predict localization ability (Barth & Foulke, 1979). Given the role of hearing in localization, it is appropriate to include localization assessment as part of the comprehensive audiological clinical test battery, particularly in the blind.

The ability to localize sounds and their source allows individuals without vision to gain information about the environment around them and travel independently. Specifically, it is their source of information for orientation and mobility beyond touch. The ability to objectively assess localization in the blind population could greatly enhance the manner in which independent mobility is taught. Furthermore, if blind individuals were observed to have keener localization abilities than normal vision listeners, it is reasonable to postulate that increasing localization ability through some form of training might be possible.

Review of Literature

Localization

"The localization of sound, which warned our ancestors of possible danger, was probably a major contributor to the early survival of our species (Martin & Clark, 2003, p. 47)." Auditory localization is the ability to identify the source of a sound in space (Hebrank & Wright, 1974). Auditory localization allows us to pinpoint a sound of interest, locate the position of another person, locate the direction and distance of a moving sound source, and allows us to quickly locate and attend to a speaker.

The localization of sound in space is a binaural phenomenon (Hebrank & Wright, 1974). Sound localization is based on the detection of binaural differences in intensity and time of arriving sound waves as well as phase differences and spectral cues. There are two planes of reference associated with tasks of localization, the vertical (up and down) and the horizontal (right and left) plane.

Three coordinate systems are utilized by the normal hearing listeners when attempting to locate a specific sound source: azimuth coordinate, elevation coordinate, and the distance coordinate. The azimuth coordinate determines if a sound is located to the left or the right of a listener. The elevation coordinate differentiates between sounds that are up or down relative to the listener. The distance coordinate determines how far away a sound is from the receiver (Rice, 1967).

There are different aspects of the coordinate systems that are important to sound localization. When identifying the azimuth coordinates of a sound, three acoustic cues are used: spectral cues, interaural time differences (ITD), and interaural intensity differences

(IID). Spectral cues are the distribution of frequencies reaching the ear. These cues give rise to differences in time (arrival) and intensity which can be accurately detected in normal hearing listeners with symmetrical hearing. ITD is the difference in time between a sound reaching the ear closest to the sound (near ear) and furthest from the sound (far ear). IID is the difference in loudness between a sound reaching the near ear versus the far ear. The auditory system uses these cues to determine the origin of a sound (Klumpp & Eady,1955; Rice, 1967).

Peripheral Anatomical Sites of Localization

The external ear receives the first cues needed for localizing a sound source. The pinna is angled so that it catches sounds originating from in front more than those originating from behind. Simply speaking, we hear sounds that are in front of us before those that are behind us by virtue of the position and shape of our ears.

From the pinna, sound is routed through the external auditory canal and received by the middle ear system. The middle ear is an acoustical transformer, an impedence matching device designed to transport the air-conducted mechanical action of the sound wave into the fluid filled cochlea.

Upon entering the cochlea, the once air-conducted vibrations are now transmitted as a fluid wave, resulting in the displacement of the basilar membrane. The basilar membrane is tonotopically organized by virtue of a stiffness gradient that is stiffer at the base than the apex. Accordingly, the high frequencies are received at the base of the cochlea and the low frequencies are received at the apex of the cochlea. Hair cells within cochlea are responsible for transmitting frequency specific information to the auditory nerve where the speech signal is transformed into a series of neuroelectrical events. Past the cochlea, at the level of the auditory nerve, the auditory system is no longer considered peripheral; it is central.

Although the structures of the inner ear are tonotopically organized, they are not organized spatially. Because of this, sound localization relies on the neural processing of hidden acoustic cues (Gelfand, 1998). Localizing perception originates in the auditory cortex of the brain, along with all other forms of auditory perception. To determine a sound's position, the brain must learn and organize these cues. These cues begin at the level of the auditory nerve.

Central Anatomical Sites of Localization

The neuroelectric signal that is carried along the auditory nerve will be coded for frequency, intensity, and time. The coded information carried by the auditory nerve is sent to the brainstem where it will be routed to higher central auditory relay points. The first of these points are the cochlear nuclei. The cochlear nuclei consist of three major branches which are also arranged tonotopically (Musiek & Baran, 1986): the anterior ventral cochlear nucleus, the posterior ventral cochlear nucleus, and the dorsal cochlear nucleus. Each nucleus is composed of a variety of cells that differ morphologically and physiologically. These cells are responsible for modifying the incoming signal. Although not completely understood, it is known that these modifications are additional coding features which probably enhance or organize the acoustic signal.

Following the cochlear nuclei, the acoustic signal is received by the superior olivary complex. There are three major neural tracts that project from the cochlear nuclei to the superior olivary complex. The first tract is the dorsal stria and its fibers originate from the dorsal cochlear nucleus and projects contralaterally to the lateral leminscus and the inferior colliculus. The second, intermediate stria, originates from the posterior ventral cochlear nucleus and projects contralaterally to the lateral lemniscus. The third tract, ventral stria, originates from the anterior ventral cochlear nucleus and projects contralaterally to the superior olivary complex and to other nuclei groups along the lateral lemiscus (Musiek, 1986).

The superior olivary complex has five main nuclei groups that also have a tonotopic arrangement (Musiek, 1986). These five groups are the lateral superior olivary nuclei, medial superior olivary nuclei, nuclei of the trapezoid body, and two preolivary nuclei.

The medial superior olivary nucleus is the largest component of the superior olivary complex (SOC) in humans. It is the first place in the auditory system where what is heard in the right ear and what is heard in the left ear come together at individual neurons, allowing for binaural interaction (Musiek & Baran, 1986). Neurons of the medial superior olivary (MSO) analyze the difference in arrival times of a sound that reaches first one ear and then the other. They propagate action potentials whose pattern is dependent on that difference. Thus, they code for sound localization in the horizontal plane. The axons of the MSO neurons extend into, and contribute to, the ipsilateral lemniscus, which is a large auditory tract extending to the midbrain.

The lateral superior olivary (LSO) nucleus is another site of binaural interaction. LSO neurons, like those of MSO, are active in horizontal sound localization. However, while MSO neurons code for time differences and arrival of low frequency sounds (250-1400 Hz), LSO neurons code for intensity differences and arrival of high frequency sounds (1500 Hz- 8000 Hz). The neuronal coding is explained by the difference in wave lengths. Wave lengths of low frequencies (250-1400 Hz) are long relative to high frequency waves; they are therefore refracted around objects, such as a head, and in most head orientations will reach one ear sooner than the other. The wave lengths of high frequencies are equal to or shorter than the dimensions of the head and therefore reflect off the head. This creates a partial “sound shadow” at the ear opposite the sound source, which makes the sound more intense at the ear nearer the source than at the opposite ear.

Next along the central auditory pathway is the inferior colliculus. The inferior colliculus lies in the upper portion of the brainstem (Chermak & Musiek, 1997). The inferior colliculus is associated with the visual and auditory systems. The information it receives is responsible for reflexes involving eye and head positions. The inferior colliculus projects fibers ipsilaterally to the medical geniculate body.

The medial geniculate body is the prinicipal auditory nucleus of the thalamus and is located on the surface of the thalamus. The medial geniculate body has three branches: ventral, dorsal, and medial divisions. The fiber tracts of the medial geniculate body are uncrossed and the inputs come from the branchium of the inferior colliculus. The medial geniculate body’s ventral division receives auditory information, which is then responsible for sending the signal to the auditory cortex. The medial division of the medical geniculate body relays information to cortical and noncortical areas of the forebrain. Once the acoustic signal leaves the medial geniculate body, it is received by the auditory cortex.

The auditory cortex contains Heschl’s gyrus, which is one of the primary areas for language processing. Heschl’s gyrus is also considered to be the primary area for auditory processing (Musiek, 1986). Another important landmark within the cortex is the Sylvian fissure, which contains a primary auditory area. The supramarginal gyrus, the inferior portion of the partial lobe, and the inferior portion of the frontal lobe have also been identified as areas responsive to acoustic stimulation. Auditory information is transferred from one hemisphere to the other through the corpus callosum. The corpus callosum is one of the last central auditory structures to mature, which is not complete until approximately 11 years of age (Musiek, 1986).

Theories

The primary theory for explaining horizontal sound source localization is the duplex theory. The duplex theory describes horizontal sound displacement through the use of two properties: interaural time differences (ITD) and interaural intensity differences (IID). ITDs are the dominant cues for human localization of low-frequency sounds. ITD is defined as the difference in arrival time for a sound between the two ears. IID is defined as the difference in intensity generated between the right and left ears by a sound. The sound will be louder at the ear closest to the source. The acoustical property of frequency determines whether ITD or IID will contribute more to localization. At frequencies greater than 1.5 KHz, intensity differences provide the basis for localization.

In this theory, Rayleigh modeled the head as a sphere and solved equations for wave propagation around this firm sphere. The duplex theory established fundamental characteristics of interaural time and intensity differences. For example, if a subject is sitting facing 0 degrees azimuth and a 500 Hz tone is presented at a 45 degree angle into the left ear, phase differences will be used to determine the sound is at their left side. The 500 Hz wavelength is able to wrap around their head to the right ear, however the listener will perceive the sound in their left ear first because the wave arrived at that ear sooner. If a 4 KHz tone is presented in the same manner, intensity differences account for detection on the left side. A 4 KHz wavelength is short and not able to wrap around the head, so it will be heard with less intensity in their right ear. From this the listener can determine that because the sound is louder in the left ear, it must originate from that side.

The Rayleigh head model is accepted and has proven reliable in localization experiments. However, Rayleigh's model does not account for all cues used in localization. For example, it soon becomes evident that there are multiple sound locations which produce identical ITDs and IIDs. In those instances the ability to localize the source of a sound is not possible through auditory cues alone; creating what is called a cone of confusion.

If interaural differences do not vary with sound source changes in location, a cone of confusion will be created (Mills, 1958). ITDs for high frequencies can become vague. For instance, when the wavelength of a sound wave is smaller than the diameter of the head, the ITD will be larger than one period of the wave. As a consequence, frequencies below approximately 1.4 KHz play a larger role in evaluating ITDs, because for these frequencies, the phase difference between ears will provide a distinctive ITD.

Interaural differences are not linear with frequency. Frequencies below 1.4 KHz do not appear to be shadowed significantly by the head because their wavelength is larger than the diameter of the head. Higher frequencies have a wavelength smaller than the diameter of the head and can be attenuated a great deal. As a result, higher frequency sounds (above 1.4 KHz) are more important when evaluating IID since they are most influenced by the head shadowing effect.

Tests of Localization

Localization is an important aspect of audition both for effective communication and safety. However at present, tests of sound localization are not part of the auditory test battery, though evidence indicates that the audiogram alone cannot be used to predict performance on binaural tests, including localization. (Gabriel, Koehnke, & Colburn, 1992). Binaural capabilities have been studied extensively, but clinical tests of binaural information for sound localization in clinical environments are unavailable, primarily because sound field testing of localization is difficult to accomplish in the traditional clinical setting (Vermiglio, Nilsson, Soli, et al., 1998). There is currently no clinical standard or consensus for assessing localization.

The difficulty for establishing a recommended clinical test of localization is one of instrumentation. To properly observe localization, a review of the literature reveals three methods of assessment. One method is through the use of a single speaker, hidden from the listener's view, which is moved to various locations (Norlund, 1964). A second method uses multiple fixed speakers in a predetermined array (Vermiglio et.al,1998). Both of these methods are ideally conducted in an anechoic chamber to reduce or eliminate the possibility of standing waves and reverberation, but can be used in a sound treated room.

A third method used to assess localization is through the use/creation of virtual auditory pathways. This manner of assessment uses headphones as opposed to sound field speaker(s). Natural sounding, digitally produced temporal cues, based on head related transfer functions, are presented to the listener under headphones that create realistic free field experiences. The advantage of this method is that it offers a high degree of control as compared to free field presentations. However, the expense involved in this application is considerable and precludes it from clinical applications.

The common clinical audiology sound treated booth consists of two sound field speakers, one to the left and right of the listener with 180° of separation between the two. Although efficient and sufficient for the majority of audiological sound field testing, it is inadequate for assessing localization accuracy. To address this, researchers have suggested many variations of sound field speaker array and assessment techniques, as well as stimuli and listener response paradigms.

Dillion (2001) recommends a localization test that can be performed in most sound treated booths. His task has the listener point to a low intensity, hand held noisemaker held by the examiner while wearing a blindfold. A correct response would be when the listener points to within approximately 20 degrees of the correct direction. Dillon recommends at least ten presentations given in each condition tested (i.e. unaided versus aided fitting, or unilateral versus bilateral fitting). By scoring as correct or incorrect, the significance of a difference in scores is percent correct between conditions and assessed in the same way for speech identification tests. Test accuracy and sensitivity will increase with the number of trials used.

Dillon's recommendation presents a number of problems the first is the intensity of the noise maker. Listeners with varying degrees of hearing impairment may or may not be able to properly hear the tone and therefore incorrect responses may be due to limitations of audibility. Secondly, the examiner physically holding the noise maker creates additional issues. The physical presence of the examiner may unknowingly provide the listener with subtle cues as to the position of the examiner, and thus the noise maker. Correct responses may be due to the ability of the listener to sense the location of the examiner. Also, knowing that different frequency sound waves are affected differently by head shadow, using a noise maker of a limited bandwidth may not provide a realistic assessment of localization ability or accuracy.

Dillon's recommended test does however present a clinically feasible option for some degree of localization assessment. In fact, it presents the only such method of assessing localization that can be conducted in a traditional sound field setup that is found in the literature. An examiner could potentially modify Dillon's recommendations to assess localization in more depth.

Recommendations regarding participants of localization testing have also been offered. Dillion (2001) recommended that in order for a listener to participate in location testing, they are required to have: 1) An SRT that is 25 dB or better in each when tested with headphones; 2) Low frequency hearing loss in one or both ears averaging 50 dB at the frequencies of 500 and 1000 Hz should be disqualifying; 3) Conditions involving fluctuating hearing loss should be disqualifying; and 4) Unresolved or chronic conductive hearing loss in one or both ears, where the air bone gaps exceed an average of 25 dB at the frequencies of 500 and 1000, should be disqualifying.

The majority of published data on localization assessment does not focus on the clinical efficiency or the ability to collect data in a traditional audiological booth, but rather the number and placement of speakers in the sound field array. There is no readily apparent manner in which two sound field speakers can be used to sufficiently assess localization. Therefore, researchers have used various numbers and positioning of sound field speaker(s) in the array and documented their results.

Tonning (1975) examined the localization abilities of thirty normal hearing listeners in an anechoic chamber using a single speaker (hidden from view) from12 positions, equally separated by 30° intervals. With the listener seated in the center of the chamber, white noise was presented from each position and listeners were asked to point to the location of the sound. The results of the experiment demonstrate the efficiency of the external ear for localizing sounds when presented in front (from 90° to 0° to 270°) of the listener. Responses to stimuli from the front position revealed nearly perfect accuracy. As the stimuli moved behind the listener, accuracy was significantly reduced for all listeners. This decrease in accuracy was attributed to the shadowing effect produced by the head and external ear for sounds originating behind the listener. Sounds originating from these positions present no differences in arrival time or intensity, thus falling within the previously mentioned cone of confusion.

Nordlund (1964) investigated 51 normal hearing adults for their ability to localize sound in a free field environment. He used the term directional audiometry to describe his experiment and used a single free field speaker which was positioned on an arc, approximately 1 meter from the listener that could be moved between 1° and 140° from the listener who was facing the sound arc. His stimuli consisted of pure tones (500, 2000, and 4000 Hz) and low-pass filtered white noise. The speakers were hidden from listener view and the listener was asked to identify the source of the stimuli by pointing. Nordlund found that the higher frequency stimuli (2000 and 4000 Hz) were more readily localized than the 500 Hz tone and the low-passed filtered white noise which he attributed to the ability of the listeners to detect IIDs, which are provided by head shadowing effects. The ITDs, which play a larger role in detecting lower frequency sounds, were not significant enough to allow for accurate localization.

These experiments (Nordlund, 1964 and Tonning, 1975) demonstrate that a single, movable free field speaker can be used to assess localization ability. Specifically, pinna and head shadow effects can readily be observed. However, these experiments also demonstrate that frequency specific variables (i.e. low versus high frequency stimuli) also plays a large role in localization ability.

A review of localization assessment literature reveals that as opposed to using a single, movable free field speaker, more experiments utilize a fixed, multi-sound field speaker array. Single, movable speaker instrumentation is advantageous in that fewer speakers mean less cost and less complication for routing sound. However, fixed multi-speaker arrays offers two significant experimental advantages. First, it eliminates the need for the moving of a speaker which reduces the chance of incorrect speaker placement among stimulus conditions and listeners. Secondly, it eliminates the need to conceal the position of the speaker from the vision of the listener. The speakers that are not producing stimulus act as "dummy" speakers and do not provide localization cues to the listener.

However, using a multiple, fixed speaker array is not without its disadvantages. When multiple speakers are used, additional speaker wires and patch cables are needed as well as some form of instrumentation to route the sound to the desired speaker. It also increases calibration efforts before and after testing. Perhaps more importantly, there is no general consensus as to what the appropriate number of speakers is for localization assessment. It would be reasonable to hypothesize that the greater the number of speakers and the closer their proximity, the greater the potential accuracy of the assessment, in terms of establishing the finest degree of localization. However, as the number of speakers increases, the manner in which listeners are instructed to identify the target speaker can become complicated, particularly if they are blind.

Researchers have used varied numbers and arrangements of speakers for the purpose of assessing the accuracy of localization (Vermiglio, 1999; Nordlund, 1964; Tonning, 1975). In general, listeners are seated in the center of the sound room or anechoic chamber with their head positioned at a consistent location for each presentation. Speaker placement is approximately 1 meter from the listener's head and vertically positioned at approximate adult ear level. Listener response is given in the form of pointing or verbally identifying the source speaker.

As stated earlier, the larger the speaker array number, the more difficulty involved in producing an effective response paradigm for the listener. However, more speakers provide a more detailed observation of localization. The Source Azimuth in Noise Test (SAINT), developed by Vermiglio in 1999, employs 24 speakers in a horizontal array with 15° of separation between each. The large speaker array used in the SAINT (Figure 1) would therefore provide a more detailed observation of assessment than previously cited localization tests.

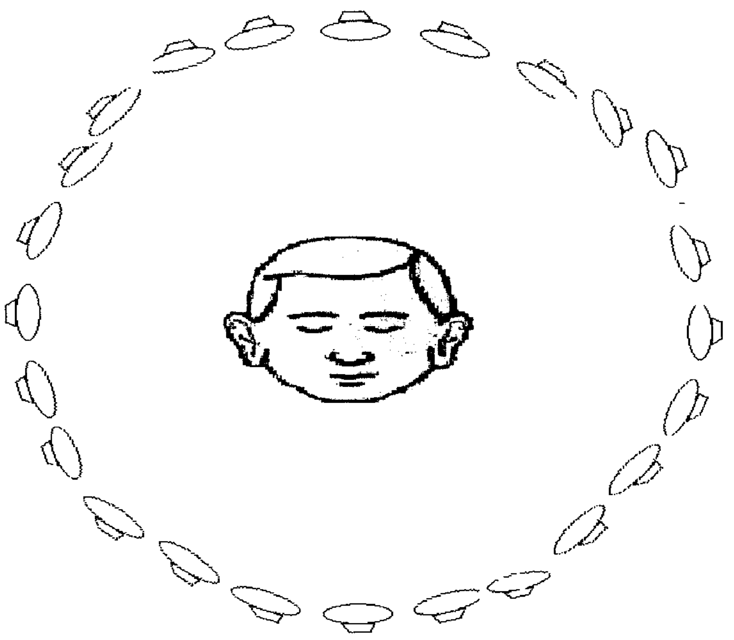

Figure 1: Example of 24 speaker array used in Source Azimuth in Noise Test (SAINT).

However, given that most response paradigms involve some form of visual modality; this presents a significant challenge for assessing blind listeners.

Considerations of Localization Tests

Potential Responses. An important restriction or limitation in most behavioral experiments of sound localization is that the potential responses are often restricted to a few locations (e.g. a subject must select from a small number of loudspeakers located on a particular plane). Traditional sound field testing utilizes only two speakers, a left and a right. Based on the literature, it would appear that detailed localization assessment is not feasible with the traditional sound field array and therefore, should not be conducted.

Manner of Responses. The literature reveals that when a single, movable speaker is used for localization assessment, listeners with normal vision are blindfolded and point to the signal source. When multiple speakers are employed the listeners are asked to point to or verbally identify the signal source. If visual auditory fields are generated under headphones, listeners respond by either identifying the right or left headphone as the signal source.

When considering the variables of cost, speaker manipulation and thoroughness of assessment, the use of multiple sound field speakers offers perhaps the most convenient choice. However, if blind listeners are to be assessed for localization, a response paradigm that relies on the visual modality will not be possible. Verbal and/or tactile responses will be relied upon for identifying the signal source.

Monaural Versus Binaural

Hebrank and Wright (1974) investigated if it is necessary to have two ears to correctly locate sources of sound. The purpose of their experiment was two fold: 1) test the hypothesis that binaural subjects can localize unfamiliar sounds more accurately than monaural subjects, and 2) to evaluate monaural localization accuracy after training. The results showed that binaural and monaural subjects had the same difficulty when trying to localize an unfamiliar sound. It was also shown that monaural subjects can be trained to localize as well as they normally localize with two ears. These results indicate that binaural localization is not always superior to monaural assessment and that localization performance can be improved with practice sessions.

Vision Loss

Blindness is described as a visual acuity worse than 20/400 with the best possible correction, or a visual field of 10 degrees or less. In the United States, the term “legally blind,” means a visual acuity of 20/200 or worse with the best possible correction, or a visual field of 20 degrees or less. The expression (20/400) means a person sees at 20 feet, the same detail that another person having normal acuity sees at 400 feet (National Center for Health Statistics, 1998). There are many possible causes for vision impairment, including damage to the eye and the failure of the brain to interpret messages from the eyes correctly. Additionally, many individuals have monocular vision-perfect or nearly perfect vision in one eye, but little or no vision in the other. Vision impairment can occur at any time in life, but as a person's age increases, so does the likelihood that he or she will have some form of vision impairment.

The most common causes of vision impairment in American adults are diabetic retinopathy, age-related macular degeneration, cataracts, and glaucoma (National Center for Health Statistics, 1998). Diabetic retinopathy is a disease of the eye that is associated with diabetes that causes retinal blood vessels to leak into the retina causing macular edema. It is estimated that nearly 5.4 million Americans, ages 18 and over currently have diabetic retinopathy. It causes over 8000 cases of new blindness annually, and is the primary cause of blindness for people ages 25 to 74 (National Center for Health Statistics, 1998).

Age-related macular degeneration is caused by the malfunction of photosensitive cells in the macula which results in a loss of the central field of vision (National Center for Health Statistics, 1998). The peripheral vision of people with macular degeneration is unaffected. Although the disease affects nearly 1.7 million Americans over the age of 50, and is the leading cause of blindness is developing countries, no exact cause is known (National Center for Health Statistics, 1998).

Cataracts result from a clouding (opacification) of the normally slightly yellowish lens of the eye (National Center for Health Statistics, 1998). The loss of transparency causes light to be diffused as it enters the eye which impacts the clarity of the visual image. The lens slowly develops a greenish and later a brownish tint which impedes the ability of light to pass through the lens. Symptoms of cataract include blurred vision, light sensitivity, double vision, and an apparent fading or yellowing of colors.

Glaucoma is a disease of the eye that is caused by a gradual degeneration of cells in the optic nerve. The loss of these cells leads to a gradual narrowing of the field of vision beginning at the periphery. There is no known cause for the most common form of glaucoma, primary open angle glaucoma, but it is commonly believed to be associated with the inability of fluid to properly drain from the eyes causing an increased intraocular pressure. Primary open angle glaucoma affects more that 2.2 million people, ages 40 and over in American alone (National Center for Health Statistics, 1998).

Orientation and Mobility

Safety and efficiency are two key aspects of movement and navigation. According to Schenkman & Jansson (1989), the process of blind movement can be divided into two functions: walking toward and walking along. Walking toward involves the process of maintaining one's orientation toward a goal. Walking along refers to the ongoing processing of environmental features and acting in accordance with them. The ability to maintain orientation and control constitutes efficient travel, but efficiency must take into account safety.

Orientation and Mobility (O&M) training teaches individuals who are visually impaired, blind, or deaf and blind to travel safely and independently in both familiar or unfamiliar environment. Orientation is an awareness of where you are in space. O&M training provides an individual with a selection of travel techniques to be employed indoors and outdoors. Students learn the most basic self-protective techniques using the natural extension of their arms and hands. Most orientation and mobility instructors hold advanced degrees in education. Many instructors have combined certification as an O & M Specialist and Teacher of the Visually Impaired.

In order to prepare students for independent travel, the O&M specialist must have a realistic understanding of the auditory functioning of each individual. The specialist should ensure that in addition to a battery of social, medical, and opthalmogic information, each student's file includes valid audiometric information. The specialist should be sufficiently skilled in the interpretation of audiograms to evaluate general auditory function as a starting point in communication with the student. Audiometric data are useful, but must be combined with observation of auditory functioning in natural environments because people with very similar audiograms can function very differently.

Studies in blind mobility (Leonard, 1972; Kohler,1964) have identified three factors that constitute secure travel: the ability to stay on a path without accidental departure, the ability to avoid bodily contact with objects, and the ability to cross streets quickly and directly without incident. Barth and Foulke (1979) discuss variables of safety in terms of "preview"- the ability to perceive adequately the features of an environment in advance of one's position. They argue compellingly that advanced awareness allows for effective planning and appropriate responses to conditions ahead.

Blind localization users are known to self generate a wide variety of signals from hand claps and finger snaps, to vocal and oral signals. Hand clapping and finger snapping have the advantages of strong intensity, medium spectral complexity, and quick onset and duration. But these signals are unfocused, and require the use of the hands which may not be conveniently available. Oral signals require no extra manipulation, are more directional, and are quite flexible. The most common type of signal referred to in the human echolocation literature is the oral click. Several studies that examine localization in the blind mention the oral click as a common signal (Kish, 1995; Schenkman & Jansson, 1986; Kohler, 1964).

In the blind, localization serves to establish what type of setting is being approached and if caution should be used. For example, the sound of moving and stationary vehicles alerts the listener as to their position relative to a busy intersection. Accelerating traffic that is parallel to one's direction of travel would indicate that the traffic light has changed, and safe for crossing. By localizing the sound of cars stopped behind a crosswalk, one can determine their position at a street corner.

Independent Travel

Proper dog guide and/or cane training can prevent most obstacles from impeding independent mobility in the blind. In addition, electronic traveling aids that assist independent travel are available for use with proper training. However, these assistive devices are rarely used due to expense, availability, and length of training time.

Assistive Technology

The Miniguide, developed by GDP research based in Australia, is a small handheld device intended as an accessory to the more traditional mobility techniques such as the guide dog and white cane. This device uses ultrasonic echolocation to detect objects. The aid vibrates to indicate distance to objects- the faster the vibration rate the nearer the objects.

The Miniguide has various modes and options. The main modes are: 4 meter, 2 meter, 1 meter, half meter, 8 meter. The aid allows you to scan both left and right when you are walking, sending out ultrasonic beams that bounce off objects nearby. When the Miniguide detects objects, it provides vibratory feedback. The closer you are to an object, the faster the Miniguide vibrates.

Research is also being conducted towards the development of a "Personal Guidance System" that could help blind people travel independently (Loomis, Golledge, Klatzky, Speigle, and Tietz, 1994). The system includes a computer, electronic compass, headphones, receiver, and a transmitter. This personal equipment then communicates with satellites in orbit. These satellites can determine location based on the person's transmitter location. With the coordinates from the transmitter, the system can identify the precise location of the person. This technology is currently used by the general public and more popularly known as Global Positioning System (GPS). GPS systems are capable of determining exact locations to within one meter.

The Personal Guidance System cannot identify objects that are not in the map, however. For instance, objects including people, cars, and things lying around on the sidewalk will not be detected by the GPS. This Personal Guidance System is currently unavailable for public use.

Borg, Ronnberg, and Neovious (1999) developed a sound localization aid using eyeglasses with three microphones and four tactile devices shown in Figure 2.

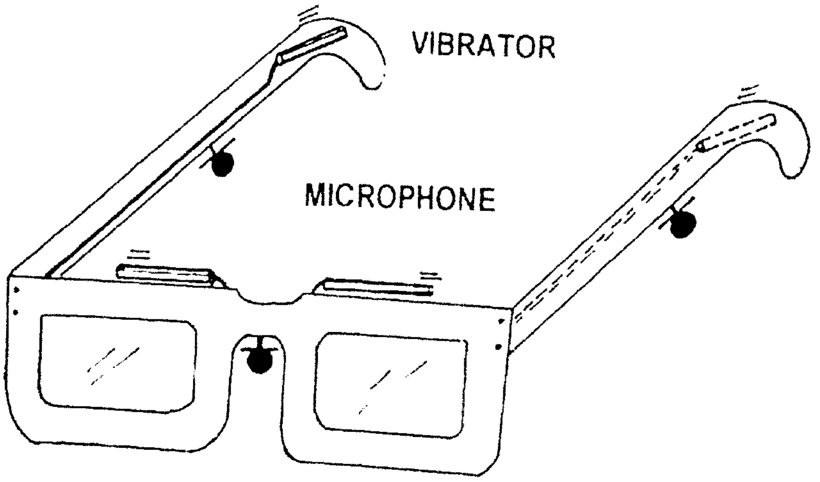

Figure 2: Eyeglass Sound Localization Aid attached to Four Tactile Devices.

This aid was tested in a sound treated chamber and in an office room, i.e., two environments with different acoustic conditions and ecological validity. The participants were nine deaf subjects in the age range of 26-48. In addition, three deaf-blind subjects, 23, 33, and 82 years of age, took part in the study. All three had hearing aids, but did not use them in the test situation.

There were difficulties in the instruction of the deaf-blind subjects. One had difficulty maintaining a stable position due to a motor disorder and another made intermittent noises that activated the vibrator system. The researchers reported a hit rate of almost 100 percent, but indicated that the eyeglasses need to be modified before further testing.

Guide Dogs

The primary role of a guide dog is to assist its user to avoid obstacles in their immediate path. The dog walks slightly forward of its user and will stop at or walk around objects or people. The user holds onto a handle which is connected to a body harness fitted to the dog. A guide dog will allow a person to walk at their preferred pace and provide an efficient means of navigation, particularly in complex situations such as crowds. The dogs are taught special techniques for using stairs and lifts, as well as all forms of public transportation.

Blind individuals who request a guide dog are first expected to demonstrate competency using a cane. Guide dogs have proven to be competent guides for the blind, but they require extensive training. The cost of training the dog and providing instruction for the guide dog user is approximately $38,000 (Kish, 1995). Dogs are commonly provided at no cost to the blind user. Organizations that provide guide dogs receive no government (local, state, or federal) money. They rely solely upon voluntary contributions from individuals, corporations, organizations, foundations, and other groups. The useful life of the guide dog is typically about five years to seven years.

Many blind and visually impaired people do not want to care for another living being and find the task difficult and time consuming. Techniques and methods that promote self reliance and independence are preferred. Approximately 1% of the two million visually impaired or blind persons in the United States use guide dogs (Shoval, Ulrich & Borenstein, 2000).

White Canes

The white cane is the most successful and widely used travel aid for the blind (Schenkman & Jansson, 1986). The device is used to detect obstacles on the ground, uneven surfaces, holes, steps and other hazards. The reflection of the tapping sounds made by the end of white cane can assist in localization, by echolocation, of people and objects. The white cane officially came into use after World War II for returning blinded veterans. Shortly after inception, specific standards were created for mass manufacturing of white canes.

Three types of traditional canes are currently used, including: the rigid or non-collapsible (Figure 3); the folding, which usually has between four and six sections and is held together by an elastic cord; and the telescopic, which collapses.

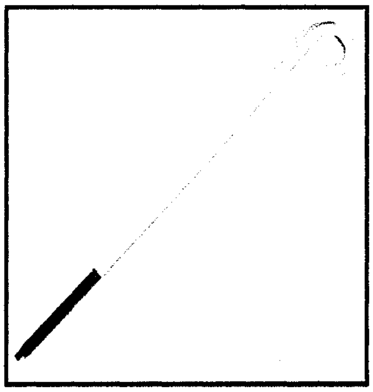

Figure 3: Rigid traditional cane used for independent travel in blind population.

Canes are generally constructed of fiberglass, aluminum, graphite, or plastic and consist of three basic parts: the grip, where the hand is placed; the shaft, which has white and red reflective tape; and the tip.

Tips come in different styles and colors. Depending on the person's location and area traveled, specific tips might be more effective. Using the instructor's recommendation, the individual user decides on the type of cane and the tip. In the event that one of the traditional types of white cane is not compatible with a blind user's needs, a special type of cane called an adaptive cane may be fabricated. These canes are usually made of PVC material and are specifically produced for an individual who cannot use a standard cane.

The majority of adaptive canes are used with children or individuals who have additional medical issues along with their vision loss.

Schenkman and Jansson (1986) studied the usefulness of white cane tapping sounds for localization/echolocation in blind people. The authors found that long cane tapping sounds can be used for the detection and localization of objects, but it was observed that detection and localization were difficult to perform on the basis of tapping sounds alone. To receive proper benefit from a white cane, the user should be trained in its use for more than one hundred hours.

Although the specific anatomical mechanisms underlying the detection and perception of localization in humans have been studied extensively and are well understood, no systematic study of comprehensive training for complex echo-mobility has been reported. Research in this area has been limited to trial and error methods for very basic skills (Shoval et al, 2000; Schenkman & Jansson, 1986). These experiments indicate that echolocation can be learned. However, the application of echolocation skills to daily independent mobility, and the question of how such skills should be actively taught for optimal effect, remains to be addressed.

Localization ability is a crucial factor for independent mobility in the blind. The need for accurate localization is perhaps most evident when navigating alongside automobile traffic. Blind pedestrians judge traffic by sound, even if they travel with the aid of a white cane or with a guide dog. For all pedestrians, on a per-mile basis, walking is more dangerous than driving, flying, or commuting by a bus or train.

Localization and Vision

Auditory information is not received only from objects making sound, but also from objects reflecting sound. Echolocation is an aspect of auditory perception which may be broadly defined as the ability to perceive echoes. Research has shown that the reflection of sound is used by the blind to enhance localization, and ultimately mobility (Carlson-Smith & Wiener, 1996). On the surface, such an ability may seem unremarkable and of little use - largely because echoes are not commonly believed to convey much information.

When a sound in the free field hits a baffle, an object or wall, an array of events can happen. The sound can be transmitted through, absorbed, reflected, diffracted, refracted, or a combination of these. What happens depends upon the wavelength of the sound and the baffle with which it comes in contact with. High frequency sounds whose wave lengths are short relative to the size of the baffle tend to be absorbed or reflected. Low frequency sounds are transmitted or diffracted. For example, a blind person entering a room uses reflected sound to establish the size of the room and if obstacles, such as furnishings, are there (Carlson-Smith and Wiener, 1996). Reflected sound is also used in determining orientation relative to walls or other obstacles.

People with normal vision use localization/echolocation to supplement visual information. In the blind, localization takes on much more importance because it is the sole process used to detect environmental surroundings past their reach. It has been suggested that blind individuals develop a keener sense of hearing to compensate for their loss of vision (Roder, Tedar-Salajarvi, Sterr, Rosler, Hillyard, & Neville, 1999).

Lessard, Pare, Lepore and Lassonde (1998) examined the ability of blind individuals to compensate for their loss of vision through their auditory senses. Four groups were tested on their ability to localize sound in the horizontal plane: totally blind subjects, blind subjects with residual vision, normally sighted but blindfolded controls, and sighted controls. All subjects were tested under monaural and binaural conditions. The sounds were delivered randomly through 16 loudspeakers mounted on a semicircular perimeter. The results show that blindfolded and sighted controls were indistinguishable from each other. The results in the binaural condition indicated that totally blind subjects were at least as accurate as sighted controls. Blind subjects with residual vision were less accurate than all other subjects. This was an unexpected result because it had been predicted that these subjects would show normal localization behavior in peripheral fields (where vision was present), and a performance similar to that of the early-blind subjects in central vision field (where vision was lacking).

The authors suggested three possible explanations for the results of the blind subjects with residual vision. First, these subjects would need to develop an auditory map of space in part supported by vision and in part independent of vision. Second, if auditory compensation in blind subjects depends on the recruitment of the damaged sensory areas, the latter would not show a similar amount of plasticity if they were stimulated. Third, these partially blind subjects demonstrated abnormal orienting behaviors, as they often would fixate the source of a sound by turning their head so that the source would be visible by their residual visual field (Lessard, Pare, Lepore, and Lassonde, 1998).

In the monaural condition, sighted and blindfolded controls localized the sound on the side of the unobstructed ear. As in the binaural condition, the performance of blind subjects with residual vision was worse than that of others. They also showed positional bias in favor of the unobstructed ear when localizing a sound presented on the side of the obstructed ear. However, the performance of the totally blind subjects was exceptional. Half of the totally blind subjects localized the sound on the appropriate side, even when it was presented on the side of the obstructed ear. The remaining totally blind subjects appeared to respond like controls with a positional bias favoring the side of the unobstructed ear.

These results indicate that vision is not necessary for calibrating space. The compensation of early-blind subjects may result from the increased use of spectral information within or between the structures normally used to process visually images, including the superior and inferior colliculus and the medial superior olive and lateral superior olive, as well as the primary auditory cortex (Lessard, Pare, Lepore, and Lassonde, 1998).. Alternately, compensation may occur through the recruitment of brain structures left unused by the lack of visual input.

A question frequently posed in human as well as animal studies is whether, in some conditions, blind listeners perform better than sighted listeners due to compensatory plasticity in the visual and auditory systems. This compensation may be due to the reorganization of neuronal populations (Rauschecker, 1995), improved learning (Lessard et al, 1998), or the sharpening of the non-visual senses (Rauschecker, 1995).

Rauschecker & Harris (1983) found that in cats, visual deprivation beginning shortly after birth results in compensatory effects at the collicular level. Likewise, Rauschecker & Korte (1993) found improved auditory responses in neurons involved in visual processing in cats. These results indicate that neural plasticity does occur between the auditory and visual systems.

Durlach, Thompson, & Colburn (1981) showed that normal subjects fitted with an earplug, who demonstrate a prominent displacement their localization judgment towards the side of the open ear, can increase their precision with learning through practice. These results indicate that the neuroplasticity observed in animals can be seen behaviorally in humans after relatively short time periods.

It is recognized that the extent of reorganization is dependent upon the time of onset (Brainard and Knudsen, 1998) and degree of blindness (Lessard et al, 1998). Recent studies have consistently demonstrated that congenitally blind human listeners behave differently than blind subjects who lost their sight after puberty (Brainard and Knudsen, 1998). For example, flurodeosyglucose (FDG) positron emission tomography (PET) studies have demonstrated elevated metabolism in the visual cortex of early, but not late blind subjects (Veraart, De Volder, Wanet-Defalque, Bol, Michel, & Goffinet, 1990).

Neuroimaging studies of blind persons performing nonvisual tasks, including hearing, show activity in brain areas normally associated with vision (Gougoux, Zatorre, Lassonde, Voss, & Lepore, 2005). Nineteen people, seven sighted and twelve who lost their sight at an early age, were placed in an anechoic chamber and asked to indicate where a sound was coming from, using either one or both ears. The participants then performed the same tasks while being analyzed through PET imaging.

Five of the blind participants could accurately localize sounds monaurally; most of the sighted listeners could not. Only the blind individuals with superior localization skills showed increased metabolism in the visual cortex while performing monaural localization skills. During binaural localization, the sighted participants showed decreased metabolism in visual cortical areas. These results indicate significant differences for both perceptual and physiological responses to localization tasks among blind and sighted listeners.

Statement of the Problem

Independent travel can pose a significant obstacle for the blind, yet the blind can learn to travel independently through orientation and mobility training. This training relies on the blind individual to make maximum use of hearing, specifically localization ability which allows for echolocation.

Localization ability is not assessed as part of the standard audiological evaluation, nor is it assessed as part of orientation and mobility training. This would appear counterintuitive considering the importance of localization and the fact that the audiogram alone can not predict localization ability (Carlson-Smith & Wiener, 1996) Also, differences in localization ability have been observed among the blind (Lessard et al, 1998), and when compared to individuals with normal vision (Lessard et al, 1998). These differences suggest that localization assessment would provide important information in determining the potential safety and efficiency of independent mobility in blind individuals. Furthermore, results from localization testing could potentially lead to training exercises to improve localization ability and ultimately, independent travel.

There are currently over 1 million individuals with a significant vision impairment in the United States. By age 65, one in nine people will experience vision loss that cannot be corrected by lenses (National Center for Health Statistics, 1998), age 80, it will be one in four. It is estimated by the year 2015, an additional 50% growth in the population of blind Americans is expected. These trends, in conjunction with the role of localization in independent travel, demonstrate the need for assessing localization.

CHAPTER 2

PROTOCOL

The protocol for this experimental design study is intended to provide a foundation for future research on auditory localization skills assessment in the blind population. Localization skills will be measured in two groups, normal vision and blind individuals, both with normal hearing. Research has shown that the reflection of sound is used by the blind to enhance localization, and ultimately mobility (Carlson-Smith & Wiener, 1996). Additionally, research has revealed differences between sighted and blind listeners for localization ability (Gougoux et al, 2005; Kish, 1995; Lessard et al, 1998).

Participants will be 18-40 years of age. This age group was chosen because research has indicated that the structures primarily responsible for auditory processing are matured by age 13 and will not yet have begun to deteriorate as a result of aging (central presbycusis) at 40 years of age (American Speech-Language-Hearing Association, 1996)

To further ensure normal auditory processing, each potential participant will complete the SCAN-A (Keith, 1996), a screening tool used for the detection of auditory processing disorders in adults. Only participants who receive a passing score will be allowed to continue in the experiment. Those who do not will be referred for a full audiological evaluation to include a central auditory assessment, thanked for their time, and excused from the experiment.

The 1996 ASHA Task Force on central auditory processing agreed that central auditory processing involves the auditory system and is responsible for the following behaviors: sound localization, lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition, auditory performance decrements with competing acoustic signals, and auditory performance decrements with degraded acoustic signal (ASHA, 1996).

Normal, symmetrical hearing will be a requirement of the participants in this study. Normal thresholds will be defined as 20 dB HL or better for the octave frequencies 250 through 8000 Hz using insert earphones. Research has shown that hearing impairment can greatly affect localization ability (Mickunas & Sheridan, 1963). Frequency specific hearing loss results in the decreased ability to detect spectral cues that generate accurate localization ability. Also, hearing loss that exceeds 20 dB HL increases the possibility that inaccurate localization responses may be due to insufficient audibility rather than localization.

Symmetrical hearing will be defined as between ear differences that do not exceed 5 dB HL for any octave frequency tested. Asymmetries of 10 dB HL or greater are known to decrease localization ability by confusing the listener's perception and identification of the near versus far ear (Hausler, Colburn, Marr, 1983).

Two groups will be involved in the study: normal vision/normal hearing group and blind/normal hearing group. The literature has identified differences in localization ability between normal vision and blind individuals (Gougoux, Zatorre, Lassonde, Voss, Lepore, 2005). Onset of blindness will be documented, but blind participants will not be grouped according to age of onset. It is beyond the scope of this experiment to analyze localization ability differences based on onset. The purpose of the study is to identify possible differences in localization ability between the two previously defined groups.

The instrumentation used for the localization test will be modeled after the design developed by for the National Center for Auditory and Rehabilitative Research Center (NCARRC) by Jacobs Technologies LLC and placed in an IAC sound treated booth (ANSI S3.1-1991(R1999).The equipment for the 24-loudspeaker sound localization test system include: 24 loudspeakers (MC50 Soundworks Newton Series Main/Center/Surround Speakers), 4 six-channel amplifiers, 4 six-channel soundcards (C-Media Digital Surround PCI Sound Cards), Touchscreen (Eloutouch Desktop 1224L LCD 12" Accutouch Monitor, Serial Touch Interface), PC with 4 PCI slots and 2 serial ports (Asus Intel Motherboard P4 Socket 478 PCI/ATA 133). The 24 speaker array was placed in the international acoustic sound-treated chamber (ANSI S3.1-1991(R1999)) with 15 degrees separation in the horizontal plane.

The 24 loudspeakers will present the experimental stimuli. Responses will be collected through the use of a touch screen monitor which will be equipped with a Braille overlay. Responses will be digitally recorded as indicated by the touch screen. In this manner, participants will not have to point to the source speaker. This eliminates potential incorrect scores due to the inability of the investigator to visualize the speaker the listener is pointing to.

The 24 loudspeakers will be mounted on microphone stands on a circular perimeter at ear level (1.5 meters). The speakers will have 15 ° of separation beginning from an azimuth of 0°. Each speaker will approximately 1 meter from the listeners head. The speaker array was chosen based on research that indicates that the ability to localize sound accurately decreases as the number of loudspeakers increases or the separation between loudspeakers decreases (Kusumoto, Jacobs, Saunders, Lewis and Fausti, 2004). Additionally, Perrot and Musicant (1977) have suggested a limitation of most behavioral experiments of sound localization is that the potential responses are restricted to a few locations (e.g. an individual must select from two loudspeakers located on a particular plane). This study will address the restriction of limited speaker locations.

Three types of stimuli will be used to evaluate localization assessment, unfiltered broadband noise, broadband noise that is low-pass filtered at 1500 Hz, and broadband noise that is high-pass filtered at 1500 Hz. This frequency has been identified as the point at which interaural differences in intensity and time are used to localize sound (Hebrank & Wright, 1974). Each stimulus presentation will be 3 seconds in length and randomly presented through one of the 24 speakers in the array. Each stimuli condition (unfilitered,1500 low- and high-pass filtered) will be presented 5 times through each speaker for a total of 360 presentations. Following the participants identification of the source speaker, a 3 second delay will precede the following stimulus. Testing time will take approximately 25 minutes.

All experimental stimuli will be filtered using CoolEdit Pro 2.0®, a commercially available software program, and saved to disk. Stimuli will be low and high-pass filtered (Butterworth, 64 dB/octave) at a corner frequency of 1500 Hz.

CHAPTER 3

EXPERIMENTAL METHODS AND PROCEDURES

Research Design

The type of research design for this study will be experimental. The purpose of this study is to compare localization ability in normal vision and blind listeners with normal hearing.

Statement of Intent

The purpose of this study is to determine if localization differences exist between and/or among a normal vision/normal hearing group and a blind/normal hearing group. Results of this study may indicate the addition of localization assessment in the audiometric test battery as a recommended measure for orientation and mobility training. If differences are observed among the blind listeners, clinical implications may be the development of localization training.

Participants

Normal vision/normal hearing

There will be twenty adult participants (male and female) with normal vision ranging in age from 18-40 in this study. Participants will be recruited through the Louisiana Tech University Speech and Hearing Center. The participants will have hearing within the normal limits (pure tone thresholds less than or equal to 15 dB HL for the octaves 250- 8000 Hz, re: ANSI, 1989, and asymmetry no greater than a 5 dB HL difference between ears at any frequency tested. Speech discrimination scores will be no less than 90% for either tested at 50 dB HL. All listeners will complete the SCAN-A, a central auditory screening, to determine auditory processing ability. To be included in the study, all listeners must receive a passing score on the screening. To further verify normal auditory processing, participants will complete a case history form as shown in Appendix B for the purpose of ruling out any type of disorder associated with auditory processing.

Blind/normal hearing

Twenty blind participants will serve as the experimental group. The participants in this study will be male and female adults ranging in age from 18-40. These participants will be recruited through the Louisiana Center for the Blind and the Louisiana Tech University Institute for the Blind, both located in Ruston, LA.

Documentation must be provided from a licensed ophthalmologist that includes the diagnosis with supporting numerical description including a summary of assessment procedures and evaluation instruments used to make the diagnosis and a summary of evaluation results including the standardized scores. Documentation must be from within the past three years. Additionally, participants in this group must meet the same inclusion criteria as the normal vision group

Participants from either group who meet the experimental qualifications will be allowed to participate in the study. Those who do not will be thanked for their time, counseled appropriately, and dismissed from the study.

Experimental Procedures

The informed consent will be read aloud to each participant and signed (APPENDIX B). All experimental testing will be performed in an international acoustic sound-treated booth (ANSI S3.1-1991(R1999)).

Experimental Instrumentation

An audio localization test system developed for the National Center for Auditory and Rehabilitative Research Center (NCARRC) by Jacobs Technologies LLC will be used. The equipment for the 24-loudspeaker sound localization test system include: 24 loudspeakers (MC50 Soundworks Newton Series Main/Center/Surround Speakers), 4 six-channel amplifiers, 4 six-channel soundcards (C-Media Digital Surround PCI Sound Cards), Touchscreen (Eloutouch Desktop 1224L LCD 12" Accutouch Monitor, Serial Touch Interface), PC with 4 PCI slots and 2 serial ports (e.g. figure 6)(Asus Intel Motherboard P4 Socket 478 PCI/ATA 133). The 24 speaker array will be placed in the international acoustic sound-treated chamber (e.g. figure 5)(ANSI S3.1-1991(R1999)) with 15 degrees separation in the horizontal plane. The equipment for calibration include: sound-level meter (SLM) (Bruel & Kjaer 2231 or 2260 Observer), microphone (Bruel & Kjear 4134), and interface module (BZ 9101).

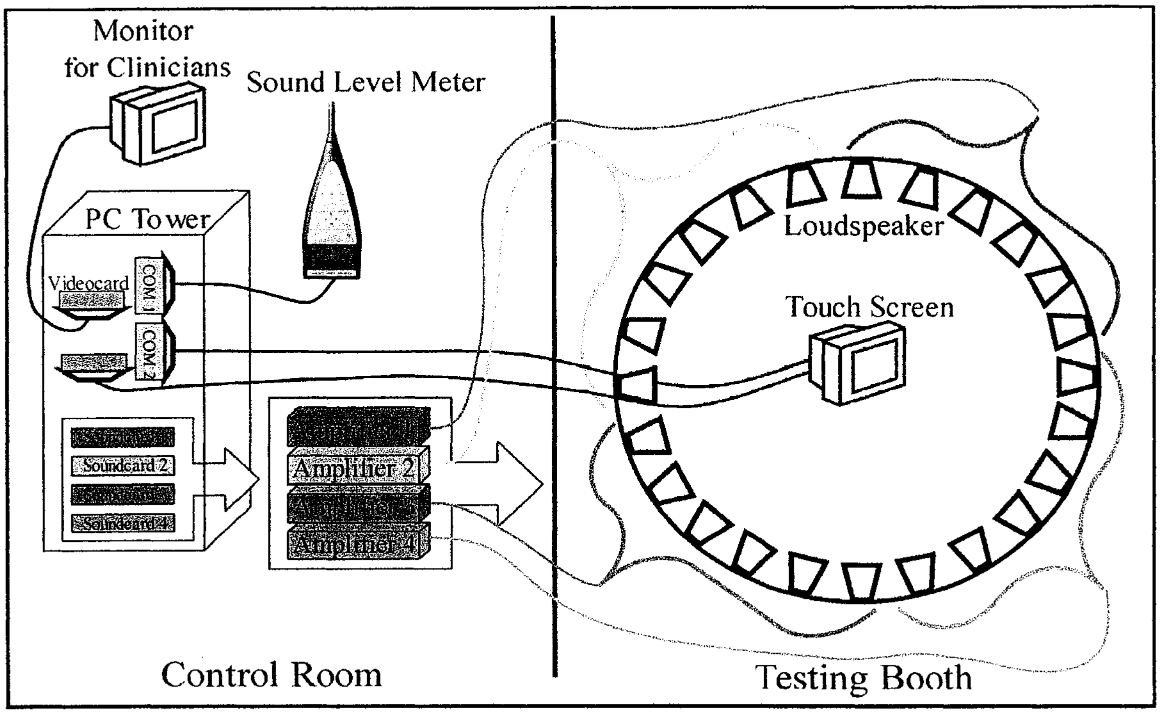

Figure 4: Localization assessment setup for testing.

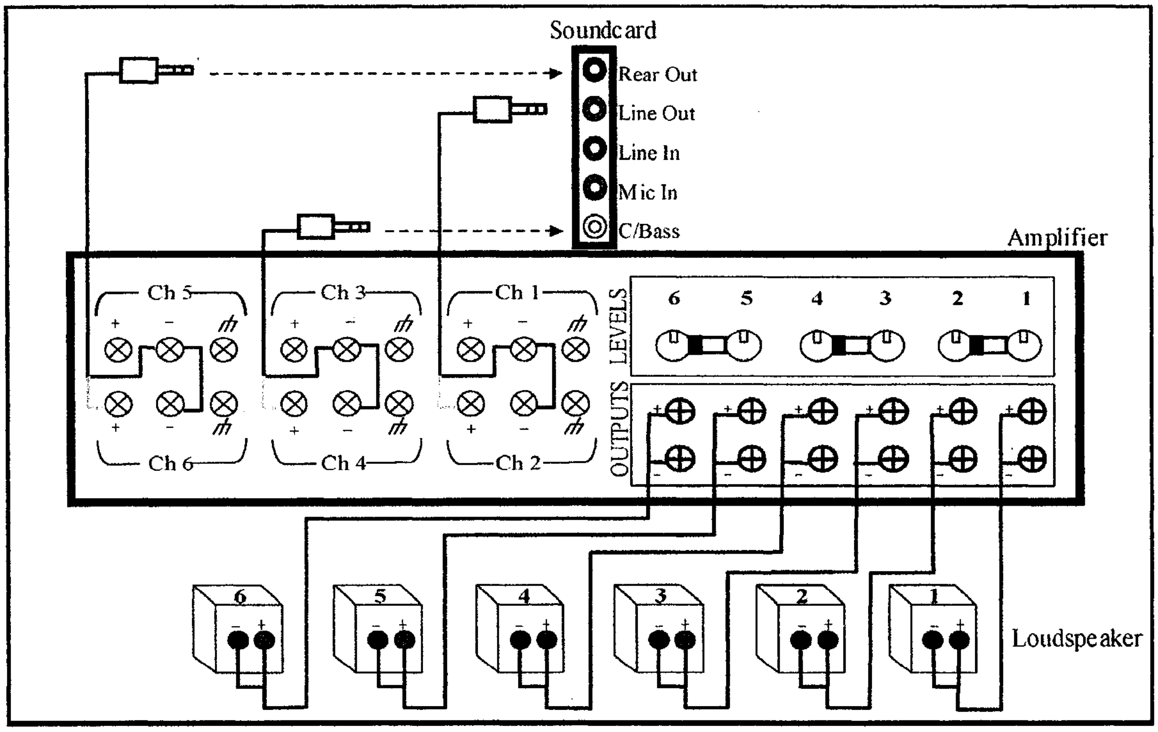

Figure 5: Schematic of individual sound card, amplifier and loudspeaker for localization assessment testing.

Experimental Stimuli

Three types of stimuli will be used to evaluate localization assessment, unfiltered broadband noise, broadband noise that is low-pass filtered at 1500 Hz, and broadband noise that is high-pass filtered at 1500 Hz. This frequency has been identified as the point at which interaural differences in intensity and time are used to localize sound (Hebrank & Wright, 1974). Each stimulus presentation will be 3 seconds in length and randomly presented through one of the 24 speakers in the array. Each stimuli condition (unfiltered, 1500 low- and high-pass filtered) will be presented 5 times through each speaker for a total of 360 presentations. Following the participants identification of the source speaker, a 3 second delay will precede the following stimulus. Testing time will take approximately 25 minutes.

All experimental stimuli will be filtered using CoolEdit Pro 2.0®, a commercially available software program, and saved to disk. Stimuli will be unfiltered, low and high-pass filtered (Butterworth, 64 dB/octave) at a corner frequency of 1500 Hz.

All experimental testing will be performed employing a stimulus level of 60 dB HL. Three types of stimuli will be used to evaluate localization assessment, unfiltered broadband noise, broadband noise that is low-pass filtered at 1500 Hz, and broadband noise that is high-pass filtered at 1500 Hz. This frequency has been identified as the point at which interaural differences in intensity and time are used to localize sound (Hebrank & Wright, 1974). Each stimulus presentation will be 3 seconds in length and randomly presented through one of the 24 speakers in the array. Each stimuli condition (unfilitered,1500 low- and high-pass filtered) will be presented

5 times through each speaker for a total of 360 presentations. Following the participants identification of the source speaker, a 3 second delay will precede the following stimulus. Testing time will take approximately 25 minutes.

Localization Test

The participants will be read the instructions (APPENDIX D) for the localization test. Each participant will be seated with their eyes forward for each presentation. The participants will use the touch screen monitor to indicate their responses. For the blind participants, a brail overlay will be placed on the touch screen. Each stimulus will be presented for three seconds, with a three second delay following their response.

Data Analysis

An analysis of variance (ANOVA) will be used to determine any significant differences between the blind and normal vision participants.

APPENDIX A

INFORMED CONSENT

INFORMED 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: Sound localization accuracy in the blind population

PURPOSE OF STUDY: To determine if there is a difference is sound localization accuracy between the visually-impaired and normal vision populations.

PROCEDURE: Case History, Hearing Evaluation, and Localization Assessment will be performed.

RISKS: There are no risks involved in the study. The participation of the individuals is voluntary.

BENEFITS: None

INSTRUMENTS AND MEASURES TO INSURE PROTECTION OF CONFIDENTIALITY, ANOYMITY: Individuals will voluntarily participate in the study. Informed consent will be obtained from the client. All collected information will be kept confidential and only viewed by the investigators.

CONTACT INFORMATION: The principal investigators listed below may be reached to answer questions about the research, subject's rights, or related matters:

Mary DeLoach	**Dr. Steve Madix**
deloachmary@hotmail.com	**smadix@latech.edu**
(772) 940-9232	**(318) 257-4764**

Member of the Human Subjects Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the investigators

Dr. Terry McConathy (318) 257-2924
Dr. Mary Livingston (318) 257-2292
Stephanie Herrmann (318) 257- 5075

I attest with my signature that I have read and understand the following description of this study and its purpose and methodologies. I understand the my participation in this research is strictly voluntary and my participation or refusal to participate in this study will in no way affect my relationship with the Louisiana Tech University Speech and Hearing Center, the Louisiana Center for the Blind or the Louisiana Tech University Institute for the Blind. Further, I understand that I may withdraw at any time or refuse to answer any questions without penalty. Upon completion of this study, I understand that the results will be freely available upon request. I understand that the results of the study will be anonymous and confidential, accessible only to the principal investigators, myself, or a legally appointed representative.

By signing and returning this form, I confirm that I have received a copy of the Informed Consent and questionnaire.

______________________________ ________________

Participant's Signature Date

APPENDIX B

CASE HISTORY FORM

Case History

Normal vision/ normal hearing group

Name:________________________ Date of Evaluation:_____________

DOB:__________________ Age:________ Sex:__

Referred by:_________________________

Case history obtained by:___________________________

Medical History

EAR:

______Pain ______Vertigo

______Ringing ______Hearing Loss

______Noise Exposure ______Drainage

______History of Infection

VISION:

______Normal ______Vision-Impairment

If vision-impairment is present, is the impairment:

______Congenital ______Acquired

Description: ____________________________________

____

____

How many years have you been visually impaired? ______

DISORDERS:

______ Central Auditory Processing Disorder

______ Attention Deficit Hyperactive Disorder

LIST ALL MAJOR ILLNESSES OR INJURIES

____

____

COMMENTS: ____

____

Case History

Blind/ normal hearing

Name:________________________ Date of Evaluation:______________
DOB:___________________ Age:_________ Sex:__
Referred by:__________________________
Case history obtained by:___________________________

Medical History

EAR:
______Pain ______Vertigo
______Ringing ______Hearing Loss
______Noise Exposure ______Drainage
______History of Infection

VISION:
______Normal ______Vision-Impairment
Documentation from licensed ophthalmologist that includes diagnosis attached? ______Yes ______No
If vision-impairment is present, is the impairment:
______Congenital ______Acquired
Description: _____________________________________
____
____
How many years have you been visually impaired? ______
List all eye illnesses or injuries___________

ORIENTATION & MOBILITY:
If you have a vision-impairment, have you ever been trained in orientation and mobility?_____________
When was your training?____________________
Where were you trained?____________________

DISORDERS:
______ Central Auditory Processing Disorder
______ Attention Deficit Hyperactive Disorder

LIST ALL MAJOR ILLNESSES OR INJURIES
____
____

COMMENTS: ____
____
____

APPENDIX C

AUDIO TEST FORM

AUDIO TEST FORM

Participant's Name____________________ Group_________________
Audiometer______________

AUDIOLOGICAL EVALUATION

Tympanometry

	Right	Left
Type		
Peak Pressure		
Gradient		
Static compliance		
Base volume		

Pure Tone Audiometry

	250	500	750	1000	1500	2000	3000	4000	6000	8000
Right Ear Air Conduction										
Right Ear Bone Conduction										
Left Ear Air Conduction										
Left Ear Bone Conduction										

Test Reliability: Good Fair Poor

Speech Audiometry

EAR	SRT	Score/level	Score/level	MCL/UCL
Right				
mask				
Left				
mask				

APPENDIX D

DIRECTIONS FOR LOCALIZATION ASSESSMENT

Directions for Localization Assessment

This is a test of your ability to identify the source or direction from which a sound is presented. Stimulus presentation will be 3 seconds in length and randomly presented through one of the 24 speakers in the array. Each stimuli condition will be presented 5 times through each speaker for a total of 240 presentations. Following your identification of the source speaker, a 3 second delay will precede the following stimulus. Testing time will take approximately 25 minutes. You will use the touch screen monitor to indicate your responses. (For the blind participants, a Braille overlay will be placed on the touch screen.) Do you have any questions?

APPENDIX E

LOCALIZATION ASSESSMENT RESPONSE FORM

Localization Assessment Response Form

Name:__________________ Date:_____________

Examiner:_______________

STIMULUS NUMBER	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
1						
2						
3						
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STIMULUS NUMBER	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER 76	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER 162	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER 205	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER 248	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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STIMULUS NUMBER	STIMULUS	CHANNEL	dBSL	RESPONSE	HIT	MISS
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