Outcomes of conventional amplification for pediatric unilateral hearing loss

Lauren A. Wendorf

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Abstract: Although some children with unilateral hearing loss (UHL) are at-risk for educational difficulties and behavioral problems, research in treatment outcomes for pediatric UHL is limited. The objective of this study was to examine the benefits of a conventional hearing aid in children with mild to moderately severe UHL, using speech perception measures and subjective assessments from the child, parent, and teacher.
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All the children and families that participated in this study.
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ABBREVIATIONS

UHL: Unilateral Hearing Loss
MD: Monaural Direct
MI: Monaural Indirect
SNR: Signal to Noise Ratio
BKB-SIN: Bamford-Kowal-Bench Speech-in-Noise-Test
NST: Nonsense Syllable Test
CHILD: Children’s Home Inventory of Listening Difficulties
LIFE: Learning Inventory for Education
SIFTER: Screening Instrument for Targeting Educational Risk
HEAR QL: Hearing Environments And Reflection on Quality of Life Measurement for Children
INTRODUCTION AND REVIEW OF THE LITERATURE

Unilateral hearing loss (UHL) has an estimated prevalence of .04 to 3.4% in newborns (Barsky-Firkser & Sun, 1997; Finitzo, Albright, & O’Neal, 1998; Mehl & Thomson, 1998; Widen et al., 2000) and 0.1% to over 5% in school-age children (Everberg, 1960; Niskar et al., 1998; Oyler, Oyler, & Matkin, 1988). With the implementation of universal newborn hearing screening programs, the age of identification for UHL has decreased substantially from school age to infancy (Lieu, 2004). Even though age of UHL identification has decreased, it still remains unclear how these children should be managed audiologically. It was previously believed that children born with UHL would not experience any handicap because they have one normal hearing ear. In the past, it has even been stated that children with UHL “will be able to go through school and learn like any other child” (Northern & Downs, 1978, p. 143). These children were not typically fit with amplification, and preferential classroom seating was the only educational recommendation. Some research, however, has shown that this population is at risk for educational and behavioral problems. It has been found that 22-35% of children with UHL failed at least 1 grade and 20% were identified with behavioral problems by teachers (Lieu, 2004; Bess & Tharpe, 1984; Bovo et al., 1988). Furthermore, 12-41% of children with UHL received additional educational services (Oyler, Oyler, & Matkin, 1988; Lieu, 2004; Bess & Tharpe, 1984; Bovo et al., 1984). The adaptation of listening with one ear is also not without quality of life consequences. Recent studies have shown that children with UHL reported lower total quality of life and psychosocial functioning than their normal hearing peers (Borton, Mauze, & Lieu, (in press); Streufert, 2008).
Given the disadvantages imposed by hearing with only one ear, it is not a surprise that some children with UHL are experiencing difficulties. Specifically, children with UHL are at a disadvantage for localizing sound and listening in noisy environments. Listening with two ears provides a binaural advantage over listening with one ear due to binaural summation, head shadow effect, sound localization, and binaural squelch. Binaural summation refers to the phenomenon that when listening to sounds with two ears, the sound is 3 dB louder at threshold and 6 dB louder at suprathreshold compared to listening with one ear alone (Valente, 2002). Furthermore, two ears are needed for sound localization. Individuals are able to localize low frequency sounds by interaural time differences and high frequency sounds by interaural intensity differences. Head shadow is a term used to describe the effects of sound having to go around the head to reach an ear. When speech arrives at one side of the head the intensity of the signal is decreased across the head by 6.4 dB before that signal reaches the opposite ear (Valente, 2002). A 6.4 dB reduction in signal level at the far ear can have a significant impact on speech recognition, especially when speech is delivered to the poorer ear and noise is in the better ear. Lastly, binaural squelch is an advantage of binaural hearing that reduces the effects of background noise and reverberation on speech recognition (Valente, 2002).

The performance deficits in tasks that utilize the binaural advantage have been studied in children with UHL. Children with UHL have been found to exhibit greater difficulty localizing sounds in the horizontal plane than normal hearing controls (Bess & Tharpe, 1984; Bovo et al., 1988; Bess, Tharpe, & Gibler, 1986; Humes, Allen, & Bess, 1980). Furthermore, the amount of difficulty has been found to increase as degree of hearing loss increased (Humes, Allen, & Bess, 1980). Studies looking at speech recognition in children with UHL have often used the monaural direct (MD) and monaural indirect (MI) testing conditions. In the MD testing condition the
signal is coming towards the good ear and noise is directed to the poorer ear, while in the MI condition the signal is coming towards the poorer ear and noise is directed to the good ear. Studies using these test conditions have shown that children with UHL perform worse in the MI condition for all signal to noise ratios (SNRs) compared to normal hearing controls (Bovo et al., 1988; Bess, Tharpe, & Gibler, 1986; Hartvig, Johansen, & Borre, 1989). One study only found this deficit in the MI condition (Hartvig, Johansen, & Borre, 1989), while two other studies also show that children with UHL perform worse than normal hearing controls in the MD condition (Bovo et al., 1988; Bess, Tharpe, & Gibler, 1986). This exhibited that even when the signal is directed toward the normal hearing ear, UHL children did not perform as well as their normal hearing peers. As would be expected, UHL children were found to perform worse in the MI condition than MD condition (Bovo et al., 1988; Bess, Tharpe, & Gibler, 1986; Hartvig, Johansen, & Borre, 1989). Furthermore, it has been demonstrated that children with UHL need greater SNRs than normal hearing controls for speech recognition of a MI signal and a signal from 0 degrees azimuth in the presence of continuous noise at 45, 135, 225, and 315 degrees azimuth (Ruscetta, Arjmand, & Pratt, 2005).

In summary, children with UHL do not experience the benefits of listening with two ears. Instead, they have difficulties with localization and hearing speech in the presence of background noise. Furthermore, thresholds are elevated from only listening with one ear and the head shadow effect prevents some acoustic signals from being heard when presented at the hearing loss side.

Although some children with UHL are at-risk for educational difficulties and behavioral problems, research in treatment outcomes for pediatric UHL is limited. The main assistive listening options that have been studied in children with UHL include conventional hearing aids,
CROS (contralateral routing of signal) hearing aids, and frequency-modulated (FM) systems. These treatment options all operate very differently. Conventional hearing aids amplify sound to the poorer ear, while a CROS hearing aid picks up sound from a microphone on the poorer ear and delivers it to a receiver in the better ear. A FM system uses FM waves to deliver the signal directly from the microphone located near the mouth of the talker to a hearing aid or speaker near the listener. Nonconventional hearing technology, such as the bone anchored hearing aid (BAHA) and Transcranial CROS, have also been explored in adult patients with UHL, however, more studies are needed before they are recommended for use in the pediatric population (Mckay, Gravel, & Tharpe, 2008).

To date, FM systems are the only assistive technology that has been found to improve word recognition abilities in quiet and in noise for children with UHL (Kenworthy, Klee, & Tharpe, 1990; Updike, 1994). Kenworthy, Klee, and Tharpe (1990) compared unaided speech recognition to aided recognition with CROS aids and with personal FM systems in 6 children, ages 8-12 years, with moderately severe to profound sensorineural UHL. Testing was performed in three conditions: MD, MI, and 0 degrees azimuth signal with omni-directional noise. The Nonsense Syllable Test (NST) (Levitt & Resnick, 1978) and Bamford-Kowal-Bench Standard Sentence Lists (BKB Lists) (Bench & Bamford, 1979) were presented at 62 dB SPL with a +6 SNR to evaluate speech perception. The study found that the children experienced the most difficulty in the MI condition. The CROS aid improved speech recognition in the MI condition, but speech recognition decreased in the MD condition. The FM system was found to improve speech recognition scores in all listening conditions.

In a pilot study, Updike (1994) examined the use of FM systems, CROS aids, and conventional hearing aids in 6 children, ages 5 to 12 years, with varying degrees of UHL ranging
from mild to profound. The Goldman-Fristoe Woodcock Test of Auditory Discrimination (Goldman, Fristoe, Woodcock, 1970) was used to evaluate speech discrimination at 77 dB SPL in quiet and in noise with a +6 SNR. The speech signal was presented at 0 degrees azimuth and noise was presented at 90 degrees azimuth. Results showed a significant improvement in speech perception scores in quiet with the hearing aid in two subjects, a decrease in one subject, and no change in one subject. In noise, one subject showed a decrease in performance and the remaining three subjects showed no significant change in performance. The study concluded that hearing aids and CROS aids do not enhance speech understanding and may even be detrimental when listening in noise. They also concluded that the use of the FM system improved speech understanding in quiet and in noise for all degrees of UHL.

Pediatric UHL research focusing on the use of conventional amplification is limited and based largely on subjective findings. Kiese-Himmel et al. (2000) conducted a longitudinal study in Germany on the acceptance of hearing aids in 35 children with bilateral and unilateral sensorineural hearing loss using a standardized parent rating on hearing aid use at four points in time over 30 months. They found that children with UHL wore their aids less than children with bilateral hearing loss. This difference was not seen initially, but became significant at the end of the 30-month study. They also found that children with mild to moderate UHL accepted their hearing aids while children with severe to profound UHL did not.

Kiese-Himmel (2002) conducted another study that looked at 31 children, ages 1-10 years old, with sensorineural UHL. The children were followed audiologically, with a complete hearing evaluation and hearing aid fitting, and psychologically, with nonverbal and verbal cognitive tests. The length of time that the child wore the hearing aid was assessed with a rating scale administered to parents. Based on the daily use reported from the rating scale, they found
81% of subjects with moderately severe or better UHL accepted the use of a hearing aid. Acceptance was considered a rating of satisfactory, meaning the child wore the hearing aid most of the day except for Saturday and Sunday, or higher on the scale. Subjects with a severe or profound UHL reported very little to no hearing aid use.

A study by Davis et al. (2002) used subjective reports from surveys to measure hearing aid benefit for children with mild bilateral hearing loss or unilateral hearing loss. Twenty-seven children with UHL that wore amplification returned the survey. Twenty-six percent reported wearing their hearing aid all the time, 4% reported only wearing it in school, and 50% reported never wearing the hearing aid. The children's parents were also asked to report on their child's ease of listening in quiet and noisy environments. It was found that children who wore hearing aids were judged by the parents to have a greater ease of listening in both quiet and noisy environments.

McKay (2002) gave retrospective surveys to the parents of 20 children, ages 2-17 years, with a moderately severe or better UHL after a hearing aid fitting with a three-month trial period. Results from the surveys showed that 72% of parents felt their child improved or greatly improved in various listening situations after being fit with a hearing aid on the poorer ear. Furthermore, 100% of parents were happy they chose to fit their child with a hearing aid and 50% of parents expressed that they wished a hearing aid were fit sooner.

A recent study by McKay et al. (2007) mailed the Children’s Home Inventory of Listening Difficulties (CHILD) (Anderson & Smaldino, 2000) questionnaire and a questionnaire about hearing aid use, FM use, and special services in school to 243 subjects with UHL between 7 and 12 years of age. Out of the 53 subjects that returned the surveys, 32% of all subjects wore a hearing aid and 46% of subjects with a moderately severe or better UHL wore a hearing aid.
Furthermore, parents reported that 100% of UHL hearing aid users wore their hearing aid at school and 59% wore their hearing aid outside of school. A correlation between hearing aid use and special services was also seen, with 71% of UHL hearing aid users receiving special services at school. Parent reports on the CHILD revealed that that children who wore hearing aids scored poorer than those who did not wear hearing aids.

Overall, it is evident that more research needs to be completed in the area of treatment for pediatric UHL. There is strong support for FM use in children with UHL, however support for use of a conventional hearing aid is still lacking. Almost all of the studies on conventional amplification for UHL only utilized subjective measures, and many of these studies have not yet been published in peer-reviewed journals. To date only one study, Updike (1994), has been published on speech perception measures with conventional hearing aids in children with UHL. This study laid a much-needed foundation in this area, however, several limitations are apparent: only four children were tested, the aid used was analog, the fitting formula and verification were unknown, and no acclimatization period was used. There have been substantial improvements in hearing aids since this study was completed, such as compression technology, output limiting, extended bandwidths, and feedback cancellation. The outcomes of a hearing aid with current technology need to be explored in children with UHL. It is crucial that the fit of the hearing aid be verified using electroacoustic measures. This verification should ideally use a prescriptive formula that has been validated on children, such as the Desired Sensation Level (DSL) (Seewald, Moodie, Scollie, & Bagatto, 2005). Furthermore, studies involving assistive devices, such as hearing aids, must provide the child with an acclimatization period with the hearing aid. Taylor (1997) concluded from a literature review of hearing aid acclimatization in adults that an average of 30 days is required to become accustomed to hearing aids, and this acclimatization
time may be longer in children. In the McKay (2002) study, a three-month hearing aid trial period was given to children with UHL. It is unknown if children with UHL in other previous studies would have benefited from hearing aid use if given an adequate period of acclimatization with the hearing aid. Additionally, when studying the effects of conventional hearing aids on UHL it is important to examine subjects that are considered appropriate candidates for hearing aids, such as mild to moderately severe UHL with usable speech recognition. Using subjects with severe to profound hearing loss, that are expected to receive little to no benefit from conventional amplification, may make benefits in lesser degree UHL unapparent in group data analysis.

In summary, limited objective findings in the literature suggest conventional hearing aids in children with UHL do not enhance speech understanding and may even be detrimental when listening in noise. Subjective findings suggest that children with mild to moderately severe UHL accept hearing aids. Additionally, parents of children with UHL fit with a hearing aid report improvements with the aid at home and are happy they chose amplification for their child. There are substantial gaps in the literature on conventional amplification for pediatric UHL that need to be addressed. Objective measures on a larger number of children with UHL are needed. Subjective measures should be obtained from not only the parent, but also the child and teacher. At this point in time, the question still remains: should children with mild to moderately severe UHL be fit with conventional amplification? The objective of this pilot study was to examine the potential benefits of a conventional hearing aid in children with mild to moderately severe UHL, using speech perception measures and subjective assessments from the child, parent, and teacher.
METHODS

The Institutional Review Board and the Human Studies Committee at Washington University School of Medicine reviewed and approved the research protocol. Informed consent was obtained from all parents of participants in the present study.

Overview

This was a pre- and post-intervention pilot study. Each speech perception testing condition was performed without amplification and after a three-month trial with amplification. Participant, parent, and teacher questionnaires were administered prior to amplification and after a three-month trial with amplification. Participants also answered a series of questions developed about hearing aid use, satisfaction, and personal experiences after the hearing aid fitting.

Study Participants

The recruitment criteria for this study were children between 7 and 12 years of age with a known UHL and no cognitive impairment. Hearing thresholds were <20 dB at 250-8000 Hz in the normal hearing ear and a pure tone average between 20 dB and 70 dB in the ear with hearing loss. The subject age range of 7 to 12 years was chosen to focus on school age children and this range was appropriate for all of the objective and subjective measures implemented. Furthermore, it has been suggested that speech recognition abilities become adult-like between 14-15 years of age (Johnson, 2000). Based on these results, participants 12 years of age and under may exhibit speech recognition abilities that have not yet matured. This may make the
adverse listening conditions more difficult for this age group, especially with only one normal hearing ear.

Participants for this study were 8 children, 6 males and 2 females, ages 7 to 12 years old, with a permanent mild to moderately severe UHL and no cognitive impairment. The participants had hearing thresholds of 20 dB or better at 250-8000 Hz in the normal hearing ear, with the exception of one subject who only met this criterion at 250-3000 Hz. All participants had hearing thresholds worse than 20 dB at four or more consecutive frequencies in the poorer hearing ear. See Table 1 for individual subject information on UHL ear, type, degree, shape, and word recognition score (WRS). Six subjects had normal to high normal IQ scores, while two subjects had low normal IQ scores as measured by the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999). Three of the participants had previous hearing aid experience, and one of those three participants currently wore a hearing aid. For this participant, hearing aid use was discontinued for one month prior to participation in the study. Additionally, one participant was home schooled, and education data was analyzed separately for this participant due to the very different learning environment from the other subjects. See Table 2 for individual subject demographic information.
<table>
<thead>
<tr>
<th></th>
<th>UHL Ear</th>
<th>UHL Type</th>
<th>UHL Degree</th>
<th>UHL Shape</th>
<th>WRS</th>
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<tbody>
<tr>
<td><strong>Subject 1</strong></td>
<td>Left</td>
<td>Conductive</td>
<td>Mild to Moderate</td>
<td>Flat</td>
<td>Slight Difficulty (76-88%)</td>
</tr>
<tr>
<td><strong>Subject 2</strong></td>
<td>Right</td>
<td>Sensorineural</td>
<td>Moderate to Moderately Severe</td>
<td>Flat</td>
<td>Very Poor (&lt;50%)</td>
</tr>
<tr>
<td><strong>Subject 3</strong></td>
<td>Right</td>
<td>Sensorineural</td>
<td>Moderately Severe</td>
<td>Sloping</td>
<td>Slight Difficulty (76-88%)</td>
</tr>
<tr>
<td><strong>Subject 4</strong></td>
<td>Left</td>
<td>Sensorineural</td>
<td>Mild to Moderate</td>
<td>Mid to High Frequency Notch</td>
<td>Normal (90-100%)</td>
</tr>
<tr>
<td><strong>Subject 5</strong></td>
<td>Right</td>
<td>Sensorineural</td>
<td>Mild to Moderate</td>
<td>Flat</td>
<td>Normal (90-100%)</td>
</tr>
<tr>
<td><strong>Subject 6</strong></td>
<td>Left</td>
<td>Sensorineural</td>
<td>Mild to Moderate</td>
<td>Mid-Frequency Loss</td>
<td>Normal (90-100%)</td>
</tr>
<tr>
<td><strong>Subject 7</strong></td>
<td>Right</td>
<td>Mixed</td>
<td>Mild to Severe</td>
<td>Flat to Sloping</td>
<td>Normal (90-100%)</td>
</tr>
<tr>
<td><strong>Subject 8</strong></td>
<td>Right</td>
<td>Mixed</td>
<td>Moderate to Mild</td>
<td>Rising</td>
<td>Slight Difficulty (76-88%)</td>
</tr>
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*Table 1: Subject Audiologic Profiles*
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<tr>
<th></th>
<th>Gender</th>
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<th>IQ</th>
<th>Race</th>
<th>HA Experience</th>
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<td>6</td>
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<tr>
<td>Subject 2</td>
<td>Male</td>
<td>10</td>
<td>4</td>
<td>80</td>
<td>Black</td>
<td>Yes</td>
</tr>
<tr>
<td>Subject 3</td>
<td>Male</td>
<td>10</td>
<td>5</td>
<td>109</td>
<td>White</td>
<td>Yes</td>
</tr>
<tr>
<td>Subject 4</td>
<td>Male</td>
<td>9</td>
<td>4</td>
<td>106</td>
<td>White</td>
<td>No</td>
</tr>
<tr>
<td>Subject 5</td>
<td>Female</td>
<td>10</td>
<td>5</td>
<td>129</td>
<td>White</td>
<td>No</td>
</tr>
<tr>
<td>Subject 6</td>
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<td>12</td>
<td>7</td>
<td>113</td>
<td>White</td>
<td>No</td>
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<tr>
<td>Subject 7</td>
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<td>9</td>
<td>4</td>
<td>98</td>
<td>White</td>
<td>No</td>
</tr>
<tr>
<td>Subject 8</td>
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<td>2</td>
<td>112</td>
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<td>No</td>
</tr>
</tbody>
</table>

*Table 2: Subject Demographic Information*

**Hearing Instrument**

Each child was fit with an Oticon Epoq XW behind the ear (BTE) hearing aid on the poorer ear. One participant was fit with an Epoq Power XW, a power BTE with the same features, to allow for additional gain if the hearing loss worsens. This hearing instrument was chosen to give the participants the widest possible bandwidth. The hearing instrument was set to each participant’s hearing loss and had one program in the omnidirectional microphone mode. The volume control on the hearing instrument was disabled. The hearing aid fitting was verified with both electroacoustic verification using the Audioscan Verifit with DSL 5.0a fitting formula, as well as verification through aided soundfield thresholds and word recognition testing with masking in the better ear. The hearing aids were provided by the Oticon Pediatrics Research Initiative (OPRI). Each participant was allowed to keep the hearing instrument at the end of the study, regardless of amount of benefit reported.

**Test Materials**
Speech perception materials included the Bamford-Kowal-Bench Speech-in-Noise-Test (BKB-SIN) (Etymotic Research, 2005) and the Nonsense Syllable Test (NST) (Edgerton & Danhauer, 1979). The BKB-SIN and NST were chosen to obtain speech perception scores with contextual cues (BKB-SIN) and without contextual cues (NST). The BKB-SIN and NST were also chosen because they have been used successfully with normal hearing school age children and children with hearing impairment (Danhauer, Lewis, & Edgerton, 1985; Etymotic Research, 2005). The BKB-SIN is a speech-in-noise test that uses BKB sentences and a four-talker babble presented at different signal to noise ratios (SNR), decreasing the SNR by 3 dB for each sentence, to determine the participant’s signal to noise ratio loss. The NST is a 25-item speech recognition test that uses an open set of CVCV (consonant vowel consonant vowel) bi-syllables that do not have semantic content in English. Four-talker babble from the BKB-SIN was used as background noise for both the BKB-SIN test, as well as the NST testing in noise.

Subjective assessments of the child’s hearing were from obtained from the participants, their parents, and their teachers. Participant subjective measures included the CHILD Child (Children’s Home Inventory of Listening Difficulties) (Anderson & Smaldino, 2000), LIFE Student (Learning Inventory for Education) (Anderson & Smaldino, 1998), and the HEAR-QL (Hearing Environments And Reflection on Quality of Life Measurement for Children) (Streufert, 2008). The CHILD Child is completed by the child and has 15 situations that measure the child’s communication needs and listening skills in the home. Each situation is rated by the child on a scale of 1 through 8 based on listening difficulty. The highest rating of 8 indicates the child is able to hear every word and understands everything, while the lowest rating of 1 indicates the child is unaware someone is talking and misses the entire message. The LIFE Student is also completed by the child and has 15 questions that identify classroom situations
that are challenging for the child. It is divided into two sections, Classroom Listening and Additional Listening Situations. The Classroom Listening section includes 10 questions and a rating scale of 0 to 10, with 10 being the highest possible score and indicating the listening situation is always easy, and 0 being the lowest possible score and indicating the listening situation is always difficult. The Additional Listening Situations section contains 5 questions and a rating scale of 0 to 20, with 20 being the highest possible score and indicating no listening difficulty. The Classroom Listening and Additional Listening Situations are scored separately and have a total possible score of 100. The HEAR-QL is a hearing-related quality-of-life questionnaire that is completed by the child and includes 26 questions to identify how hearing loss affects the child’s quality of life. The questions are divided into 3 subscales: Environments, Activities, and Feelings. The child answers each question as never, almost never, sometimes, often, or almost always. The score for each section and total score is calculated. Higher scores indicate a higher quality of life.

Teacher subjective measures included the LIFE Teacher (Anderson & Smaldino, 1998) and the SIFTER (Screening Instrument for Targeting Educational Risk) (Anderson & Matkin, 1996). The LIFE Teacher is a questionnaire that is filled out by the teacher and has 16 questions that identify changes in listening and learning behaviors in the classroom after a hearing aid trial. The teacher answers each question by using a scale stating if they agree, disagree, or saw no change. The total appraisal score is then interpreted into a scale of hearing aid benefit. The SIFTER is a questionnaire with 15 items that is completed by the teacher and identifies children at risk for educational failure. The 15 items are divided into 5 sections: academics, attention, communication, class participation, and school behavior. The total of each section is scored and the score indicates if the student received a pass, marginal, or fail for that section.
The parent subjective measure included the CHILD Parent (Anderson & Smaldino, 2000). The CHILD Parent is a questionnaire that is completed by the parent and has 15 situations that measure the child’s communication needs and listening skills in the home. The situations and rating scale are the same as the CHILD Child.

In addition to these questionnaires, the participants answered a list of “Calling Questions” about hearing aid use, satisfaction, and personal experiences that were developed for this study.

**Test Conditions**

All speech perception measures were performed in the soundfield in a double-wall sound-treated booth using a GSI-61 audiometer. The BKB-SIN, NST, and four-talker babble were calibrated using a sound level meter with the microphone positioned at ear level, 1.0 meter from the speakers. Calibration was conducted with a B&K 2230 sound level meter with a B&K 4155 half-inch microphone using A weighting, RMS detector, and slow time weighting.

The subject was placed in the center of the booth, facing 0 degrees azimuth for all speech perception testing. Two speakers were located 45 degrees from the midline, one meter to the left and one meter to the right of the subject. Speech in quiet was evaluated using the NST delivered through the speaker on the side of the good ear (monaural direct, MD) and then through the speaker on the side of the poorer ear (monaural indirect, MI). Speech in noise testing using the BKB-SIN and the NST was evaluated in the MD condition (speech to the good ear and noise to the poorer ear) and MI condition (speech to the poorer ear and noise to the good ear).

Speech perception measures were performed using the split track 1 version of the BKB-SIN to enable the signal to be presented from separate speakers in order to test in the MD and MI conditions. A 65 dB SPL signal was used to represent average speech level. Both audiometer
attenuators were set to 65 dB SPL to maintain the same automatic signal to noise ratio changes, from +21 dB down to -6 dB, as on the standard recording. The subjects responded by repeating each sentence presented. Two list pairs were used in each condition and the list pairs were averaged and scored. Scores were then converted to dB SNR Loss for each condition as indicated in the BKB-SIN manual.

The NST was performed in quiet (65 dB SPL) and in the presence of four-talker babble background noise at a set +6 dB SNR (signal at 65 dB SPL & noise at 59 dB SPL) to simulate a classroom environment. A two-channel audiometer was used to deliver the signal and the noise. Testing was performed in the MD and MI conditions in both quiet and noise. The subjects responded by repeating each word presented. One list (100 phonemes) was used in each condition and was scored by percent of correct phonemes.

Procedures

The participants were asked to make four separate visits for this study. The first visit consisted of a complete audiogram, tympanometry, an ear mold impression, and pre-amplification speech perception and subjective measures evaluation. The teacher subjective questionnaire was mailed to the child’s teacher between the first and second visit.

The second visit was scheduled one month following the first visit. This visit consisted of the hearing aid fitting, electroacoustic verification of the hearing aid using the Audioscan Verifit, aided soundfield thresholds and word recognition testing with the better ear masked, and hearing aid orientation and counseling. The list of “Calling Questions,” developed about hearing aid use, satisfaction, and experiences, were given to each participant by telephone at 2, 4, 8, and 12-weeks after the hearing aid fitting.
The third visit was scheduled one month after the second appointment. This visit consisted of hearing aid adjustments and additional counseling.

The fourth visit was scheduled at least three months after the second visit to allow for a minimum of a three-month hearing aid trial. This visit consisted of post-amplification aided speech perception measures and subjective measures evaluation. These measures were the same measures obtained at visit one, but with the hearing aid. The subjective questionnaires from the teacher were obtained by mail after at least three months of participant hearing aid use.

**RESULTS**

*Data Analysis*

Statistical significance was examined using the SPSS (Version 17.0) software. Paired two-tailed t-tests were performed to determine statistical significance between pre- and post-measures (Table 3). P values less than .05 were considered significant. Items found significant are noted in the figures with an asterix (*). Additional qualitative analysis of subjective data was also performed.
<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Pre Avg.</th>
<th>Post Avg.</th>
<th>Difference</th>
<th>SD</th>
<th>Paired T Value</th>
<th>DF</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BKB-SIN MD</td>
<td>8</td>
<td>-5.53</td>
<td>-6.47</td>
<td>-.944</td>
<td>1.34</td>
<td>-1.99</td>
<td>7</td>
<td>.086</td>
</tr>
<tr>
<td>BKB-SIN MI</td>
<td>8</td>
<td>-3.03</td>
<td>-4.59</td>
<td>-1.56</td>
<td>2.33</td>
<td>-1.90</td>
<td>7</td>
<td>.099</td>
</tr>
<tr>
<td>NST MD Quiet</td>
<td>8</td>
<td>85.1</td>
<td>85.1</td>
<td>.000</td>
<td>5.04</td>
<td>.000</td>
<td>7</td>
<td>1.00</td>
</tr>
<tr>
<td>NST MD Noise</td>
<td>8</td>
<td>84.3</td>
<td>81.9</td>
<td>-2.38</td>
<td>3.58</td>
<td>-1.88</td>
<td>7</td>
<td>.103</td>
</tr>
<tr>
<td>NST MI Quiet</td>
<td>8</td>
<td>82.1</td>
<td>83.4</td>
<td>1.25</td>
<td>5.78</td>
<td>.612</td>
<td>7</td>
<td>.560</td>
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<td>NST MI Noise</td>
<td>8</td>
<td>81.6</td>
<td>78.3</td>
<td>-3.38</td>
<td>4.81</td>
<td>-1.99</td>
<td>7</td>
<td>.088</td>
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<td>CHILD Child</td>
<td>8</td>
<td>5.74</td>
<td>6.99</td>
<td>1.25</td>
<td>.667</td>
<td>5.30</td>
<td>7</td>
<td>.001</td>
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<tr>
<td>CHILD Parent</td>
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<td>5.38</td>
<td>6.56</td>
<td>1.18</td>
<td>.868</td>
<td>3.83</td>
<td>7</td>
<td>.006</td>
</tr>
<tr>
<td>LIFE Student Classroom Listening</td>
<td>7</td>
<td>65.1</td>
<td>81.3</td>
<td>16.1</td>
<td>12.9</td>
<td>3.32</td>
<td>6</td>
<td>.016</td>
</tr>
<tr>
<td>LIFE Student Additional Situations</td>
<td>7</td>
<td>57.9</td>
<td>78.6</td>
<td>20.7</td>
<td>8.86</td>
<td>6.18</td>
<td>6</td>
<td>.001</td>
</tr>
<tr>
<td>HEAR-QL</td>
<td>7</td>
<td>66.6</td>
<td>86.7</td>
<td>20.1</td>
<td>10.5</td>
<td>5.06</td>
<td>6</td>
<td>.002</td>
</tr>
</tbody>
</table>

Table 3: Pre and Post Hearing Aid Two Tail T-Test Statistical Values

**BKB-SIN Results**

Pre and Post hearing aid average SNR loss scores for the BKB-SIN MD and MI conditions can be seen in Figure 1 and Figure 2, respectively. Each line shown in Figures 1 and 2 refers to an individual subject and the bold black line refers to the average across subjects. Scores are shown in dB SNR loss. A better result is a more negative dB SNR loss, indicating an ability to recognize a signal in louder background noise. A SNR loss of 0-3 dB is interpreted as
normal for adults and interpretations are not given for children because the effects of SNR loss are more pronounced and variable. No statistically significant increase or decrease in the group average score was seen on the BKB-SIN in any condition (Table 3). Inspection of individual cases revealed that six of the eight children showed an increase of scores (i.e. lower SNR loss) on both the BKB-SIN MD and MI conditions that ranged from 0.75 to 2.3 dB and 0.5 to 4.5 dB, respectively.

![BKB SIN: Monaural Direct SNR Loss](image)

*Figure 1: BKB-SIN MD Pre and Post SNR Loss*
Figure 2: BKB-SIN MI Pre and Post SNR Loss

NST Results

Pre and Post hearing aid average scores for the NST can be seen in Figures 3 through 6 for the MD Quiet, MI Quiet, MD Noise, and MI Noise conditions, respectively. Each line shown in Figures 3-6 refers to an individual subject and the bold black line refers to the average across subjects. Scores are shown in percent of phonemes correct, with 100% as the highest possible score. No significant increase or decrease in the group average score was seen on the NST in any condition (Table 3).
Figure 3: NST MD Quiet Pre and Post Phoneme Scores

Figure 4: NST MI Quiet Pre and Post Phoneme Scores
Figure 5: NST MD Noise Pre and Post Phoneme Scores

Figure 6: NST MI Noise Pre and Post Phoneme Scores
**CHILD Results**

Pre and Post hearing aid group average scores and average individual question scores for the Child CHILD can be seen in Figure 7 and the Parent CHILD are shown in Figure 8. The rating scale ranges from 1 to 8, with 8 being the highest possible score and indicating no listening difficulty. A statistically significant improvement in the group average post hearing aid score was found on both the Child CHILD and the Parent CHILD (Table 3).

Additional analysis of the average individual questions on the Child CHILD showed a statistically significant increase in post hearing aid scores on 8 of 15 questions (Question # 2, 5-6, 8-9, 12-14) (Appendix A). A significant increase in the average post hearing aid scores was also observed on 10 of 15 questions on the Parent CHILD (Question # 2, 5-7, 9-14) (Appendix B). Questions with significant differences in the pre- and post-hearing aid evaluations are marked with an asterix (*) on the figures.

![CHILD Child Ratings](image)

**Figure 7: CHILD Child Pre and Post Scores**
**LIFE Results**

Pre and Post hearing aid group average total scores for the Student LIFE are shown in Figure 9. The rating scale on the Classroom Listening section ranges from 0 to 10, with 10 being the highest possible score and indicating no listening difficulty. The rating scale for the Additional Listening Situations section ranges from 0 to 20, with 20 being the highest possible score and indicating no listening difficulty. Statistically significant improvements in the group average post hearing aid scores were observed on the Student LIFE for the section pertaining to Classroom Listening, as well as for the section pertaining to Additional School Listening Situations (Table 3).
Pre and Post hearing aid average scores for individual questions on the Student LIFE Classroom Listening and Additional School Listening Situations are shown in Figures 10 and 11, respectively. Questions with significant differences in the pre- and post-hearing aid evaluations are marked with an asterix (*) on the figures. Further analysis of the group average on individual questions on the Student LIFE showed a statistically significant improvement on 1 of 10 classroom listening questions (Question # 2) (Appendix C) and on 2 of 5 additional situations questions (Question # 11 and 13) (Appendix D).
Figure 10: LIFE Student Pre and Post Classroom Listening Scores

Figure 11: LIFE Student Pre and Post Classroom Listening Scores
The LIFE Teacher, a post intervention only test, revealed half of the subjects’ teachers found hearing aid use to be beneficial or highly beneficial. Three of the subjects’ teachers saw no change and none of the teachers reported a negative change from the hearing aid (Table 4). Subject 1 was not included because the questionnaire was not returned.

<table>
<thead>
<tr>
<th>Appraisal Score Interpretation</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Support for Positive Change: Use is Highly Beneficial</td>
<td>2</td>
</tr>
<tr>
<td>Support for Positive Change: Use is Beneficial</td>
<td>2</td>
</tr>
<tr>
<td>No Change: Benefit of Use Note Identified</td>
<td>3</td>
</tr>
<tr>
<td>Support for Negative Change: Use is Unfavorable</td>
<td>0</td>
</tr>
<tr>
<td>Strong Support for Negative Change: Use is Highly Unfavorable</td>
<td>0</td>
</tr>
</tbody>
</table>

*Table 4: LIFE Teacher Post Hearing Aid Appraisal Score Interpretation*

*SIFTER Results*

The SIFTER results were grouped by subject IQ. Subject 8 was not included because he was home-schooled, and Subject 1 was not included because the post hearing aid questionnaire was not returned. The SIFTER results showed no significant increase or decrease in group scores with the hearing aid (Table 5).
<table>
<thead>
<tr>
<th></th>
<th>Average or Higher IQ Subjects (n=5)</th>
<th>Low Average IQ Subjects (n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academics</td>
<td>Pre Pass (11.8) Fail (6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Pass (11.6) Fail (6)</td>
<td></td>
</tr>
<tr>
<td>Attention</td>
<td>Pre Pass (10.8) Fail (3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Pass (10.4) Fail (6)</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>Pre Pass (11.6) Fail (6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Pass (11.4) Fail (7)</td>
<td></td>
</tr>
<tr>
<td>Class Participation</td>
<td>Pre Pass (11.2) Marginal (7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Pass (11.8) Fail (6)</td>
<td></td>
</tr>
<tr>
<td>Social Behavior</td>
<td>Pre Pass (12.6) Fail (5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Pass (12.4) Fail (5)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: SIFTER Pre and Post Hearing Aid Scores Grouped by IQ

**HEAR QL Results**

Pre and Post hearing aid group average total scores and group average subscale scores for the HEAR-QL are shown in Figure 12. Total or subscale scores that were significant after hearing aid use are marked with an asterisk (*) on the figures. Higher scores indicate a high quality of life. A statistically significant improvement in the group average total post hearing aid score was seen on the HEAR-QL (Table 3). Further analysis of each subscale of the HEAR-QL showed a statistically significant improvement on the Environments subscale (Appendix E).
Data Logging

Data logging from 7 of the 8 subjects hearing aids is shown in Table 6. One subject’s hearing aid broke and data logging could not be recovered. Over a 3-4 month trial period the average daily use across the 7 subjects was 5.1 hours per day with a range of 0.7 to 9.4 hours per day.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Hours/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>N/A</td>
</tr>
<tr>
<td>Subject 2</td>
<td>6.4</td>
</tr>
<tr>
<td>Subject 3</td>
<td>0.7</td>
</tr>
<tr>
<td>Subject 4</td>
<td>2.2</td>
</tr>
<tr>
<td>Subject 5</td>
<td>9.4</td>
</tr>
<tr>
<td>Subject 6</td>
<td>3.7</td>
</tr>
<tr>
<td>Subject 7</td>
<td>5.5</td>
</tr>
<tr>
<td>Subject 8</td>
<td>7.5</td>
</tr>
<tr>
<td>Average (n=7)</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Table 6: Data Logging by Subject (3-4 month trial)
Calling Questions

Qualitative analysis was performed on the calling questions created for this study and asked at 2, 4, 8, and 12-week intervals after the hearing aid fitting. Results from hearing aid use questions revealed 75% of subjects reported consistently wearing their hearing aid at school, 50% reported consistently wearing their hearing aid at home, 50% reported wearing their hearing aid while playing with friends outside of school, and 25% of subjects reported wearing their hearing aid on the weekend. More than half of the subjects reported consistently wearing their hearing aid during sports, gym, and/or recess.

The hearing aid satisfaction results showed that all participants reported benefit with the hearing aid in more than one situation when responding to the open ended question: Are there situations you have noticed the hearing aid has helped you hear better? All situations where improvement was reported are shown in Table 7. The situations that were reported by the subjects are shown in the table below.

<table>
<thead>
<tr>
<th>Improved Aided Listening Situation</th>
<th># of Subjects that Reported Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing the Teacher</td>
<td>7</td>
</tr>
<tr>
<td>Hearing Classmates</td>
<td>7</td>
</tr>
<tr>
<td>Hearing in Noise</td>
<td>6</td>
</tr>
<tr>
<td>Hearing from a Distance</td>
<td>5</td>
</tr>
<tr>
<td>Hearing Friends</td>
<td>3</td>
</tr>
<tr>
<td>Hearing Quiet Classmates</td>
<td>2</td>
</tr>
<tr>
<td>Hearing Conversations in the Cafeteria</td>
<td>2</td>
</tr>
<tr>
<td>Hearing Conversations at Home</td>
<td>2</td>
</tr>
<tr>
<td>Hearing the TV</td>
<td>2</td>
</tr>
<tr>
<td>Hearing Speaker at School Assembly</td>
<td>1</td>
</tr>
<tr>
<td>Hearing During Gym/Recess</td>
<td>1</td>
</tr>
<tr>
<td>Hearing While Playing Sports</td>
<td>1</td>
</tr>
<tr>
<td>Hearing When People Whisper</td>
<td>1</td>
</tr>
<tr>
<td>Hearing Multiple Conversations</td>
<td>1</td>
</tr>
<tr>
<td>Hearing Male Voices</td>
<td>1</td>
</tr>
<tr>
<td>Sound Localization</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7: Subject Reported Improved Aided Listening Situations. Reports Obtained through open-ended questions
mentioned by the largest number subjects include improvements in hearing their teacher (88%),
their classmates (88%), in noise (75%), and from a distance (63%). When asked if there were
situations that they heard worse with the hearing aid, 75% of subjects reported that there were no
situations in which they heard worse with the hearing aid. Two subjects reported one situation
that they heard worse with the hearing aid. One subject reported hearing worse in the cafeteria
and the other reported it was harder to hear his younger sisters.

The personal questions asked about the hearing aid revealed that only 25% of subjects
reported not liking the hearing aid during the trial. Furthermore, 25% of subjects reported being
made fun of for wearing the hearing aid, and one subject reported being embarrassed to wear the
hearing aid. All of the participants reported that people did treat them or speak to them
differently when they were wearing the hearing aid.

Subject specific comments that support benefits of hearing aid use were made by all eight
participants and can be seen in Appendix F. Additionally, subject-specific negative comments
were made by three subjects and can be seen in Appendix G.

Parent Comments

Throughout the hearing aid trial, 75% of parents made at least one comment about
improvements they saw with the hearing aid. Comments were voluntary and no question was
asked. Specific parent comments that support benefits of hearing aid use can be seen in
Appendix H. None of the parents voiced negative comments about the hearing aid.
DISCUSSION

The main purpose of this study was to examine the effects of hearing aids for children with mild to moderately severe UHL. Pre- and post-amplification speech perception measures in quiet and in noise were examined in the MD, signal towards the good ear, and MI, signal towards the poorer ear, conditions. Additionally, pre- and post-amplification subjective assessments were obtained from the child, parent, and teacher.

Group average speech perception results revealed no significant increase or decrease in speech perception scores in any condition for the BKB-SIN and NST. These results, obtained on children with mild to moderately severe hearing loss using conventional hearing aids, are in contrast to results obtained by Kenworthy, Klee, and Tharpe (1990). They demonstrated that speech recognition decreased in the MD condition with a CROS hearing aid for children with severe to profound UHL. Results from the current study revealed speech perception performance with a conventional hearing aid on the poorer ear does not decrease in the MD condition. Unlike the current study, Updike (2004) found a significant improvement in speech perception scores in quiet with the hearing aid in two subjects, a decrease in one subject, and no change in one subject. In noise, the study found a decrease in performance in only one subject and the remaining three subjects showed no significant change. While the group averages in the present study showed no differences in noise, inspection of individual cases revealed that six of the eight children increased scores (i.e. lower SNR loss) on both the BKB-SIN MD and MI conditions that ranged from 0.75 to 2.3 dB and 0.5 to 4.5 dB, respectively. The individual results from the NST in noise in both the MD and MI condition show little to no change with six of the eight subjects having a change in score of four phonemes or less (i.e. one word), and two
subjects scoring worse. The results of this study support an overall trend towards better performance in noise for the majority of subjects on the BKB–SIN, a test that may be considered more representative of real world listening conditions compared to the NST. Updike (2004) concluded that use of a conventional hearing aid had detrimental effects, particularly in a noisy environment. The present study revealed that on average, the fitting of a conventional hearing aid on children with UHL provided no significant improvement or detriment to speech perception scores in quiet or in noise; however, scores varied across individuals, with a trend towards improved scores in noise found in the majority of the children.

Although no significant changes were seen for speech perception scores, subjective findings from the present study revealed that the majority of children and their parents reported benefits for a variety of listening environments. Statistically significant improvements in the group average post-hearing aid scores were seen on both the Child CHILD and the Parent CHILD. Additionally, significant improvements were seen on 8 out of 15 questions on the Child CHILD and on 10 out of 15 on the Parent CHILD. The improvements seen on the Parent CHILD are in agreement with McKay (2002) who found that 72% of parents felt their child improved or greatly improved in various listening situations after a 3-month hearing aid trial. Results from the CHILD questionnaire suggest hearing aid use at home was beneficial for children with UHL, and benefits were apparent to both the child and the parent.

Statistically significant improvements in the average post hearing aid scores were seen on the Student LIFE for the Classroom Situations section, as well as the Additional School Listening Situations section. Results suggest a conventional hearing aid provided benefit in the classroom and in other difficult listening situations encountered at school, and the benefits were apparent to the student. The LIFE Teacher, a post-intervention only test, revealed that half of the
subjects’ teachers found hearing aid use to be beneficial or highly beneficial. None of the teachers reported a negative change from the hearing aid, suggesting the use of conventional hearing aid had no evident detriment in the classroom for children with UHL. The SIFTER results from the teacher did not show a significant increase or decrease in scores with the hearing aid and suggest that the fitting of a hearing aid alone was not enough to produce major academic changes, such as making a child that was at risk for educational failure no longer be at risk and vice versa. Results from the teacher questionnaires suggest some UHL students demonstrated benefits in the classroom from a hearing aid that were recognized by their teacher, while others had no recognizable changes. Overall, the findings from the student and teacher questionnaires suggest that children with UHL may demonstrate benefits in the classroom from the use of a conventional hearing aid, and benefits apparent to the student may or may not be recognized by the teacher.

The results from the HEAR-QL showed a significant increase in the group average total quality of life score post-hearing aid. Additionally, a significant improvement was observed in the group average on the Environments subscale. Recent studies have shown children with UHL reported lower total quality of life and psychosocial functioning than their normal hearing peers (Borton, Mauze, & Lieu, (in press); Streufert, 2008). The results from the present study show that the fitting of a hearing aid may improve this lower quality of life seen in children with UHL. Furthermore, the results support exploring treatment options for these children, not only to give them the most access to sound as possible, but also to help improve their quality of life.

Data logging from the hearing aids of seven subjects showed hearing aid use varied across subjects from less than one hour to over nine hours of use per day. Four of the seven subjects used the hearing aid six hours or more hours per day over a three to four month period,
which is lower than previous findings. Kiese-Himmel (2002) found 81% of subjects with moderately severe or better UHL accepted the use of a hearing aid based on the daily time the child was using the aid. Acceptance was based on parent report that the child wore the hearing aid most of the day, except for Saturday and Sunday. The higher acceptance rate in the Kiese-Himmel (2002) study based on parent report, compared to the present study based on data logging, may be attributed to parental reports overestimating their child’s hearing aid use or to the subject age. The subjects in the Kiese-Himmel (2002) study were slightly younger than the subjects in the present study, suggesting the age of the hearing aid fitting may be a factor in hearing aid acceptance. The variance in daily use found in the present study suggests hearing aid acceptance is different for each child. Further research with a larger sample size is needed to draw conclusions between type, degree, and configuration of UHL and hearing aid acceptance. Additionally, the age of the hearing aid fitting may affect hearing aid acceptance.

Although results from the CHILD and LIFE questionnaires suggest hearing aid use is beneficial at home and at school, the data on hearing aid use at home and at school from the “Calling Questions” and data logging provide additional insight into the acceptance of these hearing aids. Subjective data from all 8 children revealed 75% of subjects reported consistently wearing their hearing aid at school, while only 50% reported consistently wearing their hearing aid at home. These results are lower than data reported by the children’s parents in McKay (2007) who found 100% of UHL users wore their hearing aid in school and only 59% wore their hearing aid outside of school. This difference may be due to child reports and a smaller sample size in the current study versus parent reports and a larger sample size in the McKay study. The current results agree with McKay in that UHL hearing aid use at school is reported higher than hearing aid use at home.
Data from the hearing aid data logging suggests lower usage at home and in school than the children reported in the “Calling Questions.” Data logging showed that 4 of the 7 subjects (57%) with data logging wore their hearing aid 6 hours or more hours per day. The average school day is about 6.5 hours, which suggests 57% of subjects wore the hearing aid for most of the school day, while the remaining 43% of subjects did not wear their hearing aid for the entire school day. Additionally, data logging showed only 2 of the 7 subjects wore their hearing aid more than seven hours per day, suggesting the remaining 5 subjects had little to no hearing aid use at home. It is important to note that in the “Calling Questions” only 25% of subjects reported wearing their hearing aid on the weekends. The data logging divides the total number of days by the total number of hours the hearing aid is on to get a daily average. This means the data logging reflects weekday and weekend use, as well as use during the subjects’ winter break. This may make hearing aid usage at school and at home on weekdays appear lower in the data logging. The higher amount of hearing aid use at school, despite significant benefits seen at home, may be attributed to the demands of the listening environment and the expectations associated with that listening environment. The listening environments at school are demanding, and the children may perceive expectations to work hard and perform well in school. The listening environment at home is often less demanding, and time at home and on the weekends may be associated with a time for recreation, rather than work. Even though hearing aid use at home and on the weekends was found to be lower than hearing aid use at school, significant improvements observed with the hearing aid on the Child CHILD, Parent CHILD, and the HEAR-QL are evidence of benefit outside of school. It is important to recognize that hearing aid benefits are not just seen in the classroom and the recommendation of a hearing aid only during school may be a disservice for these children. Furthermore, the recommendation of an FM
system alone may help the child at school, but it will not improve the child’s listening abilities or quality of life outside the classroom. Therefore, the recommendation of a hearing aid, in addition to an FM system, should be considered.

Overall, most of the subjects reported higher amounts of hearing aid use in the subjective “Calling Questions” than the usage recorded from data logging. This suggests subjective reports may overestimate hearing aid use and objective data, such as data logging, are important to collect to obtain accurate measures of hearing aid use. Results from the data logging and “Calling Questions” suggest the majority of subjects are consistently wearing their hearing aid most of the school day, but hearing aid use was less consistent at home and on weekends. Although hearing aid use at home was lower than at school, results from the Child CHILD, Parent CHILD, and the HEAR-QL showed significant hearing aid benefit at home, and the recommendation of a hearing aid only in school, or an FM system alone, may be a disservice for these children.

The benefits noted by the children from the open ended “Calling Questions” were not found to be statistically significant; however, it is noteworthy that each child reported more than one situation that they found the hearing aid beneficial. Through the individual comments, it is apparent that specific benefits varied by individual subject. Common benefits included improvements in hearing their teacher, hearing their classmates, hearing in noise, and hearing from a distance. It is important to note that only two subjects reported a situation where they heard worse with the hearing aid, suggesting few detrimental effects from conventional amplification on children with UHL. Negative comments made about the hearing aid focused on a dislike of wearing something in the ear, rather than a decrease in understanding. It is also worth mentioning that two of the three subjects who made a negative comment about the hearing
aid had the lowest hours of daily use in data logging, while the subject who made the most comments about hearing aid benefits had the highest hours of use in data logging. It is unclear if more benefit was perceived because the hearing aid was being worn more, or if the hearing aid was being worn more because more benefit was being perceived. Results from the “Calling Questions” suggest that conventional hearing aids provided a wide range of benefits that differed for each child, with common benefits including improvements in understanding of the teacher, understanding classmates, listening in noise, and hearing from a difference. Negative comments during the hearing aid trial gave little to no support for detriment caused by the hearing aid. A trend was seen between perceived benefit and daily hearing aid use.

Since this was a pilot study, the main limitations were a small sample size and no control subjects. Although the sample size included only 8 subjects, to date this is the largest study of conventional hearing aids in children with UHL that obtained objective pre- and post- speech perception data. Furthermore, this is the first study that looked at the whole child using pre- and post-hearing aid subjective assessments from the child, parent, and teacher to analyze treatment outcomes.

Future research on the outcomes of conventional hearing aids for children with UHL is needed. Studies with a larger sample size, and varied types, degrees, and configurations of hearing loss are crucial for drawing conclusions on which children with UHL benefit from a hearing aid. Additional objective pre and post measures, using speech perception measures that more accurately reflect real world listening environments are needed. In future studies these children need to be tested using various types of noise, talkers, and signal levels. Research investigating sound localization abilities with and without conventional amplification is another very important area that needs to be addressed, especially because the difficulties children with
UHL have with sound localization pose a threat to their safety. Additional research looking at the affects of a hearing aid alone, FM alone, and hearing aid and FM would provide significant information for treatment decisions for children with UHL.

**CONCLUSION**

This pilot study reported the outcomes of a conventional hearing aid on children with mild to moderately severe UHL. We concluded that the fitting of a conventional hearing aid on children with UHL, on average, revealed no significant benefit or detriment on speech perception scores in any condition. However, inspection of individual data from sentence testing in noise, in the MD and MI conditions, revealed that the majority of the children showed a trend for improved results. Results from the child, parent, and teacher questionnaires suggest children with UHL experience significant benefits from a hearing aid at home, at school, and in their quality of life. Based on the significant benefits shown by the questionnaires, combined with no significant support for detrimental effects, we concluded that a hearing aid trial should be considered for children with mild to moderately severe UHL. Each child with UHL is different, as evidenced by variances in performance, daily hearing aid usage, and patient reports, and should be monitored for benefit on an individual basis during the hearing aid trial.
REFERENCES


### Appendix A: CHILD Child Two Tail T-Test Statistical Values by Question

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<td>In class it helps me hear my teacher and classmates because sometimes I mishear them.</td>
</tr>
<tr>
<td>3</td>
<td>I don’t have to ask people to repeat as much. I can hear the teacher better in class. I can hear better in noise, but it is still more difficult to hear than in quiet.</td>
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<td>It helps me hear my English and Math teacher better. It also helps me hear my science teacher. They talk more quiet than my homeroom teacher.</td>
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<td>5</td>
<td>I have been hearing more and remembering more in some subjects, so I have been raising my hand more because I know the answers more. I used to have to ask a friend sometimes what the teacher or classmate said and now I don’t have to as much.</td>
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<td>In soccer my teammates are calling my name from across the field and it used to be hard to hear and understand who they were calling because a lot of names sound like my name. With the hearing aid I can hear them call my name clearly and where the sound is coming from. It was also harder knowing where sounds were coming from during soccer before.</td>
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<td>Whenever I am in class and other kids are talking quiet or answering a question or telling a story I can hear them better with the hearing aid. It is easier to hear the teacher over the sound of the overhead. It is also easier to hear the teacher talk when other kids are talking.</td>
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<td>I like that it helps me hear. I hear things I never heard before. I like everything about it.</td>
</tr>
<tr>
<td>6</td>
<td>I can hear sounds I never heard before. It makes listening easier. I like that it helps me hear better and I don’t have to ask “What’d you say?” and “Huh?” and “I can’t hear you” anymore.</td>
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<td>I have noticed a difference and it has helped. I can tell the difference when I put it on. I can hear 1 to 2 notches up.</td>
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<td>It helps me with low voices. It helps me hear my dad and uncle.</td>
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<td>2</td>
<td>The hearing aid doesn’t bother me at school, but it does at home because I lay on my ear when I watch TV. Most things sound the same if it is in or out.</td>
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<td>3</td>
<td>It gets kind of annoying to have to wear it sometimes. It is comfortable, but weird having something in my ear.</td>
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<td>I don’t really want to wear it anymore. It is annoying to remember before school.</td>
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### Appendix H: Parent Comments Supporting Beneficial Hearing Aid Use

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<td>When he did not have his hearing aid on a few weeks ago in church I tried to tell him a friend was here on his poorer side and he did not even know I was talking to him. He had to turn all the way around, so his good ear faced me, for him to hear. Also, without the hearing aid he misunderstands words. His word comprehension is better with the hearing aid.</td>
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<td>4</td>
<td>Mom</td>
<td>He has definitely been hearing better.</td>
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<td>5</td>
<td>Mom</td>
<td>She is hearing things she has never heard before. She wants to wear it constantly. At parent teacher conferences the teacher said she is participating more and has been more outgoing in class since she has been wearing the hearing aid.</td>
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<td>Mom</td>
<td>I noticed a big difference when he is watching TV. He does not listen to it as loud and I can tell if he has it in or not by how loud the TV volume is. I also noticed a big difference for hearing conversations in the car when he is in the back seat. I never thought it would make a big difference, but it is so many different little things. He is doing really great with it.</td>
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<td>Mom</td>
<td>We thought her hearing loss was so miniscule, why bother participate in the study? But, we have noticed a big difference. Not just in noise, but in everyday conversation we don’t have to repeat ourselves fifty times. It also helps when she is across the room. She also notices a big difference and plans on continuing to wear the hearing aid after the study.</td>
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<td></td>
<td>Dad</td>
<td>She hears better at home. Before we would say her nickname and she would not respond for 3-4 times. Now she responds on the first time. She seems to hear better when we call from a distance. She definitely picks up on more subtle things from a distance.</td>
</tr>
<tr>
<td>8</td>
<td>Dad</td>
<td>I see a difference. When his hearing aid isn’t in he says “huh” and “what” much more than when his hearing aid is in. He is also not watching TV as loud.</td>
</tr>
</tbody>
</table>