Abstract

HEARING AIDS IN OLDER ADULTS:

AUDIBILITY, OUTCOMES, STATUS, CHARACTERISTICS, AND SKILLS

By

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The current study explored hearing aid outcomes for a group of participants who were dispenser fit rather than protocol fit. Participants could have been fit and followed by any hearing aid practitioner increasing the likelihood that verification and validation measures were not used to confirm optimal amplification. Outcome measures in the current study examined audibility, word recognition performance in noise, self-reported outcomes, hearing aid visual-listening check status, participant report of hearing aid characteristics, and a modified hearing aid skills assessment. For inclusion in the study, participants were required to be between 60-89 years of age, have normal outer ear and middle ear function, a bilateral sensorineural hearing loss, normal cognition and vocabulary, as well as be fit bilaterally with hearing aids that were functioning. Thirty participants were recruited from the surrounding community

Results from this study determined that with hearing aids, participants had a significant improvement of audibility for speech at both soft and average presentation levels, as indicated by the Speech Intelligibility Index. Also, there was a significant improvement in word recognition performance in noise at both soft and average conversational levels with the use of amplification, as measured by the QuickSIN. In addition, a significant relationship between audibility and word recognition performance in noise was found. Of particular note, there were no significant relationships between audibility and self-reported outcomes as measured by the Glasgow Hearing Aid Benefit Profile. When compared to word recognition performance in noise, only the satisfaction scale on the Glasgow Hearing Aid Benefit Profile was significantly related. Other significant relationships between outcome measures including hearing aid status, hearing aid characteristics questionnaire, and ability to manipulate one's hearing aids were examined.

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: REVIEW OF THE LITERATURE

For older adults, there are a number of sensory changes with aging that are to be expected including hearing loss. Hearing aids are typically the best option available to assist with hearing impairment for older adults. Hearing aid research in this population is based on consideration of hearing loss and other characteristics of older adults and the prevalence and use of hearing aids in older adults. In addition to hearing aid use, there are important hearing aid verification measures (e.g., real-ear probe tube measures to assess audibility) and hearing aid outcome measures (e.g., benefit, satisfaction, management skills). The following sections will address this foundational knowledge and lay the groundwork for establishing the rationale for the research questions to be addressed.

Hearing Loss in Older Adults

Hearing loss is documented as one of the most common chronic health conditions (Bogardus, Yueh, & Shekelle, 2003; Cruickshanks et al., 2003; McBride, Mulrow, Aguilar, & Tuley 1994; Mulrow et al., 1990a; The National Council on the Aging, 1999; Yueh, Shapiro, MacLean, & Shekelle, 2003). It affects individuals of all ages in countries all around the world. Mathers, Smith, and Concha (2000) offered estimates of approximately 588 million individuals with hearing loss worldwide, with 248 million having at least a moderate severity of hearing loss. Hearing loss, and its societal impacts, is an issue that crosses age barriers and borders and is thus a public health concern. Whereas hearing loss affects individuals of all ages, older adults, typically categorized as 65 years and older, are most likely to suffer from hearing loss.

Before considering hearing loss in older adults, it is important to consider the growth in this age sector of the population. In 2009, it was reported that there were 39.6 million Americans aged 65 and over which was an increase of 300% since 1900 (American Psychological Association, 1997) and an increase of 12.5% since 1999 (A Profile of Older Americans, 2010). In 2020, it is projected that the older adult population will increase by 36% to approximately 55 million (A Profile of Older Americans, 2010; Schoenborn, Vickerie, & Powell-Griner, 2006) with those over 60 years of age constituting the fastest growing population (WHO, 2002). This trend highlights the need for increased attention to the health and behavioral concerns associated with aging such as the following: hearing loss, vision changes, hypertension, diabetes, heart disease, arthritis, osteoporosis, cataracts, cognitive changes including information processing, need for repetition, slower rate of learning and memory problems, slower reaction times, difficulty ignoring extraneous information, as well as task switching (American Psychological Association, 1997).

In 2005, Kochkin reported that 31.5 million people in the United States had hearing loss with a prevalence of 283 out of 1000 households (Kochkin, 2005). This number had grown to 34.25 million in 2008 (Kochkin, 2009). As stated earlier, a majority of those suffering from hearing loss are older adults. The reported prevalence of hearing loss in older adults varies from as little as 24% to as high as 90% (Cacciatore, Napoli, Abete, Marciano, Triassi, & Rengo, 1999; Cohen-Mansfield and Taylor, 2004a; Cohen-Mansfield and Taylor, 2004b; Gates and Mills, 2005; Herbst and Humphrey, 1980; Jerger, Chmiel, Wilson, & Luchl, 1995; Jones, Victor, & Vetter, 1984; McBride et al, 1994; Meisami, Brown, & Emerle, 2007; Mulrow et al., 1990a; Mulrow et al., 1990b; Pichora-Fuller and Singh, 2006; Schoenborn et al, 2006; Sprinzl and Riechelmann, 2010; Weinstein, 1994). These prevalence rates vary primarily due to differences in populations sampled (e.g., community dwelling vs. nursing home sample), measurement tools (e.g., audiometric evaluation vs. self-report), definitions of hearing loss (i.e., cut-off decibel levels or degree of self-reported difficulty), and age cut-offs for those studied (i.e., studies including adults in their 60s versus studies including only adults 70 years and older).

The Beaver Dam, Wisconsin Epidemiology of Hearing Loss Study, conducted between 1993-1995, reported the incidence of hearing loss in adults 48-92 at 45.9% with an increase to 89.5% in those over the age of 80 (Cruickshanks et al., 1998). These researchers defined hearing loss as a pure tone average (i.e., four-frequency average of thresholds at 500, 1000, 2000, and 4000 Hz) of greater than 25 dB HL in the poorest hearing ear. This definition would allow for inclusion of individuals with unilateral hearing loss, which is not common in research on hearing loss prevalence. The prevalence of hearing loss severity was as follows: 58.1% mild impairment, 30.6% moderate impairment, and 11.3% marked impairment (Cruickshanks et al., 1998). Of those with hearing loss, 94.8% had a bilateral impairment. Another widely cited study, the Framingham Cohort study, assessed 1662 individuals when they were between the ages of 57-89 years. Hearing loss was defined using a traditional three-frequency pure tone average (i.e., using thresholds at 500, 1000, and 2000 Hz) of greater than or equal to 25 dB HL in the better ear. It was determined that 29% of their sample (32.5% of men; 26.7% of women) had hearing loss (Gates, Cooper, Kannel, & Miller, 1990).

Other demographic characteristics associated with hearing loss have been based on studies using participant self-report. According to these studies, those with hearing loss are more likely to be older, male, of Caucasian descent, have less education, and have lower income (Cacciatore et al., 1999; Chen, 1994; Cruickshanks et al., 1998; Gates et al., 1990; Gilad and Glorig, 1979a; Herbst and Humphrey, 1980; Ives, Bonino, Traven, & Kuller, 1995; Jerger et al., 1995; Jones et al., 1984; Meisami et al., 2007; National Academy on an Aging Society, 1999; Reuben, Walsh, Moore, Damesyn, & Greendale, 1998; Stach, Spretnjak, & Jerger, 1990;

Strawbridge, Wallhagen, Shema, & Kaplan, 2000; Wallhagen, Strawbridge, Cohen, & Kaplan, 1997). Those less likely to report hearing impairment are females, African Americans, and those living in the northeast section of the United States (Campbell, Crews, Moriarty, Zack, & Blackman, 1999). In addition, self-reported hearing loss is more prevalent in males than in females (Ives et al., 1995) and increases with age (Slawinski, Hartel, & Kline, 1993).

Despite varying prevalence values for hearing loss in older adults, it is still apparent that a significant percentage of older Americans have hearing loss. The age of onset for first presenting with hearing difficulties is reported to be between 70-80 years of age (Kiessling et al., 2003) with a mean age of 71.5 years (Ives et al., 1995). It should be noted, however, that many older adults will wait, for years, before actually presenting concerns regarding hearing difficulties. Kochkin (2009) reported that individuals reported waiting 6.7 years to obtain hearing aids after hearing loss was identified.

Using the World Health Organization (WHO, 2001) descriptors for health conditions, hearing loss can be described using three main categories of features: hearing structure and function, activity limitations, and participation restrictions. First, one can describe hearing structures and functions. For an individual with hearing loss, this would include information on physiological changes within the auditory system and loss of auditory function such as hair cell damage and hearing loss. Assessments commonly used to describe hearing structures and functions in older adults include but are not limited to: otoscopy, pure tone air conduction and bone conduction threshold testing, and supra-threshold word recognition testing. In accordance with WHO (WHO, 2001), a second important feature related to the condition of hearing loss is an individual's hearing activity limitations or listening difficulties. For many older adults, the greatest difficulties are experienced in acoustically challenging environments (e.g. noisy situations, listening to those with a foreign accent, reverberation, attempting to obtain information from a distance, and listening to those with fast speaking rates; Kricos, 2006). Hearing activity limitations or listening difficulties are typically assessed using self-report questionnaires. Finally, one can describe the hearing participation restrictions which are the social, vocational, and emotional effects of hearing activity limitations on one's lifestyle, including reduced social interactions (Tye-Murray, 2009). These hearing participation restrictions are also commonly evaluated using self-report questionnaires. Using the WHO framework, hearing loss (due to structural and/or functional change) can lead to an inability to hear in noise (hearing activity limitation) which may cause an individual to withdraw from social events (hearing participation restriction). The following discussion will address findings related to hearing structures and functions, hearing activity limitations, and hearing participation restrictions in older adults.

Hearing Structures and Functions in Older Adults

In the World Health Organization classification, the physiological changes in the auditory system due to aging are characterized as changes in hearing structure and function (Tye-Murray, 2009). Age-related hearing loss is typically referred to as *presbycusis* and is reported to be one of the most common causes of hearing loss (Gates, Cobb, Linn, Rees, Wolf, and D'Agostino, 1996). Although some dispute that presbycusis can be separated from other potential causes of hearing loss throughout the lifespan (e.g., noise, disease), most researchers consider presbycusis to be a heterogeneous process that is a result of all conditions that lead to hearing loss (Gates and Mills, 2005). "Presbycusis [is] a mixture of acquired auditory stresses, trauma, and otological diseases superimposed upon an intrinsic, genetically controlled, ageing process" (Gates and Mill, 2005, p. 1111). In a majority of cases, presbycusis is reported as gradual in onset, bilateral (sequential or simultaneous), and is a symmetrical sensorineural hearing loss with onset and severity more prevalent in the higher frequencies (Gates et al., 1996; Gates and Mill, 2005; Gilad and Glorig, 1979a; Meisami et al., 2007; Pichora-Fuller and Singh, 2006; Sprinzl and Riechelmann, 2010). Presbycusis can affect the entire auditory system from periphery to central functions and impact cognitive processes (Chisolm, Willott, & Lister, 2003; Gates and Mills, 2005). Typically, presbycusis is associated with difficulties in identifying acoustic stimuli, reduced dynamic auditory range, impaired spectral and temporal processing abilities, difficulties in localizing sound sources, and decreased ability to understand speech, especially when in acoustically hostile environments (Gates and Mills, 2005, Kiessling et al., 2003; Mazelova, Popelar, & Syka, 2003; Wingfield, Tun, &, McCoy, 2005).

Historically, presbycusis affecting the physiology of the peripheral auditory system has been divided into four categories: sensory, neural, strial/metabolic, and cochlear conductive (Chisolm et al., 2003; Schuknecht and Gacek, 1993). Sensory presbycusis has been characterized as progressive with onset in middle age, steep high frequency sensorineural hearing loss, good word recognition and no reported recruitment. Physiologically, it is considered to be a result of atrophy of the organ of Corti including the sensory and supporting hair cells, with damage to the outer hair cells occurring first (Chisolm et al., 2003; Gates and Mills, 2005; Lowell and Paparella, 1977; Schuknecht, 1955; Schuknecht, 1964; Schuknecht and Gacek, 1993). Neural/neuronal presbycusis is considered to be caused by loss of spiral ganglion and neurons with onset later in life. It results in either a flat or a sloping to steeply sloping sensorineural hearing loss with poorer than expected word recognition abilities, and no reported recruitment effect (Chisolm et al., 2003; Gates and Mills, 2005; Lowell and Paparella, 1977;

Schuknecht, 1955; Schuknecht, 1964; Schuknecht and Gacek, 1993). The third type of presbycusis, known as strial/metabolic, results in a progressive, flat or slightly descending mild to moderate sensorineural hearing loss with good word recognition scores with a possibility of recruitment. Deterioration/atrophy of the stria vascularis is thought to be associated with this type of presbycusis (Chisolm et al., 2003; Gates and Mills, 2005; Lowell and Paparella, 1977; Schuknecht, 1964; Schuknecht and Gacek, 1993). Finally, the fourth category of presbycusis is known as cochlear conductive/mechanical presbycusis, which results in a progressive, downward straight sloping hearing loss that has no proven pathology with suspected changes in cochlear properties including stiffening of the basilar membrane (Chisolm et al., 2003; Gates and Mills, 2005; Lowell and Paparella, 1977; Schuknecht, 1964; Schuknecht and Gacek, 1993). It is thought to affect the high frequencies more so than the low frequencies with word recognition abilities associated with the audiometric configuration (Schuknecht, 1964; Schuknecht and Gacek, 1993). Two other categories of presbycusis have also been recently introduced: mixed and intermediate which define changes in more than one auditory structure as well as submicroscopic changes in the cochlea, respectively (Chisolm et al., 2003; Gates and Mills, 2005; Schuknecht and Gacek, 1993).

Dayal and Nussbaum (1971) determined that 92% of individuals with presbycusis had audiometric configurations that did not change over time. Some of the physiological changes noted can co-occur and result in a mixed presentation of symptoms and audiometric results. In addition, changes in the stria vascularis and spiral ligament can in turn negatively affect the frequency specificity of the cochlear mechanism (Gates and Mills, 2005). The loss of frequency specificity can affect one’s ability to effectively listen in noisy and acoustically hostile environments. There is also a reported genetic component in presbycusis (Christensen, Frederiksen, & Hoffman, 2001; Meisami et al., 2007).

Clinically, the changes in hearing structure and function as a result of the aging process can be documented in a variety of assessments. These include: increases in pure tone thresholds at various frequencies, decreases in word recognition abilities, and decreased prevalence and amplitudes of otoacoustic emissions (Mazelova et al., 2003, Schuknecht, 1955, Willott, Hnath Chisolm, & Lister, 2001).

Age-related hearing loss is not only suspected of affecting peripheral components, but also central components of the auditory system as well (Chisolm et al., 2003; Mazelova et al., 2003; Meisami et al., 2007, Stach et al., 1990). As reported by Cooper and Gates (1991) using the cohort of the Framingham Heart Study, 22.6% of respondents had abnormal results on at least one central auditory measurement (i.e., word recognition testing using the W-22 word lists in quiet, the Synthetic Sentence Identification test, and/or the Staggered Spondaic Word Test). There is a reportedly higher prevalence of central auditory processing disorders with increasing age (Jerger et al., 1995; Stach et al., 1990). Stach et al. (1990) attempted to determine the prevalence through the use of the Synthetic Sentence Identification assessment and the phonetically-balanced word test (PB-50). For participants between 50-54 years, 17% were determined to have central presbycusis compared to 58% in the 65-69 age range and increasing further to 95% in those 80 years of age and older. Degeneration of the central auditory nervous system is believed to affect speech understanding, processing of auditory stimuli, and understanding of speech in noisy and reverberant environments (Gates and Mills, 2005; Stach et al., 1990).

Hearing Activity Limitations and Hearing Participation Restrictions

The impact of hearing loss in the older adult population is widespread and clearly documented and can result in activity limitations and participation restrictions, as described earlier (Tye-Murray, 2009). Hearing loss can detrimentally affect daily communication situations such as conversing with loved ones, caregivers, co-workers, and the public; can limit awareness of safety concerns which could include fire alarms, car horns, and oncoming traffic; can lead to misunderstanding of important information such as medical instructions from a physician; and can negatively impact social gatherings and leisure activities; as well as many other areas of life (Weinstein, 1996; Gates et al., 1996; Gilad and Glorig, 1979a; Jerger et al., 1995; Resnick, Fries, & Verbrugge, 1997). Many older adults may be content with and have ingrained communication patterns. Due to hearing difficulties, changes in those communication behaviors may be needed to allow for more effective communication in social situations. One of the greatest concerns with hearing loss is the associated difficulties with understanding speech, especially when in noisy and reverberant environments.

Many studies have detailed how hearing loss can negatively affect the quality of life in older adults (Cacciatore et al., 1999; Carabellese et al., 1993; Chia, Wang, Rochtchina, Cumming, Newall, & Mitchell, 2007; Dalton, Cruickshanks, Klein, Klein, Wiley, & Nondahl, 2003; Resnick et al., 1997; Sprinzl and Riechelmann, 2010), especially when uncorrected by intervention. Chia et al. (2007) documented that quality of life decreases as the severity of hearing loss increases. Hearing loss, especially when untreated, can lead to overall dysfunction (Bess, Lichtenstein, Logan, Burger, & Nelson, 1989; Bogardus et al, 2003), most notably causing a barrier to communication (Cohen-Mansfield and Infield, 2006; Dalton et al., 2003).

The National Council on the Aging (1999) sought to determine the effects of hearing impairment in regards to quality of life, including a comparison of those who wore hearing aids and those who had not worn hearing aids. The sample included 2,304 older adults with hearing loss. A number of negative outcomes associated with untreated hearing impairment were determined. When compared to those who were aided, those without hearing aids were more likely to experience negative outcomes such as sadness, depression, worry, anxiety, paranoia, and decreased social activity. For those individuals who wore hearing aids, benefits included better relationships, better mental health, security, independence, and "better feelings about themselves" (The National Council on the Aging 1999, p.2). Overall, those with hearing aids reported improved quality of life. Family members of individuals who wore hearing aids also reported improvement in relationships and quality of life. In regards to not seeking assistance through hearing aids, denial was reportedly the most common factor.

The loss of sensory acuity in older adults is well documented (Crews and Campbell, 2004; Meisami et al., 2007). Many times, sensory deficits coincide in that many older adults might suffer from hearing loss as well as vision loss, thus compounding the effects of each (Blumsack, 2003; Jang, Mortimer, Haley, Small, Chisolm, & Graves 2003; Kiessling et al., 2003; Schluter, 1989). These combined effects can increase difficulties in effectively communicating leading to isolation and withdrawal from society, functional impairment, and depression (Meisami et al., 2007; Reuben et al., 1998).

A significant relationship has been determined between hearing loss and physical, cognitive, social, communication, and emotional dysfunction, even with mild to moderate hearing impairment (Mulrow et al., 1990a; Mulrow et al., 1990b). Studies have associated hearing loss occurrence with physical dysfunction, difficulty understanding speech, depression, loneliness/isolation/alienation, behavioral changes, decrease in social activities and social interactions, paranoia, insecurity, loss/decrease of self-esteem, cognitive impairment, dementia, mobility and physical abilities, sensory deprivation, reduction in intellectual and cultural stimulation, difficulty in completing instrumental activities of daily living, sickness related to dysfunction, poorer health, decrease in psychosocial function, negative effects on self-sufficiency, disability, educational success, economic success, and lower rates of retirement satisfaction (Appollonio, Carabellese, Frattola, & Trabucchi, 1996; Arlinger, 2003; Bess et al., 1989; Bess, Logan, & Lichenstein, 1990; Bogardus et al, 2003; Cacciatore et al., 1999; Campbell et al., 1999; Carabellese et al., 1993; Chen, 1994; Chia et al., 2007; Cohen-Mansfield and Taylor, 2004b; Cohen-Mansfield and Infield, 2006; Dugan and Kivett, 1994; Gates et al., 1996; Gates and Mills, 2005; Gilad and Glorig, 1979a; Herbst and Humphrey, 1980; Ives et al., 1995; Jang et al., 2003; Jones et al., 1984; Jupiter and Spivey, 1997; Mathers et al, 2000; Meisami et al., 2007; National Academy on an Aging Society, 1999; Resnick et al., 1997; National Council on the Aging, 1999; Sprinzl and Riechelmann, 2010; Strawbridge et al., 2000; Uhlmann, Larson, Rees, Koepsell, & Duckert, 1989; Wallhagen et al., 1997; Wallhagen, Strawbridge, & Kaplan, 1996; Weinstein and Ventry, 1982; Weinstein, 1994; Yueh et al, 2003). It should be noted that association does not imply causation. In addition, many of the co-occurring problems mentioned increase in severity as the severity of hearing loss increases. Wallhagen et al. (1996) compared results regarding hearing impairment to a baseline of basic health information which was conducted six years prior. It was determined that those with hearing loss had a greater likelihood of depression, had poor perceived health, were less able to enjoy spare time, and had a less active lifestyle.

Other health concerns have been associated with hearing loss including cardiovascular disease, hypertension, coronary heart disease, chronic lung disease, stroke, and diabetes (Campbell et al., 1999; Gates and Mills, 2005; Gilad and Glorig, 1979b; Ives et al., 1995; Moscicki, Elkins, Baum, & McNamara 1985; Mulrow and Lichtenstein, 1991). However, as noted previously, association does not indicate causation and further study is needed to determine why hearing loss may be associated with these other conditions.

In contrast to the above studies, there have been other studies that have been unable to find links between hearing loss and other health conditions, including: anxiety (Andersson and Green, 1995); dementia (Herbst and Humphrey, 1980); as well as disability (Jang et al., 2003). In addition, Rudberg, Furner, Dunn, and Cassel (1993) determined that hearing loss was not independently related and did not independently predict disability as defined by ability to conduct physical activities of daily life. They suggested that while these changes might coincide, they are a result of increases in age. Thomas, Hunt, Garry, Hood, Goodwin, and Goodwin (1983) stated that untreated hearing loss had no harmful effects on emotional well-being or social interactions and that there was no relationship between hearing loss and depression, hostility, mental status, or social interactions. Some have found that hearing loss did not significantly affect participation restrictions such as socializing with friends (Campbell et al., 1999). Stuck, Walthert, Nikolaus, Bula, Hohmann, and Beck (1999) completed a review of previous studies and determined that there was only a weak association between hearing loss and overall functional status decline in the elderly population.

The effects of hearing loss and aging on binaural and spatial tasks have been assessed and these include: difficulty in performing tasks with binaural signals presented in noise, difficulty with localization in noisy and quiet environments, need for increased signal to noise ratios for word recognition, and improved speech understanding when noise and speech are separated in location of origin (Koehnke and Besing, 2001; Willott et al., 2001). Not only does hearing loss affect the individual, it also affects the quality of life of loved ones. Those who have a spouse with hearing loss are more likely to have "poorer physical, psychological, and social well-being" with the impact being greater on the wife than the husband (Wallhagen, Strawbridge, Shema, & Kaplan, 2004). Hearing loss can have a detrimental impact on ingrained communication patterns, especially between marriage partners (Wallhagen et al., 2004). For example, a wife may be used to conversing with her husband from another room in the house. But, if her husband now has hearing loss, the wife may not realize the need for moving into the same room for adequate communication.

Surprisingly, even though hearing loss is so prevalent in the older adult population and linked to decreased quality of life, there is a reported under-detection of hearing impairment. This may occur for a number of reasons including, but not limited to, perceived severity of hearing impairment (i.e., hearing loss perceived as only mild) and lack of appropriate referral by health care providers (Cohen-Mansfield and Taylor, 2004a). In the Beaver Dam, Wisconsin study, 36% of respondents had never had a hearing test (Cruickshanks et al., 1998). In one recent study, only 10% of patients in a nursing home setting had been assessed for hearing function in the prior 12 months and 81% had never had a hearing evaluation or follow-up care (Cohen-Mansfield and Taylor, 2004a). A range of only 12.5% to 60% of primary care physicians reportedly screen for hearing loss (Cohen, Labadie, & Haynes, 2005; Kochkin, 2005; Mulrow et al., 1990a; Mulrow et al., 1990b). In the study described by Kochkin (2009), 14.6% of the respondents reported a hearing screening by a physician. To qualify as a screening any of the following could be completed: rubbed fingers, whispered in ear, use of tuning fork, hand held screener, audiometer, and a questionnaire. This is unexpected since 97.6% of physicians in one study agreed that hearing impairment was associated with poorer quality of life (Cohen et al., 2005). These physicians cited time constraints and other major medical concerns as a reason for not addressing hearing loss in this population (Cohen et al., 2005).

Not only do physicians need to acknowledge the importance of hearing healthcare, but patients need to as well. Singer and Brownell (1984) attempted to assess hearing healthcare knowledge in adults. Adults, most notably older adults, had limited knowledge regarding hearing. Singer and Brownell (1984) determined that the more educated the person was, the more hearing healthcare knowledge they possessed. In addition, poorer knowledge was associated with those who had never had his/her hearing assessed.

Koike and Johnston (1989) attempted to determine follow-up responses of twenty-five elderly individuals who had been advised to seek further evaluation for hearing healthcare after identification of hearing loss. In their study, 52% of these participants received additional evaluation (i.e., audiological or medical), as recommended. Of those that followed the recommendation for further evaluation, 85% pursued treatment (i.e., hearing aids and/or aural rehabilitation). In regards to choosing intervention, Laplante-Levesque, Hickson, and Worrall (2012) determined that those with lower socioeconomic status were less likely to choose intervention whether it be hearing aids or an aural rehabilitation program.

In summary, the population, deemed as older adults, is rapidly growing and health problems within this age group are also increasing as well, including hearing loss. As described above, there are many studies detailing the effects of hearing loss on quality of life and other physical and psychosocial consequences. The next section details the intervention option of hearing aids, which is available to many of those suffering from hearing impairment.

Hearing Aid Use in Older Adults

Presbycusis cannot be medically corrected, but there are options for improving one's hearing abilities. Currently, the best option for most individuals with a sensorineural hearing loss and no medical contraindications is the use of a hearing aid (Garstecki and Erler, 1998; Willott et al., 2001). Studies have noted that hearing aid use can result in self reports of improved quality of life and less perceived hearing handicap (Appollonio et al., 1996; Jerger et al., 1995; Mulrow et al., 1990a; The National Council on the Aging, 1999; Weinstein, 1996), even in as little as six weeks of use (Mulrow et al., 1990a). Hearing aids, used as a treatment, can improve cognitive function, social function, communication function, family interactions, mental health, emotional function, independence, self-esteem and reduce symptoms of depression (Mulrow et al., 1990a; National Council on the Aging, 1999). In addition, family members of hearing aid users have also noted improvements, especially in quality of life for the hearing aid user (National Council on the Aging, 1999; Stark and Hickson, 2004).

Despite the reported positive effects of hearing aids, the prevalence of those with hearing loss that use hearing aids is quite low (i.e., approximately 25%; Cacciatore et al,. 1999). An estimated 75% of those with hearing loss have never tried a hearing aid (Gates et al., 1990) and 22 million adults with hearing loss do not wear hearing aids (Kochkin, 2007). Uncorrected hearing impairment costs an estimated $56 billion in "lost productivity, special education, and medical care" (National Academy on an Aging Society, as reported by Better Hearing Institute, 1999). Specific estimates of hearing aid ownership ranges from 10-33% of the hearing impaired population (Campbell et al., 1999; Chia et al., 2007; Cohen-Mansfield and Taylor, 2004a; Cruickshanks et al., 2003; Dalton et al., 2003; Gates et al., 1990; Herbst and Humphrey, 1980; Ives et al., 1995; Kochkin 1993; Mulrow et al., 1990a; National Academy on an Aging Society, 1999; Popelka, Cruickshanks, Wiley, Tweed, Klein, & Klein, 1998). Eighty-six percent of those with hearing loss in both ears and wearing hearing aids have been fitted binaurally (Kochkin, 2005). The typical average age for a first-time hearing aid user has been reported as 66.3-70 years of age (Kochkin, 1999; Kochkin, 2005; Kochkin, 2007). Prevalence of hearing aid use is associated with increased age of patient, greater severity of hearing loss, poorer word recognition scores, greater self-reported hearing loss, and greater hearing handicap/perceived disability (Popelka et al., 1998).

Reportedly, only 18-29.3% of those who own hearing aids are currently using them (Chia et al., 2007; Cohen-Mansfield and Taylor, 2004a; Kochkin, 2007; Popelka et al., 1998) with 1.2 million hearing aids in the drawer (Kochkin, 2005). When assessed 8-16 years after hearing aid fitting, only 43% of the respondents were continuing hearing aid use (Gianopoulos, Stephens, & Davis, 2002). However, approximately 71% of those who rejected hearing aids were interested in trying new hearing aid technologies (Gianopoulos et al., 2002). There are a multitude of factors that influence hearing aid ownership as well as rejection of hearing aid use including: denial of hearing loss or its severity, cost, influence of family members and medical personnel, stigma, vanity, dissatisfaction with hearing aid, discomfort with hearing aid, lack of hearing aid benefit, inability to manipulate or operate hearing aid, hearing aid limitations, poor sound quality of hearing aid, dissatisfaction with dispenser, fear of losing instrument, limited social interactions, other pressing health concerns, perceived value lower than cost, and that the individual had not received a hearing assessment (Cohen-Mansfield and Taylor, 2004b; Cohen-Mansfield and Infield, 2006; Franks and Beckmann, 1985; Garstecki and Erler, 1998; Kochkin, 1993; Kochkin, 2003; Kochkin, 2005; Kochkin, 2007; Mulrow and Lichtenstein, 1991; National

Academy on an Aging Society, 1999; National Council on the Aging, 1999; Wingfield, et al., 2005).

In recent years, there has been an onslaught of digital hearing aid instruments replacing analog hearing aids. Digital hearing aids are programmed through computer software and allow for better manipulation of hearing aid features, gain, and output. Features in digital hearing aids can include: multiple program options, gain adjustment in frequency channels, directional microphones, frequency transposition, noise reduction, wind noise suppression, feedback control to reduce acoustic feedback, and compression of certain stimuli (Gordon-Salant, 2005; Sprinzl and Riechelmann, 2010).

Success with hearing aids is attainable. It can be measured through assessments which evaluate associated hearing aid benefit, satisfaction, and use. Long-term hearing aid success has been associated with previous experience with hearing aids, the configuration of one’s hearing loss (with better results when there was more high frequency hearing loss), better auditory processing abilities, and higher initial expectations for benefit (Humes and Humes, 2004). Jupiter and Spivey (1997) noted that hearing aids were helpful for nursing home residents; however, they did not resolve all hearing difficulties associated with hearing loss. Their participants reported that even with hearing aid use, it was still difficult to listen to the television and radio as well as hear in large groups of people (Jupiter and Spivey, 1997). This complaint is typical in the older adult population and is not restricted to older adults in nursing homes.

Kochkin (2003) reported on survey data for hearing aid users and indicated that for those wearing hearing aids for less than three years, 75% felt that the hearing aids had improved hearing with a little more than half stating they felt the value of the hearing aid was satisfactory. Kochkin (2005) offered more specific data related to years of hearing aid use and related satisfaction. In that survey, the percentage of individuals wearing hearing aids for less than four years and reporting satisfaction was 73.1%. For those who had worn hearing instruments for less than a year, 77.5% reported satisfaction.

Hearing aid success may be related to differences in cognitive function, such as working memory capacity. Working memory capacity is the ability to store and process information, for a small period of time, when it is presented in the auditory or visual modalities (Lumner, 2003). Working memory may be a factor because speech is a rapidly occurring signal, often masked or distorted by noise or reverberation.

As can be gleaned from the aforementioned research, hearing loss is a widespread health concern. However, only a minority of these individuals are seeking hearing healthcare through the use of hearing aids. Research has shown that individuals wearing hearing aids have shown positive outcomes both objectively (i.e. measured changes) and subjectively (i.e. reported changes). The following sections will discuss ways that one can measure the benefit of hearing aids through objective methods (i.e., audibility indices and word recognition performance) as well as subjective means (i.e., questionnaires).

Audibility

A primary goal of hearing aid fittings is that of restoring and ultimately achieving optimum audibility, especially for conversational speech (Ching, Dillon, Katsch, & Byrne 2001; Galster, 2011). Audibility measures during hearing aid fittings indicate how much of a speech signal is actually available to or above the hearing thresholds of the hearing aid wearer. Audibility is an important component in hearing aid success (Galster, 2011). If a stimulus is not audible to a person with hearing loss, obviously there is no way that the individual can take advantage of that auditory information. Most individuals pursuing hearing aid use have access to some speech acoustic information even without amplification. They are hoping to access more speech acoustic information with amplification. There are several proposed ways to verify that hearing aids are offering improved speech audibility. These include real-ear aided response measures through use of a probe tube microphone system and speech passages as well as the use of index calculations such as the Articulation Index (ANSI S3.5, 1997) and the Speech Intelligibility Index (ANSI S3.5, 1997) to estimate the relative proportion of speech above the listener's thresholds. These measures will be discussed in the following sections.

Real-Ear Probe Tube Measures of Speech Audibility

One approach to the verification of audibility utilizes real-ear probe tube microphone measurements with a probe tube allowing for the recording of sound pressure levels within the ear canal and near the tympanic membrane. Probe tube microphone systems can provide information on the audibility of speech passages at various input levels. These real-ear measurements can provide a measure of hearing aid benefit (Aarts and Caffee, 2005; Humes, 1999). Many researchers have emphasized the importance of probe-microphone measurements during hearing aid fittings to verify prescribed gain and speech audibility, including Dillon and Keidser (2003).

There are a number of different measurements one can conduct with a probe tube microphone measurement system. The two main approaches to real-ear measures, real-ear insertion gain (REIG) and real-ear aided response (REAR) will be discussed. When determining REIG, one must measure the real-ear unaided response (REUR) and the REAR. The REUR is measured with the probe tube placed within approximately 5 mm of the tympanic membrane without a hearing aid on the ear (Filips and Hernandez, 2010). This measure primarily reflects the resonance of an individual's ear as a function of frequency (Filips and Hernandez, 2010). The REAR is measured with the same probe tube placement and the hearing aid on and placed in the ear (Filips and Hernandez, 2010). The probe tube system analyzer calculates the mathematical difference between these two measurements or the REIG. The REIG represents the gain of the hearing aid above and beyond the natural resonance of the ear (Filips and Hernandez, 2010). Historically, the REIG measure was more commonly used in the verification process. However, REAR measures alone are more commonly made today (Mueller and Picou, 2010). REAR measures do not include the unaided response or difference between the aided and unaided responses. With the REAR approach, only one measurement is made, the real-ear SPL across the speech frequency range, and compared to prescribed aided sound pressure level targets (Filips and Hernandez, 2010). This is typically displayed using a graph known as the Speechmap, which shows real-ear aided response and prescription targets across the frequency range.

The Speechmap is essentially a "map of [the] amplified speech region within [the] residual auditory area" (Cole, 2005, p. 1). It displays intensity in dB SPL on the vertical axis and frequency in Hertz (Hz) on the horizontal axis. When measuring the real-ear aided response, the amplified long-term average speech spectrum (LTASS) is plotted on the graph itself along with the individual's hearing thresholds and prescription targets. The audiologist can examine how closely the aided LTASS matches the prescribed targets. If the amplified LTASS does not match the prescriptive targets, then the audiologist can adjust the gain of the hearing aid to better approximate those targets.

Probe tube microphone measures have been recommended as an essential means for verifying audibility, except in fittings where aided sound pressure levels (SPLs) are not produced by the device such as with cochlear implants and bone anchored hearing aids/devices (Valente et al., 2006) or with devices that are deep fit within the ear canal (e.g., invisible-in-the canal hearing aids). However, reports of the frequency of use of probe tube microphone measurements are disappointing. Results from a 2002 hearing aid dispenser survey (Strom, 2003), indicated that approximately 66% of respondents had access to real-ear measurement systems/hearing aid analyzers. Thus, many practitioners have probe tube microphone systems. In another study, a survey of both audiologists and hearing instruments specialists (HIS), it was determined that only 22% of audiologists and 15% of HIS always or nearly always conducted real-ear measurements compared to 28% of audiologists and 30% of HIS who never conducted real-ear measurements (Kirkwood, 2004). Similarly, in a 2005 dispenser survey (Strom, 2006), only 25% of respondents regularly used real-ear measurements with 57% having access to a probe microphone/real-ear measurement system. In comparison, 80% of those surveyed by Filips and Hernandez (2010) had access to the equipment, but only 40% conducted routine measurements. As a result of a Consumer Reports commentary on best hearing aid fitting practices, Kirkwood (2010) surveyed audiologists and HIS. Kirkwood found that 48% of respondents completed probe tube measurements most of the time with adult patients while 30% rarely or never completed these measurements. In that survey, 55% of the respondents reported access to probe tube equipment most of the time. In regards to the judged importance of real-ear measures, 39% strongly agreed that real-ear measurements are a "must-do procedure" while 23% somewhat agreed, 26% disagreed, and 10% strongly disagreed (Kirkwood, 2010).

Another study by Mueller and Picou (2010) surveyed both audiologists and HIS on the usage of probe tube measurements with adult patients. Fifty-two percent of respondents reported using probe tube measurement verification methods sometimes while 40% reportedly used them routinely. Fifty percent of the respondents indicated that they owned a probe tube measurement system, but did not regularly utilize it. In regards to the most important goal of hearing aid fitting, respondents stated that is was to offer improved audibility for speech. When asking the patient, Kochkin (2010) reported that 40% of respondents had received probe tube measurements as part of the fitting process. In summary, probe tube measures offer an objective means of documenting speech audibility. While the majority of practitioners fitting hearing aids have access to real-ear probe tube systems, the majority of practitioners do not use them routinely for adult hearing aid verification.

Hearing Aid Prescriptions

Modern day hearing aid prescriptions (e.g., DSLv.5 [Scollie et al., 2005], NAL-NL1 [Dillon, 1999], NAL-NL-2 [Dillon, Keidser, Ching, Flax, & Brewer, 2011]) provide aided sound pressure level targets based on a person's auditory thresholds across the speech frequency range. These aided SPL targets are intended to offer improved speech audibility with acceptable sound quality and loudness. As stated previously, these aided SPL targets can be evaluated using real-ear probe tube microphone systems.

There are a number of hearing aid prescriptions intended for use with today's non-linear hearing aids. Examples of non-linear prescription methods in use at this time include: NAL-NL1; NAL-NL2, DSL v.5, and the Cambridge models (Moore, Alcantara, Stone, & Glasberg, 1999a; Moore, Glasberg, & Stone, 1999b; Moore, 2000).

Hearing aid prescriptions may be proprietary and associated with a hearing aid manufacturer or non-proprietary and associated with research laboratories. Typically, companies offer proprietary prescriptions with fairly general rationales and little empirical data. Research labs that offer non-proprietary prescriptions offer more extensive information on rationale and data related to development, use, and validation of the prescription. Some examples of non-proprietary prescriptions include NAL-NL1, NAL-NL2, and DSL v.5.

Every hearing aid prescription has its own rationale and mathematical calculation for establishing aided sound pressure level targets to offer audibility and comfort. One of the most popular prescriptions in current use with adults is from the National Acoustics Laboratory (NAL). The rationale for the latest versions of the NAL prescriptions (NAL-NL1 and NAL-NL2) is to maximize speech intelligibility for a predetermined input level while still normalizing overall loudness (Byrne, Dillon, Ching, Katsch, & Keidser, 2001; Dillon, 1999). When loudness is normalized through a hearing aid fitting, a hearing impaired listener would judge low intensity speech as “soft,” moderate intensity speech as “comfortable,” and high intensity speech as “loud,” but not uncomfortable as would a normal hearing listener.

According to best practice, one verifies hearing aid prescribed gain using a probe-tube system and yet many practitioners may only use a *first-fit* or *quick-fit* to program hearing aids. In the hearing aid programming software, the first-fit or quick fit is a software based estimation of the gain and output needed to match a selected prescription based on the age, hearing thresholds, acoustic coupling used with the hearing aid (i.e., tubing, venting) and average ear canal resonance data. The hearing aid practitioner can typically choose to program the first-fit estimated gain and output for either the manufacturer’s prescription or a non-proprietary prescription (e.g., NAL-NL1 or NAL-NL2). Some practitioners use first-fit only as the initial gain adjustment and then make further adjustments using real-ear probe tube measures to approximate prescription targets. A practitioner using only first-fit would not be verifying the prescription using probe tube measures but would leave the hearing aids on the estimated first-fit settings. Aazh and Moore (2007) determined that 64% of first-fit responses were not within 10 dB (i.e. the researchers' criteria for a poor match to target) of NAL-NL1 targets for at least one assessed frequency. This is of concern for fittings that rely on first-fit as they may not be providing optimal audibility for a hearing impaired person. Aazh and Moore (2007) reported that first-fit often underamplifies (i.e., amplified values are below prescribed targets), especially in the higher frequencies. Once again, this is a concern for speech audibility.

It is important to note that prescription methods vary, and an individual patient could receive different hearing aid gain depending on the prescription used. While the prescribed gain differs by prescription, Johnson and Dillon (2011) found that the predicted speech intelligibility index (SII) did not significantly differ for several non-proprietary prescriptions including NAL-NL1, NAL-NL2, and DSL m[i/o] for speech presented at a normal conversational level (i.e., 65 dB SPL) in both quiet and in noise. This finding suggests that various prescriptions may result in comparable overall speech audibility. One might argue for using any non-proprietary research-based prescription and then confirming that the hearing aid is set to offer audibility through approximating that prescription's targets. Since the researcher will not have knowledge of the hearing aid prescription used, in this study, speech audibility will be evaluated through an audibility index (SII).

Speech Audibility Indices

Audibility and speech intelligibility are important factors in determining hearing aid benefit. While audibility represents the proportion of the speech acoustic signal available to a listener, speech intelligibility represents the percentage of speech stimuli (i.e. nonsense syllables, words, sentences) correctly identified. There are two major indices for determining the audibility of speech: the articulation index (AI) and the speech intelligibility index (SII).

Articulation Index (AI). The articulation index, first introduced by French and Steinberg (1947), is "a weighted fraction representing, for a given speech channel and noise condition, the effective proportion of the normal speech signal which is available to a listener for conveying speech intelligibility" (Kryter, 1962b, p. 1689). The AI ranges from 0.0 (representing no speech audibility) to 1.0 (representing full audibility) and can be mathematically calculated.

The mathematical formula for calculating the AI varies across research groups. The goal however, for any of these AI calculations, is to reflect audibility and aid in the prediction of speech intelligibility (Kryter, 1962a). The articulation index can provide objective data on audibility. Also, by the use of a transfer function, the predicted word recognition abilities of an individual can be determined based on their AI. Kryter (1962b) determined that the articulation index is a valid predictor of speech intelligibility in a variety of communication situations including those with noise and distortion. The transfer function predicting word recognition is dependent on the type of speech materials used (Amlani, Punch, & Ching, 2002; Hornsby, 2004; Pavlovic, 1989; Scollie, 2008; Sherbecoe and Studebaker, 2002).

A more user-friendly method of determining the articulation index and estimating the audibility of speech is the count-the-dot method introduced by Mueller and Killion (1990) with further revisions offered by Killion and Christensen (1998) and Killion and Mueller (2010). The original count-the-dot method included an audiogram plot with 100 dots with each dot representing audibility of 0.01. The dots were not equally spread across the speech frequency range of 250 to 6000 Hz with more dots being placed in frequency bands showing greater importance to speech intelligibility. Thus, an individual whose hearing sensitivity allowed for the detection of 85 dots would have an AI of 0.85. Killion and Mueller (2010) revised the count-the-dots AI calculation to reflect research on the SII and moved dots into the 6000-8000 Hz frequency range. The main proposed use for the count-the-dots method is in clinical practice.

A number of potential modifications have been suggested for use with the articulation index (Kryter, 1962a). Pavlovic and Studebaker (1984) suggested the use of a proficiency factor for each individual listener. This proficiency factor reflects both the enunciation of the talker and the listener’s familiarity with that talker’s speech. Another factor, suggested by Pavlovic, Studebaker, and Sherbecoe (1986), is a desensitization factor which is used for those with severe hearing loss. This correction aims to provide a more appropriate audibility calculation for those with severe sensorineural hearing loss who often have poor speech intelligibility due to the inability to use all of the auditory information provided. In more recent years, a second audibility index, based on the AI, has been more widely used and it will be discussed next in greater detail.

Speech Intelligibility Index (SII). The SII (ANSI S3.5, 1997) is similar to the articulation index in that it reflects how much useable auditory information is actually reaching an individual. The SII is based on two mathematical functions: a frequency band function and a band audibility function (ANSI S3.5, 1997). The frequency band function takes into account the significance of each frequency band to the intelligibility of speech (ANSI S3.5, 1997). It is dependent on the speech material used and is denoted as I_i (ANSI S3.5, 1997). The band audibility function reflects the proportion of the residual dynamic range within each band that is audible to the listener and contributes to the intelligibility of speech, and it is denoted as A_i (ANSI S3.5, 1997). The SII is essentially a "product of band importance function and band audibility function, summed over the total number of frequency bands in the computational method" (ANSI S3.5, 1997, p. 2-3). With n denoting the number of bands, it can be mathematically shown as:

$$S=\sum_{i=1}^{n} I_i A_i$$

The SII mathematically represents the proportion of auditory information available to the listener (ANSI S3.5, 1997). Like the AI, the SII ranges from a minimum of 0.0 to a maximum of 1.0 with 0.0 representing no useable auditory information reaching an individual and 1.0 representing that all presented auditory information is reaching the individual (ANSI S3.5, 1997). According to ANSI S3.5 (1997), a good communication system has a SII of greater than 0.75 while a poor communication system has a SII of less than 0.45. The SII is a measurement that is highly correlated with the intelligibility of speech under various listening situations (ANSI S3.5, 1997). It should be noted that those high correlations were found using otologically normal listeners (ANSI S3.5, 1997). The SII can be determined mathematically, most commonly through use of a computer program.

There are four proposed methods in the ANSI S3.5 (1997) standard to compute the SII. Each method uses a different number of frequency bands. The more frequency bands assessed, the more precise the SII. In order of accuracy, the procedures would be ranked as follows: 1) the critical band procedure (21 critical bands); 2) the one-third octave band procedure (18 bands); 3) the equally-contributing critical band procedure (17 bands); and 4) the octave band procedure (6 bands).

A few researchers have attempted to use the SII in determining hearing aid benefit and predicting word recognition abilities through the use of a transfer function. As stated by Hornsby (2004), the SII "allows us to quantify the impact hearing loss has on the audibility of speech, both in quiet and in noise" thus allowing "us to predict speech understanding in specific test settings and compare the predicted and measured performance of persons with hearing loss" (p. 14). Scollie (2008) used a transfer function to predict consonant recognition scores in both children (with and without hearing loss) and adults (with normal hearing). The transfer function was a good predictor of word recognition for the adult population with normal hearing. However, the transfer function created for adults over-predicted pediatric speech recognition scores in children with and without hearing loss. Thus, that transfer function was not appropriate for all ages.

The SII can be calculated with inclusion of additional factors to reflect the spread of masking, the speech stimuli used, presentation levels, number of frequency bands, and reverberant environments (Amlani et al., 2002; Hornsby, 2004). For example, since the SII is based on otologically normal listeners, in order to account for individuals with elevated thresholds, a speech level distortion factor can be added to the calculation to represent the higher levels at which they might be listening to speech when amplified (ANSI S3.5, 1997). Ching et al. (2001) introduced a modified SII based on the following additional factors: level distortion (i.e. listener performance is degraded at high presentation levels), hearing loss configuration and degree, and desensitization (i.e. listener performance is degraded when severe sensorineural hearing loss is present). Research by Magnusson, Karlsson, Ringdahl, and Israelsson (2001b) validated the desensitization and distortion factors in predicting speech recognition abilities in hearing aid users. They found that including these factors was sufficient for predicting word recognition abilities in noise, even with differing hearing aid frequency-gain characteristics.

Use of AI and SII in Hearing Aid Verification

There have been a number of studies focused on the use of the AI and SII in hearing aid verification. Key studies related to the AI and SII will be discussed.

Since the AI can be used to aid in determining audibility, it has been suggested that it might be a good predictor of speech intelligibility. However, some researchers have suggested that it may only be a good predictor of speech intelligibility for those with mild to moderate hearing loss (Amlani et al., 2002; Magnusson, Karlsson, & Leijon, 2001a). Kamm, Dirks, and Bell (1985) determined that the AI was a good predictor of word recognition abilities for those with normal hearing and those with hearing loss and better word recognition scores. However, these researchers suggested that the AI may not be a good predictor of speech intelligibility for individuals with hearing impairment and poorer speech recognition scores. The latter conclusion should be interpreted with extreme caution as there was only one person in their study with hearing impairment and a poor word recognition score. Further study comparing audibility indices for individuals with a wide range of speech recognition abilities would allow that claim to be supported or refuted.

The AI and SII provide information on audibility, but some studies have suggested that greater audibility does not necessarily mean better speech intelligibility. Hogan and Turner

(1998) sought to determine if greater high-frequency audibility would result in improved non-sense syllable recognition abilities in those with high frequency sensorineural hearing loss. They studied individuals with normal hearing and those with a high frequency hearing loss ranging from mild to severe. Low pass filtering was used to vary the amount of high frequency speech acoustic information on the nonsense syllable materials presented to the listeners. The researchers examined whether listeners benefited from increased high frequency speech acoustic information. They found that for those with severe high frequency hearing loss, increasing high frequency speech acoustic information resulted in either no improvement or a decline in nonsense syllable recognition. In contrast, listeners with normal hearing or a mild high frequency sensorineural hearing loss showed improved nonsense syllable recognition with increased high frequency acoustic information. From this study, greater high frequency audibility did not necessarily improve nonsense syllable recognition, depending on the severity of the high frequency hearing loss. These results are similar to those of Turner and Cummings (1999), who determined that higher presentation levels for nonsense syllables may increase audibility, but does not always provide greater intelligibility. For those with high frequency hearing loss exceeding 55 dB HL, increased audibility did not increase speech intelligibility for nonsense syllable stimuli. Ching et al. (2001) also reported that those with severe-profound hearing loss showed little or no benefit with increased audibility in the high frequencies.

Ching, Dillon, & Byrne (1998) evaluated the ability to utilize auditory information at different frequencies and sensation levels (SL) in individuals with a variety of audiometric configurations. Fifty-four individuals participated with fourteen of them normal hearing, nineteen with mild to moderate hearing loss, and twenty-one with severe to profound hearing loss. Using filtered BKB sentence stimuli (Bench and Doyle, 1979), the researchers determined word recognition abilities at varying presentation levels (6, 12, 18, 24, 30, and 36 dB SL). In addition, a SII was calculated and a transform function was utilized to determine predicted word recognition performance. The researchers stated that the unmodified SII "overpredicted speech performance at high sensation levels for listeners with severe hearing losses, and in many cases, underestimated speech scores at low sensation levels" (Ching et al., 1998, p. 1128). Greater audibility at frequencies with severe hearing loss was actually detrimental to word recognition and thus maximal audibility was not always associated with better speech intelligibility, especially maximal audibility the higher frequencies (Amlani et al., 2002; Ching et al., 1998). It has been suggested that as hearing loss increases, the SII predicted speech intelligibility overestimates the actual intelligibility of speech. For those with mild and moderate losses, the actual word recognition performances were similar to or better than predicted performance (from the SII). Ching et al. (1998) did determine that the SII was a better, albeit not great, predictor of speech recognition scores when an individual level distortion factor and a frequency-dependent proficiency factor were included in the SII formula.

Research has also examined the relationship between the AI and hearing handicap. Hearing handicap represents the perceived listening difficulties and negative emotional consequences of hearing loss. Holcomb, Nerbonne, and Konkle (2000) calculated a modified unaided AI for individuals with hearing loss and compared these results to hearing handicap scores on the Self-Assessment of Communication (SAC; Schow and Nerbonne, 1982) and the Significant Other Assessment of Communication (SOAC; Schow and Nerbonne, 1982). As expected there was a significant correlation between the AI and the SAC ($r = -0.59$) and SOAC ($r = -0.57$) results ($p < 0.01$). It was found that the higher the articulation index, the less perceived hearing handicap (i.e., greater audibility associated with less perceived listening difficulty). In addition, it was determined that the degree of hearing loss was the only variable that influenced the correlation between the AI and the self-reported hearing handicap score. There was a stronger correlation between the articulation index and the communication-related items (range from r =-0.42 to r =-0.57 on six items) on the SAC as compared to the social-emotional items (range from r =-0.34 to r =-0.45 on four items). No other variables (i.e., gender, age, and audiometric configuration) were significantly related to audibility or self-perceived hearing handicap.

Souza, Yueh, Sarubbi, and Loovis (2000) attempted to determine the relationship between improved audibility as measured by the difference in aided and unaided AI and hearing aid effectiveness as measured by global satisfaction and use. A total of 115 individuals, ages 39-88, participated in this study with a majority having sensorineural hearing loss (93%) and some (7%) having a mixed hearing loss. All had binaural analog (peak clipping or compression limiting), non-programmable hearing aids. It is important to note that these hearing aids were set on prescription using real-ear probe tube measures, which as stated earlier is not a common practice in adult hearing aid fittings. The difference between unaided AI and aided AI, known as the AI increase, was measured with the Audioscan. Overall, there was an average AI increase of .30. There was no clear relationship between audibility increase and self-reported changes in communication abilities using the Abbreviated Profile of Hearing Aid Benefit (Cox and Alexander, 1995) and satisfaction using the Satisfaction with Amplification in Daily Life (Cox and Alexander, 1999). There was no "strong" relationship reported between AI increase and self-reported hearing aid benefit through the use of the APHAB. Essentially, no matter the amount of audibility available to the hearing aid user, similar communication abilities were reported. Also, those with high audibility had more difficulty listening in background noise, which the authors postulate could perhaps be due to the use of linear hearing aids. Greater audibility was related to greater adherence in hearing aid use (calculated as days/week and hours/day). There was a moderate positive relationship between the AI and hearing aid use as measured in hours per day and days per week of use.

Magnusson et al. (2001a) compared the estimated SII with word recognition abilities and responses for the just-follow-conversation assessment with two types of background noises (i.e., unmodulated speech-weighted noise and low-frequency noise) and three different hearing aid frequency responses for 29 older adults with mild to moderate hearing loss. Each was fit monaurally with linear amplification. The SII calculation was computer-generated and did include a desensitization factor. Three hearing aid frequency responses were measured: the actual (participant's current frequency response); NAL (response adjusted to meet NAL-R prescription); and H-SII (response adjusted to maximize SII for each participant). In conclusion, the researchers determined that the SII was a good predictor of word recognition abilities for those with mild-moderate hearing loss. The researchers stated that the SII has good validity and is good for hearing aid fittings and evaluating different frequency response characteristics. The H-SII frequency response mode provided the best predicted performance and the best speech recognition and just-follow-conversation performance.

Several researchers have used the articulation index/SII in the development of new prescription methods. Hou and Thorton (1994) aimed to maximize the articulation index through a prescription known as the Optimal Integrated Articulation Index, which included a level distortion factor (i.e., representing speech presentation level). It was determined that this new prescription method, tested on linear hearing aids, was similar to the NAL and POGO prescriptions, when comparing speech recognition in quiet conditions inputs ranging from 30 to

90 dB HL. The OIAI prescription setting did provide better speech intelligibility when comparing performance in a noise condition with input signal ranging from 30 to 90 dB HL with a SNR of -3.

As described above, the SII with modifications may be used to predict speech intelligibility in various listening situations. Some authors have determined that it might not provide an accurate prediction due to variations in audiometric configurations. Hornsby (2004) suggested that the calculated difference between the unaided and aided SII might be a valid hearing aid benefit measure that could be compared to speech and self-report benefit measures. Newman and Sandridge (1998) used the FONIX real-ear/hearing aid analyzer to set hearing aids on various prescriptions and compare the unaided and aided AI values. Twenty-five adults ranging in age from 47-84 with mild to moderately severe hearing loss configurations were fit either monaurally or binaurally with one of three hearing aid technologies. The first hearing aid was a one-channel linear mini behind-the-ear hearing aid set to POGO-II. The next hearing aid technology was a two-channel nonlinear mini behind-the-ear hearing aid with the goal of compensating for recruitment in the low frequencies and improving speech intelligibility as well as comfort in the high frequencies using both wide dynamic range compression and POGO-II. The third hearing aid assessed was a seven band, two channel digital signal processing hearing aid set to a proprietary prescription of ASA (Schum, 1996). The unaided AI was estimated using the individual's thresholds while the aided AI was computed using stimuli presented at both a 50 and 80 dB HL input level. The researchers found a significant change in AI between unaided and aided conditions for all of the hearing aid technologies analyzed ($p<0.001$) thus showing that hearing aids significantly improved audibility.

Gatehouse (1999) evaluated the unaided and aided SII measurements as well as the improvement in SII for 943 individuals with varying degrees of hearing loss. Hearing aid performance was evaluated by the use of a clinical probe tube measurement system. He determined that 80.9% of individuals had an improved SII (for a 65 dB SPL input signal) of at least 0.05 with amplification. Degree of hearing loss was related to SII improvement, as would be expected. Those with milder hearing loss have higher unaided SIIs which restricts the amount of improvement possible. To these authors' knowledge, there is limited research using audibility indices, measured by a real-ear system, as hearing aid outcome measures. The current research study will include use of the SII as an outcome measure.

Word Recognition Performance Measures

One inherent goal of hearing aid fitting is to restore audibility for speech. Improved audibility may be expected to offer improved word recognition abilities and self-perceived benefit and satisfaction from the use of hearing aids. As noted in the previous section, aided speech audibility for a hearing aid user can be estimated through the use of audibility indices (AI and SII). The change in SII can be considered an objective measure of hearing aid benefit. There are other methods of determining aided performance that can be used separately or in conjunction with the AI and SII, including other objective measurements as well as subjective measurements. While some define objective measures as those requiring no human response or judgment, in hearing aid research word recognition tests are often considered objective in the sense that there is no subjective rating offered. Objective measures are named as such because they allow for scoring of items as correct or incorrect. In hearing aid research, objective assessments typically focus on how an individual performs with and without the use of hearing aids on word recognition tests (although nonsense syllables and sentences have also been used). There are a number of studies that have described word recognition performance for hearing aid users with words presented at suprathreshold levels in quiet and/or in the presence of noise. The following studies are presented in chronological order. It is of interest, that few studies have been published recently even though hearing aid technology has changed drastically. In addition, unless otherwise noted, performance in these studies transformed the percent correct scores using the rationalized arcsine units (rau; Studebaker, 1985), a statistical method utilized to stabilize error variance in percent scores.

Humes and Hackett (1990) utilized the CUNY Nonsense Syllable Test (CUNY NST; Resnick, Dubno, Hoffnung, & Levitt, 1975) to assess speech recognition with hearing aids using three different prescriptive methods (i.e., NAL-R (Byrne and Dillon, 1986), Memphis State or COX (Cox, 1988), and POGO-II (Schwartz, Lyregaard, & Lundh, 1988). Twelve individuals with sensorineural hearing loss were divided into three groups (flat hearing loss, steeply sloping hearing loss, and moderately sloping hearing loss) and participant ages ranged from 33-67 years old. Each participant was fit with a behind-the-ear hearing aid which was adjusted to meet each of the three hearing aid prescriptions to allow for testing with each prescription. The CUNY NST was presented in both a quiet condition and in background noise. The CUNY NST was presented at 70 dB SPL in the soundfield at a 0° azimuth. For the noise condition, a cafeteria competing noise was presented at 65 dB SPL from the same loudspeaker resulting in a +5 SNR. When presented in quiet, aided scores were, on average and for all prescriptions, 15% better than unaided scores. For the condition with background noise, no differences in performance for aided versus unaided conditions were found for any of the prescriptions.

Cox and Alexander (1991) compared performance with and without hearing aids in three different listening situations and with three different hearing aid prescriptions, which varied by frequency gain response characteristics. This study included 33 individuals divided into three groups according to assigned listening environment. Individuals were matched in each group according to hearing loss configuration, age, unaided word recognition abilities in quiet, and speech reception thresholds. All participants had symmetrical, “essentially” sensorineural hearing loss with audiograms of different configurations including: flat, moderately sloping, and sharply sloping. Each participant received a hearing aid in each of the three prescriptions and was fit monaurally. The hearing aids were of varying models, but all were linear, non-directional, analog or hybrid digital circuitry worn over the ear, depending on current use of a hearing aid by some patients. The investigators used the Connected Speech Test (CST; Cox, Alexander, & Gilmore, 1987) in both the audio only and audiovisual modalities through the soundfield in the presence of 6-talker speech babble and the participants were asked to repeat each test sentence. The three environments simulated included: one environment similar to face-to-face conversations in quiet with a SNR of +7 dB L_{eq} [stimulus presented at 55 dB L_{eq} and one meter from the listener (i.e., L_{eq} is defined as the equivalent continuous dBA level)]; an environment similar to communicating over a distance with a SNR of +8 dB L_{eq} (stimulus presented at 63 dB L_{eq} and five meters from listener); and an environment similar to a face-to-face conversation in a noisy environment with a SNR of +2 dB L_{eq} (stimulus presented at 64 dB L_{eq} and one meter from listener). The background noise emanated from four loudspeakers. Benefit with the use of hearing aids was significant and was the greatest for the quiet environment (first environment), which was indicative of the most favorable listening condition with improvement of at least 20% in speech intelligibility. The least benefit with hearing aids was noted for listening to speech in a noisy environment (third environment). When analyzing individual data, 76% of participants in this study demonstrated significant benefit using at least one of the hearing aid prescription methods in the aided condition ($p<0.05$).

Bentler, Niebuhr, Getta, and Anderson (1993) assessed hearing aid benefit through the first year following fitting. In this study, sixty-five adults ranging in age from 21-84 years participated. Approximately half (i.e., 51%) of the participants had a gently sloping hearing loss while the remainder had a flat or steeply sloping hearing loss configuration. Seventy percent were fit with in-the-ear hearing aids and 30% had behind-the-ear hearing aids with appropriate function assessed using real-ear probe tube measures. These researchers used the Speech Perception in Noise Test (SPIN; Kalikow, Stevens, & Elliot, 1977) and the NST for benefit measures. The SPIN was presented at a +8 SNR in 12-talker babble through soundfield, while the NST was presented by a loudspeaker in both quiet and in speech-weighted noise at a +5 SNR. Location of the stimuli and noise presentations in regards to the listener's position were not described. The presentation level was set by the researchers and varied between 50-60 dB HL, dependent on activation of nonlinear circuit. Aided testing was performed one, three, six, and twelve months post-fitting. In contrast to some of the other studies discussed previously, there was no significant group improvement in objective measures with the use of hearing aids over time. The researchers postulated that this lack of change could be due to the fact that all assessments were made with the hearing aids meeting prescribed target (NAL-R; Byrne and Dillon, 1986) when all speech recognition measures were made. This finding does not support the hypothesis that hearing aid users may show improved speech recognition over time, also known as acclimatization.

Using FM tonal thresholds, Taylor (1993) assessed the difference between unaided and aided performance, known as functional gain, at pre-fitting, three weeks post, three months post, six months post, and one year post fitting. Stimuli were presented at 0° azimuth and 1 meter from the participant. Fifty-eight new hearing aid users ranging in age from 65-81 years with a minimum of a mild high frequency sensorineural hearing loss participated. Thirty-seven were fit monaurally while twenty-one wore hearing aids binaurally with real-ear insertion gain responses measured with a real-ear probe tube system. Forty-two of the participants wore in-the-ear hearing aids while sixteen wore behind-the-ear hearing aids. In conclusion, the researcher determined that there were significantly better FM tonal thresholds in the aided condition, thus showing measureable benefit with the use of hearing aids. When comparing the evaluation measures taken at three weeks, three months, six months, and one year, no significant changes were found over time. This finding is consistent with finding of Bentler et al. (1993) who also reported no change over time in aided benefit (i.e., no acclimatization).

Humes, Halling, and Coughlin (1996) assessed hearing aid outcome at 7, 15, 30, 60, 90, and 180 days post-fitting by evaluating unaided and aided word recognition performance. Twenty individuals ranging in age from 63-78 years old with bilateral mild to severe high frequency sensorineural hearing loss participated. All participants were fit with behind-the-ear hearing aids, either monaurally or binaurally using a quick-fit prescription provided by the manufacturer. The CUNY NST was administered at 70 dB SPL in quiet with the loudspeaker positioned eighteen inches from the participant's head at a 45° azimuth. As a group, statistically significant benefit (i.e., improved NST scores) was shown in the aided condition. When examining individual performance, significant benefit with amplification was shown when individuals performed less than 65-70% in the unaided condition. The Hearing In Noise Test

(HINT; Nilsson, Soli, & Sullivan, 1994), an adaptive test where sentences generally are presented in multitalker babble with adjustments made to determine the SNR for 50% performance, was also used. For this particular study, the HINT adaptive procedure was not used, but instead the sentences and noise were presented at a SNR of +8 and with a 0° azimuth. Statistically significant benefit was obtained with improved scores in the aided condition. When examining individual results, significant benefit was shown with hearing aids only when the unaided performance was less than 80%.

Humes, Christensen, Bess, and Hedley-Williams (1997) assessed 110 individuals with flat or gently sloping symmetrical sensorineural hearing loss to determine hearing aid benefit on speech recognition measures. These participants were fit with linear in-the-canal hearing aids bilaterally with an optional automatic low-frequency gain reduction, when presented at high levels (known as bass increase at low levels, or BILL) with frequency response of hearing aid verified by use of a real-ear probe tube system. Two assessments, the Northwestern University Auditory Test No. 6 (NU-6; Tillman and Carhart, 1966) and CST, were both presented at 60 and 75 dB SPL with competing cafeteria and multitalker speech babble at a SNR of +5 and a SNR of +10. The stimuli and competing noise were presented at 0° azimuth and one meter from the listener. There was a statistically significant benefit obtained with the use of hearing aids for both the NU-6 and CST assessments at these SNRs. Greater benefit was obtained at the higher SNR (+10) when compared to the smaller SNR of +5. In contrast, there was no reported benefit for individuals with mild or moderate hearing loss when the stimuli were presented at 75 dB SPL. Also, greater benefit was obtained when the stimuli were presented in cafeteria noise as compared to the multitalker speech babble. Finally, greater benefit was obtained for the CST passages compared to the NU-6 monosyllabic words. Using a change in rau of 18.1 for the NU-

6 and 15.5 rau for the CST, "60-80% of the participants showed significant improvement in at least half of the conditions when speech is presented at normal conversational levels (60 dB [SPL])" (Humes et al., 1997, p. 684). In addition, 20-60% of participants with moderate to severe hearing loss showed significant improvement from the unaided to the aided speech recognition in noise conditions when presented at 75 dB SPL. These findings once again indicate that audibility for words without amplification is a critical factor in determining hearing aid benefit. Those with milder hearing losses who are not wearing hearing aids may receive high levels of audibility at higher presentation levels and thus receive little or no additional benefit with amplification.

In order to determine hearing aid benefit for word recognition performance and communication abilities with three different hearing aid technologies, Newman and Sandridge (1998) assessed performance on the SPIN (more fully described in the audibility section). Twenty-five adults with ages ranging from 45-87 years participated. Each had a bilateral, mild to moderately severe sensorineural hearing loss. Monaural amplification was fit on 44% of participants while the remaining 56% had binaural amplification. Behind-the-ear hearing aids were worn by 28% of the participants while 72% wore in-the-ear hearing aids. The SPIN sentence stimuli were presented via a loudspeaker at 50 dB HL and 0° azimuth with multitalker noise at a SNR of +8 presented and emanating from three different azimuths (90°, 180°, and 270°) for different test conditions. Significant benefit (improved SPIN scores) was obtained in the aided conditions, when compared to the unaided conditions, for all hearing aid technologies assessed ($p<0.001$). It should be noted that these researchers used a 50 dB HL presentation level, which is more likely to show benefit.

Using the NU-6 and CST tests, Humes, Christensen, Thomas, Bess, and Hedley-Williams (1999) attempted to compare benefit for two hearing aid circuit types (linear and two-channel wide dynamic range compression; WDRC) in both quiet and noise. In this study, 55 individuals participated and all had a flat or gently sloping bilateral sensorineural hearing loss with thresholds ranging from 25-85 dB HL. Twenty-three individuals had a mild hearing loss, 25 had a moderate hearing loss, and 7 participants had a severe hearing loss. Each was fit with in-the-ear hearing aids representing both circuit types (total of two sets) with frequency response of the hearing aids verified by use of a real-ear probe tube system. Both assessments were presented in the soundfield at a 0° azimuth and one meter from the participant. Each test was presented in quiet at 50 and 60 dB SPL and in multitalker babble at 60 and 75 dB SPL with a SNR of +5 and +10. Significant improvement with the use of hearing aids was determined ($p<0.05$). The researchers also found that more participants showed improvement in the quiet condition than when stimuli were in the presence of background noise. In the noisy condition, more participants had improvement for the 60 dB SPL presentation level (compared to 75 dB SPL). In addition, overall, more participants showed improvement on the NU-6 test materials as compared to the CST assessment.

Using the CUNY NST and CST assessments, Humes (2002) reported on word recognition performance with and without hearing aids in the older adult population. In the described study, 171 individuals, who ranged in age from 60-87 and had a symmetrical flat or gently sloping sensorineural hearing, were fit with linear in-the-ear hearing aids with output compression and Class D amplifiers. To ensure real-ear insertion gain matched the NAL-R prescription method, a real-ear probe tube microphone system was utilized. Slightly over half (53.7%) of participants were fit binaurally and 46.3% were monaurally fit. Both assessments were presented with the stimuli at 0° azimuth, one meter from the participant and with the competing multitalker babble at 180° azimuth, one meter from the participant. The CUNY NST assessment was presented at 65 dB SPL in multitalker babble at a SNR of +8. For the CUNY NST, it was determined that significant benefit was obtained in the aided condition, when compared to the unaided condition ($p<0.001$). The CST was presented in three conditions: 1) at 50 dB SPL in quiet; 2) at 65 dB SPL with multitalker babble at a +8 SNR; and 3) at 80 dB SPL with multitalker babble at a 0 SNR. Across all conditions, significant benefit with hearing aids, as measured by the CST, was ascertained ($p<0.001$). Aided performance was better than unaided performance in the quiet condition and at a +8 dB SNR, however, there were no differences between unaided and aided performance at the highest presentation level with a SNR of +0. Using the same data, Humes, Garner, Wilson, and Barlow (2001) performed a factor analysis on twenty-six hearing aid outcomes measures to determine which areas should be assessed for hearing aid benefit. There were seven areas that were deemed to be necessary and these included: subjective benefit and satisfaction, aided speech recognition performance, hearing aid use, objective benefit for soft and conversational levels of speech, speech communication at high levels in noise, hearing handicap, and judgments of sound quality.

In a large-scale, multi-site study, known as the NIDCD/VA study, a number of objective hearing aid benefit measures were assessed (Larson et al., 2002; Shanks, Wilson, Larson, & Williams, 2002). There were 360 adults enrolled who ranged in age from 29-91 years with bilateral sensorineural hearing loss. Each participant was fit with in-the-ear hearing aids binaurally with three different circuits: peak clipping, compression limiting, and single-channel WDRC. In a double-blind experiment, each of the participants wore the hearing aids adjusted to the three aforementioned circuits for ninety days each. In two articles detailing this study

(Shanks et al., 2002; Larson et al., 2002), hearing aid benefit was reportedly measured in each of these circuit configurations using NU-6 monosyllabic word lists in quiet and the CST. Word recognition was assessed in quiet and in the presence of background noise with varying signal-to-noise ratios (SNRs) and presentation levels without the use of hearing aids and with the use of hearing aids before and after wearing each of the circuits for ninety days. All of the test stimuli were presented at 0° azimuth and 1 meter from the listener with the competing six-talker babble positioned at +45° azimuth and -45° azimuth. The NU-6 test was presented at 62 dB SPL in quiet. For the CST, there were ten different listening situations including presentation at 74 dB SPL in quiet as well as nine multitalker babble conditions with varying presentation levels (52, 62, and 74 dB SPL) with changing SNRs of -3, 0, and +3 (based on individually determined reference SNR needed to achieve 50% ± 4%). Hearing aid benefit was evidenced by improvement in word recognition with hearing aid use when compared to the unaided condition. The authors determined that significant hearing aid benefit was determined with an improvement of 32-34 rau in all three hearing aid circuit configurations for the NU-6 test. Not surprisingly, the authors determined that greater hearing aid benefit or greater improvement was obtained at higher SNRs on the CST. Also, as expected, the largest hearing aid benefit was found when the presentation level was lower in intensity (i.e., higher presentation levels may offer audibility for words in the unamplified condition and then little or no improvement with amplification). For both tests (i.e., the NU-6 and CST), significant differences were found between the aided test scores and the unaided test scores ($p<0.001$). The significantly better aided scores, again, were offered as evidence for hearing aid benefit. Greater benefit was also found for hearing impaired listeners with greater severity of hearing loss. Both sets of investigators (Shanks et al., 2002;

Larson et al., 2002) concluded that significant benefit was achieved with the use of all hearing aid circuits in both quiet environments and in the presence of noise.

Alcantara, Moore, Kuhnel, and Launer (2003) sought to determine hearing aid benefit three months post-fitting similar to the time course of the NIDCD/VA multi-center study. These researchers assessed noise reduction features in digital hearing aids by evaluating aided and unaided test results. Eight experienced hearing aid users with bilateral sensorineural hearing loss of moderate degree participated in this study. The participants' ages ranged from 49-83 years and each were fit with in-the-ear hearing aids binaurally. Aided and unaided performance was based on measurement of the speech recognition threshold (SRT) from a standardized list when measured in quiet and in four types of background noise (stationary noise, stationary noise with temporal dips of a single talker, stationary noise with spectral dips, and stationary noise with temporal and spectral dips). The background noise was presented at 65 dB SPL. It was determined that the SRTs were significantly lower (i.e. better) for the aided conditions than the unaided conditions ($p<0.05$) and that the use of hearing aids provided benefit. In the presence of background noise, aided listeners can improve performance and take advantage of the temporal and spectral cues.

Walden and Walden (2004) compared the unaided and aided QuickSIN (Killion, M. C., Niquette, P. A., Gudmundsen, G. I., Revit, L. J., & Banerjee, S., 2004) assessment to determine differences in SNR loss. These researchers assessed fifty adult males ranging in age from 49-94 years with a bilateral sloping sensorineural hearing loss. Thirty-nine of the participants were fit binaurally while eleven were fit monaurally with various makes and models of hearing aids. The QuickSIN was presented at 70 dB HL with the test sentences and 4-talker babble presented at different SNRs (from +25 to 0) via a loudspeaker positioned at 0° azimuth. A significant positive correlation was determined between the unaided and aided performance (r=0.75). The SNR loss was significantly smaller (i.e., improved) in the aided QuickSIN condition compared to the unaided condition ($p<0.01$). The researchers did note however, that those with large SNR losses in the unaided condition tended to have larger SNR losses in the aided condition. They concluded that hearing aid success might be predicted by the amount of SNR loss in the unaided condition and that those requiring larger SNRs will not be as successful with hearing aids. The researchers sought to determine if there were relationships between patient and hearing aid characteristics when compared to hearing aid success as measured by the following: unaided and aided articulation index scores, unaided and aided QuickSIN performance, the pure tone average, and performance on the NU-6 when aided. There was a significant correlation between all of these measures in the hypothesized and expected direction. Some of the highest correlations were found for the measures reflecting audibility: unaided and aided AI calculations (r=0.80) and unaided AI and pure tone average (r= -0.81). In addition, a high correlation was shown between the unaided and aided QuickSIN.(r=0.75). The use of hearing aids as indicated by patient reported hours of daily use was significantly correlated with the pure tone average (r= -0.39) and unaided AI (r=0.28). Finally, age of the participant was significantly correlated with the unaided QuickSIN (r=0.59) and aided QuickSIN (r=0.44)

Using assessments that differ from those discussed above, Hallgren, Larsby, Lyxell, and Arlinger (2005) aimed to determine hearing aid effect on word recognition and perceived effort in both quiet and noisy environments. The participants had mild-moderate sensorineural hearing loss and wore binaural hearing aids. There were two age groups (25-45 and 65-80) each with twelve participants. Word recognition performance was assessed through the Hagerman speech test where SNR of the participant was calculated to correspond to individual performance of 40%

as well as the Speech and Visual Information Processing System (SVIPS). The assessments were presented in quiet and in two types of noise (speech babble and single female speaker speech). The SVIPS was presented at 75 dB SPL in the unaided condition (unless an increased level was necessary for audibility) and always at 75 dB SPL in the aided condition with the loudspeaker located one meter from participant. The researchers did not discuss location or the azimuth of the presentation. In the quiet condition, significant benefit was obtained with the use of hearing aids in that respondents were able to obtain 40% correct on the Hagerman speech test at an intensity 7 dB SPL lower with hearing aids than without the use hearing aids ($p<0.001$). In addition, both assessments showed that with the use of hearing aids, there was a significant improvement ($p=0.008$) in the required SNR (1.6 dB) to obtain 40% correct. In addition, word recognition abilities improved significantly with the use of hearing aids ($p=0.022$). The greatest benefit was obtained when no noise was present and the worse performance was noted when a single talker speech was used as the competing signal. Significant benefit was only obtained in the presence of quiet or in Hagerman noise, and no significant benefit was obtained when the competing signal was the single talker speech.

Mendel (2007) assessed word recognition abilities in the presence of background noise through three assessments. Twenty-one adults ranging in age from 33-75 years of age with bilateral sensorineural hearing loss of varying severity participated. Seventeen of the participants were fitted with hearing aids binaurally, while four were fit monaurally and all with real-ear probe tube microphone system verification. Participants were fit with both behind-the-ear and in-the ear hearing aids of different makes and models. The three speech recognition tests used were: the HINT, the Revised Speech Perception in Noise (R-SPIN; Bilger, Nuetzel, Rabinowitz, and Rzeczkowski, 1984), and the QuickSIN. In this study, the HINT was presented in a quiet condition as well as in noise conditions, as specified by the developers, with the speech presented at a 0° azimuth and noise emanating from different azimuths (0°, 90° to the left, and 90° to the right) for different test conditions. The researcher determined that there was significant benefit when comparing performance on the HINT in the aided quiet condition to the unaided quiet condition ($p<0.001$). However, there was no significant benefit with hearing aid use compared to not wearing hearing aids for the HINT in noise conditions (i.e., noise front, noise left, and noise right). It also was determined that the location or azimuth of the noise did have an effect on hearing aid benefit. When the noise was presented to the front of the participant, the unaided and aided responses were significantly worse than when the noise was presented to the right of the participant ($p<0.001$) as well as when the noise was presented to the left ($p<0.001$). When the noise was presented to the left of the participant, performance in both the aided and unaided conditions were significantly better than when the noise was presented to the right ($p=0.008$).

In this study (Mendel, 2007), the R-SPIN sentence stimuli were presented at 50 dB HL with a +6 SNR and the participant repeating the last word heard. The R-SPIN is unique in that half of the words are of high predictability (i.e. contextually meaningful) and the other half are of low predictability (i.e. not contextually meaningful). On the R-SPIN, aided performance was significantly better when compared to the unaided performance ($p=0.023$). The QuickSIN measures SNR loss which is defined as the additional gain required for a person with hearing loss to understand speech presented in the presence of background noise when compared to a person with normal hearing. Four QuickSIN test lists were presented at 70 dB HL at 0° azimuth, one meter from the participant. Each participant was required to repeat the test sentences. The researcher evaluated performance on sentences at each of the SNRs on the QuickSIN (+25, 20, 15, 10, 5, and 0) and calculated the average SNR loss across the four lists. Performance in the aided condition resulted in significantly better results when compared to testing in the unaided condition ($p<0.05$) for almost all SNRs assessed (+25,+ 20, +15, +10, +5), except 0 SNR. The SNR loss in the aided condition was also significantly better than the SNR loss in the unaided condition ($p=0.03$). Mendel (2007) concluded that the most sensitive assessment for determining benefit from hearing aids using word recognition are the HINT in quiet, the R-SPIN, and the SNR loss of the QuickSIN.

Humes, Ahlstrom, Bratt, and Peek (2009) also sought to assess hearing aid benefit using the CST. In this study, 213 individual, with sloping sensorineural hearing loss bilaterally were fit with one of four different hearing aid technologies: single-channel linear, two-channel WDRC analog, and 4-channel digital WDRC with and without directionality with gain verified by the use of a real-ear probe tube microphone system. The CST was administered with the spoken passages presented at 65 dB SPL via a loudspeaker situated one meter from the listener at a 0° azimuth. The competing multitalker babble was presented at 57 dB SPL (i.e., +8 SNR), one meter from the listener, and at 180° azimuth. The unaided results were established at two weeks post-fitting and the aided results were measured at four to six weeks post-fitting. The researchers concluded that there was significant benefit in the aided condition for all hearing aid technologies assessed. This data confirmed that hearing aid users may receive significant benefit when listening to speech in the presence of background noise at a +8 SNR. The amount of benefit did vary by hearing aid technology with the 4-channel digital WDRC with directional microphones offering the most benefit. An additional group of 120 participants to the original set were included and detailed in Humes et al., (2009). This new sample had an age range of 60-80 years of age. Based on data from this sample, the investigators provided normative data for expected aided CST performance based on the unaided CST score. Clinicians can measure unaided CST performance and use this data to determine expected performance on the CST when wearing hearing aids.

As can be gleaned from the studies on aided and unaided speech recognition measures, benefit from hearing aids can be determined objectively. Word recognition performance can be enhanced with the use of hearing aids. It has been shown that benefit is more likely when the stimulus is presented in quiet conditions. Results differ when participants listen in the presence of noise. Some studies show no benefit with hearing aids in the presence of background noise while others show benefit, but perhaps not as much benefit as compared to use in quiet environments. This is not surprising in that benefit in noise appears to differ with the type of noise, level of noise to speech (SNR), and location of noise with reference to the location of the speech. One other important factor to note is that the audibility of speech in the unaided condition is critical in determining whether or not benefit with hearing aids will be significant. Those with good audibility in the unaided condition (i.e. due to mild hearing loss, better SNR, louder presentation level) are unlikely to show significant benefit when wearing hearing aids. The next section will take into account subjective measures of hearing aid benefit.

Self-Reported Hearing Aid Benefit

Subjective hearing aid benefit measures typically employ the use of a questionnaire, which compares performance with and without the use of hearing aids. There are no correct or incorrect answers, but instead judgments made by the hearing aid user. These assessments can address issues related to hearing aid benefit, satisfaction, quality of life, use, comfort, perceived handicap and disability, and even sound quality.

There are a multitude of available subjective hearing aid benefit measures. However, this discussion will focus on the following measures all of which have some literature offering information on development, normative data, reliability, and or validity supporting their use. These include: the Hearing Aid Performance Inventory (HAPI; Walden, Demorest, and Hepler, 1984), the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox and Alexander, 1995), the Client-Oriented Scale of Improvement (COSI; Dillon, James, and Ginis, 1997), and the Glasgow Hearing Aid Benefit Profile (GHABP; Gatehouse, 1999). Each will be discussed in chronological order as to when they were first introduced.

Hearing Aid Performance Inventory (HAPI)

The HAPI was developed by Walden, Demorest, and Hepler (1984) and attempts to determine relative benefit by examining the "helpfulness" of the hearing aids and if they are successful in reducing associated hearing activity limitation and/or hearing participation restriction. Individuals rank hearing aid benefit by degree of change with the use of amplification in a variety of listening situations. The HAPI consists of 64 items describing listening situations in four categories: listening in noise, listening in quiet, listening with reduced auditory cues, and listening to non-speech stimuli. Listeners respond to stated communication situations and the extent to which hearing aids assist. There are five response categories which range from "very helpful" (scored as 1) to "no help: (scored as 4). There is also a category known as "hinders performance," which is scored as a 5. The lower the score, the greater the benefit from hearing aid use.

Originally, the HAPI was administered to 119 men and nine women ranging in age from 19-87 years who wore hearing aids. The average participant had a sloping sensorineural hearing loss. Overall, participants had an average score of 2.13 on the HAPI, which is between "helpful" and "very little help". The developers stated that the HAPI has high internal reliability (alpha=0.96). They performed an item analysis to determine which situational feature(s) were most closely related to overall hearing aid benefit on the HAPI. The presence of background noise was the feature that was most closely related to overall benefit, with less benefit found with background noise situations. A significant but small negative correlation between hearing aid use (hours/day) and benefit as measured by HAPI (r= -.23) was determined. This results means that those who wear their hearing aids the most are more likely to report benefit from them, although the correlation is relatively weak. Several studies describe the use of the HAPI and some of the abbreviated assessments based on the original HAPI will be discussed next.

Schum (1992) developed a shortened version of the HAPI, the SHAPI (Shortened Hearing Aid Performance Inventory), which was geared towards the elderly. The original HAPI was administered to an age range of 19-87 years while Schum administered the HAPI, and eventually developed the SHAPI, on 65-80 year old participants. The goal was to reduce the length of the original HAPI and remove certain situations, mainly occupation-based, that do not apply to the elderly. The development of the shortened version is based on 75 respondents ranging in age from 65-80 years who all had sensorineural hearing loss. The shortened version has 38 items and still has high internal reliability. On all four situational factors (i.e., (1) listening to speech in noise, (2) listening to speech in quiet, (3) listening to speech without visual or supplementary cues, (4) listening to non-speech or non-live speech signals) and the combined overall score, these respondents were found to have less benefit than those in the Walden et al. (1984) study. However, it is important to note that the participants in Schum's study did receive benefit from hearing aid use. Overall, respondents had an average rating of 2.30, which is between “very little help” and “helpful.” Most benefit occurred when listening to speech in quiet with a mean score of 1.94, which corresponds to between “helpful” and “very helpful.” The least benefit was noted for listening to speech in noisy environments where the mean score was 2.57, which is between “very little help” and “helpful.” In addition, the more one wore hearing aids, the more benefit was achieved.

Dillon (1994) proposed and analyzed the SHAPIE (Shortened Hearing Aid Performance Inventory for the Elderly), which is another shortened version of the HAPI. As stated, the original HAPI is a rather long assessment and was originally assessed on a sample with a large age range. Dillon sought to decrease the number of questions as well as focus on elderly hearing aid users. In developing the SHAPIE, 107 subjects (mean age of 71 years) participated with a total of 174 administrations of the assessment, with many participants completing the assessment twice. The assessment was given three weeks to six months post-fit. From the original HAPI, there were minor modifications made to wording of the questions and the resultant questionnaires included two versions: one that has 25 questions and one that has 40 questions. Dillon found the shorter questionnaires to be as reliable and as internally consistent as the longer questionnaire. Both of the shortened questionnaires showed hearing aids were “helpful” with a mean score of 2.07 for the 40-item questionnaire and 1.97 for the 25-item questionnaire.

Jerram and Purdy (1997) utilized the SHAPI (Schum, 1992) and incorporated it into a larger questionnaire on hearing aid use and accessibility. They studied 129 individuals with a mean age of 72.3 and ranging in age from 53-92. All were hearing aid users with 57% fit monaurally. Hearing aids were worn for an average of 59.8 hours/week. Average overall benefit was 2.50, which is halfway between “very little help” and “helpful.” This overall benefit score was significantly higher (i.e., showing less benefit) than the overall benefit score of 2.30 reported by Schum (1992) as well as the 2.13 score reported by Walden et al. (1984). There was also a positive linear relationship between age and benefit (i.e., as one ages, hearing aid benefit decreases). On the other hand, there were no differences in benefit in regards to binaural versus monaural use, the duration of using hearing aids, or the hours of use. The highest benefit (2.21) was obtained when listening to speech in quiet environments while the lowest benefit (2.92) was obtained when listening to speech in noise. The researchers suggested the SHAPI is a good measure of hearing aid benefit and that one should consider three separate subscale scores (listening in quiet, listening in noise, and listening with reduced cues) as opposed to an overall benefit score.

By examining differences in objective and subjective benefit post-fit, Humes et al. (1996) used the HAPI to analyze the subjective results at 0, 7, 15, 30, 60, 90, and 180 days post fit. There were no significant differences in benefit noted at these post-fit intervals. However, participants did state that the hearing aids were considered "helpful" or "very helpful"

In a 1997 study by Humes et al. (more fully described in the word recognition section), 110 hearing aid users were presented the HAPI in an attempt to determine how hearing aids affect communication situations with options from "hinders performance" to "very helpful". In conclusion, significant benefit with the use of hearing aids was found. Most participants considered their hearing aid to be helpful with both linear and BILL processing. In another study also described previously, Humes et al. (1999) attempted to compare benefit for two hearing aid circuit configurations (two-channel WDRC and linear) in both quiet and in noise. Subjective benefit was assessed using the HAPI. The use of hearing aids provided subjective benefit and most participants found the hearing aids "helpful."

In a 2001 study by Humes et al. (more fully described in the word recognition section), 26 measures of hearing aid outcome were assessed at 1, 6, and 12 months post-fit in a group of 173 elderly hearing aid users. The HAPI was administered and it was determined that hearing aids were deemed "helpful" and offered the greatest assistance when listening in quiet and the least amount of assistance when listening in the presence of background noise.

Humes, Wilson, Barlow, and Garner (2002) measured amplification benefit, both subjectively and objectively, in 134 hearing aid users one, six, and twelve months post-fit. In addition, they assessed a subset of 49 users at two-years post fit. Participants ranged in age from 60 to 89 years and each had bilateral sensorineural hearing loss. The 134 participants were a subset of 205 enrolled in a larger study. Participants wore in-the-ear hearing aids with linear circuits and output limiting compression and Class D amplifiers. The gain of hearing aids was consistent over the three-year period as confirmed using the NAL-R prescription. Benefit was assessed through use of the HAPI. Hearing aids were deemed "helpful" with the most benefit obtained for speech in quiet situations and non-speech sounds. Overall, there was no improvement in subjective benefit scores over time (i.e., as proposed by those who suggest acclimatization). And when changes in benefit scores were found, participants actually showed a decline at six and twelve months post-fit.

Humes and Wilson (2003) followed nine hearing aid users over the course of three years. This sample was a subset of users described in Humes et al. (2002). At 1-month post-fit, 17.4% of respondents had a significant change when measured by the HAPI with 11.1% declining (i.e. less benefit) and 6.3% improving (i.e. more benefit) on the HAPI subscales. By comparing the HAPI over the course of three years, there was little evidence of acclimatization or improvement as measured by all of the objective and subjective measures, including the HAPI.

In the 2007 study by Mendel (more fully described in the word recognition section), the HAPI was used to subjectively determine benefit in the following situations: “perception of environmental sounds in quiet and noise,” “conversation in quiet with familiar talkers,” “conversation in quiet situations with unfamiliar talkers,” “conversation in noisy situations with familiar talkers,” and “conversation in noisy situations with unfamiliar talkers.” Significant benefit was determined with hearing aid use in all situations except for perception of environmental sounds in quiet and noise. In addition, some significant correlations were found between the HAPI benefit scores and the objective word recognition scores (i.e., R-SPIN, HINT in quiet, and QuickSIN). Higher benefit on the HAPI correlated with better performance on word recognition measures.

In the 2009 study by Humes et al. (more fully described in the word recognition section), 213 individuals were fit with four different hearing aid circuit configurations and several subjective assessments were administered, including the HAPI. For all hearing aid circuit configurations, hearing aids were deemed beneficial. Hearing aids were most beneficial in quiet environments ($p<0.05$) and least beneficial in noisy environments ($p<0.01$). As can be gleaned, hearing aids are considered beneficial and helpful in a variety of situations, albeit more helpful in some environments than others.

Abbreviated Profile of Hearing Aid Benefit (APHAB)

The APHAB is a hearing aid benefit tool that aims to assess activity limitation as a result of the hearing loss as well as if the hearing aids meet the concerns expressed by the listener (Cox and Alexander, 1995; Cox, 2005). This assessment is based on the Profile of Hearing Aid Performance (PHAP; Cox and Gilmore, 1990), which consists of 66 items divided into four scales and seven subscales. The scales and subscales are as follows: speech communication in favorable environments (familiar talkers and ease of communication), speech in unfavorable listening conditions, but not a result of background noise (reverberation and reduced cues), speech in noise (background noise), and perception of environmental sounds (aversiveness to sounds and distortion to sounds). Hearing aid users were instructed to respond to various listening situations and indicate the proportion of time in which statements were true with options ranging from “always” (99%) to “never” (1%). As noted, responses have both a verbal descriptor as well as a corresponding percentage. To quantify benefit, each subscale score is computed by calculating the average percent related to responses. From the PHAP, the Profile of Hearing Aid Benefit (PHAB; Cox and Rivera, 1992) was developed. On the PHAB, hearing aid users are asked to respond to each of the PHAP items twice, once without the use of hearing aids and once with the use of hearing aids. Benefit is scored by determining the difference between the two responses for each statement. This tool was “designed to measure the proportion of time that a hearing aid: (1) improves speech communication in situations that are frequently encountered in daily life and, (2) increases the aversiveness or decreases the quality of sounds” (p. 242-243). The benefit derived from hearing aid use is determined by calculating the difference in the final percentage with hearing aids and the percentage without hearing aids. According to Cox and Alexander (1995), administration of the PHAB typically takes about 20-30 minutes. Due to the length of the PHAB, the Abbreviated Profile of Hearing Aid Benefit (APHAB) was developed and is a more popular choice in clinical settings.

As described by Cox and Alexander (1995), the APHAB consists of twenty-four statements divided into four subscales: ease of communication (word recognition in ideal listening conditions), reverberation (word recognition in reverberant environments), background noise (word recognition in noisy environments), and aversiveness of sounds (reaction to unpleasant environmental sounds). Three of the original PHAB subscales were dropped (familiar talkers, reduced cues, and distortion of sounds) due to potential ceiling effects, low internal consistency, and/or low test-retest correlation. The APHAB can be administered in no more than ten minutes (Cox and Alexander, 1995). The listener responds to each statement by indicating the proportion of time that they experience the stated situation on a seven-point scale with response options including: “never” (1%); “seldom” (12%); “occasionally” (25%); “half-the-time” (50%); “generally” (75%); “almost always” (87%); and “always (99%). Each question is answered twice; with the use of hearing aids and without the use of hearing aids. The difference between these two conditions reflects hearing aid benefit. Scores can be calculated separately for each subscale (i.e., average of percentages within the subscale) or a global score can be calculated by averaging the percentage scores from the ease of communication, reverberation, and background noise subscales. The higher the percentage, the more frequently individuals are experiencing problems. The lower the score, the better the individual is performing. The APHAB can provide direct information on the benefit of wearing amplification for the patient’s particular listening difficulties (Cox, 2005). It can be used pre- and post-fitting or simply as a post-fit measure with the listener required to reflect back on his ability and function in the stated listening environments before wearing hearing aids (Humes, 1999).

Cox (1997) provided other practical applications for the APHAB including: predicting hearing aid success from unaided scores, comparing two different hearing aids or fitting rationales, comparing individual responses to normative data, quantifying benefit, and determining satisfaction with hearing aids. In regards to the normative data, there are three data sets which were provided: one for experienced users of linear hearing aids, one for elderly individuals with minimal self-described hearing problems, and one for normal hearing young listeners. Cox (1997) provided numeric data for establishing significant hearing aid benefit. Significant benefit was associated with a difference score of twenty-two points between aided and unaided conditions on the ease of communication, background noise, or reverberation subscales. Overall, a significant benefit was associated with a positive change of at least five points on the ease of communication, background noise, or reverberation subscales. Cox also suggested that higher APHAB scores might be associated with hearing aid satisfaction, as related to keeping hearing aids past the trial period. She found that a higher APHAB score (25 or higher) was associated with keeping hearing aid(s) while lower scores (20 or lower) were associated with the likelihood of returning the instrument(s).

The APHAB and its norms was originally developed using samples of elderly hearing aid users (conventional analog: 42% binaural and 58% monaural; 71% in-the-ear and 29% behind-the-ear) with a majority suffering from mild to moderate sloping or flat hearing loss (Cox and Alexander, 1995). The researchers determined that the APHAB has good internal reliability (0.78 to 0.87) and was sensitive to individual differences in hearing aid benefit with minimal likelihood of a ceiling effect.

In 2010, Johnson, Cox, and Alexander reassessed the 1995 APHAB norms, which were established with linear hearing aids, to devices that are currently in use (WDRC digital). The participant pool was comprised of hearing aid users from seven private practice facilities. There were a total of 142 participants who ranged in age from 50-92. Each individual was fit bilaterally with hearing aids (no open fit configurations were included) and who subjectively reported a moderate to moderately severe hearing difficulty (i.e., no audiometric data was available). The researchers stated that similar normative data was determined for the ease of communication, reverberation, and background noise subscales when comparing the two samples of individuals ($p>0.05$). However, participants from the 2005 study did report less aversiveness to unpleasant sounds when compared to those in the 1995 study ($p<0.01$). This essentially means that there were less negative reactions to background noises with the WDRC digital hearing aids. There was a large difference between the percentage of individuals who were deemed “successful” hearing aids users though. The researchers defined successful users by those who had worn hearing aids for at least one year and for at least four hours per day. It was determined that twice as many participants in the 2005 sample were considered “successful” compared to the participants in the 1995 data collection (82% vs. 43%).

Even though the APHAB is much shorter than the original PHAB, Cox (2005) did express some drawbacks with using the APHAB. It can be considered potentially burdensome on the clinician, as preparation is required to learn how to administer and interpret the assessment. In addition, it can be difficult for the patient to complete because some of the statements are reversed with some statements denoting problems with higher ratings and other statements denoting problems with lower ratings.. For ease of use, a computer software program is available for score tabulation and comparison to normative data (Cox, 2005).

The following studies show the use of the APHAB and its ability to determine benefit with the use of hearing aids. Kochkin (1997b) sent surveys to 3000 users of hearing aids and 3500 individuals who had hearing loss, but no hearing aids (i.e., a subset of households who were balanced based on US Census information on households). In total, 80% of individuals responded with an average age of 68 years. Of the hearing aid users, 41% had in-the-ear hearing aids, 15% had behind-the-ear hearing aids, and 44% had in-the-canal hearing aids. The majority (65%) of respondents were fitted binaurally. The researchers measured self-perceived benefit through the APHAB and normative data was established based on individuals who wear hearing aids. The scores on the APHAB were significantly related to the age of the hearing aids in that less benefit was perceived as the age of the hearing aid increased.

Kochkin (1997a) compared and contrasted owners of hearing aids. The following were suggested as criteria for using the APHAB to determine hearing aid candidacy: if an individual scores less than 30% on the APHAB, then they were “probably a non-user or weak candidate,” if a respondent scores between 31% and 59%, the individual was deemed a “possible candidate,” and finally, if an individual has a score greater than 59%, then they were a “probable user or hearing aid candidate.”

In addition to assessing word recognition in hearing aid users (as described in an earlier section), Newman and Sandridge (1998) also used the APHAB. These researchers used the APHAB to evaluate hearing aid benefit in twenty-five adults ranging in age from 47-87 years. Significant benefit was found for the aided condition for three of the four subscales: ease of communication, background noise, and reverberation. Communication difficulties were reduced with the use of a hearing aid in quiet environments, noisy environments, and in reverberant listening conditions.

Souza et al. (2000) compared APHAB results to the difference in unaided versus aided articulation index measurements (discussed in more detail in the audibility section). The APHAB was administered pre-fit (unaided) and at one month post-fit (aided). There was improvement on the ease of communication, reverberation, and background noise subscales in the aided condition. However, no significant differences were shown between the aided and unaided condition on the aversiveness scale.

Kochkin (2003) reported on a compilation of previous hearing aid surveys numbering over 16,000 individuals from 1990-2002, with more than half including the APHAB as a benefit measurement. Overall, the average age was 69 years old with 82% reporting bilateral hearing loss. Of those with hearing aids, 66% were fit binaurally. There were 28% using behind-the-ear instruments with similar numbers of programmable and non-programmable devices as well as 5% noting directional or digital signal processing technologies. Using the percentages afforded by the APHAB, unaided scores were 63%, aided were 35%, and benefit (aided-unaided) was 28%. This distribution shows that individuals more frequently experience performance problems without the use of hearing aids than with the use of hearing aids. The relative change in hearing disability was calculated using the APHAB benefit and unaided APHAB scores (APHAB benefit / unaided APHAB). For this sample, the relative change in hearing disability was 43%. In a smaller sample (8,654 individuals), Kochkin (2003) reported a strong relationship between satisfaction and changes in hearing disability, as reflected by change scores on the APHAB (i.e., APHAB benefit / unaided APHAB). The researcher determined that the greater the hearing disability improvement, the higher the overall satisfaction.

Plyler and Fleck (2006) sought to determine if high frequency amplification affected the objective performance and subjective responses of individuals with varying severities of hearing loss. In this study, twenty adults with bilateral sensorineural hearing loss and no previous hearing aid experience participated. The sample was divided into two groups based on audiometric configuration: group A (11 participants) had a high-frequency PTA (measured at 3, 4, and 6 kHz) of less than or equal to 55 dB HL while group B (9 participants) had a high frequency PTA of 56-75 dB HL. Each participant wore two four-channel digital WDRC completely-in-the-canal instruments. There were two six-week trials periods with one maximizing high frequency audibility (i.e., fit to the DSL [i/o] prescription) and one minimizing high frequency audibility (i.e., fit to the DSL [i/o] prescription except minimized gain in the high frequency channel of the hearing aids). The APHAB was administered after each trial period. It was concluded that maximizing high frequency amplification had no significant effect, as measured by the APHAB. When asked, participants stated that they preferred high frequency amplification in quiet environments, did not prefer high frequency amplification in noisy environments, and did not prefer high frequency amplification for overall use.

Cox, Alexander, and Gray (2007) assessed several underlying factors contributing to self-reported hearing aid benefit measures including the listener's personality, current hearing difficulties, and actual hearing aid characteristics. Participants included individuals ages 47-87 years from eleven audiology clinics (i.e., several Veterans Affairs clinics, private practices, and a university-based clinic) with bilateral mild to moderately-severe sensorineural hearing loss. The researchers used the APHAB to assess activity limitations (average of three subscales of reverberation, ease of communication, and background noise) as well as sound aversiveness (aversiveness subscale). The results were compared to personality trait results as measured by the NEO Five-Factor Inventory (Costa & McCrae, 1997) with factors including neuroticism, extraversion, openness, agreeableness, and conscientiousness. In conclusion, individuals in the unaided condition were less likely to report aversiveness to environmental sounds if they had higher scores in extraversion (i.e. outgoing, self-confident), openness (insightful, flexible), and agreeableness (trusting, helpful). Individuals who had higher neuroticism (i.e., negative emotions, anger) scores were more likely to report higher aversiveness to environmental sounds (i.e., more problems). Greater activity limitations were reported for individuals with lower extraversion scores and higher neuroticism scores. Some researchers believe that personal traits of hearing aid users should be further explored as those traits may impact hearing aid fittings, benefit, and success.

As can be seen from the multitude of studies, the APHAB has been a widespread subjective measurement tool for determining hearing aid benefit. It has been used to assess hearing aid benefit in a variety of settings and individuals as well as with other instruments including the bone anchored hearing aid/device and cochlear implant.

Client-Oriented Scale of Improvement (COSI)

The COSI (Dillon, James, and Ginis, 1997) is an open-ended self-assessment tool for evaluating hearing aid benefit and satisfaction. The goal in developing the COSI was to provide an outcomes measurement tool where the listener could describe personal goals for hearing aid use as opposed to the pre-set listening situations assessed in other benefit measures. This assessment is more patient-specific as opposed to generalized. Prior to the hearing aid fitting, a listener is asked to identify up to five specific listening situations where s/he would like to improve hearing with the use of hearing aids as well as the relative importance of each. For research purposes, one can take the individually generated listening situations and categorize them using sixteen classifications offered by Dillon et al. (1997). At a follow-up appointment and after hearing aids have been used (post-fit), the listener rates improvement by the degree of change with the use of hearing aids in each of the specified listening situations. The response options available include: worse, no difference, slightly better, better, and much better. In addition, the listener rates his/her final (residual) ability with the use of a hearing aid along with associated percentages related to how the person hears with hearing aids. Response options include: hardly ever, 10%; occasionally, 25%; half the time, 50%; most of the time, 75%; and almost always, 95%. The goal is to determine relative benefit by examining the degree of change and final ability. The higher the percentage, the greater the benefit. The developers of the COSI determined that, on average, listeners perceive benefit with the use of hearing aids as measured by this assessment. Also, there was reasonable test-retest reliability for the degree of change (r= 0.73) as well as the final ability (r= 0.84). By using this assessment, a clinician can determine exact problems posed by the listener, how rehabilitation has helped, and how the listener is coping in important listening situations. However, use of the COSI could be difficult to interpret across individuals because the situations vary from person to person. There are normative data to aid in determining whether or not a client's scores are typical, unusually low, or unusually high.

Dillon, Birtles, and Lovegrove (1999) sought to provide normative data for the COSI from routine clinical patients from a number of different clinicians (i.e, more than 200). Of the original sample of 4421 adult participants with a mean age of 76 years, 1770 completed the COSI. There was no audiometric data reported, but researchers assumed the hearing loss was sensorineural in nature due to previous surveys of the same population. In the sample evaluated, 97% were fit with digital programmable single-channel hearing aids with compression limiting. Of these, 67% wore in-the-ear instruments while 32.7% wore behind-the-ear hearing aids. Since the listener can state up to five listening situations, not all respondents offered five situations. In this sample, the average number of situations offered was 2.8. In regards to the specific listening situations described, the one that was described most commonly was listening to radio or television. The next most listed situation was conversing with one or two other people in quiet. The least stated category was related to emotional changes including feeling left out or angry. In regards to the post-fit measures, the most common listening situation, listening to radio or television, had the largest degree of change score and the highest residual ability. Overall, the average degree of change score was 4.47 (between better and much better) while the final residual ability was 4.45 (between most of the time and almost always). There were no significant differences between new hearing aid users and experienced hearing aid users. A score of at least 4.0 in degree of change (slightly better) was achieved by 89% of the respondents while a degree of change of 5.0 (much better) was achieved by 40% of respondents. Benefit was reported for listening in quiet and in noisy environments, with greater benefit found for listening in quiet environments.

The COSI provides a subjective evaluation with much more patient input in determining the situations to be assessed. It can be a great starting point for hearing aid fittings and determining outcomes.

Glasgow Hearing Aid Benefit Profile (GHABP)

Gatehouse (1999) developed the Glasgow Hearing Aid Benefit Profile (GHABP) which is a subjective self-report measure of hearing aid benefit. The GHABP is based on the Hearing Disability and Aid Benefit Interview (HDABI) with the goal of determining if amplification relieved the handicaps and disabilities associated with hearing impairment. It is typically completed in interview fashion. In the assessment, four pre-determined listening situations are provided and the listener is invited to add up to four other listening conditions in which they would like to see improvement. If asked to generate their own situations, most people offered two to four of their own specific listening situations.

The four pre-determined situations include: “listening to the television with other family or friends when the volume is adjusted to suit other people”, “having a conversation with one other person when there is no background noise", "carrying on a conversation in a busy street or shop", and "having a conversation with several people in a group." If the listener does in fact encounter the particular situation (occurrence), then there are six questions that are asked (two questions pre-fit and four questions post-fit). For each listening situation that occurs in the life of the respondent, the hearing aid user answers questions with ratings on a five-point scale. The pre-fit (unaided) section includes questions related to: initial disability/hearing difficulty (from "no difficulty" to "cannot manage at all") and handicap (from "not at all" to "very much indeed"). The post-fit (aided) section includes four questions related to: use/proportion of time wearing hearing aid (from "never/not at all" to "all the time"), benefit/helpfulness of hearing aid (from "hearing aid no use at all" to "hearing is perfect with aid"), residual disability (from "no difficulty" to "cannot manage at all"), and satisfaction (from "not satisfied at all" to "delighted with aid"). Normative data has been provided for the GHABP (based on a sample from the United Kingdom), and it has been translated to other languages. Gatehouse proposed that hearing aid outcome measure results should be related to improved audibility. He found that speech intelligibility index (SII) improvement was significantly related to use time, benefit, and satisfaction ratings in this sample (as measured by the HDABI, the precursor to GHABP).

In the Humes et al. (2001) study described previously, the GHABP was administered using only the four pre-specified listening situations. In conclusion, it was determined that in this sample of 173 participants hearing aids were beneficial and that there was a significant decrease in hearing disability. Participants reportedly were using their hearing aids approximately 75% of the time in the stated situations. Also, the "hearing aid was [deemed] quite useful" with hearing aid users noting "slight difficulty" in the four pre-specified situations, and overall they were "reasonably satisfied" (p. 476).

A subset of the NIDCD/VA study, described earlier in the word recognition section, participated in subjective measurements assessments at a six-year follow-up appointment (Takahashi et al., 2007). Of the original 360 participants, 164 completed these subjective assessments. The participants ranged in age from 39-96 and all had sensorineural hearing loss (11% wore peak-clipping hearing aids). One of the assessments used was the GHABP, which was administered via interview to all 164 current hearing aid users and an additional subset of 32 nonusers of their hearing aids. Overall, hearing aid users were "very satisfied" with a mean score of 3.7 (i.e., on a scale ranging from of 1 to 5 with greatest satisfaction scored at 5.0). On all of the questions in the GHABP, hearing aid users had higher scores when compared to individuals who were considered nonusers with significant differences on the disability and use scales ($p < 0.001$). There were significant differences determined for the initial disability and use ($p < 0.05$). Moderate or great difficulty was reported for hearing aid users in the television condition and when listening in noise. Most hearing aid users reported that the hearing aids were of "great help." In both easy and difficult listening situations, hearing aids were determined to have high use and benefit. The greatest benefit and satisfaction was noted when listening in quiet. Overall though, it was determined that hearing aid use was high, no matter the listening situation. In conclusion, "more than 75% of the participants were either 'reasonably satisfied,' 'very satisfied,' or 'delighted with aid' when in conversational situations in groups or in background noise, and more than 70% thought hearing aids were 'quite helpful,' 'a great help,' or 'hearing is perfect with aid' in these same situations" (p. 346).

In a study by Vestergaard (2006) a variety of subjective hearing aid outcomes measurements, including the GHABP, were assessed in twenty-five hearing aid users over a period of thirteen weeks (although one was later excluded so in total there were 24 participants).

Participants had a steeply sloping hearing loss and had an average age of 60.4 years. They were fit binaurally and five of the participants were prior hearing aid users while twenty were first-time users. Hearing aids were programmable and had two-channel compression. The GHABP was assessed at one week, four weeks, and thirteen weeks post-fit and was completed individually at home (i.e., not by interview). There were significant correlations noted between the individual subscales of the GHABP. The two pre-fit measures (initial disability and handicap) were strongly and positively correlated ($r= 0.80$; $p=0.001$). Three of the four post-fit measures (benefit, residual disability, and satisfaction) were moderately to strongly correlated, with the strongest correlation between benefit and satisfaction ($r=0.90$ at one week, $r=0.84$ at four weeks, and $r=0.75$ at thirteen weeks; $p<0.001$ for all time intervals). New hearing aid users who wore hearing aids greater than four hours per day showed improvement in subjective benefit measures compared to new users who wore hearing aids less than four hours per day and those who had previously worn amplification.

The 2009 study by Humes et al. (described more fully in the word recognition section) compared four hearing aid circuit configurations. The GHABP was administered to the 213 participants to determine hearing aid use, helpfulness of hearing aids, and satisfaction from hearing aid use. No matter the configuration utilized, the participants reportedly received benefit and were satisfied with their hearing aids, a finding which was also evidenced by an average use of 7-8 hours per day.

Similar to the other subjective measures described, the GHABP can provide information on a variety of hearing aid outcomes including use, satisfaction, and benefit. While objective measures such as word recognition testing and AI/SII can provide information on benefit with hearing aids, including subjective measures of hearing aid benefit is paramount because they provide information on the experiences and difficulties from the user's point of view.

Overall, there are a number of studies that have determined the effects of hearing aids on both objective word recognition performance as well as on self-reported outcomes. Taylor (2007) reviewed studies that compared unaided word recognition testing in both quiet and in noise as well as aided word recognition testing in both quiet and noise. He determined that there was no significant relationship between pre-fit unaided word recognition and hearing aid outcomes after a review of eleven studies, when age of patient is considered. In addition, once age is considered, Taylor determined that there was no significant relationship between aided word recognition testing and hearing aid outcomes after a review of eight studies. From the review, there was a weak, but positive relationship for sentence in noise testing to self-reported benefit.

Hearing Aid Status, Participant Skills, and Participant Report of Hearing Aid Characteristics

Information on current status of hearing aids as well as how they are functioning for users is scarce. Most of the information available relates to those in nursing and/or retirement homes which may not represent findings in the general public. For example, reportedly, 70% of those with hearing aids living in a nursing home verbally expressed a problem with hearing aids including that they were not working properly, did not fit properly, were difficult to maneuver, and were awkward (Cohen-Mansfield and Taylor, 2004b).

Thibodeau and Schmitt (1988) attempted to assess the functioning of hearing aids in both retirement and nursing home settings through a visual/listening check as well as electroacoustic analysis. Those living in the nursing home setting were more likely to be fit monaurally while those in retirement homes were more likely to wear hearing aids in both ears. Overall, 72% of the 36 hearing aids evaluated were not functioning adequately. Sixty-one percent of the hearing aids were determined to be malfunctioning by visual/auditory inspection. The most common reasons for problems in the nursing home setting were dead/weak battery and a clogged vent/sound opening. For hearing aid owners in the retirement homes, non-functioning hearing aids were most commonly a result of malfunctioning controls and dead/weak batteries. In regards to electroacoustic analysis, 58% of the hearing aids were not within manufacturer specifications based on ANSI S3.22 testing. Four hearing aids that were electroacoustically diagnosed as malfunctioning were not diagnosed as such during the visual-listening check.

Ferguson and Nerbonne (2003) conducted a more recent study of hearing aid function, using both visual/listening as well as electroacoustic assessment, in nursing home and retirement center settings. Of the hearing aids assessed, 78% were not programmable or digital and 71% of them were 1-5 years old. A majority of the hearing aids were in-the-ear models. Overall, 45% of the hearing aids failed at least one criterion for satisfactory function on either the visual listening check or the electroacoustic analysis. Based on that criterion, hearing aid dysfunction was noted in 58% of those wearing hearing aids in nursing homes and 37% of those in retirement centers. Thirty-five percent of the hearing aids failed the visual/listening check with the most common concerns being battery function and cerumen blockage. All of the hearing aids except for sixteen were adjusted to full-on gain and analysis was in accordance with ANSI S3.22 (ANSI, 1987). In regards to the electroacoustic evaluation, three parameters were assessed (distortion, gain, and frequency response) and as a result, 28% of the hearing aids failed at least one of the parameters assessed. The most common problem was excessive harmonic distortion.

Behind-the-ear instruments were compared to manufacturer specifications and 65% of the instruments did not meet these specifications. These reported problems cause concern in that hearing aids can improve one's quality of life, but many hearing aids may not be functioning properly.

Another important factor in hearing aid success is an individual's ability to use and manipulate his/her hearing aids. Many older adults need assistance with using hearing aids. According to reports of older adults residing in nursing homes, only 35% of those with hearing aids did not require any assistance, 43.3% needed assistance with putting on the hearing aids, 12.9% needed assistance in taking the hearing aids off, and most residents, 62.1%, needed assistance with replacing batteries (Cohen-Mansfield and Taylor, 2004b). While hearing aids can be very helpful, some older adults will need additional assistance to achieve success.

It is also important to assess and document the abilities of hearing aid users on hearing aid use and care tasks. By only verbally asking if the patient is able to perform certain tasks, a clinician may not receive an accurate view of the patient's true skills. Desjardins and Doherty (2009) developed the Practical Hearing Aid Skills Test (PHAST) to aid in objectively assessing the skills of experienced hearing aid users in eight basic areas of hearing aid manipulation. The eight skills assessed included "(a) hearing aid insertion, (b) hearing aid removal, (c) opening the battery door, (d) changing the hearing aid battery, (e) cleaning the aid, (f) manipulating the volume control, (g) telephone use, and (h) use of the directional microphone or noise program" (p. 71). Administration of the assessment takes about ten minutes. Each assessed skill has a list of steps that are required to successfully perform the task. The ability to complete these tasks is scored on a five-point Likert scale with options including: excellent (scored as a four), better than satisfactory (scored as a three), satisfactory (scored as a two), less than satisfactory (scored as a one), and cannot perform (scored as a zero). To determine performance, the total score is calculated and then divided by the maximum number of points possible (i.e., 32). Then, a percentage is calculated by multiplying the quotient by 100. "The percentage scores were defined as excellent (90%-100%), good (80%-89%), fair (65%-79%), and poor (below 65%) performance" (p. 71).

The PHAST was developed on fifty experienced hearing aid users ranging in age from 49 to 89 years using different makes and models of hearing aids. The average participant had a sloping mild to severe hearing loss. All respondents were "personally responsible for the use and care of their hearing aid(s)" (p. 70). Overall, participants scored between 48% and 100% with a mean score of 78.56%. Only 18% of the participants scored "excellent". All participants in this study were successfully able to open the battery door and remove the hearing aid, but hearing aid users encountered the most trouble when trying to clean the hearing aid as well as use the telephone and noise programs. Even though some participants reported that they received satisfactory orientation to use of the hearing aid, they still performed "poorly" on the PHAST. There was also a disparity between the perception of participants in their ability to use and manipulate their hearing aids and the results on the PHAST. "Ninety-six percent of [respondents[reported that they did know how to use their hearing aids well, and 88% reported they knew how to clean their hearing aids well. Yet only 48% of participants demonstrated excellent or good performance on the PHAST, and only 38% of participants scored either better than satisfactory or excellent on the PHAST cleaning skill task" (p. 74). The researchers compared the PHAST scores to a benefit measurement, APHAB, and a satisfaction questionnaire, the Satisfaction with Amplification in Daily Life (SADL, Cox and Alexander, 1999). No significant correlation was found between PHAST scores and APHAB scores or between PHAST scores and SADL scores. The researchers did determine that the age of the participant was significantly, but weakly associated with the PHAST percentage score (r=-0.31; p=0.014). Also, there was a trend for those showing greater hearing aid use hours to have better PHAST scores.

To make the PHAST more clinically useful, the authors made revisions to the original assessment and a new assessment, known as the PHAST-R, was developed (Doherty and Desjardins, 2012). The PHAST-R is scored on a three-point Likert scale (0, 1, or 2) and some additional steps to better judge success of completing the task were added to the eight assessed skills. In contrast to the PHAST, the maximum score possible on the PHAST-R is 16. However, calculation of the percentage score is still the same. The researchers suggest that individuals who score a two (performs task with no difficulty) need no further instruction. While those who score a one (performs task with some difficulty) will require reinstructing on a task and those who score a zero (cannot perform the task) will need to be reinstructed as well as possibly need his/her instrument(s) reprogrammed. The PHAST-R was administered to fifteen experienced hearing aid users who ranged in age from 63-93 years. The average hearing loss was sloping and mild to moderate in degree of severity. All participants wore behind-the-ear instruments binaurally. For this population, the PHAST-R scores ranged from 61.29%-100%. Only 40% of the participants received “excellent” on all of the PHAST-R tasks, even though 80% of all the participants stated they knew how to use their hearing aids and were satisfied with them. The tasks needing most reinstruction were that of cleaning the hearing aid and using the telephone with the hearing aid. The PHAST-R is a quick and easy tool to aid in determining if a hearing aid patient truly grasps concepts of hearing aid manipulation or if more counseling is needed for successful hearing aid use.

The PHAST-R requires the hearing aid user to manipulate the hearing aid either through increasing the volume (volume control or remote) or using the hearing aid in a noisy situation (press the program button to the “noise” program). Banerjee (2011b) assessed these two features in a group of hearing aid users. Ten experienced hearing aid users ranging in age from 49-78 years with a bilateral sloping mild-to-moderate sensorineural hearing loss participated. They were fit with behind-the-ear instruments binaurally. The researcher analyzed the use of multi-memory (optional programs) of hearing aids as well as the use of a volume control through a PDA-based data logger over a four to five week period. A multi-memory option “adjusts the status of DSP algorithms, modifies the frequency-gain response, and/or alters overall gain” (p. 360). The volume control only changes the gain of the hearing aid. Three memories/programs, accessible through a program button, were available in the hearing aid. The programs were as follows: memory 1 was the best fit to the hearing aid’s manufacturer fitting software (“default”); memory 2 was programmed specifically for noisy situations with less gain in the lower frequencies; and memory 3 was designed for listening to music where more gain was provided at low frequencies with no expansion. Volume manipulation was available through a wheel with ability to decrease gain down 14 dB and increase gain up to 10 dB. The individuals had access to the volume control for one-week, the program button for one-week, and then access to both the volume control and program button for two weeks. The hearing aids were in the default setting unless changed by the participant. If changed, the hearing aid automatically reverted back to the default program after thirty minutes in the chosen alternative program. The researcher determined that the hearing aid users were in the default setting approximately 75-85% of the time. When given the option to use both, the hearing aid users manipulated the volume control more (66%) than the program button (33%). It is interesting that many of the participants did not frequently utilize the additional features of a hearing aid, even though this is a task that hearing aid users are often expected to use and master.

Not only is it important to manipulate a hearing aid, but also to have a working knowledge of the various features and components available within a hearing aid. Banerjee (2011a) attempted to analyze the automatic hearing aid features of expansion, directionality, and noise management in users of amplification through assessing real-world encounters via a custom data-log application. There is no mention as to whether this was the same group as the Banerjee (2011b) study, but ten experienced hearing aid users ranging in age from 49-78 years with a bilateral sloping mild-to-moderate sensorineural hearing loss were fit with digital multi-channel with WDRC behind-the-ear instruments binaurally. To assess these features, a "PDA-based data logger… [was] designed to gather the instantaneous broadband input level, channel-specific expansion status, directional status, noise management status, and channel-specific magnitude of gain reduction from the hearing aids at 5 sec intervals" (p. 38) over a four to five week period. The researcher determined that participants spent about half of the time wearing hearing aids in quiet environments with an input signal of no more than about 50 dB SPL. In less than about 5% of situations, the input level was more than 65 dB SPL. Expansion was activated 42-54% of the time. Directionality was activated only 10% of the time. Even in the louder environments, the directionality was activated only about 50% of the time. The noise management feature was activated 21% of the time. As the input level increased, the noise management activation increased as well. Even with the major complaint of hearing in noise, it appears that hearing aid users are in noise relatively infrequently. This observation could also be due to the fact that hearing aid users avoid loud and noisy environments because they do not function as well as desired. Even though some of the automatic features of hearing aids are not utilized as often as one would think, it is important for hearing aid users to understand what these features can and cannot offer.

Hearing aid user knowledge may be based on initial orientation activities and usefulness of hearing aid user manuals. It has been reported that 40-80% of presented healthcare information is forgotten (Kessels, 2003). Little information is available as to how helpful hearing aid manuals are with respect to establishing good patient knowledge and use of hearing aids. A patient's health literacy (literacy related to a specific healthcare area) may be lower than the language level used in hearing aid manuals (Nair and Cienkowski, 2010). Brooke, Isherwood, Herbert, Raynor, and Knapp (2012) assessed the ability of forty non-hearing aid users to perform specified tasks relating to hearing aid use simply by reading the manufacturer's user manual. All participants ranged in age from 46-72 years and reported no hearing problems or hearing aid knowledge. The participants were asked to perform tasks such as cleaning and maintaining the hearing aid and earmold and changing the battery. In addition, participants were asked questions regarding health and safety issues as well as troubleshooting. Some of the tasks were completed successfully; however, no tasks were completed without difficulty by a number of participants. This emphasizes the importance of a hearing aid orientation, but also explains that possession of a user manual will not provide all the necessary information on the functions and features of a hearing aid.

This study described herein will aim to assess characteristics of hearing aids and hearing aid fitting practices as reported by participants to determine specific features as well as assess a basic understanding of hearing aid features that are a selling point in today's hearing aid market. Kochkin (2009, 2010) developed the MarkeTrack VIII survey which aims to extract similar information on hearing aid users regarding features, motivations, and current practices.

Interestingly, the biggest factor in individuals deciding to receive hearing aids is that their hearing loss was getting worse while other reasons included being influenced by family members and by hearing healthcare professionals (Kochkin, 2009). Demographically, hearing aid users are more likely to be retired or employed part-time as opposed to full-time employment (Kochkin, 2009). From the same survey, approximately 85% of hearing aid users were tested in a sound isolated booth (Kochkin, 2010). In regards to outcome measurements, 66% of respondents were tested with speech materials with and without the use of hearing aids and as reported in a previous section, only 40% had probe tube measurements completed at the hearing aid fitting (Kochkin, 2010). For usage, 25% of respondents use their hearing aids for no more than two hours per day (Kochkin, 2010).

In order to determine the current status of hearing aids, a visual listening check is necessary. For the study described herein, no electroacoustic analysis will be conducted because of the nature of the hearing aids. The study is open to all hearing aid users with all makes and models of hearing aids fit from a variety of offices. Electroacoustic analysis of each of these hearing aids would require access to all software programs and equipment. Also, ANSI standards now require access to company's software fitting programs and a change to the frequency characteristics of the hearing aid which could lead to user concerns of possible program changes. Earlier ANSI measures did not require these kinds of programming actions. In addition, for comparison purposes, one would have to acquire ANSI datasheets for each hearing aid, and for, custom products one would need to request ANSI test information for that individual hearing aid from the manufacturer, assuming that the make, model, and serial number are obtainable. Due to these hindrances, only a comprehensive visual-listening check will be conducted in this study to ascertain information on the current status of hearing aids in the community.

Research Questions

The study described herein analyzes the status of dispenser fit hearing aids in older adults. These hearing aids may have been fit and adjusted by an Internet provider, hearing instrument specialist, and/or audiologist and may or may not be adjusted to prescription using real-ear probe tube measures. In most studies focused on hearing aid outcomes, hearing aid settings are validated through prescriptions with real-ear probe tube measurements. This study will not validate the hearing aid responses, but instead is determining outcomes based on how the dispenser has fit the hearing aids. In the current study, hearing aid function was evaluated through use of audibility measures (speech intelligibility index, SII), word recognition performance in noise (QuickSIN), self-reported outcomes (Glasgow Hearing Aid Benefit Profile, GHABP), hearing aid status (visual-listening check), participant report of hearing aid characteristics (questionnaire), and hearing aid skills assessment (modified Practical Hearing Aid Skills Test-Revised, PHAST-R). Studies typically include hearing aid users who are fit using protocols either established by a researcher or a clinic. However, those fittings may not reflect the status of most hearing aids in any given community. Determining the status of dispenser fit hearing aids is important because it may better reflect hearing aids in the real world that other seniors observe and hear about.

The following research questions are posed:

1. Is audibility (as measured by the SII) significantly improved for soft conversational speech (i.e. 50 dB SPL) and average conversational speech (i.e. 70 dB SPL) with the use of hearing aids on dispenser settings?
2. Is word recognition performance (SNR Loss) significantly improved for soft conversational speech (i.e. 50 dB SPL) and average conversational speech (i.e. 70 dB SPL) with the use of hearing aids on dispenser settings?
3. Is better ear audibility (best aided SII) significantly related to word recognition performance (aided SNR Loss) at two presentation levels (50 and 70 dB SPL)?
4. Is the change in SII (unaided to aided) at each presentation level (50 and 70 dB SPL) significantly related to the change in SNR Loss (unaided to aided) at each presentation level (50 and 70 dB SPL)?
5. Is aided audibility (best aided SII) significantly correlated to self-reported outcomes with the use of hearing aids?
6. Is aided word recognition performance (aided SNR loss) significantly correlated with self-reported outcomes with the use of hearing aids?
7. Are selected demographic factors significantly related to hearing aid status, participant reported hearing aid characteristics, and participant skills?
8. Are self-reported outcomes with the use of hearing aids significantly related to hearing aid status, participant reported hearing aid characteristics, and participant skills?
9. What is the relationship between hearing aid status, participant reported hearing aid characteristics, and participant skills?

CHAPTER 2: METHODOLOGY

This study was approved by the East Carolina University Medical Institutional Review Board (#12-001878).

Recruitment

Thirty participants were enrolled in this study and were recruited from the surrounding community through newspaper advertisements, flyers, informational talks, senior centers, retirement homes, and by word-of-mouth. All participants signed an informed consent as well as a privacy notice document. In addition, all participants answered a case history questionnaire, which included questions regarding age of participant, sex, employment status, and residence. See Appendix E for case history form.

Inclusion Criteria

The following inclusion criteria were used in the study.

1. All participants must be older adults between the ages of 60-89 years old during enrollment.
2. All participants must report English as their first language.
3. All participants must be hearing aid owners and must be fit bilaterally. No participant may be within his/her hearing aid trial period.
4. Participants are excluded if they are wearing invisible in-the-canal hearing aids as real-ear probe tube measures cannot be completed with that style of hearing aid.
5. Participants are excluded if they have one or more hearing aids with unresolved whistling or that are "dead" and whose function cannot be restored as determined through a visual listening check.

6. Participants must pass a cognitive screening and be considered to have no cognitive impairment as determined by the Mini-Mental State Exam through the use of the normalized scoring method (MMSE; Folstein, Folstein, and McHugh, 1975; Folstein, Folstein, and McHugh, 2001).
7. In order to determine that the participant has appropriate receptive vocabulary skills for his/her age, each participant must score no greater than two standard deviations below the mean on the Peabody Picture Vocabulary Test-4th Edition (PPVT-4; Dunn and Dunn, 2007)
8. All participants must have normal outer ear and middle ear function and a sensorineural hearing loss as determined by the following measures.
    a. Both ears were visually inspected by otoscopy to identify risk factors for outer and middle ear disease. Using a lighted otoscope, both ears were visually inspected to rule out “ear canal abnormalities such as obstructions, impacted cerumen or foreign objects, blood or other secretions, stenosis or atresia, otitis externa, and perforations or other abnormalities of the tympanic membrane” (ASHA, 1997, p. 344). Individuals were excluded from the study if abnormalities were observed and where appropriate, were referred to a medical professional. There is a high interexaminer reliability for trained professionals in regards to otoscopic examination with agreement ranging from 73% to 100% for identifying certain otoscopic signs including: drainage, tympanic membrane color, appearance, and position; presence of liquid; presence of perforation; collapsed ear canal; debris in ear canal; and vascularity (Nondahl, Cruickshanks, Wiley, Tweed, Klein, and Klein, 1996)

b. Using a Grason-Stadler Tympstar Middle Ear Analyzer (calibrated to ANSI 2007 standards), tympanometry was performed on both ears with a low frequency (226 Hz) probe tone. Tympanometric results, including static acoustic admittance, tympanometric width, and ear canal volume were analyzed. Participants were excluded if clinically significant tympanometry findings were observed in either ear including:

    i. Static acoustic admittance <0.2 mmhos which could be suggestive of possible middle ear dysfunction, possible fluid, or possible perforation.

    ii. Tympanometric width >125 daPa which could be suggestive of possible middle ear dysfunction or fluid.

    iii. Ear canal volume <1.0 cm^3 which could be suggestive of possible occlusion/earwax.

c. Air-conduction and bone-conduction pure tone thresholds were measured using a GSI-61 audiometer calibrated to ANSI S3.6-2004 standards in a double-walled sound attenuated booth. Air-conduction pure tone thresholds were measured for the left and right ears with Etymotic 3A insert earphones. Audiological threshold measures were determined using the method as outlined in ASHA guidelines (2005). Inter-octave frequencies from 250-8000 Hz including 3000 and 6000 Hz were assessed. A 1000 Hz reliability check was also completed to ensure the participant was within 10 dB of the original response. Bone-conduction pure tone thresholds were completed using a B-71 bone vibrator. The following frequencies were measured: 500, 1000, 2000, and 4000 Hz. When needed (i.e., air bone gap >10 dB), contralateral masking was used to confirm the type of hearing loss.

Participants with two or more unresolved air bone gaps of >10 dB in either ear were excluded from the study. See Appendix F for Audiogram.

The hearing aid status check was completed first to establish hearing aid functionality (i.e., hearing aid was not “dead” or had unresolved feedback). Subsequently, the following measures, all of which might be impacted by fatigue/order effects, were completed with assessments randomly ordered across participants: 1) QuickSIN unaided and aided measures, 2) Glasgow Hearing Aid Benefit Profile, 3) Modified PHAST-R, and 4) Participant Report of Hearing Aid Characteristics. The final assessment, the real-ear probe tube unaided and aided measures, involved no active participant participation Administration of each assessment will be described hereafter.

Hearing Aid Status

A comprehensive visual-listening check was performed by the researcher before additional data collection to ensure that hearing aid status would allow for study participation (i.e., hearing aids were not “dead” or did not have unresolved whistling) and to determine status and function of hearing aids. See Appendix G for visual-listening check sheet. Scores were calculated based on the average of numeric responses for all completed items. The hearing aids and any accompanying earmolds/domes were inspected for visible cracks, damage, blockage, or debris. The battery doors and compartments were inspected for possible corrosion and/or debris. Prior to the listening check, batteries were tested to ensure they had appropriate operating voltage. The listening check was performed using a hearing aid stethoset in order to confirm that the units were offering amplification and to check for intermittency. If a program button or volume control was available on either the hearing aids or on a remote, these controls were pushed/moved to determine functionality (i.e., audible indicator of program change; obvious volume change with the volume control).

If either hearing aid was not properly functioning, and an easy remedy was available, then this was performed. These remedies included changing the battery, repositioning the earmold or dome, and cleaning noticeable debris. If these adjustments did not resolve the problems (i.e., the hearing aid(s) was/were still "dead" or had unresolved whistling), the individual was referred back to his/her dispenser and was excluded from study participation at that time. Detailed information on the make and model of the hearing aids as well as the serial number year were recorded, if accessible.

Participant Report of Hearing Aid Characteristics and Skills

Each participant answered a set of questions regarding characteristics of his/her hearing aids. This paper and pencil assessment was administered in a face-to-face interview format. Some questions were adapted from the MarkeTrak VIII survey (Kochkin, 2009). See Appendix H for the questionnaire.

To measure management skills with hearing aids, a modified PHAST-R was administered. The modified PHAST-R assessment is located in Appendix I. Scores were calculated based on the average of numeric responses for all completed items.

Probe Tube Verification and SII Measurement

To assess audibility for unaided and aided conditions, the AudioScan RM500 SL Electroacoustic Test System with probe tube measures was used. The on-ear reference microphone was calibrated before each test participant at a distance of 0.5 meters from the loudspeaker (British Society of Audiology and British Academy of Audiology, 2007). To measure the audibility changes with the hearing aid, unaided and aided responses were measured with the RM500 SL System calculating the Speech Intelligibility Index (SII) for each response. The unaided measurement was taken with the hearing aids removed from the participant's ear. The aided portion was determined with the participant wearing his/her hearing aids. Each ear was tested separately. The RM500 SL system mathematically calculates the SII using a 1/3 octave band calculation and use of the level distortion effects. No hearing loss desensitization factor was included. The unaided and aided SII was calculated based on real-ear unaided measures using 50 and 70 dB SPL recorded digitized speech passages by a male talker. The digitized speech passage was used as this is a broadband stimulus that is available clinically and is realistic to everyday communication interactions (British Society of Audiology and British Academy of Audiology; 2007). Stimulus levels of 50 and 70 dB SPL were used based on research by Cox and Moore (1988) to encompass soft and average conversational speech, as determined by the long term average speech spectrum (LTASS). All test data was saved onto an external drive with no participant health information included (i.e., only subject number).

All probe tube measurements were completed in a sound isolated test booth with the RM500 SL positioned on a countertop with the loudspeaker facing the participant. The positioning of the client and equipment was as recommended by the American National Standards Institute: Methods of Measurement of Real-Ear Performance Characteristics of Hearing aids (2002), Caldwell, Souza, and Tremblay (2006), and the British Society of Audiology and British Academy of Audiology (2007). The participant was placed at a 0° azimuth and with his/her head at a distance of 0.5 meters (about 20 inches) from the RM500 SL loudspeaker. To ensure proper and consistent participant placement, a string attached to the RM500 SL was utilized for placement of participant.

Prior to placement of the probe tube, otoscopy was performed to gauge the ear canal's length and shape (Bagatto, 2001; ANSI, 2002). Probe tube placement is of importance in that if the tube is not close to the tympanic membrane, high frequencies will be underestimated due to the standing wave effect (Caldwell et al., 2006). A two-step process was employed for proper and consistent placement. A marker on the probe tube was situated at 30 millimeters (mm) or decreased if otoscopy determined that the ear canal appeared to be shorter than the average male (ANSI, 2002). This marker was compared to the sound outlet of the hearing aid to ensure the marker was extended at least five millimeters past the sound outlet. The probe tube was then inserted along the bottom of the ear canal with the marker placed at the intertragal notch to achieve placement within 6 mm of the tympanic membrane. The probe tubes were secured with removable tape placed on the ear and/or cheek of the participant and appropriate placement was confirmed with an otoscope. This same probe tube placement was maintained for the unaided and aided probe tube measures for the first test ear and then for the second test ear.

Prior to measuring the unaided real-ear response for the first test ear with the recorded passage (at 50 and 70 dB SPL), participants were asked to look straight ahead toward the loudspeaker and asked not to shift their position, talk, or make noises that would impact the measures. The 50 dB SPL passage was then presented with the measurement saved to a USB drive. Then the 70 dB SPL passage was presented with the measurement saved to a USB drive. After these unaided responses were completed, the researcher situated the hearing aid on the test ear with the volume set at the customary user setting and the probe tube insertion depth maintained. Prior to making real-ear aided response measures on each hearing aid, the test signal was equalized to ensure any sound that might escape from an open fitting hearing aid or vent would not affect the on-ear reference microphone. The 50 dB SPL and 70 dB SPL passages were presented again to obtain the real-ear aided responses.

Word Recognition Measurement

To evaluate unaided and aided word recognition benefit, the QuickSIN was administered. This assessment was used because it is easy to administer, readily available in many clinics, has equivalent sets of test lists (Killion, Niquette, Gudmundsen, Revit, and Banerjee, 2004) and was found to be a sensitive measure of hearing aid benefit (Walden and Walden, 2004; Mendel, 2007). In addition, one of the major complaints of individuals with hearing loss is understanding speech in noise, which this test assesses. While no significant relationship for word recognition in quiet and hearing aid outcomes has been established, there is a weak, but positive relationship for sentence in noise testing to self-reported benefit (Taylor, 2007). Each QuickSIN list consists of six sentences with five target/scored words in each sentence. The assessment is scored by the whole word and each list takes about one minute to administer (Etymotic, 2006). The sentences are presented with a competing background noise of four-talker babble and the following signal-to-noise ratios: +25, +20, +15, +10, +5 to 0. To improve reliability and as recommended, two test lists were administered per condition (e.g., unaided presentation at 50 dB SPL) and the results were averaged (Killion et al., 2004). The QuickSIN was administered via soundfield with the participant at 0° azimuth and one meter from the loudspeaker. Since this assessment was presented in the soundfield, the testing was done binaurally in both the unaided and aided conditions. Proper and consistent placement of participants was ensured by a string attached to the speaker and extended to the participant’s forehead. The researcher read the standardized instructions to the participant before beginning the test (Etymotic, 2006). For both the unaided and aided portions, two lists (Lists 1 and 2; Lists 5 and 6) of the QuickSIN were administered at 50 dB SPL (33 dB HL on the audiometer dial based on sound level meter measurements) and two lists (Lists 3 and 4; Lists 7 and 8) were administered at 70 dB SPL (53 dB HL on the audiometer dial based on sound level meter measurements). For the aided test conditions, both hearing aids were worn at the customary volume setting. Individuals were given a practice test list in the aided condition to familiarize to the test format. See Appendix J for QuickSIN stimuli lists.

Performance was evaluated on sentences at each of the SNRs (+25, 20, 15, 10, 5, and 0) and the average SNR loss across the two lists in each of the conditions was calculated. In total, eight lists were administered and results for the four test conditions were tabulated. The four SNR calculations included the following test conditions: unaided at 50 dB SPL, aided at 50 dB SPL, unaided at 70 dB SPL, and aided at 70 dB SPL.

Self-Reported Outcomes

The GHABP was used to determine self-reported, or subjective, outcomes. This assessment was used because of its extensive research background, previous comparison to the SII, inclusion of both pre-specified listening situations as well as participant-generated listening situations of concern, evaluation of satisfaction, benefit, and use, and is relatively quick to administer. The GHABP assessment was performed in a face-to-face interview fashion in a quiet room. Each participant answered the four post-fit questions related to the four pre-specified listening situations. Participants were also allowed to specify up to four other listening environments that they would like to evaluate, but this was not a requirement. See Appendix K for the questionnaire.

Participant Summary and Follow-Up

A summary sheet was provided to the participant indicating the status of the hearing aid and any problems noted. See Appendix L for the summary sheet provided to the participants. If there were problems in the status assessment or if the participant reported problems, then he/she was advised to return to his/her dispensing clinic to address the issues. If for some reason the dispensing clinic was not an option (i.e., no longer in business, located in a different city/state, participant adamantly did not want to return to the dispenser), then the participant was provided with a list of local audiologists and hearing aid dispensers who may be of assistance.

Statistics

The following statistics were utilized to analyze the study results: frequency distributions, Wilcoxon matched pairs test, Spearman's rho correlation, and Mann-Whitney U test.

CHAPTER 3: RESULTS

The results section offers demographics and characteristics of the participants, followed by presentation of results for each of the research questions posed.

Demographics and Characteristics

A total of 30 participants met the inclusion criteria and were enrolled in this study. Thirteen individuals did not meet the inclusion criteria and were not enrolled for the following reasons: conductive hearing loss (3), did not own hearing aids (1), abnormal tympanograms (4), “dead” hearing aid(s) (3), and referral on the Mini-Mental State Exam (2).

Demographic information was obtained for those enrolled including; gender, age, highest level of education achieved, current employment status, and type of residence. Of the 30 individuals enrolled, 15 were male and 15 were female. They ranged in age from 62-88 years with a mean age of 74.20 and standard deviation (SD) of 7.82.

In regards to education, six individuals received a high school diploma/GED, six individuals had completed some college, three participants completed an associate’s degree/2-year degree, nine individuals had completed a 4-year college degree, and six participants held a graduate/post-baccalaureate/professional degree. Of those who were enrolled, 76.67% (23 participants) considered themselves to be retired while two participants were employed full-time, two were employed part-time, one participant had never worked, one participant was on disability, and one participant categorized herself as a homemaker. Finally, 83.33% (25) of the participants stated that they lived in a residence with either family or friends while three participants lived alone and two participants lived within an independent living facility.

Audiometrics

Audiometric thresholds were obtained for each individual to determine the type and severity of hearing loss. A three-frequency pure tone average (PTA) was calculated based on air conduction thresholds at 500, 1000, and 2000 Hz. The three-frequency PTAs for the right ear of participants ranged from 23.33 to 86.67 with a mean of 49.11 and standard deviation of 16.01. The three-frequency PTA for the left ear of participants ranged from 26.67 to 81.67 with a mean of 51.28 and standard deviation of 14.80. The severity of hearing loss was determined based on the PTA using the following classifications recommended by Jerger and Jerger (1980): mild hearing loss (21-40 dB HL); moderate (41-60 dB HL); severe (61-80 dB HL); and greater than 80 dB HL as profound. Since symmetrical hearing loss was not a requirement for study inclusion, some participants had a different severity classification for each ear. Twenty-one participants had the same severity of hearing loss in both ears and when there were differences in severity of loss between the two ears, the differences were between two adjacent categories (e.g., mild and moderate). For the right ear, 12 (40%) participants were considered to have a mild hearing loss, 12 (40%) had a moderate hearing loss, 5 (16.7%) had a severe hearing loss, and 1 (3.3%) had a profound hearing loss. For the left ear, 7 (23.3%) of participants were considered to have a mild hearing loss, 16 (53.3%) had a moderate hearing loss, 5 (16.7%) had a severe hearing loss, and 2 (6.7%) had a profound hearing loss.

Audibility

Results for the speech intelligibility index (SII), an index which can potentially range from 0.0 to 1.0, were obtained from the Audioscan RM500SL estimates based on probe-tube real ear measures for the unaided and aided condition at two different speech presentation levels (50 and 70 dB SPL). As stated previously, the SII calculations were determined for each individual ear and the SII values for the right and left ears of individual participants under all tested conditions are offered in Appendices M and N. Appendix O presents the best aided SII values at each presentation level. Table 1 presents the means, standard deviations, and ranges for SII values for each ear at the two presentation levels of 50 and 70 dB SPL for the unaided and aided conditions.

Table 1: Means ($\bar{x}$), Standard Deviations (SD), & Ranges for Unaided & Aided SII

Audibility Characteristics		**Unaided**	**Aided**
SII, Right Ear, 50 dB SPL	$\bar{x}$	0.10	0.20
	SD	(0.12)	(0.16)
	Range	0 - 0.36	0 - 0.64
SII, Right Ear, 70 dB SPL	$\bar{x}$	0.32	0.51
	SD	(0.24)	(0.18)
	Range	0 - 0.86	0.20 - 0.86
SII, Left Ear, 50 dB SPL	$\bar{x}$	0.08	0.16
	SD	(0.10)	(0.15)
	Range	0 - 0.30	0 - 0.61
SII, Left Ear, 70 dB SPL	$\bar{x}$	0.29	0.47
	SD	(0.23)	(0.19)
	Range	0 - 0.84	0.16 - 0.93

For the right ear measures, there was an improvement of at least .01 between the unaided SII and aided SII at 50 dB SPL for 90% of participants whereas only 56.67% of individuals showed an improvement of at least 0.05 at that level. Almost all participants (96.67%) had an improvement between their unaided SII and aided SII at 70 dB SPL of at least 0.01. In addition, all but two respondents (93.33%) showed an improvement in SII of at least 0.05 at the 70 dB SPL level for the right ear.

For the left ear measures, there was an improvement between the unaided SII and aided SII for the 50 dB SPL passage of at least 0.01 for 56.67% of participants. In comparison, 40% of individuals showed an improvement of SII of at least 0.05 at the 50 dB SPL level for the left ear. In addition, 90% of respondents showed an improvement between their unaided SII and aided SII at 70 dB SPL of at least 0.01. Finally, 93.33% showed an improvement in SII of at least 0.05 at the 70 dB SPL level for the left ear.

Better ear audibility was determined based on the highest aided SII at each of the two presentation levels. At 50 dB SPL, the better ear aided audibility ranged from 0.01 to 0.64 with an average of 0.22 and a standard deviation of 0.16. For 70 dB SPL, the better ear aided audibility ranged from 0.22 to 0.93 with a mean of 0.54 and a standard deviation of 0.18.

A Wilcoxon matched pairs test was utilized to determine if there were differences between the unaided and aided conditions at each presentation level as well as if there were differences between the aided conditions at 50 and 70 dB SPL. For the right ear, there was a significant difference between the unaided and aided conditions (0.10 vs. 0.20; $p<0.001$) at 50 dB SPL as well as at 70 dB SPL (0.32 vs. 0.51; $p<0.001$). In the left ear, there was a significant difference between the unaided and aided conditions (0.08 vs. 0.16; $p<0.001$) at 50 dB SPL as well as at 70 dB SPL (0.29 vs. 0.47; $p<0.001$). When comparing the SII values for the aided condition at the 50 and 70 dB SPL presentation levels, there was a significant difference between the two levels in the right ear (0.20 vs. 0.51; $p<0.001$) and in the left ear (0.16 vs. 0.47; $p<0.001$).

The change in SII from the unaided to aided condition was also calculated by subtracting the unaided SII from the aided SII. The higher the calculated difference, the greater the change in audibility. For the right ear at 50 dB SPL, the average change in SII was 0.10 (SD: 0.11; range: 0.0 to 0.40). For the right ear at 70 dB SPL, the mean change in audibility was 0.20 (SD:

0.14; range: 0.00 to 0.51). For the left ear at 50 dB SPL, the average change in SII was 0.08 (SD: 0.10; range: 0.00 to 0.34). For the left ear at 70 dB SPL, the average change in audibility was 0.18 (SD: 0.13; range: 0.02 to 0.53)

Word Recognition in Noise Performance

Word recognition performance in noise was determined through the use of the QuickSIN. The assessment was administered in the soundfield (i.e., binaural condition) with and without hearing aids at two presentation levels (50 and 70 dB SPL). In regards to scoring, lower SNR Loss scores indicate the ability to identify words at a poorer signal-to-noise ratio and thus better performance on the assessment. The SNR Loss for individual participants is offered in Appendix P. Table 2 offers the means, standard deviations and ranges for the unaided and aided SNR Loss in the unaided and aided conditions at the two presentation levels.

Table 2: Means ($\bar{x}$), Standard Deviations (SD), & Ranges for Unaided & Aided SNR Loss

Word Recognition in Noise		**Unaided**	**Aided**
SNR Loss, 50 dB SPL	$\bar{x}$	22.90	18.32
	SD	(5.01)	(7.34)
	Range	6.50 - 25.50	0.50 - 25.50
SNR Loss, 70 dB SPL	$\bar{x}$	14.50	10.05
	SD	(9.01)	(6.64)
	Range	1.50 - 25.50	0 – 25.00

A Wilcoxon matched pairs test was used to determine if there were significant differences in word recognition performance between the unaided and aided conditions at 50 and 70 dB SPL. There was a significant difference between the unaided and aided conditions (22.90 vs. 18.32; $p<0.001$) at 50 dB SPL as well as at 70 dB SPL (14.50 vs. 10.05; $p<0.001$). When comparing the performance in the aided condition at the 50 and 70 dB SPL presentation levels, there was a significant difference between the two levels (18.32 vs. 10.05; $p<0.001$).

The improvement from the unaided to aided condition at each presentation level was also calculated for each participant by subtracting the unaided SNR Loss from the aided SNR loss. The aided SNR Loss scores tend to be lower than the unaided values such that the change scores are commonly negative in value. A score of zero means that there was no change between conditions. The average change between the unaided and aided word recognition conditions at 50 dB SPL was -4.58 with a standard deviation of 4.69 and ranged from 0 to -15.5. For the 70 dB SPL condition, the change in SNR Loss ranged from 1.5 to -18 with an average score of -4.45 and a standard deviation of 4.87.

Two QuickSIN lists were administered at each intensity level resulting in the presentation of 10 words per SNR condition (i.e., +25, +20, +15, +10, + 5 and 0 SNR). The number of correct responses out of the possible 10 words at each of the five SNRs was examined for both the unaided and aided conditions at both presentation levels. Figures 1 and 2 illustrate the number of words correct as a function of signal-to-noise ratio for each presentation level.

Figure 1: Mean # Words Correct at each SNR Presentation Level for 50 dB SPL

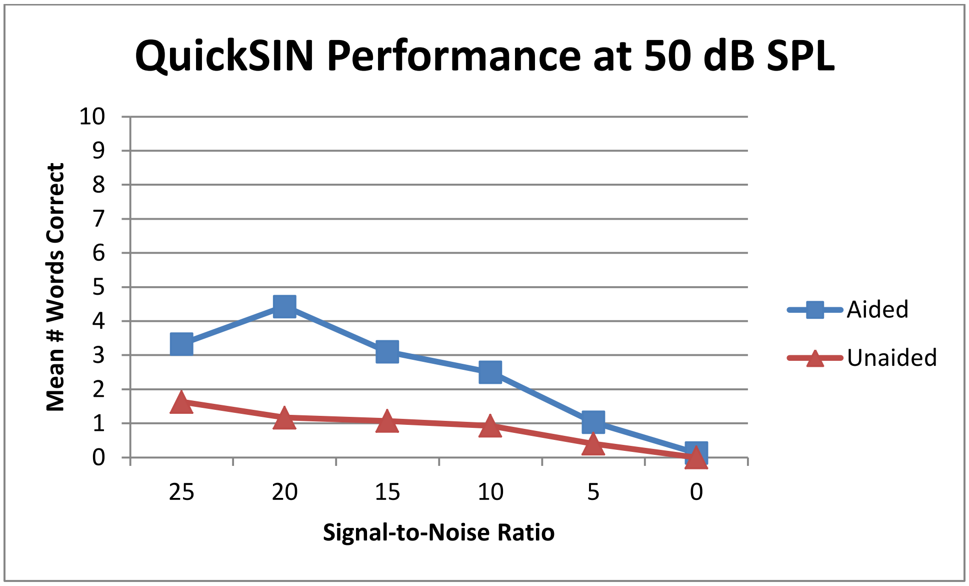
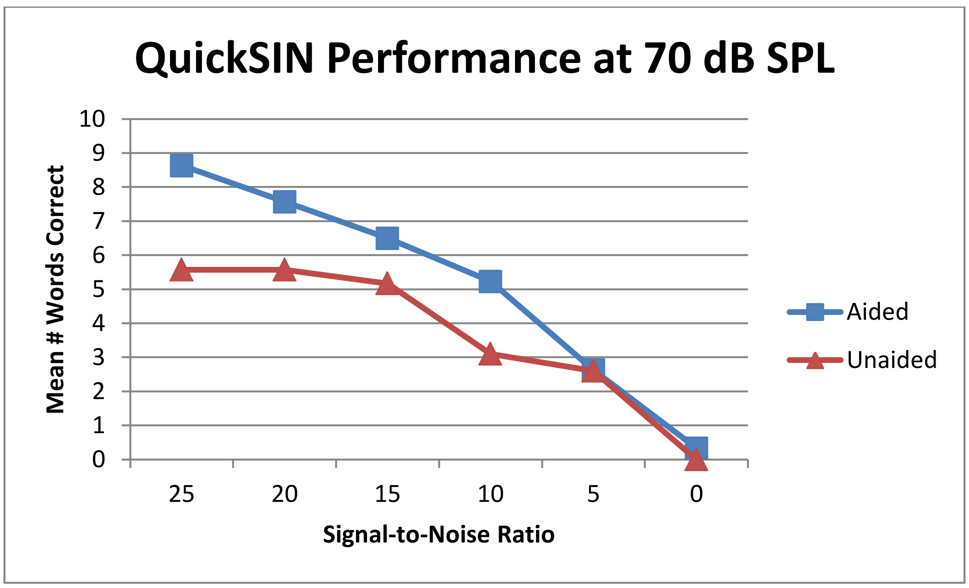


Figure 2: Mean # Words Correct at each SNR Presentation Level for 70 dB SPL



A Wilcoxon matched pairs test was used to determine if there were significant differences between the unaided and aided conditions for the following SNRs when presented at

50 dB SPL: +25 dB (1.63 vs. 3.33; p=0.001); +20 dB (1.17 vs. 4.43; p<0.001); +15 dB (1.07 vs. 3.10; p<0.001); +10 dB (0.93 vs. 2.50; p=0.004); and +5 dB (0.40 vs. 1.03; p=0.048). There was no significant difference between the unaided and aided condition at 50 dB SPL for the 0 dB SNR level (0.00 vs. 0.13; p=0.18). In addition, a Wilcoxon matched pairs test was used to determine if there were significant differences between the unaided and aided conditions for the following SNRs when presented at 70 dB SPL: +25 dB (5.57 vs. 8.63; p<0.001); +20 dB (5.57 vs. 7.57; p=0.010); +15 dB (5.17 vs. 6.50; p=0.008); and +10 dB (3.10 vs. 5.23; p<0.001) and at +0 dB SNR (0.00 vs. 0.33; p=0.041). There was no significant difference for the +5 dB SNR (2.60 vs. 2.63; p=0.917) condition.

Self-Reported Outcomes

Self-reported outcomes regarding use, benefit, residual disability, and satisfaction were determined using the Glasgow Hearing Aid Benefit Profile. Participants were asked to respond to four listening environments and invited to offer four other environments important to their communication. Use, benefit, and satisfaction outcome measurements were scored with 1 representing poorest outcome and 5 as the best. For residual disability, a score of 1 represented the best outcome while a score of 5 represented the poorest outcome. Table 3 presents the means, standard deviations, and ranges for scores on this profile, and Appendix Q presents the individual test scores for each outcome.

Table 3: Means ($\bar{x}$), Standard Deviations (SD), & Ranges of GHABP Scores

GHABP Subscales	Statistics	Values
Use	$\bar{x}$ SD Range	4.43 1.00 1.33 - 5.00
Benefit	$\bar{x}$ SD Range	2.98 0.63 1.67 - 4.00
Residual Disability	$\bar{x}$ SD Range	2.41 0.56 1.50 - 3.33
Satisfaction	$\bar{x}$ SD Range	3.11 0.63 1.33 - 4.00

A Spearman's rho correlation calculation was utilized to determine if there were any significant relationships between the four outcome measurements. Strong significant relationships were determined for residual disability and benefit (ρ= -0.539; p=0.002); benefit and satisfaction (ρ= 0.787; p<0.001); and residual disability and satisfaction (ρ= -0.659; p<0.001). There were no significant relationships between hearing aid use and the other three self-reported outcome measurements.

Visual-Listening Check

All types of hearing aids were included in this study except for invisible in-the-canal hearing aids, which preclude the use of probe-tube measures. Of the 30 participants, three had behind-the-ear (BTE) hearing aids with standard tube and earmold; six had BTE hearing aids with slim tube and dome; one had BTE hearing aids with slim tube and earmold; ten had receiver-in-the-ear hearing aids with dome, one had receiver-in-the-ear hearing aids with earmold; one had in-the-ear (ITE) hearing aids; and seven had in-the-canal (ITC) hearing aids. One person had a different type hearing aid in each ear with one hearing aid classified as a BTE with slim tube and dome and one classified as an in-the-canal hearing aid. All other participants (29) had the same style of hearing aid in each ear. No participant had completely in the canal hearing aids.

The visual-listening check scores ranged from 0.85 to 1.0 with an average of 0.97 and standard deviation of 0.04 for the right ear. For the left ear, the score average was 0.98 with a standard deviation of 0.29 and they ranged from 0.90 to 1.0. Appendix R presents the individual scores on this assessment. The problems noted for the right hearing aid included (participants could fall into more than one category): debris in sound outlet/receiver (8); cracked and discolored dome (1); hardened tube (1); debris in microphone inlets (2); and debris/corrosion in battery compartment (3). The problems noted for the left hearing aid included: debris in sound outlet/receiver (5); cracked and discolored dome (1); hardened tube (1); debris in microphone inlets (3); debris/corrosion in battery compartment (4), and broken battery door (1). For the right hearing aid, 17 (56.67%) of participants had a perfect score with no concerns noted. For the left hearing aid, 18 (60%) of respondents had perfect visual-listening check scores and no concerns were noted. Overall, scores on the visual-listening check were relatively high, even though approximately 40% of enrolled participants had at least one problem.

Participant Report of Hearing Aid Characteristics

In order to gain additional information regarding the participants' hearing aids, a questionnaire related to hearing aid characteristics was administered. In regards to the type of right hearing aid owned, seven reported that they had a BTE with standard tube, fourteen reported that they had a BTE with slim/thin tube (i.e., with or without receiver-in-the-ear), one reported that they owned half/full shell ITE; and eight reported that owned ITC hearing aids. In regards to type of left hearing aid, eight reported that they had a BTE with standard tube, fourteen reported that they had a BTE with slim/thin tube, and eight owned ITC hearing aids. No participant reported that they owned completely-in-the-canal hearing aids. When comparing the reported responses of the participants to the researcher's judgment of the type of hearing aid owned, four participants did not correctly identify his/her type of hearing aid. Two reported that they owned BTE hearing aids with standard tubes, but the tubing was actually slim/thin tube and one person stated she had ITC hearing aids, but had an ITE. One participant incorrectly identified both types of hearing aids she wore by mistakenly stating she had BTE with standard tube instead of BTE with slim tube and mistakenly stating she had an ITE, but actually had an ITC hearing aid.

Participants were asked to determine what manufacturer of hearing aids they owned. All participants owned the same manufacturer for his/her right and left hearing aids. The following manufacturers and number of responses reported included: Avada (2), Beltone (2), Bernafon (1), GN Resound (4), Miracle-Ear (3), Oticon (4), Phonak (3), Siemens (3), Starkey (1), Unitron (2), Widex (4), and one person was not sure of the manufacturer of hearing aids s/he owned. When comparing to the actual manufacturer of hearing aid as determined by the stamp on the hearing aid, five participants did not accurately report the manufacturer. One person stated that she did not know the manufacturer, but upon visual inspection, she owned hearing aids from GN Resound. One person stated she had Widex hearing aids, but actually had GN Resound while another participant stated s/he had Avada hearing aids, but had Widex. In addition, one respondent stated s/he had Unitron hearing aids, but had Oticon and finally, one person stated s/he had Siemens, but had GN Resound.

Participants were asked the age of each of his/her hearing aids and based upon these responses, the average age of the right hearing aid was 44.77 months with a standard deviation of 37.197 and ranged from 9 months to 180 months. For the left hearing aid, the age of the current hearing aid reportedly ranged from 9 to 180 months with an average of 42.77 months and standard deviation of 36.22. When asked how many hearing aids the participant had owned, participants had owned an average of 1.97 aids for the right ear (range: 1-8; SD: 1.63) and an average of 2 hearing aids for the left ear (range: 1-8, SD: 1.72). For a majority of the participants, this was their first set of hearing aids (right ear, 56.7%; left ear, 60%). Only one person had owned 8 hearing aids per ear (total of 16 hearing aids).

The average time that participants waited before purchasing hearing aids after being informed they had a hearing loss was 23.07 months (range: 0-120 months; SD: 31.02) for the right ear and 22.47 months (range: 0-120 months; SD: 31.54) for the left ear. A majority of participants (18 participants for the right ear, 60% and 19 participants for the left ear, 63.33%) waited no more than one year to pursue amplification following being informed of their hearing loss.

Reported motivation for purchasing the current set of hearing aids by the participant was varied and participants had the option to report their own motivation for pursuing the current hearing aids worn. The most popular primary motivation was that the participant’s family encouraged/insisted, which was reported by nine (30%) participants followed by wanting to hear better at church/community functions (20%), hearing got worse (13.33%), wanting to hear TV/radio better (10%), wanting to hear better in noise (6.67%), needing them for his/her job

(6.67%), receiving a free hearing aid (3.33%), and three respondents stated their own primary motivation including: wanting another set, losing a hearing aid and needing a replacement, and that his/her dog ate the prior hearing aid. Upon examining all motivations with no regard to the rank order, the following motivations were reported along with the number of respondents: family encouraged/insisted (19), wanting to hear better at church/community functions (17), wanting to hear TV/radio better (11), wanting to hear better in noise (9), recommendation by physician/audiologist/dispenser (7), hearing got worse (6), wanted to hear better on the telephone (5), needed them for his/her job (5), receiving a free hearing aid (1), and ten responses offered stated as motivation in the “other category”: hear family better (3), wanted another set (1), hear better overall (1), use money from Flex Health Savings Account (1), lost previous hearing aid (1), dog ate previous hearing aid (1), hear soft spoken speech in groups better, (1), and for tinnitus relief (1).

When asked who paid for the current set of hearing aids, a majority (25 participants; 83.33%) stated that they were responsible for the entire amount while 3 participants (10%) stated the cost was split between their insurance company and themselves and 2 individuals (6.67%) reported that their hearing aids were provided by Veterans Affairs. No participant had hearing aids that were paid for by family/friend or an assistance program.

Participants were also asked when the last time they had their hearing professionally tested. Data for one participant could not be included in this analysis because she stated that her hearing had never been professionally tested. Using information from 29 participants, the average number of months reported was 24.95 months prior with a standard deviation of 36.46 and ranged from 0.1 to 192 months. A majority of the participants (17 participants; 56.67%) had

had their hearing tested within the past twelve months while 10% of participants (3 participants) had not had their hearing tested in over three years.

There were no differences between the left and right hearing aids in average use time, so these responses were collapsed into one category. In regards to daily use of hearing aids, participants reported that, on average, they wore their hearing aids for 11.47 hours per day. This value ranged from 0 to 17 hours with a standard deviation of 5.33 hours. A majority of participants (20 participants, 66.67%) wore their hearing aids at least 12 hours per day. Also, participants were asked to determine the average number of days per week that they wore their hearing aids. The number of days per week that the respondents wore their hearing aids ranged from 1 to 7 with an average of 6.27 days and standard deviation of 1.57. Most participants (23 participants, 76.67%) wore their hearing aids every day of the week while one person reportedly wore his/her hearing aid for only one day per week.

Twenty-two participants reported that their current set of hearing aids were originally fit by an audiologist, three reported that the dispenser was a hearing instrument specialist, while five did not know the title of the dispenser. When asked what type of office dispensed the current set of hearing aids six (20%) reported that they were fit through a hearing aid chain (i.e., Avada, Beltone, Miracle-Ear); seven (23.33%) reported they were fit at a private audiology practice; one (3.33%) was fit at a Big Box Store (Costco); one (3.33%) was fit at a university clinic; ten (33.33%) were fit at an ENT/Ear Doctor’s Office; three (10%) were fit at a hospital clinic; and two (6.67%) were fit by the Veterans Affairs. One participant noted that the hearing aids were originally purchased from an ENT/Ear Doctor’s Office, but that services were now being performed through a private practice audiologist. None of the participants was fit by any member of the study research team.

Participants were asked if certain procedures were completed during their hearing aid fitting appointments. In regards to probe tube measurements, 20% (6 participants) reported that this did occur, 60% reported that this did not occur, and 20% reported that they were not sure. When asked if a pencil and paper questionnaire was administered to determine benefit, 3.33% (1 participant) reported that this did occur, 86.67% (26 participants) reported that this did not occur, and 10% (3 participants) reported that they were not sure. Finally, in regards to whether or not the hearing aid user was asked to repeat back words with and without their hearing aids, 63.33% (19 participants) reported that this did occur, 20% (6 participants) reported that this did not occur, and 16.67% (5 participants) reported that they were not sure. One participant stated that while this method was used, it was completed in the exam room and not in a sound-isolated booth area.

Included in questions regarding hearing aid fittings and appointments, participants were asked to rate on a seven-point Likert scale (strongly agree, slightly agree, agree, neutral, disagree, slightly disagree, and strongly disagree) whether an appropriate overview or practice was offered for a variety of instructions. For hearing aid insertion, 63.33% reported that they strongly agreed that an appropriate overview/practice was offered while 13.33% slightly agreed, 16.67% agreed, and 6.67% were neutral with this statement. For hearing aid removal, 60% reported that they strongly agreed that an appropriate overview/practice was offered while 10% slightly agreed, 16.67% agreed, 10% were neutral, and 3.33% disagreed with this statement.

For changing the hearing aid battery, 56.67% reported that they strongly agreed that an appropriate overview/practice was offered while 10% slightly agreed, 23.33% agreed, 6.67% were neutral, and 3.33% disagreed with this statement. For cleaning of the hearing aid, 56.67% reported that they strongly agreed that an appropriate overview/practice was offered while

16.67% slightly agreed, 13.33% agreed, and 13.33% were neutral with this statement. For cleaning of earmolds/domes, only twenty-two respondents were able to answer this question as the other eight respondents had hearing aids that did not have domes/earmolds. Of those that responded, 45.46% reported that they strongly agreed that an appropriate overview/practice was offered while 13.64% slightly agreed, 18.18% agreed, 13.64% were neutral, 4.55% disagreed, and 4.55% strongly disagreed with this statement.

For troubleshooting of hearing aid problems, 43.33% reported that they strongly agreed that an appropriate overview/practice was offered while 3.33% slightly agreed, 10% agreed, 26.67% were neutral, and 16.67% disagreed with this statement. For storage of hearing aids, 66.67% reported that they strongly agreed that an appropriate overview/practice was offered while 13.33% slightly agreed, 6.67% agreed, 3.33% were neutral, and 10% disagreed with this statement. Overall, as can be seen from the data above, a majority of participants agreed to some extent that an appropriate overview/practice was offered for the above listed areas of hearing aid use and maintenance with only five respondents disagreeing with at least one area.

The most popular storage option for hearing aids, as reported by the participants was the use of a manufacturer's case (15) while other responses included: no container (7), drying jar or container (5), electronic drying system (1), cup (1), and one person used both a manufacturer's case and drying jar. Participants were also asked what type of cleaning tools they used and had the option to check all that applied. No participant reported that s/he used an air blower, 56.67% reported that they used a hearing aid brush, 40% reported that they used a cleaning/wax loop, 36.67% reported that they used a cloth, 3.33% reported that they used a pipe cleaner, and 33.33% reported that they used a vent cleaning line. Participants were also given the option to state what other types of cleaning tools they used and responses included: wet wipes (1), hair dryer (1), tweezers (1), needle (1), and one person used a tool to change the filters on his/her receiver-in-the-ear hearing aids .

A majority of participants (23) stated that they had at least one switch/button/toggle/wheel on their right hearing aid with 86.96% of these having one switch/button. The right hearing aid was utilized for this question as this was the hearing aid used for the Modified PHAST-R assessment. Of the 23 individuals that had only one button, 9 responded that it was used to change the program, 10 responded that they used it to change volume, 1 reported that the button was not activated, 1 reported that they did not know the function of the button, 1 reported that it was an on/off switch, and 1 had multiple functions with the same button (program change and volume control). Of the individuals that had two buttons on his/her right hearing aid, one button was for program change and the other button for volume control. One participant also stated that she did not have any buttons on her right hearing aid, but it appeared that there was one button, but it was not activated. For the individual who stated that the toggle switch turned the hearing aid on/off, from the visual-listening it appeared that this actually changed the volume. In addition, two responded that their button changed the volume, but it appeared that it changed to a program with the overall volume increasing or decreasing, but it did not appear to be a true volume adjustment.

When questioned regarding telephone use, no respondents changed to a different hearing aid program while 53.33% (16) held the phone next to his/her ear, 23.33% (7) held the phone at an angle, 6.67% (2) took the hearing aid out, 6.67% (2) stated that they did not use his/her hearing aid with the telephone, and 10% (3) of respondents used multiple methods to talk on the phone including: holding his/her home phone at an angle while using a streamer for his/her cell phone (1), holding his/her cell phone at an angle while using speakerphone at home, and finally taking his/her hearing aid out and using Captel services (1).

In regards to the ability to change the program for the right hearing aid, 12 (40%) reported that they did this with a switch/button/toggle/wheel on the hearing aid while 2 (6.67%) reported that this was accomplished through a remote control, and 16 (53.33%) reported that they did not have the ability to change the program on the hearing aid. For changing the program on the left hearing aid, 11 (36.67%) reported that they did this with a switch/button/toggle/wheel on the hearing aid while 2 (6.67%) reported that this was accomplished through a remote control, and 17 (56.67%) reported that they did not have the ability to change the program on the hearing aids. For the ability to change the volume on his/her hearing aids, 11 (36.67%) reported that they did this with a switch/button/toggle/wheel on their hearing aid while 4 (13.33%) reported that this was accomplished through a remote control, 14 (46.67%) reported that they did not have the ability to change the volume on the hearing aids, and one person had the option to change the volume on his right hearing aid with either a toggle or a streamer.

Of the 30 participants, ten of them reported that they used some other assistive listening device to help them hear. Of those who responded, the most popular option was a television (TV) amplifier/headset (4) with others including: TV captioning (2) amplified telephone (1), FM system (1), streamer for phone, TV, changing volume (1), and one person who used all of the following: amplified telephone, telephone captioning, and TV captioning.

To gain a sense of knowledge of the hearing aids functions, participants were asked if their hearing aids had certain selected features as well as what they think best describes the feature through a short definition. Only two individuals reported that their hearing aids had frequency compression/transposition while two said they their hearing aids did not have this feature, and the remaining twenty-six were not sure. In regards to noise reduction technology, 43.33% (13) reported that their hearing aids had this feature while 13.33% (4) reported that their hearing aids did not have this feature, and 43.33% (13) were not sure. When asked about the purpose of noise reduction, 53.33% responded correctly that noise reduction is used to “make noisy situations more comfortable” while 0% stated that this was used to “remove all noise”, 43.33% reported that noise reduction was supposed to “improve hearing for speech in noise” and 6.67% of respondents did not know. For existence of directionality/directional/dual microphones, 26.67% (8) reported that their hearing aids had this feature while 6.67% (2) reported that their hearing aids did not have this feature, and 66.67% (20) were not sure. When asked about the purpose of directional microphones, only 23.33% responded correctly that this was used to “improve listening for speech when the noise is from the back or sides of the listener” while 43.33% stated that this was used to “improve listening when the noise is all around the listener,” 10% reported that directionality was supposed to “improve listening for speech when the noise is in front of the listener” and 23.33% of respondents did not know.

Modified PHAST-R

In order to determine the ability of participants in hearing aid management skills, the modified PHAST-R was administered. The average score for the modified PHAST-R for all participants was 0.83 with a standard deviation of 0.12 and scores that ranged from 0.65 to 1.0. Seven participants (23.33%) scored a perfect 1.0 on this assessment. The most common problem observed on the modified PHAST-R was identifying the different components of the hearing aid. Overall, 76.67% of participants improperly identified at least one of the components on his/her hearing aid (i.e., sound outlet, microphone inlets, and/or air vent). Other difficulties that some participants had included: cleaning of the hearing aid (13.33%) and needing extended time and multiple attempts to change the battery (6.67%). No participant had difficulty with inserting or removing his/her right hearing aid. Appendix S shows the individual scores on this assessment.

Research Questions

Question 1: Is audibility (as measured by the SII) significantly improved for soft conversational speech (i.e. 50 dB SPL) and average conversational speech (i.e. 70 dB SPL) with the use of hearing aids on dispenser settings?

A Wilcoxon matched pairs test was utilized to determine the difference with amplification at each presentation level and at each ear. With the hearing aids on dispenser fit settings, it was determined that there was a significant difference between the unaided and aided conditions at both presentation levels of 50 dB SPL (0.10 vs. 0.20; $p<0.001$) and 70 dB SPL (0.32 vs. 0.51; $p<0.001$) in the right ear as well as the left ear at 50 dB SPL (0.08 vs. 0.16; $p<0.001$) and 70 dB SPL (0.29 vs. 0.47; $p<0.001$). Average scores for each condition can be seen in Figures 3 and 4. The aided conditions did provide greater audibility than the unaided conditions when using the SII as a measurement tool. In addition, there was a significant difference between the two presentation levels. The aided SII at the louder presentation level (70 dB SPL) yielded a higher aided SII when compared to the 50 dB SPL presentation level for the right ear (0.20 vs. 0.51; $p<0.001$) as well as the left ear (0.16 vs. 0.47; $p<0.001$).

Figure 3: Unaided & Aided Mean SII at 50 dB SPL & 70 dB SPL, Right Ear

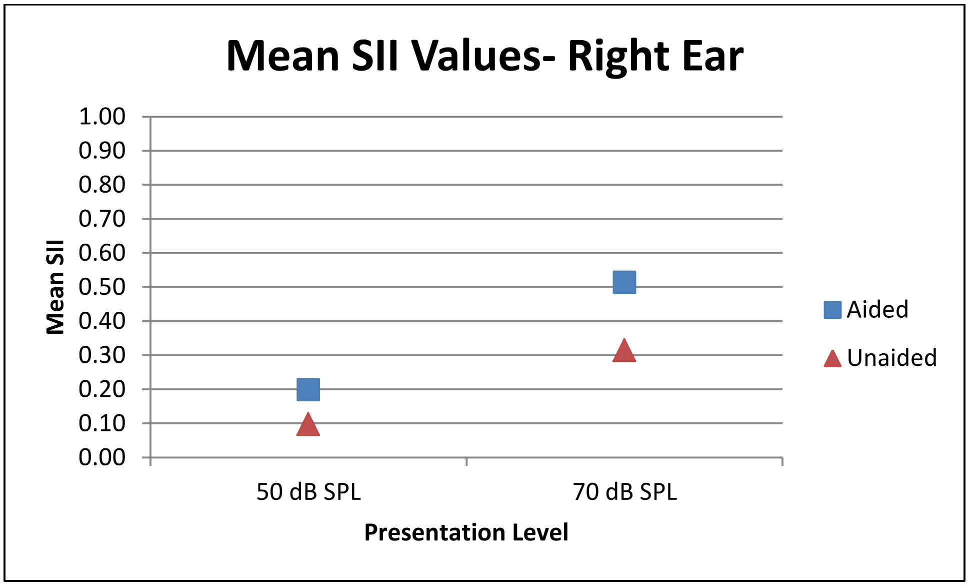
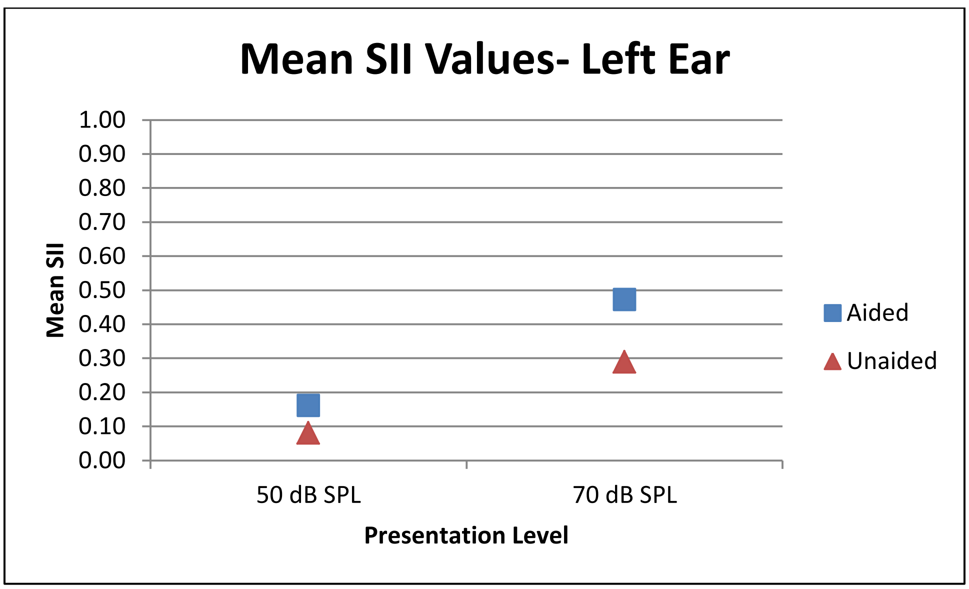


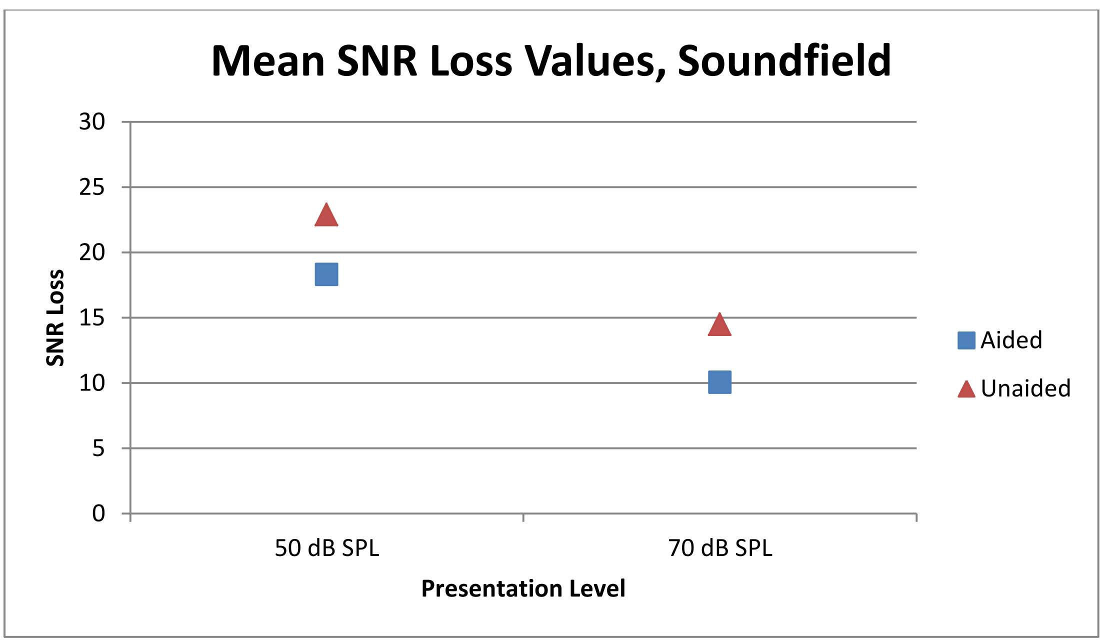
Figure 4: Unaided & Aided Mean SII at 50 dB SPL & 70 dB SPL, Left Ear



Question 2: Is word recognition performance (SNR Loss) significantly improved for soft conversational speech (i.e. 50 dB SPL) and average conversational speech (i.e. 70 dB SPL) with the use of hearing aids on dispenser settings?

A Wilcoxon matched pairs test was utilized to determine the difference with amplification at each presentation level. Since this assessment was presented in the soundfield, all results are considered to be binaural responses. With the hearing aids on dispenser fit settings, there was a significant difference between the unaided and aided conditions at both presentation levels of 50 dB SPL (22.90 vs. 18.32; $p<0.001$) and 70 dB SPL (14.50 vs. 10.05; $p<0.001$). The aided conditions did provide better performance than the unaided conditions when assessing one's ability in word recognition performance in noise. In addition, there was a significant difference between the two presentation levels. The aided SNR Loss at the louder presentation level (70 dB SPL) yielded better performance compared to the 50 dB SPL presentation level (18.32 vs. 10.05; $p<0.001$). Figure 5 graphically displays the difference between aided conditions and presentation levels.

Figure 5: Unaided & Aided Mean SNR Loss (Binaural) at 50 dB SPL &70 dB SPL



In order to determine if there were any differences in performance at each of the SNR levels on the QuickSIN for aided performance, a Wilcoxon matched pairs test was utilized to compare performance across SNR levels. At 50 dB SPL, there were no significant differences in performance between +25 and +15 ($p=0.8750$); between +25 and +10 ($p=0.077$); and between +15 and +10 ($p=0.229$). There were significant differences between performances at all other SNR levels. At 70 dB SPL, there were significant differences between all SNR levels (i.e., significant difference between +25 and all SNR levels; significant difference between +20 and all other SNR levels; etc.). Again, Figures 1 and 2 graphically display the results from each SNR level.

Question 3: Is better ear audibility (best aided SII) significantly related to word recognition performance (aided SNR Loss) at the two presentation levels (50 and 70 dB SPL)?

To compare the better ear audibility and word recognition performance, the better aided SII was correlated to the aided SNR Loss at each of the presentation levels (50 and 70 dB SPL) using the Spearman's rho correlation. There was a significant relationship between better ear audibility as measured by the aided SII and word recognition as measured by the aided SNR Loss at 50 dB SPL ($\rho= -0.814$; $p<0.001$) and at 70 dB SPL ($\rho= -0.709$; $p<0.001$). A scatterplot noting the relationships and best fit line can be seen in Figures 6 and 7.

Figure 6: Spearman's Rho Correlation of Aided SNR Loss & Best Aided SII at 50 dB SPL

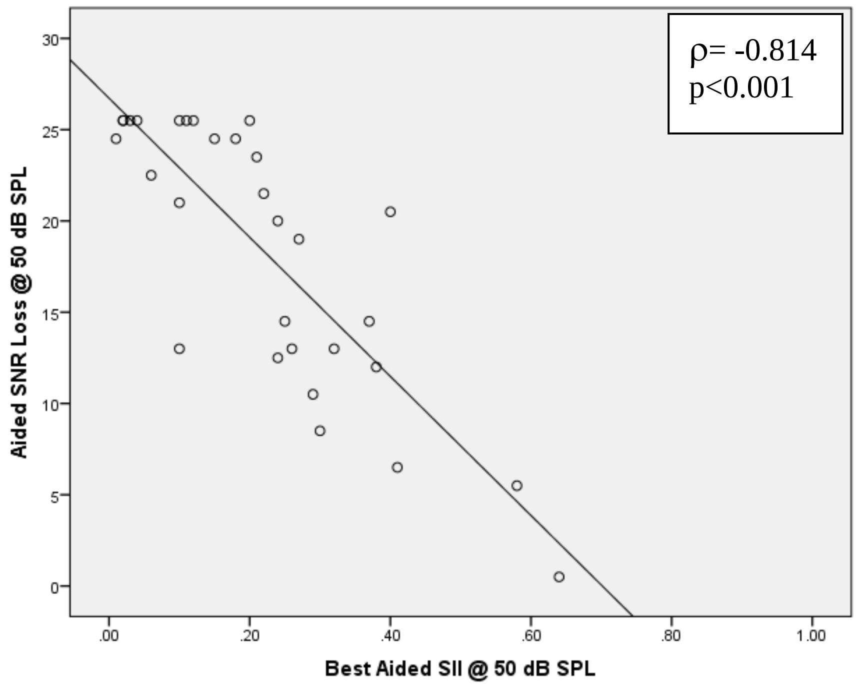
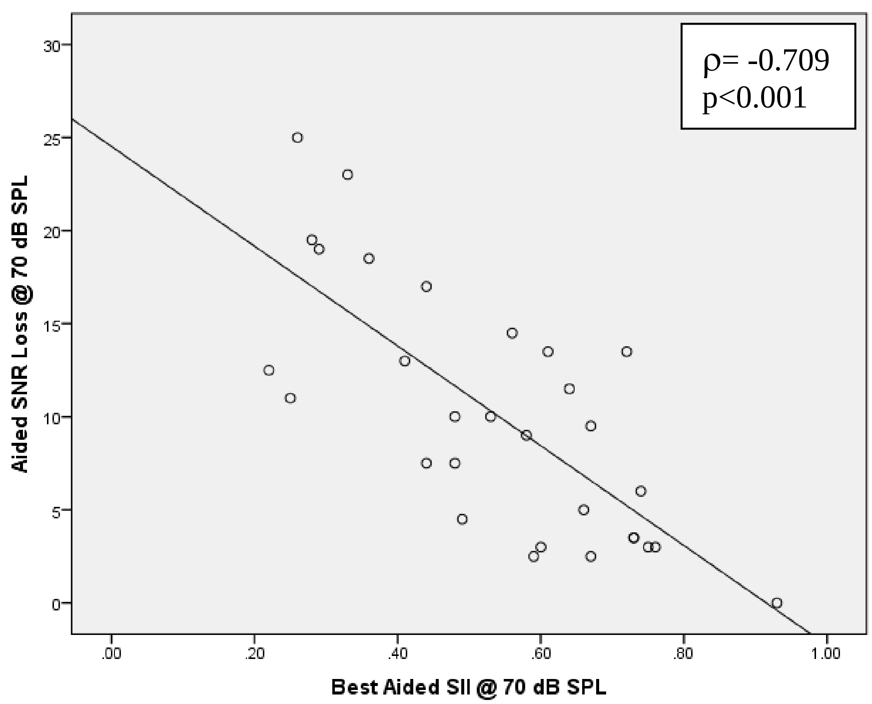


Figure 7: Spearman's Rho Correlation of Aided SNR Loss & Best Aided SII at 70 dB SPL



Question 4: Is the change in SII (unaided to aided) at each presentation level (50 and 70 dB SPL) significantly related to the change in SNR Loss (unaided to aided) at each presentation level (50 and 70 dB SPL)?

To determine if the change in SII was significantly related to the change in SNR Loss at each presentation level, a Spearman's rho correlation calculation was utilized for each presentation level (50 and 70 dB SPL) and each ear. At 50 dB SPL, there was a significant negative correlation between right ear SII change and right ear SNR Loss change (ρ= -0.456; p=0.011) and a significant negative correlation between left ear SII change and left ear SNR Loss change (ρ= -0.471; p=0.009). At 70 dB SPL, there was a significant negative correlation between right ear SII change and right ear SNR Loss change (ρ= -0.429; p=0.018) and a significant negative correlation between left ear SII change and left ear SNR Loss change (ρ= -522; p=0.003). To illustrate this significant relationship, a scatterplot noting the relationships and best fit line can be seen in Figures 8, 9, 10 and 11.

Figure 8: Spearman's rho Correlation of Change in SNR Loss & Change in Right Ear SII at 50 dB SPL

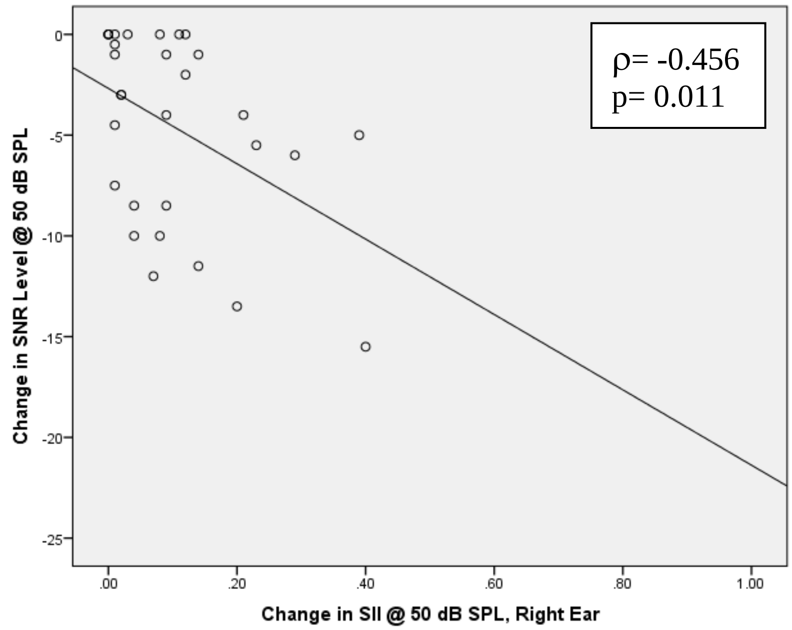


Figure 9: Spearman's rho Correlation of Change in SNR Loss & Change in Left Ear SII at 50 dB SPL

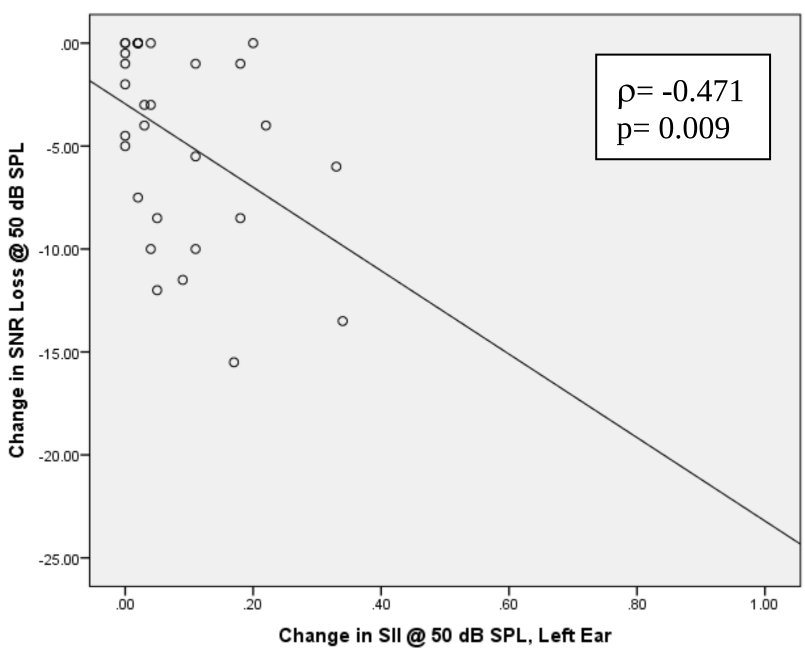


Figure 10: Spearman's rho Correlation of Change in SNR Loss & Change in Right Ear SII at 70 dB SPL

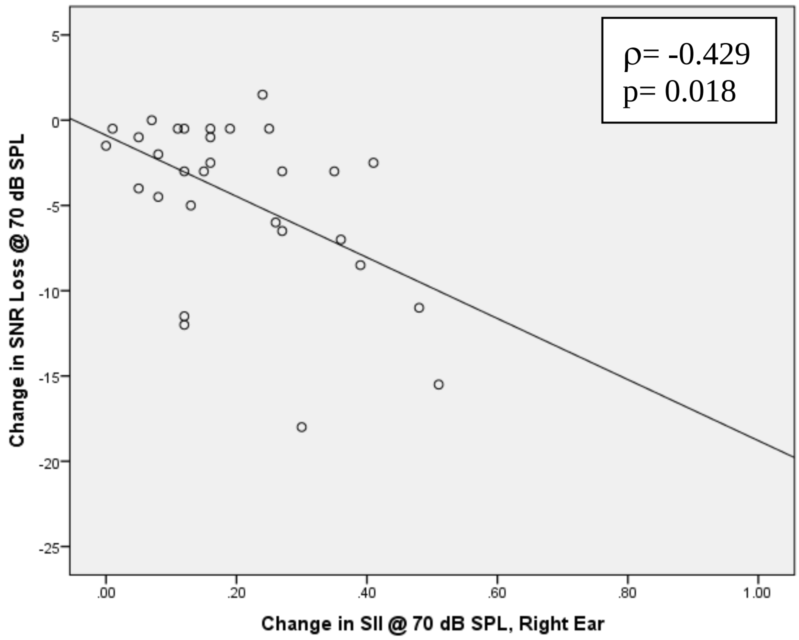
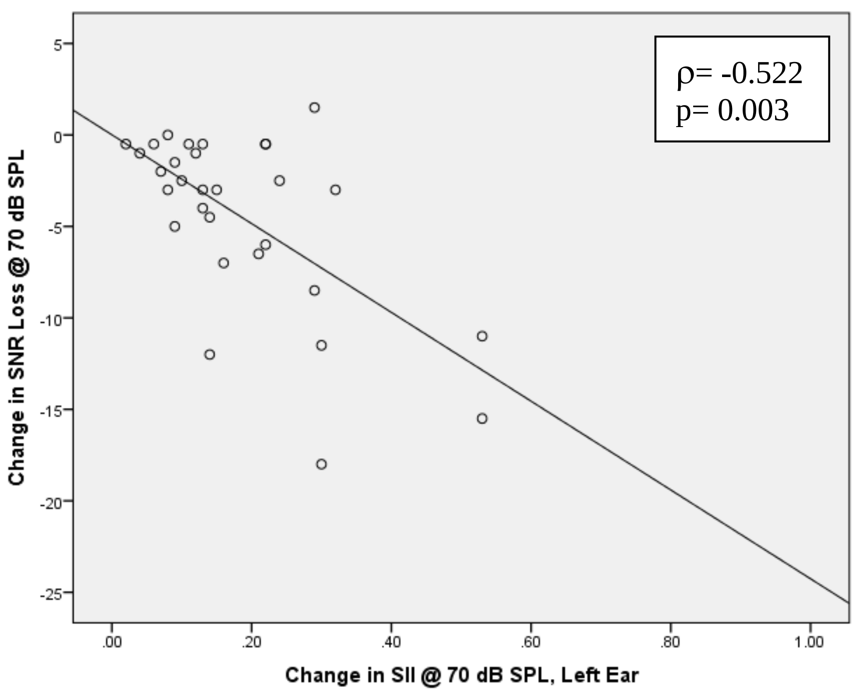


Figure 11: Spearman's rho Correlation of Change in SNR Loss & Change in Left Ear SII at 70 dB SPL



Question 5: Is aided audibility (best aided SII) significantly correlated to self-reported outcomes with the use of hearing aids?

In order to determine if there is a significant relationship between aided audibility at each of the presentation levels and self-reported outcomes, a Spearman's rho correlation was utilized. The best aided SII at each level was correlated to the self-reported outcome responses on the GHABP. Results showed that there was no significant relationship between aided audibility and any of the self-reported outcomes: use (ρ= -0.142; p=0.454); benefit (ρ= 0.202; p=0.284); residual disability (ρ= -0.110; p=0.563); and satisfaction (ρ= 0.275; p=0.141) at 50 dB SPL. At 70 dB SPL, there was also no significant relationship between aided audibility and any of the self-reported outcomes: use (ρ= 0.331; p=0.074); benefit (ρ= 0.072; p=0.706); residual disability (ρ= 0.096; p=0.615); and satisfaction (ρ= -0.236; p=0.209). Table 4 displays the relationships between the GHABP results and best aided SII at each presentation level.

Table 4: Spearman’s rho correlations & p-values for GHABP & Best Aided SII at 50 & 70 dB SPL

SII	GHABP	Correlation	p-Value
Best Aided SII @ 50 dB SPL	Use	-0.142	0.454
	Benefit	0.202	0.284
	Residual Disability	-0.110	0.563
	Satisfaction	0.275	0.141
Best Aided SII @ 70 dB SPL	Use	0.331	0.074
	Benefit	0.072	0.706
	Residual Disability	0.096	0.615
	Satisfaction	-0.236	0.209

Question 6: Is aided word recognition performance (aided SNR Loss) significantly correlated with self-reported outcomes with the use of hearing aids?

Similar to the previous research question, in order to determine if there was a significant relationship between aided word recognition performance and self-reported outcomes, a Spearman’s rho correlation was used. Results showed that there was a significant relationship between word recognition performance and satisfaction at both 50 dB SPL (ρ= -0.439; p=0.015) and 70 dB SPL (ρ= -0.427; p=0.019). As word recognition improved, satisfaction with hearing aids also improved. There was no significant relationship between word recognition in noise performance and any of the other self-reported outcomes at 50 dB SPL: use (ρ= 0.143; p=0.450); benefit (ρ= -0.310; p=0.095); and residual disability (ρ= 0.281; p=0.132) as well as at 70 dB

SPL: use (ρ= 0.156; p=0.410); benefit (ρ= -0.166; p=0.380); and residual disability (ρ= 0.183; p=0.332). Table 5 displays the relationships between the GHABP results and aided SNR Loss at each presentation level.

Table 5: Spearman's rho correlations & p-values for GHABP & Aided SNR Loss at 50 & 70 dB SPL

SNR Loss	**GHABP Scale**	**Correlation**	**p-Value**
Aided SNR Loss @ 50 dB SPL	Use	0.143	0.450
	Benefit	-0.310	0.095
	Residual Disability	0.281	0.132
	Satisfaction	-0.439	0.015*
Aided SNR Loss @ 70 dB SPL	Use	0.156	0.410
	Benefit	-0.166	0.380
	Residual Disability	0.183	0.332
	Satisfaction	-0.427	0.019*

*Correlation significant at the 0.05 level

Question 7: Are selected demographic factors significantly related to hearing aid status, participant reported hearing aid characteristics, and participant skills?

To determine if there was a relationship between selected demographic factors and the following assessments: hearing aid status, selected responses from the hearing aid characteristics questionnaire, and participant skills, a Mann-Whitney U test was utilized. Scores from the visual listening check (VLC) were averaged for each ear to calculate an overall visual listening check score. The selected responses from the characteristics questionnaire included: hours/day worn, days/week worn, length of hearing aid ownership, age of current set of hearing aids, number of hearing aid sets owned, length of time since hearing was last professionally tested, and length of time the participant waited to get hearing aids after being informed that s/he had a hearing loss.

Gender (male or female) was a demographic factor that was used to further examine data since an equal number of males and females were enrolled in this study. It was determined that there were no significant differences when comparing males and females for any of the measurements including: average VLC (p=0.744); modified PHAST-R (p=0.050); age of right hearing aid (p=0.389); age of left hearing aid (p=0.512); number of months right hearing aids have been owned (p=0.285); number of months left hearing aids have been owned (p=0.461); number of sets owned for right ear (p=0.902); number of sets owned for left ear (p=0.967); number of months waited to purchase hearing aid for right ear (p=0.217); number of months waited to purchase hearing aid for left ear (p=0.161); number of hours hearing aids worn per day (p=0.512); and number of days hearing aids worn per week (p=0.838).

Since there were similar numbers of individuals who had a college degree (18) and those who did not have a college degree (12), two groups were formed and compared to particular assessments, as described above. There were no significant differences found when comparing the following measures for those with and without a college degree: average VLC (p=0.917); modified PHAST-R (p=0.884); age of right hearing aid (p=0.346); age of left hearing aid (p=0.415); number of months right hearing aids have been owned (p=0.851); number of months left hearing aids have been owned (p=0.723); number of sets owned for right ear (p=0.573); number of sets owned for left ear (p=0.518); number of months waited to purchase hearing aid for right ear (p=0.723); number of months waited to purchase hearing aid for left ear (p=0.851);

number of hours hearing aids worn per day (p=0.146); and number of days hearing aids worn per week (p=0.950).

Question 8: Are self-reported outcomes with the use of hearing aids significantly related to hearing aid status, participant reported hearing aid characteristics, and participant skills?

A Spearman's rho correlation was used to determine if there was a relationship between self-reported outcomes and the following assessments: hearing aid status, selected responses from the hearing aid characteristics questionnaire, and participant skills. Scores from the visual listening check were averaged for each ear to calculate an overall VLC score. The selected responses from the characteristics questionnaire included: hours/day worn, days/week worn, length of hearing aid ownership, age of current set of hearing aids, number of hearing aid sets owned, length of time since hearing was last professionally tested, and length of time the participant waited to get hearing aids after being informed that s/he had a hearing loss. There was no relationship between three of the four self-reported outcomes (use, benefit, and residual disability) and the visual listening check or the modified PHAST-R. There was a significant relationship between satisfaction and the modified PHAST-R (ρ=0.407; p=0.026).

There were also some significant relationships between the GHABP outcomes and selected responses from the characteristics questionnaire. Not surprisingly, there was a significant relationship between use on the GHABP and the number of hours worn/day (ρ=0.685; p<0.001) as well as days worn/week (ρ=0.739; p<0.001). Benefit with the use of hearing aids, as determined by the GHABP, was significantly related to the length of time since the participant had his/her hearing professionally tested (ρ= -0.379; p=0.039) as well as a significant relationship between benefit and hours worn per day (ρ= 0.394; p=0.031). There were no significant relationships between residual disability and any of the selected responses from the characteristics questionnaire. Finally, there was a significant relationship between satisfaction with hearing aids and the length of time that participants waited to purchase hearing aids for his/her right ear (ρ=0.439; p=0.015).

Question 9: What is the relationship between hearing aid status, participant reported hearing aid characteristics, and participant skills?

A Spearman's rho correlation was used to determine if there were any significant relationships between hearing aid status, selected hearing aid characteristics, and participant skills. Scores from the visual listening check were averaged across ears to calculate an overall visual listening check score. The selected responses from the characteristics questionnaire included: hours/day worn, days/week worn, length of hearing aid ownership, age of current set of hearing aids, number of hearing aid sets owned, length of time since hearing was last professionally tested, and length of time the participant waited to get hearing aids after being informed that s/he had a hearing loss.

There was a significant relationship between the visual listening check scores and the number of months that the participant owned a hearing aid for the right ear (ρ= -0.368; p=0.045). There was also a significant relationship between the visual listening check and the number of days per week the participant stated that they wore their hearing aid (ρ= -0.449; p=0.013).

There was a significant relationship between the modified PHAST-R and the age of the right hearing aid (ρ= -0.463; p=0.010) as well as the left hearing aid (ρ= -0.430; p=0.018). There was also a significant relationship between the PHAST-R and the last time the participant had his/her hearing professionally tested (ρ= -0.472; p=0.008).

The age of the current right hearing aid was significantly related to the age of the current left hearing aid (ρ=0.989; $p<0.001$). Also, there was a significant relationship between the overall number of months the participant had worn a hearing aid in the right ear and the overall number of months the participant had worn a hearing aid in the left ear (ρ=0.954; $p<0.001$). In addition, there was a significant relationship between the number of hearing aid sets owned per person in the right ear and the left ear (ρ=0.957; $p<0.001$). .

There was also a significant relationship between the number of months the participant had owned hearing aids for the right ear and the number of sets owned for the right ear (ρ=0.618; $p<0.001$); the number of sets owned for the left ear (ρ=0.623; $p<0.001$); and the number of days per week that the hearing aids are reportedly worn (ρ=0.433; p=0.028). In regards to the number of months that the participant had owned hearing aids for the left ear, there was a significant relationship between this measure and the number of sets owned for the right ear (ρ=0.708; $p<0.001$) and the number of sets owned for the left ear (ρ=0.717; $p<0.001$). Similar to the right ear, the number of months of hearing aid ownership for the left ear was significantly related to the number of days per week the hearing aids were reportedly worn (ρ=0.401; p=0.028).

There was a significant relationship between the number of years that the participant waited to purchase hearing aids after being informed they had a hearing loss for the right ear and the left ear (ρ=0.920; $p<0.001$). Finally, there was a significant relationship between the number of hours per day the participant wore his/her hearing aids and the number of days per week (ρ=0.548; p=0.002).

CHAPTER 4: DISCUSSION

Demographics and Characteristics

The participant pool for this particular study differs from previous studies of hearing aid users in that individuals were recruited from the community and could potentially be patients of any hearing aid dispenser. Some of the participants received hearing aids from local dispensers while others traveled to a larger city to obtain amplification and some of the participants had hearing aids that were purchased from other states.

For those enrolled, participant ages ranged from 62-88 years. Most participants (25) considered themselves to be retired or employed part-time which is consistent with the results from Kochkin (2009) who stated that hearing aid users were more likely to fall in these categories than to be working full-time.

Audiometrics

Inclusion in this study did not require hearing loss to be symmetrical; however, many of the participants (21) had symmetrical hearing loss (i.e., both ears had the same severity of hearing loss based on the three-frequency pure tone averages). Hearing loss severity ranged from mild to profound. Three individuals were not enrolled in this study because it was determined through pure tone threshold testing that s/he had a conductive component in at least one ear.

Audibility

The Speech Intelligibility Index (SII) determines the amount of audibility available to the listener and ranges from 0.0 (no auditory information) to 1.0 (all auditory information). The SII is not necessarily a direct percentage indicating available speech, however, the value can be thought of as indicating a proportion of available auditory information. The SII values were assessed both with and without the use of hearing aids, and those SII values are offered in Table 1. The average unaided SII for a 50 dB SPL speech passage was 0.10 (right ear) and 0.08 (left ear). On average, the participants in this study hear approximately 8-10% of auditory information for quiet speech without wearing hearing aids. The average unaided SII for a 70 dB SPL speech passage was 0.32 (right ear) and 0.29 (left ear). On average, the participants in this study hear approximately 29-32% of auditory information for average conversational speech without wearing hearing aids.

The average aided SII for a 50 dB SPL speech passage was 0.20 (right ear) and 0.16 (left ear). This suggests that for quiet speech (i.e., 50 dB SPL), on average, only between 16-20% of auditory information is available to the listener when aided. For some participants (two for the right ear and three for the left ear), amplification did not provide any auditory information (SII=0.00) at this softer presentation level. Even the highest aided SII (0.64) offered only 64% of the presented information.

The goal of amplification would be to offer optimal or good audibility. The only known index of what constitutes good audibility or a “good communication system” was offered by ANSI S3.5 (1997) and their proposed value for good audibility would be a system that offers a SII of greater than 0.75. A caveat of using this criterion is that while according to ANSI this is an ideal communication system, it might not be obtainable for many hearing aid fittings. In the current study, at 50 dB SPL, no participants received a SII of greater than 0.75 for the right ear or the left ear hearing aid fitting. ANSI S3.5 (1997) also indicates that a poor communication system would offer SII values of less than 0.45. At 50 dB SPL, all but two participants’ right ear fittings and all but one participant's left ear fitting were within the poor communication system or poor audibility range, even with amplification.

Not surprisingly, a higher aided SII was documented for the presentation level representing average speech (70 dB SPL). The average aided SII for a 70 dB SPL speech passage was 0.51 (right ear fitting) and 0.47 (left ear fitting). Again, this suggests that, on average, individuals with hearing aids are receiving about half of the auditory information when speech is at average presentation levels. Using the same criteria as mentioned above from ANSI S3.5 (1997), only two participants were considered to have good audibility for the right ear fitting and only one participant had good audibility for the left ear fitting (SII of >0.75). On the other hand, ten participants' right ear fittings and thirteen participants' left ear fittings were within the "poor communication system" or poor audibility range.

Most practitioners who use probe-tube measures fit to a prescription using real ear dB SPL targets rather than SII targets. Prescriptions take into account the degree of hearing loss as well as acceptable loudness which are two major factors that do not allow for aided SIIs of 1.0. More recently, it has been suggested that ranges of optimal aided SII be determined for differing degrees of hearing loss and used to evaluate and confirm optimal audibility (Bagatto et al., 2011). As described by Johnson and Dillon (2011), the predicted speech intelligibility index (SII) did not significantly differ for several non-proprietary prescriptions including NAL-NL1, NAL-NL2, and DSL m[i/o] for speech presented at a normal conversational level (i.e., 65 dB SPL) in quiet and in noise. Therefore, one could utilize the SII as an universal index of good fit, even when different prescription methods are used.

Word Recognition in Noise

SNR Loss is the additional gain in the SNR required for a person with hearing loss to understand speech presented in the presence of background noise when compared to a person with normal hearing. It ranges from -4.5 (best) to +25.5 (worst). In this particular study, both the sentences and noise were presented at a 0° azimuth which is considered the most challenging listening environment because the sentences and the noise are not spatially separated. See Table 2 for scores in each condition. The aided SNR Loss ranged from an average of +18.32 at 50 dB SPL to an average of +10.05 at 70 dB SPL. Again, the lower the measured SNR Loss, the better the individual performed on this assessment. This suggests that at the softer presentation level (50 dB SPL), participants needed, on average, a +18.32 dB better signal to noise ratio to understand speech in noise (for 50% identification) compared to normal hearing listeners. This is in comparison to a needed increase of +10.05 dB for the average presentation level (70 dB SPL). These findings indicate that even with amplification; individuals with hearing loss will not have the same performance in some noisy environments as normal hearing listeners.

When comparing performance at each of the SNR levels, overall, as the SNR level decreased, aided performance decreased. The only exception is that at 50 dB SPL, there was an increase in performance from +25 to +20 before declining as the SNR decreased. This result was not expected, however, one explanation could be that the sentences at this level could have been easier for participants. In regards to equivalency noted by the researchers, this was established across test lists, and not for individual sentences within a list. As a whole though, as SNR decreased, performance decreased at both soft and average conversational presentation levels as can be seen in Figures 1 and 2. Performance for normal-hearing individuals at each of the SNRs has not been reported for the QuickSIN. Wilson (2003) demonstrated, using the Words in Noise

Test, that listeners with hearing loss do not perform comparably to normal hearing listeners with signal-to-babble ratios ranging from 0 to 24 dB. This highlights the fact that listeners with hearing loss hear more poorly in noise at all SNR levels.

Self-Reported Outcomes

The GHABP was utilized to determine self-reported outcomes of use, benefit, residual disability, and satisfaction. Scores ranged from 1 to 5 based on 4 pre-determined listening situations with the option for participants to elect up to 4 more situations to rate. See Table 3 for the mean, standard deviation, and range for each GHABP subscale. One important consideration is that these self-report questionnaires were completed by a sample of long-term hearing aid users (>12 months). In contrast, other studies that have assessed self-reported outcomes offer data collected at the end of a trial period where scores can be significantly higher.

The average hearing aid use score of 4.43 in this pool of participants is consistent with individuals reportedly wearing hearing aids between about "¾ of the time"(rating of 4) and "all the time" (rating of 5) in each of the situations. This is actually higher than that reported by Humes et al. (2001) whose participant group had a mean use score of 3.90, suggesting use closer to 75% of the time. The study by Humes et al. (2001) did have a much higher number of participants and focused on new hearing aid users.

The average benefit score of 2.98 is consistent with stating that the hearing aids are between "some help" (rating of 2) and "quite helpful" (rating of 3) across situations. This score was very similar to that found by Humes et al. (2001) who had an average score of 2.99.

The average residual disability score of 2.41 is consistent with having between "only slight difficulty" (rating of 2) and "moderate difficulty" (rating of 3) across listening environments when using amplification. This score is slightly higher (i.e., more residual disability) than that found in the Humes et al. (2001) study who had a mean score of 2.06. The GHABP assessment is unique in that few self-reports examine residual disability even with the use of hearing aids. Even with hearing aid use, listeners report residual difficulty in a variety of listening environments.

Finally, the average satisfaction score of 3.11 suggests that participants are between "reasonably satisfied" (rating of 3) and "very satisfied" (rating of 4) with the hearing aids. Again, this was consistent with that determined by Humes et al. (2001) who found that hearing aid users determined that they were "reasonably satisfied" with them with a mean score of 3.22. In addition, the score of 3.11 for the study described here is similar to that determined by Takahashi et al. (2007) who had an overall satisfaction score of 3.7. In summary, participants were wearing their hearing aids most of the time, did receive benefit with the use of hearing aids, still had difficulty even with amplification, but overall, were satisfied with them.

The current study determined that there were significant relationships between benefit, residual disability, and satisfaction. There was a strong, positive significant relationship between benefit and satisfaction. The overall trend was that as reported benefit increased, so did satisfaction. Strong, negative significant correlations were found between residual disability and benefit and between residual disability and satisfaction. There was no relationship between hearing aid use and any of the other self-reported features. These findings were similar to results by Vestergaard (2006), who found that there were significant relationships between benefit, residual disability, and satisfaction on the GHABP. In addition, both studies found the strongest correlation between benefit and satisfaction. Interestingly, there were no significant correlations with use time as reported by the hearing aid users. Anecdotally, it appeared that use was typically based on a user's daily routine rather than judging as whether the hearing aid might be beneficial in a specific situation.

Visual-Listening Check

Three participants were excluded from the research study because at least one of their hearing aids was not properly functioning and the problem could be not remedied with simple battery change, repositioning to eliminate feedback, or earwax removal. Two of the three participants had two hearing aids that were not working at all (i.e, dead) and one person had one hearing aid that was not working at all. These individuals were invited to continue participation once the hearing aid issues had been resolved, but none of them returned for the testing protocol. Also, as stated earlier one participant presented with what she deemed as hearing aids, but that were actually personal amplifiers. This person was excluded from the study as these units were not hearing aids.

Hearing aid status in the current study can be compared to findings of Thibodeau and Schmitt (1988) and Ferguson and Nerbonne (2003) which included nursing home residents and those in retirement centers. In the current study, out of the 84 hearing aids assessed (including those excluded due to "dead" hearing aids), 30 (35.7%) had an issue of concern noted on the visual-listening check. This finding is similar to that of Ferguson and Nerbonne who identified 35% of hearing aids as dysfunctional with the most common reasons being battery function and cerumen blockage. In contrast, Thibodeau and Schmitt (1988) identified 61% of hearing aids as not functioning adequately with the most common reasons being that of dead/weak battery and a clogged vent/sound opening. In the current study, debris in the sound/outlet/receiver (8 for right hearing aid; 5 for left hearing aid) was also found to be a common problem. However, only one participant who was initially enrolled in this study had an issue with a dead/weak battery, but could not continue participation due to an abnormal tympanogram.

Participants in this research study owned a variety of hearing aid styles with the most popular model being the BTE with slim/thin tube (with or without receiver-in-the-ear). These results differ from the participants in previous studies (Ferguson and Nerbonne, 2003; Thibodeau and Schmitt, 1988), but this is to be expected due to changes in technology and preferences.

Characteristics Questionnaire

In the current study, participants reported waiting an average of 23.07 months and a median of 5 months for right ear hearing aid purchase and an average of 22.47 months with a median of 3.5 months for a left ear hearing aid purchase. These wait times are shorter than those offered by Kochkin (2009) who reported an average wait of 6.7 years (79 months) and a median of 3 years (36 months). For some, there were different waits for left and right ears as a result of differing hearing loss severities and financial constraints.

Motivation to obtain hearing aids varied across participants, but the main motivation was that they were influenced by family/friends. Other top concerns included wanting to hear better in a variety of situations (e.g., church, community, noise, TV, radio) as well as changes to hearing abilities. Few participants (7) stated that their physician/audiologist/dispenser was a reason for pursuing amplification. It appears that it often requires an outside influence from significant others for individuals to pursue and purchase amplification. These results were similar to those of Kochkin (2009) who found that the most common motivating factors were that their hearing got worse and that they were influenced by family and hearing care professionals. Even though tinnitus relief with hearing aids has been a reason as to why some individuals obtain hearing aids, only one person offered this as an additional motivating factor (i.e., this was not offered as a standard response option).

It was not surprising that most participants were solely responsible for payment on their hearing aids with a few receiving insurance assistance and a few receiving assistance from the Veterans Affairs. While about half of the individuals had a professional hearing test within the past 12 months, about half had not.

It also appeared that these hearing aid users reportedly are wearing their hearing aids most of the time throughout the day and most days during the week. In addition, on average, most participants agreed that they received an appropriate overview/practice for different areas of hearing aid use and maintenance during their fitting and follow-up appointments. A manufacturer's case was the most popular choice for storage of hearing aids and many individuals stored them in a hard case. Most of the participants used the telephone with the hearing aid in and situated the phone next to his/her ear or held it at an angle.

When asked if certain procedures were completed during fitting appointments, only 20% reported that probe-tube measurements were made while 60% reported that this did not occur, and 20% reported that they were not sure. This number is lower than that presented by Kochkin (2010) who stated that 40% of respondents had these measurements performed. For our study, it is conceivable that either these measurements were not made by 80% of dispensers and/or the hearing aid users were not remembering that the measure had been completed. It is these researchers' opinions that it is probably a combination of both. Practitioners are not always making these assessments and/or for those that do, explanation of the purpose and procedures are not being offered or understood. One does have to remember that many of these individuals have owned hearing aids for a number of years and as time passes, so does the remembrance of all procedures completed. There was no way to determine definitively if these procedures had been performed.

In regards to whether or not the hearing aid user was asked to repeat back words with and without their hearing aids, 63.33% reported that this did occur, 20% reported that this did not occur, and 16.67% reported that they were not sure. One participant stated that while this method was used, it was completed in the exam room and not in a sound-isolated booth area. These results are similar to that of Kochkin (2010) who stated that 66% of respondents responded that this assessment had been conducted. It appears that the use of unaided and aided word recognition testing is a more popular method of hearing aid verification than the use of real-ear probe tube verification measurements and self-report questionnaire validation measures.

Hearing aid dispensers and hearing aid companies advertise the newest technology to their potential patients and many times it is these features (e.g., noise reduction, directionality) that determine the level of technology and associated price. Interestingly though, the understanding of these two key features was not typical within this population sample. Only about half (53.33%) of respondents correctly identified the purpose of noise reduction technology (i.e., “make noisy situations more comfortable”) while only about a quarter (23.33%) understood the purpose of directionality (i.e., “improve listening for speech when the noise is from the back or sides of the listener”). There is a trend of touting these features to potential users, but it appears based on findings from the Hearing Aid Characteristics Questionnaire that many hearing aid users are not aware, if they have these features or understand their purpose.

Modified PHAST-R

The scores on the modified PHAST-R were relatively high for this group of participants with almost a quarter of participants (23.33%) receiving a perfect score. The most commonly missed questions were those requiring identification of the different components of the hearing aid. Few individuals had issues with other elements including changing the battery and cleaning the hearing aid. Even though all of the participants in this research study were long-term hearing aid users (>12 months of use), many did not properly identify the different parts (i.e., sound outlet/receiver/loudspeaker; vent; and microphone inlets) on his/her hearing aid. Some might argue that this is not related to the manipulation and use of a hearing aid, but identifying the different components of a hearing aid is an important task during orientation and fitting appointments. Many of these components are vital to the function of the hearing aid and if they are not cared for properly, performance of hearing aids can be affected. Not knowing where the sound enters the hearing aid (i.e., sound inlet/microphone) as well as where the sound needs to exit the hearing aid (i.e., sound outlet/receiver), hearing aid users may not realize the need for protecting and carefully clearing debris from these areas. When asked to clean a particular part, in general, the ability to clean it was present for most participants, but being able to identify the different components, when named, was not.

Doherty and Desjardins (2012) developed the PHAST-R using experienced hearing aid users and reported scores that had a range similar to the ones in the current study. Their scores ranged from 61.29-100% while in the study described herein, the scores ranged from 65-100%. Similar to Doherty and Desjardins (2012) findings, some participants (4) in this study did have difficulty in cleaning the hearing aid.

Research Questions

Question 1: Is audibility (as measured by the SII) significantly improved for soft conversational speech (i.e. 50 dB SPL) and average conversational speech (i.e. 70 dB SPL) with the use of hearing aids on dispenser settings?

There was a significant improvement in SII between the unaided and aided testing conditions as can be seen in Figures 3 and 4. These results are similar to those of Newman and Sandridge (1998) who used the AI (i.e., precursor to the SII) and found a significant increase in audibility with amplification. In the current study, the mean improvement for 50 dB SPL speech was 0.10 (right ear) and 0.08 (left ear). The mean improvement for 70 dB SPL speech was 0.20 (right ear) and 0.18 (left ear). This result means that on average, there was approximately a 10% increase in audibility for soft speech and approximately 20% improvement for average speech. For both speech passage levels at both ears, there was not as great of an increase in audibility as Souza et al (2000) found (i.e., 0.30 increase in AI) for a 55 dB SPL speech passage. However, the hearing aids in that particular study were fit to the NAL-R prescription with real-ear probe tube measures. In the current study, it appears that fewer participants were fit to prescription using a real-ear probe tube system, a practice that is known to result in lower aided sound pressure levels and would be expected to yield lower SII values.

Closeness to prescription fit was determined for each hearing aid real ear aided response at each presentation level using the widely used NAL-NL1 prescription and the goodness-to-fit criteria described in Aazh and Moore (2007). Hearing aid fittings were determined to meet goodness-to-fit criteria if there was a difference of less than 10 dB between the measured real-ear aided response (REAR) and the provided NAL-NL1 targets at the following frequencies: 250, 500, 1000, 2000, 3000, and 4000 Hz. Only frequencies with NAL-

NL1 targets were used to determine closeness to prescription for each participant. Due to a technical error in obtaining a data table for one participant, only information for 29 of the 30 participants was available for left hearing aids.

For the right hearing aid at 50 dB SPL, only 2 out of the 30 participants had REAR measures (6.67%) that were deemed to have an appropriate fit. For the left hearing aids at 50 dB SPL, only 2 of the 29 included participant REAR measures (6.90%) met the criteria for closeness to fit. It is important to note that these constituted four different participants as no participant met the stated criteria for both their right and left hearing aids.

At the higher presentation level of 70 dB SPL, more participants met the criteria of less than 10 dB difference between REAR and NAL-NL1 targets at all designated frequencies. For the right ear, 7 of the 30 participants had REAR measures (23.33%) that were considered to be close to prescription while in the left ear, 5 of the 29 (17.24%) participants had REAR measures that met the criteria for appropriate fit. Overall, only 3 of the participants were within the 10 dB criteria for both the right and left hearing aid REAR measures at the 70 dB SPL presentation level.

The small number of participants that met the Aazh and Moore (2007) criteria of appropriate fit is concerning in regards to underfit and underamplification of hearing aids. As a whole, a majority of the measures that did not meet the criteria for goodness-to-fit were underamplified.

Gatehouse (1999) examined whether changes in SII from the unaided to aided condition met or exceeded 0.05. In the current study, at 50 dB SPL only 56.67% of right ear fittings and 40% of left ear fittings showed an improvement of at least 0.05. For the 70 dB SPL speech passage, 93.33% of both right ear and left ear fittings had an improvement of at least 0.05.

Gatehouse (1999) used a 65 dB SPL input signal (most comparable to the 70 dB SPL signal in the current study) and he found that 80.9% of individuals had SIIs that increased by at least 0.05 from the unaided to aided conditions. It is important to note that the hearing aids in the Gatehouse (1999) study were set to prescription using a real-ear probe tube measurement system.

While there is a significant difference in SII between the unaided and aided conditions, a consideration is warranted as to whether this change or increase was optimal. Hearing aid users often ask as to whether their hearing aids are offering the best possible hearing. While the change in audibility found in this study was significant, the question remains as to whether the participants were receiving enough auditory information to maximize audibility with the use of hearing aids. As stated previously, only a small number of participants met the Aazh and Moore (2007) criteria for goodness to fit with a majority being underfit. Thus, it is expected that SII values would have been significantly higher if many participants' hearing aids had been set at higher gain for both soft and conversational speech levels. One reason that hearing aids may not be set on or near prescription is the use of the automatic first-fit within manufacturer software rather than the use of real-ear probe tube measures to confirm aided sound pressure levels. Aazh and Moore (2007) determined that 64% of first-fit responses were not within 10 dB (i.e., the researchers' criteria for a poor match to target) of NAL-NL1 targets for at least one assessed frequency. They reported that first-fit often underamplifies (i.e., amplified values are below prescribed targets), especially in the higher frequencies.

Bagatto et al. (2011) provided optimal SII values for pediatric fittings based on audiometric thresholds. Their SII targets were based on hearing aids that were fit to the DSLv5.0a prescription (i.e., commonly used pediatric prescription). By providing targets for SII dependent on hearing thresholds, practitioners could answer the question posed by many consumers, are my hearing aids offering me the best hearing possible? If the SII meets pre-established targets, then one could possibly say that the hearing aid user is receiving as much auditory information as is possible. Data for optimal SII values in the adult population; however, is not currently available.

Question 2: Is word recognition performance (SNR Loss) significantly improved for soft conversational speech (i.e. 50 dB SPL) and average conversational speech (i.e. 70 dB SPL) with the use of hearing aids on dispenser settings?

As with the SII, there was a significant difference between unaided and aided word recognition performance in noise for both quiet and average conversation levels as can be seen in Figure 5. Better performance, as determined by SNR Loss, was noted for conditions with amplification. This result was similar to that found by Walden and Walden (2004) as well as Mendel (2007) who also utilized the QuickSIN, but at a higher presentation level (i.e., 70 dB HL).

This study described herein analyzed the performance between unaided and aided conditions at each SNR level (i.e., +25, +20, +15, +10, +5, and +0) and the number of correct responses at each SNR can be seen in Figures 1 and 2. For the 50 dB SPL presentation level, aided performance differed from unaided performance at all SNR levels except at the +0 SNR. At 70 dB SPL, there was a significant difference between the aided and unaided performance at each of the SNR levels except +5 dB. Walden and Walden (2004) and Mendel (2007) also found differences in aided and unaided QuickSIN performance except at the poorest SNRs. Overall, results show that at poor SNRs, individuals have a very difficult time identifying speech even with the assistance of hearing aids. Understanding that hearing aids do not offer assistance at the poorest SNRs is a disappointment for many hearing aid users.

With respect to analyzing individual data on the QuickSIN, Killion et al. (2004) offered that a change of at least 2.7 dB was sufficient to indicate a significant change between conditions at the 95% confidence interval, based on averaging performance across two lists per condition as was done in this study. For this particular study, it was expected that any changes in aided performance would primarily be due to improved audibility since hearing aid use with sentences and noise presented from the front would not result in improved signal-to-noise ratios. Out of 30 participants, only 17 (56.67%) were considered to have a significant change between the unaided and aided conditions at 50 dB SPL with better performance in the aided condition. Similarly, for the 70 dB SPL presentation, only 16 (53.33%) participants had a significant change of at least 2.7 dB at 70 dB SPL between the unaided and aided conditions with better performance in the aided condition. Even though overall, there was a significant difference between the unaided and aided conditions at each QuickSIN presentation level (i.e., 50 and 70 dB SPL), only approximately half of the participants actually showed a significant change representing an improvement in performance for the aided condition. The word recognition improvement documented in this study did not exceed the 95% confidence interval for change for nearly half of the participants.

By wearing hearing aids, individuals with hearing impairment often want dramatic improvement when listening to speech in noise. However, the results from this study show that in the worse listening conditions with both the speech and noise at 0˚ azimuth, individuals wearing hearing aids are not able to reach performance levels achieved by normal hearing individuals. One caveat is that improved audibility with probe tube prescription fitting could have produced greater improvement based on audibility. According to Killion et al., (2004), those with a SNR Loss of 0-3 dB are considered to have near/near normal degree of SNR Loss. Only one person in this entire sample was able to reach this performance level at 50 dB SPL while six individuals were able to reach this performance level when assessed at 70 dB SPL. These results signify the need for audiologists/hearing aid dispensers to use probe tube measures to verify audibility and to spend time counseling patients that when in noisy environments, there will still be difficult circumstances and that hearing aids do not provide “normal hearing.” Sometimes, environmental modifications are the best option for these types of situations.

Question 3: Is better ear audibility (best aided SII) significantly related to word recognition performance (aided SNR Loss) at two presentation levels (50 and 70 dB SPL)?

There was a significant strong negative relationship between better ear audibility (SII) and word recognition (SNR Loss) at 50 and 70 dB SPL as seen in Figures 6 and 7. As audibility increased, word recognition performance in noise improved on the QuickSIN at both soft and average presentation levels. According to ANSI (1997) the SII is a measurement that is highly correlated with the intelligibility of speech under various listening situations for otologically normal listeners (ANSI S3.5, 1997). In the current study, this relationship was found to hold for individuals with hearing loss when comparing the SII to the QuickSIN. One might expect that there would not be a strong relationship between SII and sentence materials because sentences can offer linguistic cues in addition to acoustic cues. Unlike some sentence tests; however, the QuickSIN sentences offer limited linguistic contextual cues causing listeners to rely more heavily on acoustic cues (i.e., audibility) which may explain the high correlations found.

Question 4: Is the change in SII (unaided to aided) at each presentation level (50 and 70 dB SPL) significantly related to the change in SNR Loss (unaided to aided) at each presentation level (50 and 70 dB SPL)?

There was a significant moderate negative correlation between the change in SII and the change in SNR Loss for both ears and at both presentation levels as can be seen in Figures 8, 9, 10, and 11. Greater SII changes were associated with greater word recognition changes at soft presentation levels (50 dB SPL) and at average presentation levels (70 dB SPL). This increase in audibility offered by hearing aids depends on the speech level and spectrum (male, female, child), background noise level and spectrum, patient's hearing sensitivity across the frequency range, & the gain of the hearing aid across the frequency range.

Question 5: Is aided audibility (best aided SII) significantly correlated to self-reported outcomes with the use of hearing aids?

There was no significant relationship between aided audibility and self-reported outcomes (i.e., use, benefit, residual disability, and satisfaction) in this study as can be seen in Table 4. This confirms the ASHA distinction between verification measures (such as the SII) and validation measures (such as the GHABP), that evaluate different hearing aid outcomes. This result may lend credence that for best practice, dispensers should not only be assessing the amount of audibility available with the use of hearing aids, but also the self-reported outcomes of the hearing aid user based on his/her real-world use of hearing aids. While it appears that use of the SII can be used to verify improved audibility, it does not reflect performance in real-world listening environments.

Question 6: Is aided word recognition performance (aided SNR Loss) significantly correlated with self-reported outcomes with the use of hearing aids?

There was no significant relationship between aided word recognition performance and the self-reported outcomes of use, benefit, or residual disability at both soft (50 dB SPL) and average (70 dB SPL) conversational levels as can be seen in Table 5. However, there did appear to be a significant relationship between aided word recognition performance at both presentation levels and satisfaction with the use of hearing aids. As word recognition in noise performance improved, reported satisfaction also improved. The ability to hear in noise, as reflected by performance on the QuickSIN, is an important issue for adults with hearing loss and it appears to be related to their overall satisfaction with hearing aids.

In contrast, it appears that word recognition performance and self-reported benefit, use, and residual disability may be evaluating different hearing aid outcome measures. Real-world environments of individuals differ greatly from those used in a test booth. When participants rated their real-world communication with hearing aids they were asked to consider listening situations that generally offer visual and contextual cues whereas the speech recognition testing in this study (QuickSIN) offered no visual information, limited semantic cues, and no spatial separation between speech and noise.

The results for the study described herein differ from those of Mendel (2007) who used the 64-item HAPI benefit questionnaire to compare to QuickSIN performance. She determined that as performance improved, scores on a number of the HAPI benefit assessment categories increased. These differences could be due to the differences in methodology of the research studies and assessment tools. Even though both the GHABP and HAPI can assess benefit, the HAPI is a much longer assessment (64 questions) as opposed to the GHABP which assesses 4-8 situations. Also, the population spanned a much larger, and younger, age range in the Mendel (2007) with individuals ranging in age from 33-75 years compared to the study described herein which included participants between 62 and 88 years old. Finally, the participants in the Mendel (2007) study had hearing aids that were fit to prescription with a real-ear probe tube measurement system.

Question 7: Are selected demographic factors significantly related to hearing aid status, participant reported hearing aid characteristics, and participant skills?

For the demographic characteristics assessed (sex; college degree), there were no significant relationships between these groups and each of the selected questions from the characteristics questionnaire, hearing aid status, and participant skills. Scores were similar for both men and women as well as for college degree and non-college degree participants.

Question 8: Are self-reported outcomes with the use of hearing aids significantly related to hearing aid status, participant reported hearing aid characteristics, and participant skills?

From the results of the current study, it appears that the ability for one to manipulate his/her hearing aids, as measured by the modified PHAST-R, is related to satisfaction with them (i.e., as shown by the moderate positive correlation). As scores on the modified PHAST-R increased, satisfaction with the use of hearing aids also increased. These results differed from those of the developers of the PHAST who compared the PHAST scores to scores on the SADL satisfaction questionnaire (Desjardins and Doherty, 2009). They found no significant correlation between the PHAST scores and the SADL scores, however it is important to note that a modified PHAST-R was used for this study and a different self-report of satisfaction was used.

As expected, there was a significant strong positive relationship between use on the GHABP and the number of hours worn/day as well as days worn/week. As the proportion of time that one wore hearing aids according to the GHABP increased, the reported number of hours/day and days/week of wearing hearing aids also increased.

Benefit, as measured by the GHABP, was moderately, but negatively significantly related to the length of time since the participant had his/her hearing professionally tested. There was also a significant relationship between benefit and hours worn per day. As the amount of time since one's hearing was professionally tested increased, the lower the benefit score. It appears that the more often one is in direct contact with his/her dispenser and receives regular hearing assessments, the greater reported benefit from the use of hearing aids. Also, the higher the benefit scores, the greater the reported daily wear time. This result differed from findings of Walden, Demorest, and Hepler (1984) who determined a small, but significant negative correlation between hearing aid use (hours/day) and benefit as measured by the HAPI benefit questionnaire. Again, the HAPI is a much longer assessment consisting of 64 questions compared to the 4-8 situations assessed in the GHABP and a much larger sample size was utilized in the Walden, Demorest, and Hepler (1984) study, which could be affecting the differences in results.

Question 9: What is the relationship between hearing aid status, participant reported hearing aid characteristics, and participant skills?

It appears that most participants had owned hearing aids for each ear for about the same length of time overall as well as had owned the current set for about the same amount of time. In addition, participants waited about the same length of time to purchase hearing aids for both the right and left ears. There was also a significant relationship for use between the ears in regards to hours/day and days/week. All of these results relate to the fact that most participants in this study purchased hearing aids for each ear at the same time and waited about the same amount of time before purchasing after being informed they had a hearing loss. Also, once they owned hearing aids they tended to wear both of them for a similar amount of hours per day and days per week.

In regards to the ability to manipulate hearing aids, participants who were able to better manipulate their hearing aids were more likely to have newer hearing aids for both the right and left ears. It may be that they were more recently taught use and maintenance compared to individuals who have had the current set of hearing aids for a longer time. Also, the higher the modified PHAST-R score, the shorter time it had been since the participant’s last hearing assessment. This result lends to the fact that individuals who are more closely followed by dispensers appear to be better at manipulating their hearing aids. The decision for appointments and testing could be at the discretion of the hearing aid user or dispenser, but it appears that a more recent trip to the dispenser with a hearing test was consistent with a better score on the modified PHAST-R.

CHAPTER 5: SUMMARY AND CONCLUSIONS

In summary, this study differs from previous hearing aid outcome research in that participants were fit by a variety of dispensers in the community. In contrast, prior research typically presents findings from participants fit using protocols that included verification measures such as real-ear probe tube measures, and validation measures such as word recognition testing and self-report questionnaires. Despite the increased likelihood of un-verified fittings, a significant improvement with amplification use was found for both audibility (SII) and word recognition performance in noise (SNR Loss) at soft and average speech presentation levels. While hearing aids do not change the signal-to-noise ratio in situations where the speech and noise arrive from the same location, as in the QuickSIN testing conducted, the improved audibility offered by amplification did result in improved word recognition performance.

Word recognition assessments, such as the QuickSIN, can offer information on performance across a range of signal-to-noise ratios which may be more informative than considering only the SNR Loss. In the current study, amplification actually allowed for improved word recognition in noise for all but the poorest signal-to-noise ratios. Anecdotally, the hearing aid users themselves were disappointed that the improvement was not as dramatic as they had wished. However, the QuickSIN lists include unrelated sentences that offer limited semantic cues whereas real-world conversations may offer visual cues and greater contextual cues. Thus, any improvement on this challenging word recognition task (QuickSIN with sentences and noise presented at 0° azimuth) is noteworthy.

A significant relationship was found between aided audibility and aided word recognition in noise in regards to performance. In addition, there was a significant relationship between the change in audibility and the change in word recognition performance from unaided to aided conditions. According to ASHA (1998), audibility is considered a verification procedure while word recognition measures are considered validation procedures and in this study these measures were highly related. While the SII has been found to be significantly related to word recognition in normal hearing listeners, the current study offers evidence that this holds true for this sample that consisted primarily of individuals with mild-moderate sensorineural hearing loss.

Changes in individual participant measures of audibility and word recognition were also examined. A majority of individual participants met the criteria for significant change in audibility for the average speech presentation level (70 dB SPL) while only about half of the individual participants met the criteria for significant change in word recognition performance in noise for the average speech presentation level (70 dB SPL). When examining individual differences in performance at the 50 dB SPL presentation level, approximately half did not show a significant change in either audibility or word recognition performance in noise. Based on this finding, it can be argued that there is a need for hearing aid dispensers to evaluate and confirm audibility and word recognition performance at conversational and softer presentation levels. In fact, Banerjee (2011a) noted from a sample of hearing aid users fit with logging devices, that hearing aid users spent about half of their time in environments with sound pressure levels at or below 50 dB SPL. These findings lend credence to the need for assessing audibility and word recognition at lower speech presentation levels.

In the current study, there were no significant relationships between audibility and self-reported outcomes and only one significant relationship between word recognition performance in noise and self-reported outcomes (satisfaction). Self-reported communication was not closely related to clinic-based measures of audibility and word recognition. The self-reported measures differ because they reflect listening in different environments which often include visual and contextual cues that the clinic-based measures do not offer.

Several noteworthy observations were made following examination of the participant report of hearing aid characteristics. Various technological features of hearing aids, such as noise reduction and directionality, are commonly offered in modern digital hearing aids. However, based on questionnaire responses from this study, hearing aid users may not know if their hearing aids offer these features or understand their purpose. This signals the need for patient counseling, written support materials, and the review of such information at follow-up visits. Also, by participant report in this sample, it appears that verification and validation tools such as real-ear probe tube measures and questionnaires were not widely used.

There were three primary limitations of the study. First, on the hearing aid characteristics questionnaire, responses were based on participant reports with no way to verify activated hearing aid features and actual procedures used during hearing aid fitting visits. Secondly, the results primarily reflect individuals with mild-moderate hearing loss and further study of those with severe to profound hearing loss is warranted. Finally, the researchers were not able to complete electro-acoustic analysis to assess hearing aid functionality due to the inability to obtain all programming software and cords for hearing aids from a wide range of manufacturers.

This study does lead to implications for future research. The possibility of using a standard audibility measure such as the SII to indicate optimal audibility for adult fittings warrants further exploration. Many hearing aid fittings in the current study were not offering aided sound pressure levels that approximate one of the most common hearing aid prescriptions used in adult fittings (i.e., the NAL-NL1 prescription). Thus, further exploration of word recognition performance contrasting first-fit and prescription-fit hearing aids would be of interest. Another research need identified is that of determining QuickSIN performance at each of the signal-to-noise ratios for normal-hearing listeners, as that data does not currently exist. Hearing aid users may forget that at some of these signal-to-noise ratios even normal hearing listeners misperceive words. Researchers need to continue to explore the question asked by so many adults with hearing loss, "What is the best hearing that hearing aids can offer me?"

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APPENDIX A: UMCIRB APPROVAL LETTER

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · www.ecu.edu/irb

Notification of Initial Approval: Expedited

From: Biomedical IRB
To: Ellen Poland
CC:
Deborah Culbertson
Date: 12/6/2012
Re: UMCIRB 12-001878
Hearing Aids in Older Adults: Audibility, Outcomes, Status, Characteristics, and Skills

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 12/6/2012 to 12/5/2013. The research study is eligible for review under expedited category #7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

The approval includes the following items:

Name	Description
Adult Consent Form | History	Consent Forms
Email Recruitment | History	Recruitment Documents/Scripts
Glasgow Hearing Aid Benefit Profile | History	Surveys and Questionnaires
Modified PHAST-R | History	Surveys and Questionnaires
Newspaper Advertisement | History	Recruitment Documents/Scripts
Participant Hearing Aid Status Sheet | History	Surveys and Questionnaires
Participant Report of Hearing Aid Characteristics | History	Surveys and Questionnaires
QuickSIN Score Sheet | History	Standardized/Non-Standardized Instruments/Measures
Real-Ear Probe Tube Measurement | History	Standardized/Non-Standardized Instruments/Measures
Recruitment Flyer | History	Recruitment Documents/Scripts
Visual-Listening Check | History	Surveys and Questionnaires

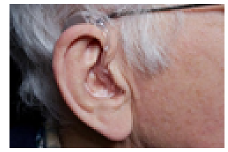
The Chairperson (or designee) does not have a potential for conflict of interest on this study.

APPENDIX B: RECRUITMENT FLYER

UMCIRB Number: 12-001878

news.consumerreports.org

Adults are Invited:
To a study on hearing aids



www.sciencedaily.com

We are looking for **adults** from the **ages of 60 to 89** who wear hearing aids in both ears.

We will be studying how you hear words with and without your hearing aids and ask you to complete a few questionnaires. A check of your hearing and hearing aids will also be completed.

This is a research study and there will be no discussion of hearing aid sales.

It will take about 2 hours and you will receive a **$20 gift card to Target** upon completion.

If interested, please
Call: **252-744-5027**

This research is being conducted by
Ellen Poland, Doctoral Candidate
Department of Communication Sciences and Disorders
East Carolina University

This research project has been approved by the ECU Medical Center Institutional Review Board.

Version Date: 2/4/13

APPENDIX C: RECRUITMENT NEWSPAPER ADVERTISEMENT

East Carolina University

Tomorrow starts here.

Adults Are Invited: To A Study on Hearing Aids

We are looking for **adults** from the ages of 60 to 89 who wear hearing aids in both ears. We will be studying how you hear words with and without your hearing aids and ask you to complete a few questionnaires. A check of your hearing and hearing aids will also be completed. It will take about 2 hours and you will receive a $20 gift card to Target upon completion.

This is a research study and there will be no discussion of hearing aid sales.

This research study is being conducted by Ellen Poland, doctoral candidate in the Department of Communication Sciences and Disorders, ECU's College of Allied Health Sciences.

For details and enrollment, please contact Ellen Poland:

252-744-5027

This study has been approved by the ECU Medical Center Institutional Review Board (#12-001878)

APPENDIX D: CONSENT FORM

East Carolina University

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Hearing Aids in Older Adults: Audibility, Outcomes, Status, Characteristics, and Skills
Principal Investigator: Ellen Crowell Poland, B.A.
Institution/Department or Division: Department of Communication Sciences and Disorders
Address: Allied Health Sciences Building
Telephone #: 252-744-5027

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of volunteers who are willing to take part in research.

Why is this research being done?
The purpose of this research is to determine a number of outcomes with the use of hearing aids that both require participant responses and those that do not require participant responses. The decision to take part in this research is yours to make. By doing this research, we hope to learn the current function of hearing aids in the real-world.

Why am I being invited to take part in this research?
You are being invited to take part in this research because you are an adult from the ages of 60 to 89 who wears hearing aids in both of your ears. If you volunteer to take part in this research, you will be one of about 50 people to do so.

Are there reasons I should not take part in this research?
You will not be able to take part in this research study if your hearing aids are not working or have whistling that cannot be resolved. In addition, your hearing loss must be occurring in your inner ear or nerve area ("sensorineural"). You cannot participate if you are wearing hearing aids that are considered "invisible" or if you are in a trial period for your hearing aids.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research procedures will be conducted at the East Carolina University Speech Language and Hearing Clinic. You will need to come to the East Carolina University Speech Language and Hearing Clinic **one** time during the study. The total amount of time you will be asked to volunteer for this study is approximately 2 hours.

What will I be asked to do?
You are being asked to do the following:

1. Have the researcher look in both of your ears to determine if your outer ears are clear.
2. Have a soft tip placed in your ear to determine how your middle ear is functioning.
3. Complete a cognitive screening.
4. Complete a vocabulary screening.
5. Respond to words and tones in a sound isolated booth to determine your type and severity of hearing loss.

6. Repeat words with and without your hearing aids to determine differences between the two situations.
7. Answer a questionnaire regarding characteristics of your hearing aids.
8. Answer a questionnaire regarding your use, satisfaction, disability, and benefit with your hearing aids.
9. Sit in a chair with a small measurement tube placed in your ear canal and listen to a person reading a passage.
10. Have your hearing aids examined by the researcher.
11. Show the researcher your ability to manipulate your hearing aids, based on a pre-determined list of questions.

What possible harms or discomforts might I experience if I take part in the research?
There are possible risks (the chance of harm) when taking part in this research.

You will have a soft ear tip and small tube placed in the outer ear canal during several measures. If you experience any discomfort, you may advise the researcher so the placement can be re-adjusted. While the size of the test booth is not small, occasionally an individual may experience claustrophobia during the task. If that occurs, you may advise the researcher and usually a small break outside the booth will resolve that problem. You may also discontinue the testing at any time.

What are the possible benefits I may experience from taking part in this research?
You will receive a brief hearing aid status report. This research may help us learn more about the real-world settings of hearing aids and how individuals are performing with the use of hearing aids. The information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?
You will receive a $20 gift card to Target for completing all study measures.

What will it cost me to take part in this research?
By participating in this research study, you will incur the following costs: time and travel expenses.

Who will know that I took part in this research and learn personal information about me?
To do this research, ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- The primary investigator (Ellen Poland) and the supervising faculty member (Deborah Culbertson, PhD).
- Any agency of the federal, state, or local government that regulates human research. This includes the Department of Health and Human Services (DHHS), the North Carolina Department of Health, and the Office for Human Research Protections
- The University & Medical Center Institutional Review Board (UMCIRB) and its staff, who have responsibility for overseeing your welfare during this research, and other ECU staff who oversee this research.

How will you keep the information you collect about me secure? How long will you keep it?
You will be assigned a number and all data entered is by that unique number. The consent form will link your name with the unique identifier. All data will be stored in a locked file cabinet within the East Carolina University Speech Language and Hearing Clinic (Room 1310D). Only researchers involved in this study will have access to your private health information which will be destroyed after six years.

What if I decide I do not want to continue in this research?
If you decide you no longer want to be in this research after it has already started, you may stop at any time. You will not be penalized or criticized for stopping. You will not lose any benefits that you should normally receive. However, those unable to complete study measures will not receive the $20 gift card.

Who should I contact if I have questions?
The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252-744-5027 (days, between 9:00 AM and 5:00 PM).

If you have questions about your rights as someone taking part in research, you may call the Office for Human Research Integrity (OHRI) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of the OHRI, at 252-744-1971

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

APPENDIX E: CASE HISTORY FORM

Case History

Participant Number:_______

1. **What is your sex?**
   ____ Male ____ Female

2. **Birthdate?** ______________ (excluded from study if not between the ages of 60 and 89 years)

3. **Is your native language English?** (excluded from study, if no)
   ____ Yes ____ No

4. **Are you still within a hearing aid trial period for either hearing aid?** (excluded from study, if yes)
   ____ Yes ____ No

5. **What is your highest level of education received?**
   ____ Less than high school diploma* ____ High school diploma/GED
   ____ Some college ____ Associate's degree/2 year degree
   ____ 4-year college degree ____ Graduate/post-baccalaureate/professional degree
   * If so, how many years of schooling have you completed? _____________

6. **What is your current employment status?**
   ____ Employed full-time
   ____ Employed part-time
   ____ Unemployed
   ____ Retired

7. **What best describes your residence?**
   ____ I live by myself
   ____ I live with family/friends
   ____ I live within a facility
   In: ____ an independent living section
   ____ an assisted living section
   ____ a nursing care/home section

8. **How did you hear about this study?**
   ____ Friend/Family Member ____ Listserv
   ____ Flyer ____ Community Presentation
   ____ Newspaper ____ Other: ______________________

APPENDIX F: AUDIOGRAM

East Carolina University

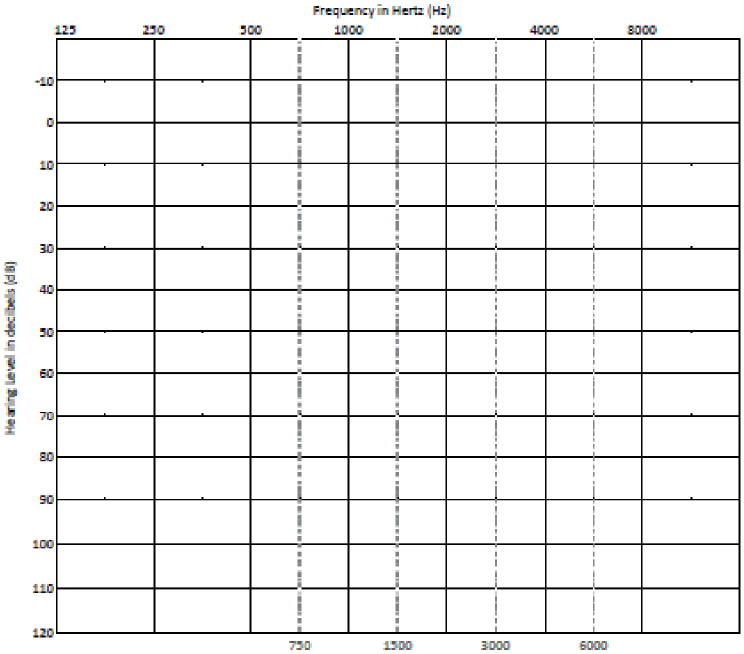
Speech-Language and Hearing Clinic
Department of Communication Sciences and Disorders
1310 Health Sciences Building
Greenville, NC 27858-4353

252-744-6104 phone
252-744-6148 fax

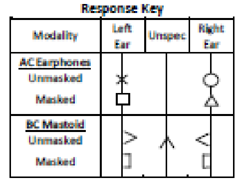
A North Carolina Scottish Rite Foundation RiteCare Clinic

Patient Name	Evaluation Date
Parent/Significant Other	Date of Birth
Referral Source	Examiner(s)
	AC Transducer

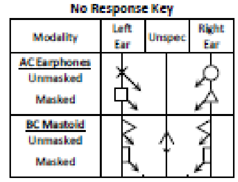
PURE TONE AUDIOMETRY (RE: ANSI 2003)



Response Key



No Response Key



Abbreviations Key

AC	Air Conduction
BC	Bone Conduction
CNT	Could Not Test
DNT	Did Not Test
FA	Fletcher Average
HL	Hearing Level
LDL	Loudness Discomfort Level
MCL	Most Comfortable Loudness
NR	No Response
PTA	Pure-Tone Average
SDT	Speech Detection Threshold
SRT	Speech Recognition Threshold
TPP	Tympanometric Peak Pressure
TW	Tympanometric Width
V_{ea}	Equivalent Ear Canal Volume
WR	Word Recognition
Y_{tm}	Peak Compensated Acoustic Admittance

TYMPANOMETRY RESULTS

Ear	Probe Hz	Y_{tm} mmho	TW daPa	V_{ea} cm3	TPP daPa
Right					
Left					

EFFECTIVE MASKING LEVELS TO NONTEST EAR

		125	250	500	750	1000	1500	2000	3000	4000	6000	8000
AC	R											
	L											
BC	R											
	L											

ACOUSTIC REFLEX THRESHOLDS IN dB HL

Test Condition	500 Hz	1000 Hz	2000 Hz	4000 Hz	Other	Reflex Decay
Right ipsilateral (stim R: probe R)						
Left contralateral (stim L: probe R)						
Left ipsilateral (stim L: probe L)						
Right contralateral (stim R; probe L)						

SPEECH AUDIOMETRY

Ear	PTA/ SDT or SRT	WR Mat'l ______ score/level	Contra mask level	WR Mat'l: ______ score/level	Contra mask level
Right	/	/		/	
Left	/	/		/	

History/Impressions/Recommendations: ____

____

____

AHS 006673 (6/10)

APPENDIX G: VISUAL-LISTENING CHECK

Visual-Listening Check Participant Number:_______

	Right	Left
Make/Model		
Type		
Serial Number Year		

Visual-Listening Check 2=Yes 1=No NA=Could Not Evaluate (CNE)

Scored Items	**Right**	**Left**
Visual/Manual Check		
Is the earhook clear? (i.e., dirt, earwax, moisture)- BTE only		
Is the standard tube/slim tube clear? (i.e., dirt, earwax, moisture)- BTE only		
Is the standard tube/slim tube pliable (i.e., not brittle or hardened)?- BTE only		
Is the earmold/dome free of cracks?- BTE only		
Is the earmold/dome clear? (i.e., dirt, earwax, moisture)- BTE only		
Is the hearing aid case free of cracks, holes, missing controls/covers/doors?		
Is the loudspeaker outlet/port clear? (i.e., dirt, earwax, moisture)- custom only		
Is/are the microphone inlet(s) clear of debris and moisture?		
The program button/switch moves as it should.		
The volume control moves as it should.		
Is the battery free of corrosion and debris?		
Is the battery compartment free of corrosion and debris?		
Does the battery have 1.1 volts or greater? (Dillon, 2001)		
Listening (start-up program/close door)		
What is the indicator? (beeps, song, voice, silent)		
There is good sound quality without excess static or hum.*		
When moving the aid from side to side, there was no intermittency.*		
With hearing aid placed by participant, there is no audible feedback.		
Final Score	___/___	___/___

Non-Scored Items	**Right**	**Left**
How many switches/buttons/controls on this hearing aid?		
When pressing button/switch 1... Indicator (beeps, song, voice, silent) Change (telecoil, volume change, unknown, no change)	______________ ______________	______________ ______________
When pressing button/switch 2... Indicator (beeps, song, voice, silent) Change (telecoil, volume change, unknown, no change)	______________ ______________	______________ ______________
How many microphones were on this hearing aid?		

*aah, eeh, ooh, ss, shh, mmm

Remedies? ____

Inclusion Criteria:

No unresolved whistling? YES NO

Hearing aid amplifying? YES NO

Version: 12/5/12 Page 1 of 1

APPENDIX H: PARTICIPANT REPORT OF HEARING AID CHARACTERISTICS

Participant Report of Hearing Aid Characteristics

Participant Number: ______

- Some questions in this assessment were adapted from the MarketTrak VIII Survey (Kochkin, 2009)

1. There are different types of hearing aids. Describe your **current** set of hearing aids (indicate all that apply with R or L designations)?
   ____ Behind-the-ear with standard tube
   ____ Behind-the-ear with slim/thin tube
   ____ Half or full shell in-the-ear (fills all or part of outer ear)
   ____ In-the-canal (fills ear canal opening)
   ____ Completely-in-the canal (not visible to others)
   ____ Other: ____________

2. What is/are the manufacturer(s) of your hearing aids (indicate all that apply with R or L designations)?
   ____ Avada ____ Beltone ____ GN Resound ____ Miracle Ear
   ____ Oticon ____ Phonak ____ Siemens ____ Sonic Innovations
   ____ Starkey ____ Unitron ____ Widex
   ____ Unknown ____ Other: ________________

3. How old (in years) is each of your current hearing aids?
   ____ Right ____ Left

4. Overall, for how many years have you owned hearing aids?
   ____ Right ____ Left

5. You may have owned more than one set of hearing aids. Overall, how many hearing aids have you owned?
   ____ Right ____ Left

6. How long (in years) did you wait to purchase hearing aids after you were informed you had a hearing loss?
   ____ Right ____ Left

7. What were the **top 3 reasons** for purchasing your current hearing aids (mark in rank order, 1, 2, 3)?
   ____ I wanted to hear the TV/radio better.
   ____ My family encouraged/insisted.
   ____ I wanted to hear better in noise.
   ____ I needed them for my job.
   ____ I received a free hearing aid.
   ___ I wanted to hear better at church/community functions.
   ___ I wanted to hear better on the telephone.
   ___ Recommendation by physician/audiologist/dispenser.
   ___ My hearing got worse.
   ___ Other: ______________________________

8. Who paid for your **current** hearing aids (indicate all that apply with R or L designations)?
   ____ Self ____ VA/Military ___ Insurance Company
   ____ Assistance program* ____ Family/Friend ____ Other ____________

   *(e.g., HEAR NOW, NCTDEP, Easter Seals)

9. When was the last time (in years) that your hearing was professionally tested with the use of headphones in a sound-isolated booth?

   ____

10. On average, how many hours per day do you wear each of your hearing aids?
    ____ Right ____ Left

11. On average, how many days per week do you wear each of your hearing aids?
    ____ Right ____ Left

12. What type of dispenser/practitioner fit your current hearing aids (indicate all that apply with R or L designations)?
    ____ Audiologist ____ Hearing Instrument Specialist ____ Unknown ____ Other

13. From what type of office were your most current hearing aids purchased (indicate all that apply with R or L designations)?
    ____ Hearing Aid Chain (i.e., Avada, Beltone, etc.)
    ____ Big Box Store (i.e., Sears, Sam's, etc.)
    ____ ENT/Ear Doctor's Office
    ____ Hospital
    ____ Other: ____________________
    ____ Private audiology practice
    ____ University Clinic
    ____ Internet/mail order
    ____ Veteran's Administration
    ____ Unknown

14. Was a probe-tube microphone system (i.e., with measurement tube placed in ear canal) used during your most current hearing aid fitting?
    ________ Yes ________ No ________ Unknown

15. In regards to your most current hearing aid fitting, was a pencil and paper questionnaire administered to determine your benefit from the use of hearing aids?
    ________ Yes ________ No ________ Unknown

16. In regards to your most current hearing aid fitting, were you asked to repeat words **both with and without your hearings aids**?
    ________ Yes ________ No ________ Unknown

17. During hearing aid appointments for your current hearing aids, an appropriate overview/practice was offered for:

    a. Hearing Aid Insertion (placement in the ear)
       __ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disagree __ Strongly Disagree

    b. Hearing Aid Removal
       __ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disagree __ Strongly Disagree

    c. Changing battery
       __ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disagree __ Strongly Disagree

    d. Cleaning of hearing aid
       __ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disagree __ Strongly Disagree

e. Cleaning of earmolds/domes
__ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disgree __ Strongly Disagree __ NA

f. Troubleshooting of hearing aid problems
__ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disagree __ Strongly Disagree

g. Storage of hearing aids
__ Strongly Agree __ Slightly Agree __ Agree __ Neutral __ Disagree __ Slightly Disagree __ Strongly Disagree

18. How do you store your hearing aids? Please check all that apply.
____ In no container ____ Drying jar or container ____ Electronic drying system
____ Manufacturer's case ____ Other: ____________________

19. Do you use any of the following tools to clean your hearing aids/earmolds? Please check all that apply.
____ Air blower ____ Hearing aid brush ____ Cleaning/Wax Loop
____ Cloth ____ Pipe Cleaner ____ Vent Cleaning Line
____ Other: ____________________

20. Do you have any switches, buttons, toggles, or wheels (S, B, T, W) on your right hearing aid?
_____ None _____ Yes, 1 _____ Yes, 2 _____ Unknown

a. What function does #1 ______________ (S, B, T, W) have (as shown by researcher)?
___ Changes program ___ Changes volume ___ Unknown ___ NA

b. What function does #2 ______________ (S, B, T, W) have (as shown by researcher)?
___ Changes program ___ Changes volume ___ Unknown ___ NA

21. How do you primarily use the telephone with your hearing aids?
____ I change to a different program. ____ I take my hearing aid out.
____ I hold my telephone at an angle. ____ I hold my phone next to my ear.
____ Other: ____

22. How do you change to a different program on your hearing aids (indicate all that apply with R or L designations)?
_____ I change the program with a switch/button/toggle/wheel on my hearing aid.
_____ I change the program with a remote control and/or Bluetooth streamer.
_____ I don't change the program.
_____ I don't know how to change the program.
_____ I am not able to change the program.

23. How do you change the volume on your hearing aids (indicate all that apply with R or L designations)?
_____ I change the volume with a switch/button/toggle/wheel on my hearing aid.
_____ I change the volume with a remote control and/or Bluetooth streamer.
_____ I don't change the volume.
_____ I don't know how to change the volume.
_____ I am not able to change the volume.

24. Do you use other devices to help you hear? Please check all that apply.

____ Amplified telephone
____ Amplified /visual alerting doorbell
____ Amplified /visual alerting fire alarm
____ FM system
____ Loop system
____ TV amplifier/headset
____ Telephone Captioning
____ Other: ____________________

25. My hearing aids have frequency compression/frequency transposition.

____ Yes ____ No ____ Unknown

26. My hearing aids have noise reduction.

____ Yes ____ No ____ Unknown

27. Noise reduction technology means that the hearing aid should:

____ Remove all noise.
____ Make noisy situations more comfortable.
____ Improve hearing for speech in noise.
____ I don't know.

28. My hearing aids have directionality/directional/dual microphones.

____ Yes ____ No ____ Unknown

29. Directionality means that the hearing aid should:

____ Improve listening for speech when the noise is all around the listener.
____ Improve listening for speech when the noise is from the back or sides of the listener.
____ Improve listening for speech when the noise is in front of the listener.
____ I don't know.

APPENDIX I: MODIFIED PHAST-R

Modified PHAST-R Participant Number:_______

Each task is scored on the following 3-point Likert scale:
2 = performs entire task with no difficulty
1 = performs task with some difficulty (i.e. extended time, missed steps, &/or multiple attempts)
0 = cannot perform task
NA= Not applicable

1. Remove your **right** hearing aid. _________ (0, 1, or 2)

2. Open the battery door in your **right** hearing aid. _________ (0, 1, or 2)

3. Change the hearing aid battery in your **right** hearing aid with this new battery. _________ (0, 1, or 2)
   a) Remove old battery
   b) Remove battery tab on new battery
   c) Insert new battery
   d) Close battery door

4. Show me the following parts of your **right** hearing aid (score 0, 1, 2, 3=NA)
   a) Sound outlet/loudspeaker/receiver _________ (0, 1, 2, or NA)
   b) Microphone inlet(s) _________ (0, 1, 2, or NA)
   c) Vent _________ (0, 1, 2, or NA)

5. Show me how you clean the following parts on your **right** hearing aid. Feel free to use any of the tools provided (i.e., cloth, brush, wax loop, vent cleaning line)
   a) Case _________ (0, 1, 2, or NA)
   b) Vent _________ (0, 1, 2, or NA)
   c) Sound outlet/loudspeaker/receiver _________ (0, 1, 2, or NA)

6. Put your **right** hearing aid back in your ear. _________ (0, 1, or 2)

APPENDIX J: QUICK-SIN STIMULI LISTS

QuickSIN　　　　　　　　　　　　　　　　　　　　Participant Number:_______

Instructions:
"Imagine that you are at a party. There will be a woman talking and several other talkers in the background. The woman's voice is easy to hear at first, because her voice is louder than the others. Repeat each sentence the woman says. The background talkers will gradually become louder, making it difficult to understand the woman's voice, but please guess and repeat as much of each sentence as possible."

Unaided at 50 dB SPL

List 1 (Track 3)

			Score
1.	A white silk jacket goes with any shoes.	S/N 25	_____
2.	The child crawled into the dense grass.	S/N 20	_____
3.	Footprints showed the path he took up to the beach.	S/N 15	_____
4.	A vent near the edge brought in fresh air.	S/N 10	_____
5.	It is a band of steel three inches wide.	S/N 5	_____
6.	The weight of the package was seen on the high scale.	S/N 0	_____
	25.5 – (Total words correct) =	_____	(SNR Loss)

List 2 (Track 4)

			Score
1.	Tear a thin sheet from the yellow pad.	S/N 25	_____
2.	A cruise in warm waters in a sleek yacht is fun.	S/N 20	_____
3.	A streak of water ran down the left edge.	S/N 15	_____
4.	It was done before the boy could see it.	S/N 10	_____
5.	Crouch before you jump or miss the mark.	S/N 5	_____
6.	The square peg will settle in the round hole.	S/N 0	_____
	25.5 – (Total words correct) =	_____	(SNR Loss)

Average = __________

Unaided at 70 dB SPL

List 3 (Track 5)

			Score
1.	Pitch the straw through the door of the stable.	S/N 25	_____
2.	The sink is the thing in which we pile dishes.	S/N 20	_____
3.	Post no bills on this office wall.	S/N 15	_____
4.	Dimes showered down from all sides.	S/N 10	_____
5.	Pick a card and slip it under the pack.	S/N 5	_____
6.	The store was jammed before the sale could start.	S/N 0	_____
	25.5 – (Total words correct) =	_____	(SNR Loss)

List 4 (Track 6)

			Score
1.	The sense of smell is better than that of touch.	S/N 25	_____
2.	He picked up the dice for a second roll.	S/N 20	_____
3.	Drop the ashes on the worn old rug.	S/N 15	_____
4.	The couch cover and hall drapes were blue.	S/N 10	_____
5.	The stems of the tall glasses cracked and broke.	S/N 5	_____
6.	The cleat sank deeply into the soft turf.	S/N 0	_____
	25.5 – (Total words correct) =	_____	(SNR Loss)

Average = __________

QuickSIN Participant Number:_______

Aided at 50 dB SPL

List 5 (Track 7)

		Score
1. To have is better than to wait and hope.	S/N 25	_____
2. The screen before the fire kept in the sparks.	S/N 20	_____
3. Thick glasses helped him read the print.	S/N 15	_____
4. The chair looked strong but had no bottom.	S/N 10	_____
5. They told wild tales to frighten him.	S/N 5	_____
6. A force equal to that would move the earth.	S/N 0	_____
25.5 – (Total words correct) = _____ (SNR Loss)		

List 6 (Track 8)

Average = __________

		Score
1. The leaf drifts along with a slow spin.	S/N 25	_____
2. The pencil was cut to be sharp at both ends.	S/N 20	_____
3. Down that road is the way to the grain farmer.	S/N 15	_____
4. The best method is to fix it in place with clips.	S/N 10	_____
5. If you mumble your speech will be lost.	S/N 5	_____
6. A toad and a frog are hard to tell apart.	S/N 0	_____
25.5 – (Total words correct) = _____ (SNR Loss)		

Aided at 70 dB SPL

List 7 (Track 9)

		Score
1. The kite dipped and swayed but stayed aloft.	S/N 25	_____
2. The beetle droned in the hot June sun.	S/N 20	_____
3. The theft of the pearl pin was kept secret.	S/N 15	_____
4. His wide grin earned many friends.	S/N 10	_____
5. Hurdle the pit with the aid of a long pole.	S/N 5	_____
6. Peep under the tent and see the clown.	S/N 0	_____
25.5 – (Total words correct) = _____ (SNR Loss)		

List 8 (Track 10)

Average = __________

		Score
1. The sun came up to light the eastern sky.	S/N 25	_____
2. The stale smell of old beer lingers.	S/N 20	_____
3. The desk was firm on the shaky floor.	S/N 15	_____
4. A list of names is carved around the base.	S/N 10	_____
5. The news struck doubt into restless minds.	S/N 5	_____
6. The sand drifts over the sill of the old house.	S/N 0	_____
25.5 – (Total words correct) = _____ (SNR Loss)		

APPENDIX K: GLASGOW HEARING AID BENEFIT PROFILE (GHABP)

GHABP | Participant Number:______

Does this situation happen in your life? 0 ___ No 1 ___ Yes	**LISTENING TO THE TELEVISION WITH OTHER FAMILY OR FRIENDS WHEN THE VOLUME IS ADJUSTED TO SUIT OTHER PEOPLE**		
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

Does this situation happen in your life? 0 ___ No 1 ___ Yes	**HAVING A CONVERSATION WITH ONE OTHER PERSON WHEN THERE IS NO BACKGROUND NOISE**		
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

Does this situation happen in your life? 0 ___ No 1 ___ Yes	**CARRYING ON A CONVERSATION IN A BUSY STREET OR SHOP**		
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

Does this situation happen in your life? 0 ___ No 1 ___ Yes	**HAVING A CONVERSATION WITH SEVERAL PEOPLE IN A GROUP**		
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

GHABP Participant Number: ______

Does this situation happen in your life? 0 ___ No 1 ___ Yes			
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

Does this situation happen in your life? 0 ___ No 1 ___ Yes			
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

Does this situation happen in your life? 0 ___ No 1 ___ Yes			
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

Does this situation happen in your life? 0 ___ No 1 ___ Yes			
In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, with your hearing aid, how much difficulty do you now have?	For this situation, how satisfied are you with your hearing aid?
0___N/A 1___Never/Not at all 2___About ¼ of the time 3___About ½ of the time 4___About ¾ of the time 5___All the time	0___N/A 1___Hearing aid no use at all 2___Hearing aid is some help 3___Hearing aid is quite helpful 4___Hearing aid is a great help 5___Hearing is perfect with aid	0___N/A 1___No difficulty 2___Only slight difficulty 3___Moderate difficulty 4___Great difficulty 5___Cannot manage at all	0___N/A 1___Not satisfied at all 2___A little satisfied 3___Reasonably satisfied 4___Very satisfied 5___Delighted with aid

APPENDIX L: PARTICIPANT SUMMARY AND FOLLOW-UP

Participant Number:_______

Notice of Hearing Aid Function

On ____________________, you, ______________________, participated in a research study at East Carolina University.

You may share this information with your hearing aid dispenser.

Concerns are marked, if observed on the study date.

Concern	Left Hearing Aid	Right Hearing Aid
No concerns.		
Noticeable debris was visualized in the earhook, earmold, or on the hearing aid.		
Cracks, holes, and/or missing covers/doors were visualized on the earhook, earmold, or on the hearing aid.		
Debris or corrosion was visualized in the battery compartment.		
There was unresolved whistling while wearing the hearing aid.		
The hearing aid was "dead" and could not be remedied with battery change, readjustment, or simple wax removal.		

Other observations/comments:
____
____
____
____.

Due to confidentiality related to the research, the researchers are unable to discuss any specific observations noted above with a hearing aid dispenser/health care provider. However, we are more than happy to discuss any further questions with participants.

APPENDIX M: PARTICIPANT SII VALUES, RIGHT EAR

Participant	3-frequency PTA	Unaided 50 dB SPL	Aided 50 dB SPL	Unaided 70 dB SPL	Aided 70 dB SPL
1	55.00	.04	.06	.18	.48
2	58.33	.06	.06	.24	.25
3	41.67	.09	.10	.44	.49
4	38.33	.18	.32	.43	.58
5	38.33	.12	.16	.52	.60
6	48.33	.05	.25	.30	.54
7	35.00	.16	.24	.54	.66
8	58.33	.00	.01	.09	.25
9	58.33	.00	.00	.08	.20
10	58.33	.00	.00	.09	.25
11	66.67	.01	.24	.05	.44
12	65.00	.00	.08	.00	.48
13	38.33	.09	.21	.51	.67
14	48.33	.01	.15	.24	.59
15	55.00	.00	.03	.17	.44
16	38.33	.14	.18	.54	.65
17	63.33	.00	.01	.02	.28
18	33.33	.18	.58	.57	.76
19	53.33	.03	.10	.22	.47
20	46.67	.01	.40	.31	.72
21	71.67	.00	.21	.00	.51
22	26.67	.35	.64	.86	.86
23	26.67	.36	.37	.62	.74
24	31.67	.29	.30	.54	.59
25	78.33	.00	.12	.00	.36
26	60.00	.01	.10	.19	.31
27	86.67	.00	.11	.02	.29
28	35.00	.20	.29	.54	.67
29	23.33	.31	.40	.68	.75
30	35.00	.25	.27	.47	.55

APPENDIX N: PARTICIPANT SII VALUES, LEFT EAR

Participant	3-frequency PTA	Unaided 50 dB SPL	Aided 50 dB SPL	Unaided 70 dB SPL	Aided 70 dB SPL
1	56.67	.03	.06	.17	.47
2	60.00	.10	.10	.24	.26
3	51.67	.02	.02	.22	.35
4	41.67	.15	.24	.39	.54
5	33.33	.20	.25	.66	.73
6	45.00	.04	.38	.35	.64
7	43.33	.08	.19	.46	.54
8	58.33	.00	.00	.13	.25
9	58.33	.00	.02	.08	.22
10	56.67	.00	.04	.09	.33
11	73.33	.00	.11	.02	.31
12	60.00	.00	.20	.03	.56
13	46.67	.03	.03	.31	.44
14	46.67	.00	.11	.29	.61
15	51.67	.00	.02	.29	.42
16	33.33	.22	.26	.62	.73
17	66.67	.00	.02	.05	.27
18	43.33	.12	.29	.41	.63
19	50.00	.03	.08	.26	.48
20	65.00	.00	.00	.06	.16
21	65.00	.00	.22	.00	.53
22	26.67	.28	.61	.84	.93
23	31.67	.30	.32	.56	.62
24	30.00	.28	.28	.55	.59
25	81.67	.00	.00	.00	.16
26	61.67	.00	.18	.11	.41
27	81.67	.00	.02	.00	.21
28	50.00	.11	.14	.38	.47
29	31.67	.23	.41	.65	.73
30	36.67	.22	.26	.46	.60

APPENDIX O: BEST AIDED SII VALUES

Participant	3-frequency PTA	50 dB SPL	70 dB SPL
1	56.67	.06	.48
2	60.00	.10	.26
3	51.67	.10	.49
4	41.67	.32	.58
5	33.33	.25	.73
6	45.00	.38	.64
7	43.33	.24	.66
8	58.33	.01	.25
9	58.33	.02	.22
10	56.67	.04	.33
11	73.33	.24	.44
12	60.00	.20	.56
13	46.67	.21	.67
14	46.67	.15	.61
15	51.67	.03	.44
16	33.33	.26	.73
17	66.67	.02	.28
18	43.33	.58	.76
19	50.00	.10	.48
20	65.00	.40	.72
21	65.00	.22	.53
22	26.67	.64	.93
23	31.67	.37	.74
24	30.00	.30	.59
25	81.67	.12	.36
26	61.67	.18	.41
27	81.67	.11	.29
28	50.00	.29	.67
29	31.67	.41	.75
30	36.67	.27	.60

APPENDIX P: PARTICIPANT SNR LOSS VALUES, SOUNDFIELD

Participant	Better Ear 3-frequency PTA	Unaided 50 dB SPL	Aided 50 dB SPL	Unaided 70 dB SPL	Aided 70 dB SPL
1	55.00	25.50	22.50	25.50	7.50
2	58.33	25.50	25.50	25.50	25.00
3	41.67	25.50	21.00	8.50	4.50
4	38.33	24.50	13.00	12.00	9.00
5	33.33	23.00	14.50	5.50	3.50
6	45.00	25.50	12.00	10.00	11.50
7	35.00	22.50	12.50	8.00	5.00
8	58.33	25.50	24.50	12.00	11.00
9	58.33	25.50	25.50	24.50	12.50
10	56.67	25.50	25.50	25.50	23.00
11	66.67	25.50	20.00	25.50	17.00
12	60.00	25.50	25.50	25.50	14.50
13	38.33	25.50	23.50	10.00	9.50
14	46.67	25.50	24.50	16.50	13.50
15	51.67	25.50	25.50	10.50	7.50
16	33.33	23.00	13.00	4.00	3.50
17	63.33	25.50	25.50	25.50	19.50
18	33.33	21.00	5.50	3.50	3.00
19	50.00	25.00	13.00	10.50	10.00
20	46.67	25.50	20.50	16.00	13.50
21	65.00	25.50	21.50	25.50	10.00
22	26.67	6.50	.50	1.50	.00
23	26.67	22.00	14.50	6.50	6.00
24	30.00	9.00	8.50	3.50	2.50
25	78.33	25.50	25.50	25.50	18.50
26	60.00	25.50	24.50	24.50	13.00
27	81.67	25.50	25.50	25.50	19.00
28	35.00	14.50	10.50	7.50	2.50
29	23.33	15.00	6.50	3.00	3.00
30	35.00	22.00	19.00	7.50	3.00

APPENDIX Q: PARTICIPANT GHABP SCORES

Participant	Use	Benefit	Residual Disability	Satisfaction
1	5.00	3.50	1.75	3.25
2	1.75	1.75	1.50	2.00
3	3.00	2.50	2.75	3.00
4	5.00	3.33	2.33	3.00
5	3.75	2.75	1.75	4.00
6	5.00	3.00	2.00	3.25
7	4.00	3.67	1.67	4.00
8	5.00	4.00	2.25	4.00
9	5.00	2.50	2.50	2.75
10	2.75	2.50	2.50	3.00
11	5.00	3.60	2.80	3.20
12	5.00	3.50	3.00	3.25
13	5.00	2.40	3.20	2.20
14	4.75	3.50	2.00	3.00
15	5.00	2.50	3.00	2.75
16	1.33	3.00	2.33	3.33
17	5.00	2.50	3.00	2.75
18	4.25	3.25	2.75	3.25
19	5.00	3.20	2.20	3.20
20	4.25	2.75	2.75	2.75
21	5.00	4.00	1.50	4.00
22	5.00	3.60	2.20	3.40
23	4.67	2.33	3.00	3.00
24	3.67	1.67	3.33	1.33
25	5.00	2.50	3.25	2.50
26	5.00	3.33	2.00	4.00
27	5.00	2.50	3.25	2.50
28	5.00	2.67	2.00	3.33
29	5.00	4.00	1.67	4.00
30	4.60	3.20	2.20	3.40

APPENDIX R: PARTICIPANT VISUAL LISTENING CHECK SCORES

Participant	Right Ear	Left Ear	Average
1	.90	1.00	.95
2	1.00	1.00	1.00
3	.96	.96	.96
4	1.00	1.00	1.00
5	1.00	.96	.98
6	1.00	1.00	1.00
7	.96	1.00	.98
8	.96	.96	.96
9	.96	1.00	.98
10	1.00	1.00	1.00
11	.96	.96	.96
12	1.00	1.00	1.00
13	1.00	1.00	1.00
14	.95	.95	.95
15	1.00	1.00	1.00
16	1.00	1.00	1.00
17	.85	.90	.88
18	1.00	1.00	1.00
19	.96	.93	.95
20	1.00	.96	.98
21	1.00	.95	.98
22	.96	.96	.96
23	1.00	1.00	1.00
24	1.00	1.00	1.00
25	.88	.92	.90
26	1.00	1.00	1.00
27	.97	.97	.97
28	.96	1.00	.98
29	1.00	1.00	1.00
30	1.00	1.00	1.00

APPENDIX S: PARTICIPANT MODIFIED PHAST-R SCORES

Participant	Modified PHAST-R
1	.70
2	.75
3	.88
4	1.00
5	.88
6	.80
7	.75
8	1.00
9	.80
10	.75
11	1.00
12	.65
13	.75
14	.70
15	.75
16	.75
17	.70
18	1.00
19	.69
20	.70
21	.90
22	.88
23	.88
24	.75
25	.70
26	.80
27	.90
28	1.00
29	1.00
30	1.00