DEAF IS NO LONGER DEAF

THE HEAR AND SAY CENTRE FOR DEAF CHILDREN SUBMISSION TO

AUSTRALIAN SENATE COMMUNITY AFFAIRS INQUIRY INTO HEARING HEALTH IN AUSTRALIA

Background

Hear and Say is an early intervention centre for children with hearing loss. We believe that listening and spoken language is the birthright of all children. Neuroscience and research is providing the evidence to support the fact that hearing loss in newborn children is a neurological emergency. The Federal Government commitment to implementing Universal Newborn Hearing Screening across Australia acknowledges the urgent nature of hearing loss in children however the existing state of early intervention services is less than adequate. With the advancement of technology and therapy techniques there is now an urgent obligation to provide early intervention and support to address speech and language development in these children to allow these children to reach their full potential.

In 2009, with available technology and utilising Auditory-Verbal techniques, deaf is no longer deaf and the traditional definition and treatment of hearing loss in children needs to bemodernized. The dilemma facing the Australian community is that information and resources are extremely limited, and consequently those service providers in the field are unable to meet the growing demand. This means that children who have the potential to listen and speak and integrate seamlessly into the wider hearing community are being forced to live a life of isolation and exclusion.

In order that the Australian government is able to address the devastating effects of hearing loss in the community and enable evidence-based, informed parental choice regarding contemporary communication options there is an ethical requirement for Australian health policy to set listening and spoken language as the benchmark and first preference for the majority of parents of children with hearing loss. This progressive approach to the definition and treatment of hearing loss will significantly improve economic, community, family and individual outcomes for the nation and position Australia as a world leader in the area of hearing health practices.

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Hearing Impairment in Queensland

The World Health Organisation identifies hearing loss as the most common disability in newborn children[1] and Australian Hearing evidence supports that this is also of significant concern for the Australian and Queensland population. In 2007, 61,249[2] children were born in Queensland, based on Australian Hearing (AH) data 1,852[3] children under the age of 21 were fitted for the first time with hearing aids with 379 of those being from QLD and 202 aged 6 or under. This figure compares to a potential rate of hearing loss in new births of 1.2 – 2.5[4] in 1000 or 73 -153 children. It is expected that these circumstances are similar across Australia. Hearing loss is caused by both genetic and environmental factors and, as a result, the incidence of hearing loss is relatively easy to predict, and, in developed countries, is generally based on the birth rate of the population in question.

There has been fairly extensive research into the costs of hearing loss to the community with ACCESS Economics calculating the real financial costs to the Australian economy in 2005 as $11.75 billion[5] with an additional $11.3 billion in quality of life costs. This significant burden to the Australian community quantifies the economic costs however does not reflect on the devastating effect that untreated hearing loss has on individuals and their families. The isolating nature of deafness not only reduces life choices for the effected individual, but also often leads to other health issues such as mental health problems.

Comment: ***Removing the handicapping nature of hearing loss by enabling age appropriate listening and spoken language outcomes provides an economic and qualitative benefit to the individual and the wider community. Due to the etiology of hearing loss (ie linkage to birth rates and known incidences of acquired hearing loss) the budget required to address this issue is finite and can be reasonably well estimated.***

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[1] World Health Organisation Fact sheet 2005
2 Australian Bureau of Statistics, BIRTHS, QUEENSLAND, 2007, Cat No 1318.3 - Qld Stats, Nov 2008
3 Australian Hearing, Report on Demographics of Persons under the age of 21 years with Hearing Aids - 2009
4Australian Hearing in ACCESS Economics Listen Hear! The economic impact and cost of hearing loss in Australia – Feb 2006 (p. 29)

[5] ACCESS Economics Listen Hear! The economic impact and cost of hearing loss in Australia – Feb 2006 (p. 67)

Access to Hearing Services

Early diagnosis is only the first step in addressing the issue of hearing loss. To remove the handicapping affects of deafness, speedy access to hearing technology and early intervention that promotes listening and spoken language is essential. This approach must be promoted as best practice and accordingly reflected in Australian hearing health policy.

Bilateral cochlear implantation is becoming the acceptable norm for those children who meet the stringent candidacy criteria. There still exists an inequality between public and private access to bilateral cochlear implants. Many children who would benefit significantly from bilateral cochlear implantation do not have access to this option due to lack of government funding.

The vast geographic expanses of the Australian landscape means that face-to-face services are unable to be provided in all locations. With the advent of web based and tele-medicine / tele-health technology, there is now the opportunity for allied health professionals to overcome the tyranny of distance and provide much needed services into these locations remotely. This type of service provision needs additional funding to be acknowledged and validated as an alternative option. Without further validation and government recognition of the viability of these methods, services providers will not be motivated to deliver services in these rural and remote localities despite the obvious economic and community benefits.

The fact that there is only a small window of opportunity to develop listening and spoken language due to the brain's neuro-plasticity is well supported by research evidence and highlights the urgency of accessing hearing technology and listening and spoken language early intervention services. As over 95% of children with hearing loss are born to parents with 'normal' hearing and who use listening and spoken language as their only form of communication, it is becoming an ethical and moral obligation to promote every child's birthright of clear listening and spoken language and accordingly provide adequate services to meet this need.

Comment: ***Based on this evidence, it is no longer responsible or ethical to promote alternative intervention approaches as an effective communication option.***

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Early Intervention Options

Across Australia there is a significant shortfall in trained professionals and programs that can provide listening and spoken language options particularly Auditory-Verbal Therapy. There are only 36 internationally certified listening and spoken language specialists[6] in Australia. This means that many Australian children with hearing loss do not have access to a professional trained in Auditory-Verbal techniques, as a result, these children and families may only have the option of accessing professionals trained in outdated visual or manual methodologies which do not optimize the potential of the new hearing technology, particularly the Australian-invented cochlear implant.

This dearth of listening and spoken language specialists is exacerbated by the traditional bias of health professionals in the field, the inability of these professionals to overturn existing doctrine, the lack of up to date professional training and the majority of government funding towards non-listening and spoken language communication methodologies.

Comment: ***The traditional definition and treatment of hearing loss does not address the needs of the majority of children with hearing loss in the new millennium.***

[6] A.G. Bell Academy of Listening and Spoken Language (www.agbellacademy.org)

Longitudinal Study of Speech Perception, Speech, and Language for Children with Hearing Loss in an Auditory-Verbal Therapy Program

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[Running title: Speech and Language Process]

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This study aimed to examine the speech perception, speech, and language developmental progress of 25 children with hearing loss (mean Pure-Tone Average [PTA] 79.37 dB HL) in an auditory-verbal therapy program. Children were tested initially and then 21 months later on a battery of assessments.

Speech and Language Progress

The speech and language results over time were compared with those for a control group of children with typical hearing, matched for initial language age as well as receptive vocabulary, gender, and socioeconomic level. Speech perception scores for the children with hearing loss showed significant improvement ($p < 0.05$) for live-voice presentations, but not for recorded voice. For both groups there was significant improvement in scores for auditory comprehension, oral expression, total language, and articulation of consonants ($p < 0.001$) over 21 months; the amount of improvement was not significantly different between groups ($p > 0.05$). At the 21-month test point, 84% of the children with hearing loss scored within the typical range for total language age, compared to 58.6% at the initial assessment. Receptive vocabulary scores were an exception, with the children with typical hearing showing significantly more gain than the children with hearing loss ($p < 0.05$). Nevertheless, the group with hearing loss scored within the typical range for receptive vocabulary. Overall, the results show that the children with hearing loss had improved speech perception skills over time and that their rate of progress for speech and language skills was similar to that of children with typical hearing.

[H1]Introduction

This research is part of a longitudinal study examining the outcomes for children with hearing loss who are enrolled in an auditory-verbal therapy program. Between 2 and 3 newborns per thousand children are born with permanent sensorineural hearing loss > 35 dB HL per year, the most common congenital disorder that can be detected in the newborn period (Fortnum, Summerfield, Marshall, Davis, & Bamford, 2001; Joint Committee on Infant Hearing, 2007; Uus & Bamford, 2006). This incidence is likely to be higher in developing countries (Olusanya, Ruben, & Parving, 2006). Untreated hearing loss in children has a significant impact on auditory brain development (Sharma, Dorman, & Kral, 2005), with serious lifetime consequences for speech, language, literacy, academic achievement, and social/emotional development (Bat-Chava, Martin, & Kosciw, 2005; Blamey et al., 2001; Nunes & Moreno, 2002; Sininger, 1999; Traxler, 2000). Hearing loss also significantly impacts the family and community (Olusanya et al., 2006). Treatment of childhood hearing loss has made many advances in the last decade, and clinical evidence shows that life-changing improvements in outcomes for children with hearing loss are now possible with the combination of new technology and intervention techniques (Geers, 2004). Rigorous research is needed to develop an evidence base that will inform professionals, decision makers, and funding bodies about the effectiveness of intervention strategies for children with hearing loss.

Early diagnosis and immediate audiological and educational intervention, preferably by 6 months of age, are vital in order to capitalize on the optimal developmental periods of the auditory brain (Joint Committee on Infant Hearing, 2007; Sharma et al., 2005; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Modern diagnostic technology, such as frequency-specific electrophysiological measurements (Cone-Wesson, Dowell, Tomlin, Rance, & Ming, 2002), and hearing technology, such as cochlear implants and digital hearing aids, are offering new opportunities for children with significant hearing loss to acquire listening and spoken language (Geers, 2004). Fitting of amplification accompanied by immediate and appropriate educational intervention must quickly follow diagnosis if the new opportunities are to lead to an improvement in spoken language outcomes (Nicholas & Geers, 2007). As technology for diagnosis and audiological intervention for hearing loss continues to advance, better speech and language outcomes have become possibilities for children with hearing loss. These developments have created more demand for listening and spoken language approaches to education, including auditory-verbal therapy (Rhoades, 2006).

However, there is a lack of high-level research (as defined by the “Levels of Evidence” of the Oxford Centre for Evidence Based Medicine, 2001) on any of the educational approaches available today (Sussman et al., 2004). There is a great need to conduct research focusing on the measurement of outcomes as evidence for “best practices” in the treatment of various populations of children with hearing loss. Prior to the use of cochlear implants, rate of language progress for children with profound hearing loss wearing hearing aids was reported as half a year of progress in a 1-year time span (Boothroyd, Geers, & Moog, 1991). With new hearing technology, many authors consider that progress of children with hearing loss may be appropriately compared to that of children who have typical hearing (Geers, 2005). This study is part of a longitudinal research project that aims to contribute to research evidence by comparing the developmental progress of speech and language skills for children in an auditory-verbal therapy program to that of children with typical hearing.

Auditory-verbal therapy is an early intervention education option that facilitates optimal acquisition of spoken language through listening by young children with hearing loss. It promotes early diagnosis, one-on-one therapy, and state-of-the-art audiologic management and technology. Parents and caregivers actively participate in therapy. Through guidance, coaching, and demonstration, parents become the primary facilitators of their child's spoken language development. Ultimately, parents and caregivers gain confidence that their child can have access to a full range of academic, social, and occupational choices throughout life (Alexander Graham Bell Academy for Listening and Spoken Language, 2007).

A number of authors have published reviews of research on auditory-verbal therapy outcomes (see Dornan, Hickson, Murdoch, & Houston, 2008; Eriks-Brophy, 2004; Rhoades, 2006). Eriks-Brophy (2004) cited significant problems related to research design, including the fact that most studies were retrospective and were without control groups. She concluded that the research overall was sparse and incomplete, and provided only limited evidence in favor of auditory-verbal therapy, a view that was supported by Rhoades (2006) and Dornan et al. (2008). The research design problems highlighted by these authors mean that comparison between studies on outcomes of auditory-verbal therapy, or indeed between studies on any of the other education options, is extremely difficult. However, several large retrospective studies (e.g., Goldberg & Flexer, 2001; Durieux-Smith et al., 1998), and a few prospective ones (e.g., Duncan, 1999; Duncan & Rochecouste, 1999; Rhoades, 2001; Rhoades & Chisolm, 2000), have provided limited evidence for the potential of auditory-verbal therapy for some children with hearing loss. The latter two papers on the same population reported that the children had progressed at the same rate as children with typical hearing, and entered school with age-appropriate language skills. However, those studies did not actually have a control group of children with typical hearing, and such a comparison would be appropriate and informative.

In an earlier stage of our own research (Dornan, Hickson, Murdoch, & Houston, 2007), the speech and language developmental progress of children with hearing loss using an auditory-verbal therapy approach was compared over a 9-month period to that of a matched group of children with typical hearing. The original group of children with hearing loss consisted of 29 children ages 2-6 years with a mean Pure-Tone Average in the better ear of 76.17 dB HL at 0.5, 1 and 2 kHz. The 29 children in the control group were matched with the children in the auditory-verbal therapy program for language age and receptive vocabulary at the start of the study, and for gender and parental education level. A battery of standardized speech and language tests was administered to all children at the start of the study and again 9 months later. Results showed that both groups improved over time and that there was no significant difference in progress between the two groups.

In this paper we report on the second stage of this longitudinal study with testing occurring at 21 months after the initial assessments. The aims of the research were to investigate the developmental progress of speech and language skills for 25 pairs of the same children who remained in the study for 21 months. Developmental progress for speech and language was again compared between the two groups. This study also aimed to extend the original study by including additional measures of speech perception and speech production skills for consonants in spontaneous discourse for the children with hearing loss.

[H1]Method

The study employed a matched group, repeated-measures design in which children with hearing loss in an auditory-verbal therapy program were individually matched with a comparison group of children with typical hearing. The rate of change for various language and speech variables was compared for the auditory-verbal therapy group (AVT group) and the typical hearing group (TH group). Participants in both groups were assessed at the start of the study (pretest) and at the 21-month point (posttest) using an assessment battery. The children in the AVT group received additional assessments of speech perception and speech production in discourse.

[H2]Participants

[H3]Auditory-Verbal Therapy Group

At the 21-month stage of the study, 25 members of the original AVT group remained in the longitudinal study, and only the original child matched from the TH group was used for comparison (n=25). The 4 original AVT group children who withdrew from the study included 2 children who had commenced investigation for other additional disorders during the first 9 months of the study and were subsequently transferred to a different type of educational program, and 2 who moved to a different area and were unavailable. The remaining 25 AVT group children had a range of sensorineural hearing losses, used hearing aids and/or cochlear implants to access sound, and were assessed on a battery of speech perception, speech, and language tests. These children attended one of four regional centers of an auditory-verbal therapy program in Queensland, Australia, which offers a range of services including audiology, early intervention, and cochlear implant services. The auditory-verbal therapy program adheres to the Principles of Listening and Spoken Language - Auditory-Verbal Therapy (endorsed by the Alexander Graham Bell Academy for Listening and Spoken Language, 2007). All children in the AVT group were receiving regular audiologic follow-up to ensure optimal amplification, and attending weekly individual therapy in which parents were guided and coached to be the primary language models for their child. Diagnostic teaching principles were also employed and children were fully integrated into mainstream education at the earliest possible age. Potential participants at the start of the study included all the program's 75 children (2 months to 6 years of age) who were in the early intervention program, satisfied the selection criteria, were geographically accessible, and whose parents agreed to participate in the research. Selection criteria were as follows:

- Pure-Tone Average (PTA) at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz of ≥ 40 dB hearing threshold levels in the better ear.
- Prelingually deafened (at ≤ 18 months old).
- Attended the educational program weekly for intensive one-to-one parent-based auditory-verbal therapy for a minimum of 6 months.
- Wore consistent hearing amplification (hearing aids and/or cochlear implants).
- Had aided hearing within the speech range or had received a cochlear implant.
- No other significant cognitive or physical disabilities reported by parents or educators.
- Ages 2–6 years at the pretest session.
- Both parents spoke only English to the child.

Although the selection criteria precluded children with other significant disabilities, the group included one child who had mild cerebral palsy. The characteristics of the AVT group are summarized in Table 1. Their mean age at pretest was 3 years, 9 months, and at the posttest was 5 years, 8 months (SD = 15 months). The 25 participants had bilateral sensorineural hearing loss ranging from moderate to profound, with a mean PTA of 79.37 dB HL. All children were fitted with hearing aids and commenced intervention within 3 months of diagnosis of the hearing loss. Three of the children had been diagnosed and commenced intervention before the critical age of 6 months identified by Yoshinaga-Itano and others (1998). These 3 children had a profound bilateral sensorineural loss, and subsequently received a cochlear implant before 19 months of age. All children with implants in this study had received unilateral Cochlear Nucleus CI 24 implants and used an Advanced Combined Encoder (ACE) processing strategy. The median age at implantation was 23.04 months (mean = 27.54 months, SD = 15.24). This relatively late mean time of implantation was due to the fact that 2 children received a unilateral cochlear implant around 4 years of age during the first 9 months of the study. All but 2 cochlear implant users in the study also wore a hearing aid in the contralateral ear. Both hearing devices were balanced by an audiologist according to the recommendation of Ching, Psarros, and Incerti (2003). All children wore their hearing aids consistently at the first follow-up (9 months after pretest), and continued to do so at the posttest (21 months after pretest).

[Insert Table 1]

[H3] Typical Hearing Group

Children in this group were recruited by families and staff of the auditory-verbal therapy program. Selection criteria were as follows:

- Unaided hearing threshold levels within the range of 0 to 20 dB at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz for both ears.
- No delay in phonetic development as assessed using the Goldman-Fristoe Test of Articulation-2 (GFTA-2) (Goldman & Fristoe, 2001). Australian norms for articulation (Kilminster & Laird, 1978) were used and results within 1 standard deviation of the mean for age were required for inclusion.
- No significant cognitive or physical disabilities (as evidenced by case history or parent report).
- Both parents spoke only English to the child.

The characteristics of the control group are summarized in Table 1. Hearing level expressed as PTA is not reported for this group. Sixty-four children with typical hearing were initially tested to ensure appropriate matching of children in the two groups. For the longitudinal study, the 25 children with typical hearing selected for the TH group were individually matched with children in the AVT group for total language age on the Preschool Language Scale (PLS-4) or the Clinical Evaluation of Language Fundamentals (CELF-3) (± 3 months), for receptive vocabulary on the Peabody Picture Vocabulary Test (PPVT-3) (± 3 months), for gender, and for socioeconomic level as assessed by education level of the head of the household. The mean age at pretest was 2 years 11 months and at posttest was 4 years 9 months (SD = 14.75 months). This meant that the AVT group were 10 months older than the TH group. Had chronological age been used for matching (instead of language age), as was done in the study reported by Duncan (1999) and Duncan and Rochecouste (1999), the children with typical hearing generally would have had a higher language level than the children with hearing loss of the same chronological age (Blamey et al., 2001), introducing the possibility that the children in the TH group might progress faster. The study was conducted in Queensland, Australia. At the time, the average age for diagnosis of a sensorineural hearing loss in Australia was over 2 years because newborn hearing screening programs were not yet in place (Wake, 2002). Thus, it was highly likely that if the children were matched by chronological age, participants in the TH group would have had a significant language age advantage over participants in the AVT group. It is also possible that matching children for language age could have resulted in the children with hearing loss being significantly older than the children with typical hearing (Blamey et al., 2001), introducing the potential that they may progress faster because of their advanced cognitive skills. However, it was considered that the potential cognitive “advantage” afforded to the children with hearing loss who were older was likely to be offset by the delays they often experience in speech and language development.

When matching the control group with the experimental group, it was difficult to achieve a complete match for each individual child for both the total language score (PLS-4 or CELF-3) and the receptive vocabulary score (PPVT-3) as the range of total language and receptive vocabulary scores was wide. However, both groups of children were initially matched for total language scores and then for receptive vocabulary. Deciding how to define socioeconomic level for matching purposes was difficult because there are many different perspectives and a number of different possible measures (Kumar et al., 2008). Some factors that might have been measured include family income, education level of the parents, and parental occupation (Marschark & Spencer, 2003). However, it was thought that questions about family income might deter parents from long-term commitment to the longitudinal study before it had commenced. Consequently, the occupations of both groups were placed in categories according to those developed by Jones (2003) for parents in education programs, as occupation category has been found to impact the vocabulary learning of a child with hearing loss (Hart & Risley, 1995) (see Table 2).

[Insert Table 2]

The heads of the household were then matched for highest education level reached (the father in the case of two-parent families or the mother/income-earning partner in the case of other family models). All except one parent in both groups had undertaken education beyond high school, suggesting a moderate to high socioeconomic level in both groups. Earlier studies have found that parents of children in auditory-verbal therapy programs are likely to come from moderate to high socioeconomic levels (Dornan et al., 2007; Easterbrooks, O'Rourke, and Todd, 2000; Rhoades & Chisolm, 2000). This is acknowledged as a limitation of the study.

A preliminary analysis was carried out to ensure the validity of matching of participant groups at the pretest; that is, the matching of language age and receptive vocabulary as indicated by total language age on the PLS-4 or CELF-3 and the PPVT-3 results, respectively. The AVT group's PLS-4/CELF-3 mean age equivalent was 3.58 years (SD = 1.39), and the mean for the TH group was 3.48 years (SD = 1.38). Between-group *t* tests showed no significant difference between these values ($t = 0.260$, $p = 0.796$). Similarly, there was no significant difference between groups for the mean vocabulary age equivalents on the PPVT-3 ($t = 2.80$, $p = 0.906$). The mean age equivalent on the PPVT-3 for the AVT group was 2.8 years (SD = 1.29), and the mean for the TH group was 2.84 years (SD = 1.31).

[H2]Materials

All speech perception and speech and language assessments are summarized in Table 3. A battery of speech perception tests was used to measure the level of understanding of speech and to ensure that the children in the AVT group were receiving sound optimally. Because of variation in the level of speech perception ability and the different ages of the AVT group, a battery of speech perception assessments was necessary to best assess the children's performance. The tests are shown in Table 3 in ascending order of difficulty, and an audiologist administered the tests in this order according to the age and stage of listening of the child both at pretest and posttest. All speech perception tests were administered in a soundproof booth that met Australian Standards AS1269. Live-voice tests were presented in the audiologist's own voice, and recorded-voice tests were presented by using a recording at 65 dBA in a quiet space.

[Insert Table 3]

[H1]Procedure

Clearance for this project was sought from the ethics committee of the auditory-verbal therapy program and was then referred to the program board of directors, which approved the project. Ethical clearance was also obtained from the Behavioural and Social Sciences Ethical Review Committee of the University of Queensland in Brisbane, Australia. After consent was obtained from the parents of each participant, arrangements were made to conduct the assessments.

The mean time between pretests and posttests was 21.88 months for the AVT group (SD = 1.22) and 21.65 months for the TH group (SD = 0.84), which was not significant (t = 1.095, p = 0.279).

[H2]Speech Perception

The speech perception battery was presented to children in the AVT group in a soundproof booth by experienced pediatric audiologists at the Hear and Say Centre. All speech perception tests were given either by live voice or by recorded voice in the best aided condition. For children with cochlear implants, the child's optimally functioning MAP as assessed by an audiologist and auditory-verbal therapist was used. Both “T” levels (threshold, or minimum amount of current allowing sound to be detected) and “C” levels (maximum amount of current causing discomfort) for the child’s MAP were measured behaviorally and confirmed objectively where necessary. Optimal implant performance was verified by the stability of the MAP, and consistent identification by the child of the seven sound test, the Australian adaptation of Ling’s Six Sound Test (Romanik, 1990). The “Ling sounds” are a range of speech sounds encompassing the frequencies that are widely used clinically to verify the effectiveness of hearing aid fitting in children (Agung, Purdy, & Kitamura, 2005). The Ling Six Sound Test was originally developed for the North American population (Ling, 2002), and in the seven sound test, /ɔ/, THIS IS “OR” AS IN “HOARD” was added to account for the differences in the production and spectral content of Australian vowels (Agung et al., 2005). Optimal implant performance was also verified through the use of other speech perception tests and the cochlear implant-assisted audiogram (a record of the child’s cochlear implant-aided thresholds for responses at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz). For the children who wore hearing aids, best aided condition was determined by an audiologist and auditory-verbal therapist, performance of the seven sound test, speech perception tests, and the child’s aided audiogram.

Comment [m1]: Please verify symbol

[H2]Language and Speech

The AVT group’s assessments took place at the child’s program center. For the TH group, testing was performed either at the head office of the Auditory-Verbal Therapy program, at the child’s education setting in a quiet room, or at the child’s home. Speech and language testing was performed by experienced and qualified speech-language pathologists. Because of geographic constraints, the most convenient and available qualified staff performed the testing, and frequently, different testers assessed the children at pretest and posttest. Tester reliability was not examined in the standardized assessments, as these were administered according to the standardized instructions in the test manuals. For the CASALA (Computer Aided Speech and Language Analysis; Serry, Blamey, Spain, & James, 1997), inter-rater reliability was performed by having each of the speech-language pathologists perform an analysis on the samples of the same 8 children. The pair-wise intertester reliability ranged from 79% to 82% for broad transcription. These levels were similar to those obtained by Shriberg, Austin, Lewis, Sweeney, & Wilson (1997), who also used CASALA to study speech development in children.

The language and speech tests were administered over one session if possible; however, several children required two sessions because of age or attention difficulties. Children were given rest breaks between assessments, and the session was discontinued if a child showed evidence of fatigue or distress. The children's responses to the GFTA-2 were not transcribed and scored at a later date. Instead, whether consonant production was correct or not was decided by the tester at the time of testing.

The order of presentation of the standardized tests used was as follows. For the pretest, the AVT group were first administered the PLS-4 or CELF-3, the PPVT-3 and the GFTA-2. A spontaneous speech sample for CASALA analysis was tape recorded at this time. The group also received speech perception assessments and a parent survey. The order of testing for the TH group was different from the AVT group in order to account first for screening and then to establish a match with a child in the AVT group before the child was unnecessarily tested. The TH group was initially screened using pure-tone audiometry in both ears to determine thresholds at 500 Hz, 1000 Hz, 2000 Hz, and 4000Hz. Thresholds needed to be within the range of 0–20 dB HL at all frequencies for both ears for inclusion in the TH group. If a child passed the screen, no further audiological tests were given to the TH group. Middle ear status was not checked unless the parent reported recent ear pain or reduced hearing. The GFTA-2 screen was also performed in the same initial session. Children who passed the screen were administered the PLS-4 or CELF-3 and the PPVT-3 for matching purposes. The TH group children were then matched for total language, receptive vocabulary, gender and socioeconomic level with the AVT group. At posttest, both groups received the same assessments, without the screening for the children in the TH group.

[H2]CASALA

A 5- to 7- minute spontaneous speech sample of each child with hearing loss was videotaped for under predefined conditions at pretest and at posttest. These conditions included using a wall-mounted video camera, not easily identified, set 2 meters above the ground, allowing for full vision of the child's face. The child was seated in a high chair at a table 3 meters from the camera, with a high-quality microphone set on the table at 1 meter from the child. The parent was seated at the child's best hearing ear and was given instructions to interact with the child using a set group of toys. The parent was also given specific instructions that the session was not a therapy lesson but a play activity. The choice of toys was grouped under different scenarios ("babies," "transport," "animals," and "craft"). The aim was to obtain a sample of approximately 50 utterances, or 250 words.

[H1]Results

[H2]Speech Perception

The speech perception results for the AVT group on a battery of speech perception tests and results for the changes in scores at pretest and posttest are summarized in Table 4. Box plots were generated that showed some skewness in some variables at the 21-month posttest. Where possible and appropriate, changes in speech perception skills from pretest to posttest were tested for significance using a Wilcoxon signed rank test, and the results are also reported in Table 4. In two subtests, PLOTT Phoneme Detection (100% at pretest [N = 25] and 100% at posttest [N = 24]) and CNC Vowels (95% at pretest [N = 11] and 98.18% at posttest [N = 22]), there was a ceiling effect at both pretest and posttest for some children, and statistical testing was not conducted. The tests were readministered at the posttest because testers were careful to check that hearing levels were consistent over time.

Also, not all tests were administered to each child, because the AVT group had a wide range of speech perception abilities, which the battery of tests was chosen to cover. If a child had not attempted a test because it was too difficult, only the child's responses on the tests that were attempted were scored. The number of children completing more difficult recorded assessments was sometimes too few for analysis. The assessments that showed significant average improvement were PLOTT Phoneme Imitation (N = 24 at both pretest and posttest); Manchester Junior Words/PBK Words with Word Score (N = 18 at both pretest and posttest); Phoneme Score (N = 18 at both pretest and posttest); CNC Words with Phoneme Score (N = 10 at pretest and N = 24 at posttest), Consonant Score (N = 11 at pretest and N = 22 at posttest); Word Score (N = 11 at pretest and N = 22 at posttest); and BKB Sentences Live Voice (N = 10 at pretest and N = 24 at posttest). All of these tests were administered via live voice (maximum 65dB) in a quiet setting.

[Insert Table 4]

[H2]Standardized Language and Speech Assessments

Table 5 contains a summary of the age-equivalent scores of the pretests and posttests for both groups on total language, receptive vocabulary, and speech. Paired sample *t*-tests were used to investigate change scores in each group. Two children from each group had reached the ceiling of the PLS-4 and were tested on the CELF-3 for language, and separate auditory comprehension and oral expression scores are not available for the CELF-3. Therefore, only 23 pairs were analyzed for these parameters, but 25 total language scores expressed as age equivalents were included in the analysis. The age-equivalent scores for the AVT group for auditory comprehension were 3.56 years at pretest (SD = 1.06) and 5.17 years (SD = 0.7) at posttest, which showed significant improvement (t = 10.28, p = < 0.001). Similarly, for oral expression, the AVT group had age-equivalent scores of 3.30 years (SD = 1.02) at pretest and 5.27 years (SD = 0.96) at posttest, which was also significant (t = 15.99, p = < 0.001). Significant improvements were found over time for both groups for total language, receptive vocabulary, and speech skills (see Table 5).

[Insert Table 5]

Between-group *t*-tests were used to investigate possible differences in change scores from pretest to posttest for both groups. The change scores for both groups were not significantly different for auditory comprehension (t = 1.44, p = 0.157), oral expression (t = 0.21, p = 0.834), total language (t = 0.12, p = 0.905), or speech skills (t = 0.8, p = 0.936). However, the change scores were significantly different for receptive vocabulary (t = 3.44, p = 0.001) with the TH group showing significantly greater improvement than the AVT group.

[H2]CASALA Speech Assessment

A within-subject analysis of variance (ANOVA) was used to analyze the AVT group's CASALA results for percentage consonants attempted and percentage correct (see Table 6). The ANOVA showed that there were significant differences between the percentage of consonants attempted at the two points in time (F = 63.59, p = < 0.0001), and that these differences varied for different consonants. Paired t-tests were subsequently conducted to determine if there was a difference between the number of consonants attempted at pretest and at posttest (Table 4). These tests showed that for five consonants (/n/, /j/, /s/, /ʃ/, and /l/), there was strong evidence for an increase over time ($p = \leq 0.006$). A conservative level of p was chosen to guard against Type 1 error. For six additional consonants (/m/, /t/, /k/, /f/, /ð/, and /z/), there was less strong evidence for an increase over time (p = < 0.05). However, the percentage increase varied depending on the particular consonant being attempted.

[Insert Table 6]

The mean increase in percentage of consonants produced correctly was also analyzed using within-subject ANOVA. There was evidence of a significant increase in percentage consonants correct from pretest to posttest (F = 16.32, p = < 0.0001). Paired t-tests showed measurable significant increases for four consonants (/p/, /k/, /g/, and /f/; $p = \leq 0.006$), and positibe but less strong evidence for six consonants (/n/, /ŋ/, /b/, /v/, /s/, and /tʃ/; p = < 0.05).

[H1]Discussion

The results showed that the AVT group made significant progress over a 21-month period in speech perception, auditory comprehension, oral expression, total language, and speech skills. Results also proved that the developmental progress of the AVT group for auditory comprehension, oral expression, total language development, and speech skills over a 21-month period was the same as that for the TH group. Both groups made the same progress in auditory comprehension, oral expression, and total language development as measured on the PLS-4 or the CELF-3 as well as speech skills as measured on the GFTA-2. However, a significant advantage was found in the TH group for receptive vocabulary as measured by the PPVT-3. Nevertheless, the AVT group scored within the typical range of the PPVT-3 for receptive vocabulary.

The AVT group showed significant improvement in speech perception skills for live-voice stimuli over the 21 months. It is suggested this may be a product of both their experience with their hearing devices and the effects of auditory-verbal therapy, but this study does not provide adequate evidence to prove the latter point. Improvements in speech perception following hearing aid fittings or cochlear implantation are well documented (e.g., Blamey et al., 2001; Svirsky, Teoh, & Neuburger, 2004). However, while increasing numbers of the children in the study were able to perform open-set, live-speech perception tasks over time, it was much more difficult when the speech was a recorded signal; only small numbers of children were able to complete the tests administered via recording. Chute and Nevins (2000) have advocated for the use of live-voice testing with this population, as recorded-voice testing is too difficult for them.

The developmental progress for language skills of the AVT group was at the same rate as the control group, and also the same as that expected for the population of children with typical hearing. Another study of developmental progress of total language in children with hearing loss was conducted by Blamey et al. (2001). The children in that study attended a listening and spoken language program and had a mean PTA of 78 dB HL. Findings indicated that these children, on average, progressed at half to two thirds the rate expected for children with typical hearing; however, a typical hearing control group was not included in the research. This rate of development was not as fast as in the present study; however, it is not possible to draw definitive conclusions about the reasons,as other variables (i.e., beyond the type of educational intervention) may be involved.

At the 21-month posttest, the majority of children in the AVT group (84%; 21/25) had total language scores within the age-appropriate range (i.e., ± 1 SD or above) for their chronological age. At the pretest, only 55% (16/29) of the group had age-appropriate total language scores. At the posttest, 84% (21/25) were within the typical range for receptive language, and 80% (20/25) were within the typical range or above for expressive language. At posttest, 2 children in the AVT group had language test scores that were more than 2 SD above the mean, while a further 2 children had scores that were more than 1 SD above the mean for their chronological age. Four children in the AVT group had scores that were 1 SD below the mean. These results for language contrast with the results of Geers, Nicholas, and Sedey (2003), who reported that only 30% of 181 children ages 8 to 9 years old with cochlear implants (received implants before 5 years of age) scored within the typical range for receptive language, and 47% did so for expressive language. However, in the Geers et al. (2003) study, the mean age of implantation was 3.5 years and may have been influential, as the mean age of implantation for the AVT children in the present study was 2.29 years and the median age of implant was 1.92 years.

The change in PPVT-3 scores for the TH group was significantly higher than the change for the AVT group, with the TH group progressing 33.68 months in 21 months compared to 23.8 months for the AVT group. Nevertheless, the mean score for the AVT group was within the typical range for the test. Similar results were found by Schorr, Roth, and Fox (2008), who reported a statistically significant difference between PPVT-3 scores for a group of 39 children who are congenitally deaf, use a cochlear implant and attend a range of different educational programs, and a matched group of children with typical hearing. As in the present study, the mean score for the children with hearing loss was still within the typical range for the test. Similarly, Pittman, Lewis, Hoover, and Stelmachowicz (2005) found that PPVT-3 scores for 37 children with moderate sensorineural hearing loss were consistently poorer when compared to scores for 60 children with typical hearing, with 5 children scoring more than 1 SD below the mean. The type of educational approach the children with hearing loss had experienced was not specified, but the authors concluded that children with hearing loss in this study had significantly less ability to learn new vocabulary than children with typical hearing.

The speech skill results for the AVT group show that their rate of progress for acquisition of consonants on the GFTA-2 was statistically the same as for the TH group. Articulation of consonants has been shown to be the major factor in speech intelligibility (Ling, 2002). At the start of the study, the results of consonant articulation for the AVT group were not statistically different from the TH group. This may reflect the fact that the children were matched for language age and had been in the AVT program for a mean of 20 months at the pretest. The excellent developmental results for speech found in the present study for the AVT group disagree with Marschark, Lang, and Albertini (2002), who reported that articulation skills are a primary area of difficulty for this population. They also disagree with Eisenberg (2007), who reported that the speech development of children with even a mild-to-moderate hearing loss is delayed. These results are in agreement with those of Schorr and others (2008), who compared GFTA-2 results for 39 children with cochlear implants (ages 5 to 14 years) with those of a group of children with typical hearing, matched for gender and chronological age. They found that the mean scores of the children with cochlear implants were within 1 SD of the mean for the typical hearing group. The speech progress rate for the AVT group may have been the effect of experience following amplification with hearing aids or a cochlear implant (e.g., Allen, Nikolopoulos, & O'Donohue, 1998), better language skills (Coerts & Mills, 1995; Svirsky, 2000; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000), or an emphasis on communicating with listening and spoken language (Tobey, Geers, Brenner, Altuna, & Gabbert, 2003). However, an interaction of factors is the most likely explanation for improved speech.

Research has indicated that the combination of the use of listening and spoken communication plus early, intensive speech intervention increases the likelihood that children with significant hearing loss can acquire speech skills that are comparable to children with typical hearing of the same age, at least at the isolated single-word level (Schorr et al., 2008). The AVT group in the present study had attended the auditory-verbal therapy program for a minimum of 4 years, wore their amplification technology constantly, used listening and spoken language communication, had language skills that were not significantly different from the TH group, and had early, intensive speech intervention as an integral part of their auditory-verbal therapy program.

In addition to the positive findings for articulation of individual consonants in single words, the study of consonant development in spontaneous speech using CASALA indicated that the AVT group's acquisition of consonants appeared to follow the typical developmental sequence of consonants for Australian children (Kilminster & Laird, 1978). These results are in agreement with an early study by Serry, Blamey, and Grogan (1997), who found that the speech of children with cochlear implants followed a development similar to that of children with typical hearing.

The present research has addressed some of the criticisms reported in studies on outcomes of auditory-verbal therapy by including a control group and carefully matching the participants in both groups, thereby providing a higher level of evidence (Oxford Centre for Evidence Based Medicine, 2001). The study design was prospective and included standardized assessments, and assessments were made at multiple points over time for both the AVT and TH groups. Also, the reasons for children dropping out of the study were described. The authors acknowledge that this group of children had minimal other disabilities, spoke only English, and were from relatively high-level socioeconomic backgrounds, which might reduce the comparability of this population with others. Further research is necessary to investigate the influence of socioeconomic status on outcomes for children with hearing loss, to determine the most appropriate way to measure this variable, and to determine if access to auditory-verbal therapy services due to of socioeconomic level affects outcomes for a range of populations.

[H1]Conclusion

Overall, the AVT group of children maintained their promising developmental progress for auditory comprehension and oral expression, total language, and articulation of consonants demonstrated in the first 9 months of this study (Dornan et al., 2007). They continued this developmental progress at a rate statistically the same as that of the TH group of children who were matched for initial language age, receptive vocabulary, gender, and socioeconomic level. However, after the 9-month point, the TH group accelerated their progress for receptive vocabulary skills, performing significantly better than the AVT group. Nevertheless, acquisition of receptive vocabulary for the AVT group also progressed steadily at a rate similar to that of children with typical hearing (a change of 23.76 months in a 21-month period), with the vast majority (84%) achieving scores that were age appropriate. This study will now continue to be extended longitudinally, using the same tests but with the addition of measures of literacy, numeracy, and self-esteem as the majority of the children enter formal schooling. In summary, for this particular population of children with hearing loss, auditory-verbal therapy was found to be an effective education option, but more information in needed over longer time periods and with different populations.

[H1]Acknowledgments

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[H1]References

Agung, K.B., Purdy, S.C., & Kitamura, C. (2005). The Ling sound test revisited. *Australian and New Zealand Journal of Audiology, 27*(1), 33–41.

Alexander Graham Bell Academy for Listening and Spoken Language. (2007). *Auditory-verbal therapy*. Retrieved January 12, 2008, from http://www.agbellacademy.org/AuditoryVerbalTherapy.htm.

Allen, M.C., Nikolopoulos, T.P., & O'Donohue, G.M. (1998). Speech intelligibility in children after cochlear implantation. *American Journal of Otology, 19*(6), 742–746.

Bat-Chava, Y., Martin, D., & Kosciw, J. (2005). Longitudinal improvements in communication and socialization of deaf children with cochlear implants and hearing aids: Evidence from parental reports. *Journal of Child Psychology and Psychiatry, 46*(12), 1287–1296.

Bench, J., & Bamford, J.M. (1979). *Speech hearing tests and the spoken language of hearing impaired children.* London, England: Academic Press.

Blamey, P.J., Sarant, J., Paatsch, L., Barry, J.G., Bow, C.P., Wales, R.J., et al. (2001). Relationships among speech perception, production, language, hearing loss and age in children with impaired hearing. *Journal of Speech, Language and Hearing Research, 44*(2), 264–285.

Boothroyd, A., Geers, A., & Moog, J.S. (1991). Practical implications of cochlear implants in children. *Ear and Hearing, 12*(4 Suppl.), 81S–89S.

Bow, C.P., Blamey, P., Paatsch, L., & Sarant, J. (2002). Comparison of methods in speech acquisition research. *Clinical Linguistics and Phonetics, 16*, 135-147.

Ching, T., Psarros, C., & Incerti, P. (2003). Management of children using cochlear implants and hearing aids. *The Volta Review, 103*(1), 39–57.

Chute, P.M., & Nevins, M.E. (2000). Cochlear implants in children. In M. Valente, H. Hosford-Dunn, & Roeser, R.J. (Eds.), *Audiology Treatment* (p. 525). New York, NY: Thieme.

Coerts, J., & Mills, A. (1995). Spontaneous language development of young deaf children with a cochlear implant. *Annals of Otology, Rhinology, and Laryngology, 166*(Suppl.), 385–387.

Cone-Wesson, B., Dowell, R. C., Tomlin, D., Rance, G., & Ming, W.J. (2002). The auditory steady state response: Comparisons with the auditory brain stem response. *Journal of American Academy of Audiology, 13*(4), 173–187.

Dornan, D., Hickson, L., Murdoch, B., & Houston, T. (2007). Outcomes of an Auditory-Verbal Therapy program for children with hearing loss – A comparative study with a matched group of hearing children. *The Volta Review, 107*(1), 37–54.

Dornan, D., Hickson, L., Murdoch, B., & Houston, T. (2008). Speech and language outcomes for children with hearing loss educated in Auditory-Verbal Therapy programs: A review of the evidence. *Communicative Disorders Review, 2*(3-4), 157–172.

Duncan, J. (1999). Conversational skills of children with hearing loss and children with typical hearing in an integrated setting. *The Volta Review, 101*(4), 193–211.

Duncan, J., & Rochecouste, J. (1999). Length and complexity of utterances produced by kindergarten children with impaired hearing and their hearing peers. *Australian Journal of Education of the Deaf, 5,* 63–69.

Dunn, L.M., & Dunn, L.M. (1997). *Peabody Picture Vocabulary Test*. Circle Pines, MN: American Guidance Service.

Durieux-Smith, A., Olds, J., Fitzpatrick, E., Eriks-Brophy, A., Duquette, C., Cappelli, M., et al. (1998). Outcome of AVT: Results of a follow-up study. *American Speech and Hearing Association Leader, 3*(16), 99.

Easterbrooks, S.R., O'Rourke, C.M., & Todd, N.W. (2000). Child and family factors associated with deaf children's success in auditory-verbal therapy. *American Journal of Otology, 21*(3), 341–344.

Eisenberg, L.S. (2007). Current state of knowledge: Speech recognition and production in children with hearing impairment. *Ear and Hearing, 28*(6), 766–772.

Eriks-Brophy, A. (2004). Outcomes of Auditory-Verbal Therapy: A review of evidence and a call for action. *The Volta Review, 104*(1), 21–35.

Fortnum, H.M., Summerfield, A.Q., Marshall, D.H., Davis, A.C., & Bamford, J.M. (2001). Prevalance of permanent childhood hearing impairment in the U.K. and implication for universal neonatal hearing screening: Questionnaire based ascertainment study. *British Medical Journal, 323*(5), 536–539.

Geers, A. (2004). The ears of the deaf unstopped: Changes associated with cochlear implantation. *Seminars in Hearing, 25*(3), 257–268.

Geers, A., Nicholas, J., & Sedey, A. (2003). Language skills of children with early cochlear implantation. *Ear and Hearing*, *24*(1), 46S–57S.

Goldberg, D.M., & Flexer, C. (2001). Auditory-verbal graduates: An updated outcome survey of clinical efficacy. *Journal of the American Academy of Audiology*, *12*(8), 406–414.

Goldman, R., & Fristoe, M. (2001). *Goldman-Fristoe Test of Articulation-2*. Shoreview, MN: American Guidance Service.

Hart, B., & Risley, T.R. (1995). *Meaningful differences in the everyday experience of young American children.* Baltimore, MD: Paul H. Brooks.

Joint Committee on Infant Hearing. (2007). [Year] 2007 position statement: Principles and guidelines for early hearing detection and intervention. *Pediatrics, 102*(4), 893–921.

Jones, R. (2003). *Parental occupation coding*. Report submitted to Performance Measurement and Reporting Taskforce, Ministerial Council on Education, Employment Training and Youth Affairs. Appendix 4, 33–34. Retrieved June 8, 2009, from http://www.curriculum.edu.au/verve/_resources/parentaloccupation_file.pdf

Kilminster, M.G.E., & Laird, E.M. (1978). Articulation development in children aged three to nine years. *Australian Journal of Human Communication Disorders, 6*(1), 23–30.

Kumar, S., et al. (2008). *Literature review of current best practice in early intervention for children with a permanent hearing loss*. Technical report produced for Queensland Health. Retrieved June 7, 2009, from http://www.health.qld.gov.au/healthyhearing/pages/publications.asp.

Ling, D. (2002). *Speech and the hearing impaired child: Theory and practice* (2nd ed.). Washington, DC: Alexander Graham Bell Association for the Deaf and the Hard of Hearing.

Marschark, M., Lang, H.G., & Albertini, J.A. (2002). *Educating deaf students: From research to practice*. New York, NY: Oxford University Press.

Marschark, M., & Spencer, P.E. (2003). *Oxford handbook of deaf studies, language, and education*. New York, NY: Oxford University Press.

Nicholas, J.G., & Geers, A. (2007). Will they catch up? The role of age of cochlear implantation in the spoken language development of children with severe to profound hearing loss. *Journal of Speech, Language, and Hearing Research, 50*(4), 1048–1062.

Nunes, T., & Moreno, C. (2002). An intervention program for promoting deaf pupils' achievement in mathematics. *Journal of Deaf Studies and Deaf Education, 7*(2), 120–133.

Olusanya, B.O., Ruben, R.J., & Parving, A. (2006). Reducing the burden of communication disorders in the developing world: An opportunity for the Millennium Development Project. *Journal of the American Medical Association*, *296*(4), 441–444.

Oxford Centre for Evidence Based Medicine. (2001). *Levels of evidence and grades of recommendation*. Retrieved May 22, 2008, from http://www.cebrn.net/levels_of_evidence.asp

Peterson, G.E., & Lehiste, I. (1962). Revised CNC lists for auditory tests. *Journal of Speech and Hearing Disorders, 27*, 62–70.

Pittman, A.L., Lewis, D.L., Hoover, B.M., & Stelmachowicz, P.G. (2005). Rapid word-learning in typical-hearing and hearing-impaired children: Effects of age, receptive vocabulary, and high frequency amplification. *Ear and Hearing, 26*(6), 619–629.

Plant, G. (1984). A diagnostic list for severely and profoundly hearing-impaired children. *Australian Journal of Audiology, 6*(1), 1–9.

Rhoades, E.A. (2001). Language progress with an auditory-verbal approach for young children with hearing loss. *International Pediatrics, 16*(1), 41–47.

Rhoades, E.A. (2006). Research outcomes of auditory-verbal intervention: Is the approach justified? *Deafness Education International, 8,* 125–143.

Rhoades, E.A., & Chisolm, T.H. (2000). Global language progress with an auditory-verbal approach. *The Volta Review, 102*(1), 5–25.

Romanik, S. (1990). *Auditory skills curriculum*. Moorebank, Australia: New South Wales Department of Education and Training.

Schorr, E. A., Roth, F. P., & Fox, N. (2008). A comparison of the speech and language skills of children with cochlear implants and children with typical hearing. *Communication Disorders Quarterly, 29*(4), 195–205.

Semel, E., Wiig, E. H., & Secord, W. A. (1995). *CELF Clinical Evaluation of Language Fundamentals* (3rd ed.). San Antonio, TX: The Psychological Corporation, Harcourt Brace & Company.

Serry, R., Blamey, P., & Grogan, M. (1997). Phoneme acquisition in the first 4 years of implant use. *American Journal of Otology, 18*(6 Suppl.), 122S–124S.

Serry, R., Blamey, P., Spain, P., & James, C. (1997). Computer Aided Speech and Language Analysis. *Australian Communication Quarterly*(Spring), 27–28.

Sharma, A., Dorman, M.F., & Kral, A. (2005). The influence of a sensitive period on central auditory development in children with unilateral and bilateral cochlear implants. *Hearing Research, 203*(1-2), 134–143.

Shriberg, L.D., Austin, D., Lewis, B.A., Sweeney, J.L., & Wilson, D.L. (1997). The percentage of consonants correct (PCC) metric: Extensions and reliability data. *Journal of Speech, Language, and Hearing Research, 40*(4), 708–722.

Shriberg, L.D., & Lof, G.L. (1991). Reliability studies in broad and narrow transcriptions (phonetic). *Clinical Linguistics and Phonetics, 5*, 225–227.

Sininger, Y. (1999). Auditory system development, experimental auditory deprivation, and development of speech perception and hearing. The case for early identification of hearing loss in children. *Pediatric Clinics of North America, 46*(1), 1–14.

Sussman, K.D., Duncan, J., Estabrooks, W., Hulme, J., Moog, J.S., & McConkey Robbins, A. (2004). *The option of spoken communication.* Proceedings of 2004 Summit on Deafness–Spoken Language Options in the 21st Century: Predicting Future Trends in Deafness. Washington, DC: Alexander Graham Bell Association for the Deaf and Hard of Hearing.

Svirsky, M.A. (2000). Language development in children with profound and prelingual hearing loss, without cochlear implants. *Annals of Otology, Rhinology, and Laryngology, 185*(Suppl.), 99–100.

Svirsky, R., Robbins, A. M., Kirk, Pisoni, & Miyamoto. (2000). Language development in profoundly deaf children with cochlear implants. *Psychological Science, II*(2), 153-158.

Svirsky, M.A., Teoh, S.W., & Neuberger, H. (2004). Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation. *Audiology and Neuro-Otology, 9*(4), 224–233.

Tobey, E.A., Geers, A., Brenner, C., Altuna, D., & Gabbert, G. (2003). Factors associated with speech production skills in children implanted by age five. *Ear and Hearing, 24*(Suppl.), 36S–45S.

Traxler, C.B. (2000). The Stanford Achievement Test, 9th Edition: National Norming and Achievement Standards for Deaf and Hard-of-Hearing Students. *Journal of Deaf Studies and Deaf Education, 5*, 337-348.

Uus, K., & Bamford, J. (2006). Effectiveness of population-based newborn hearing screening in England: Ages of interventions and profile of cases. *Paediatrics, 117*(5), 887–893.

Wake, M. (2002). Newborn hearing screening: Decision time for Australia. *Medical Journal of Australia, 177,* 172-173.

Watson, T.J. (1957). Speech audiometry for children. In A.W.G. Ewing, *Educational Guidance and the Deaf Child* (pp. 278-296). Manchester: The University Press.

Yoshinaga-Itano, C., Sedey, A.L., Coulter, D.K., & Mehl, A.L. (1998). Language of early and later identified children with hearing loss. *Pediatrics, 102*(5), 1161–1171.

Zimmerman, I.L., Steiner, V.G., & Pond, R.E. (2002). *Preschool Language Scale-4.* San Antonio, TX: The Psychological Corporation, Harcourt Brace & Company.

Table 1. Characteristics of AVT group and TH group at 21-month posttest

	AVT Group	TH Group
N	25	25
Mean age in months (SD)	68.4 (15)	57.42 (14.75)
Gender		
Male	18	18
Female	7	7
Age at identification in months	24.6	n/a
Mean PTA better ear (SD)	79.37 (22.79)	n/a
Onset of loss		
Congenital	23	n/a
Prelingual	2	n/a
Age at CI in months (SD)	27 (5.8)	n/a
Time spent in AVT program in months (SD)	41 (16.34)	n/a
Hearing Device:		
Number of children with bilateral HA	10	n/a
Number of children with unilateral HA	1	n/a
Number of children with HA in one ear and CI in the other	12	n/a
Number of children with one CI only	2	n/a

HA= Hearing Aids
CI=Cochlear Implant

Table 2. Occupation category of head of the household for AVT group and TH group

Occupation	**AVT Group**	**TH Group**
Manager	43%	15%
Professional	14%	65%
Technical/Trade	29%	5%
Community/Personnel	7%	0%
Clerical/Administrative	7%	10%
Sales	0%	5%

Table 3. Battery of assessments used

Test	Description of Test	Scoring
Speech Perception		
PLOTT (Plant, 1984)	The child is asked to repeat back 22 phonemes that represent the full range of speech frequencies; presented via live voice	If the child repeats the phoneme correctly, he or she scores 1 point for both detection and imitation. An incorrect response is scored with a detection point only, and no response receives no points. A percentage score is calculated for both detection and imitation.
Manchester Junior Words/PBK (Phonetically Balanced List for Kids) Words (Watson, 1957)	The child is asked to repeat back 10 simple monosyllabic words; presented via live voice.	The responses are scored by whole words correct and by phonemes correct. For example, if the target word is *school* and the child responds *soon*, he or she would score 2 out of a possible 4 for Phoneme Score and 0 out of 1 for Word Score. If the child responds *school*, he or she would score 4 out of 4 for Phoneme Score and 1 out of 1 for Word Score. A percentage score for phonemes correct and for whole words correct is obtained.

CNC (Consonant-Nucleus-Consonant) Words (Peterson & Lehiste, 1962)	The child is asked to repeat back 25 monosyllabic words either presented via live voice or recorded voice at 65 dBA. The pediatric list used at this auditory-verbal therapy program is half the adult list of 50 words.	The responses are phonetically transcribed and scored by whole words correct and by phonemes correct. Percentage scores for whole words, vowels, consonants, and phonemes are obtained.
BKB (Bench, Kowall, and Bamford) Sentences (Bench & Bamford, 1979)	The child is asked to repeat back 16 sentences that are presented via live voice or recorded voice at 65 dBA.	Scoring is by key words correct. For example, "The clown had a funny face" has 3 key words (maximum points for the sentence is 3). If the child repeats "The clown was funny," he or she would score 2 points. Final score is percentage key words correct.
Language		
Preschool Language Scale-Fourth Edition (PLS-4) (Zimmerman, Steiner, & Pond, 2002)	Measures young child's receptive and expressive language from birth to 6 years 11 months.	The scoring ceiling used was five consecutive items incorrect. Child's score is expressed as an age equivalent.
Clinical Evaluation of Language Fundamentals (CELF-3) (Semel, Wiig, & Secord, 1995)	Measures child's receptive and expressive language from 21 months to 6 years. Six subtests were administered only to children who achieved higher than the top score for the PLS-4. Subtests were Sentence Structure, Word Structure, Concepts and Directions, Formulated Sentences, Word Classes, and Sentence Recalling.	If a child scored the highest possible score on the PLS-4, the CELF-3 was administered. The child's score is expressed as an age equivalent.

Receptive Vocabulary		
Peabody Picture Vocabulary Test (PPVT-3) (Dunn & Dunn, 1997)	Measures child's receptive vocabulary. Because this test was developed in the United States, Australian alternatives for some items were used by the testers: *cupboard* for *closet*, *rubbish* for *garbage*, *biscuit* for *cookie*,and *jug* for *pitcher*.	Child's score is expressed as an age equivalent.
Speech		
Goldman-Fristoe Test of Articulation-2 (GFTA-2) (Goldman & Fristoe, 2001)	Assesses articulation of consonants and was administered to participants in both AVT and TH groups.	Child's score is expressed as an age equivalent.
CASALA (Computer Aided Speech and Language Analysis) (Serry, Blamey, Spain, & James, 1997)	This assessed articulation of consonants from a videotaped sample of spontaneous speech for children in the AVT group only. It was designed to transcribe and analyze phonetic aspects of speech samples. Broad transcription was chosen for reliability (Bow, Blamey, Paatsch, & Sarant, 2002; Shriberg & Lof, 1991).	For a consonant to be scored as an attempted production, two well-formed examples of phonemes are required to be present in a sample, regardless of whether the produced phoneme had an identifiable target. For a consonant to be scored as correctly produced, it had to be produced correctly at least twice within a sample, with a minimum of 50% of the phoneme targets to be correctly produced. Score is measured as percent consonants attempted and percent correct consonants.

Table 4. AVT group speech perception results at pretest and posttest (expressed as percentage correct) for PLOTT Phoneme Detection, Manchester Junior Words, CNC Words, and BKB Sentences

	Pretest				Posttest					
Name of Test	N	Mean Score %	SD	Range	N	Mean Score %	SD	Range	Wilcoxon z	*p*
PLOTT										
Phoneme Detection	25	100	0	100–100	24	100	0	100–100	not tested	-
Phoneme Imitation	25	66.47	12.04	45–100	24	79.51	9.84	64–100	3.83	< 0.0001*
Manchester Junior Words/PBK Words										
Phoneme Score	18	75.68	13.43	50–100	18	90.87	6.73	77–100	11.3	< 0.0001*
Word Score	18	45.8	21.18	40–75	18	75	17.91	50–100	24.94	< 0.0001*
CNC Words Live Voice (Quiet)										
Phoneme Score	10	80.82	16.15	55–100	22	85.97	8.26	76–95.9	9.35	0.0139*
Vowel Score	11	95.64	6.05	80–100	22	98.18	2.68	92–100	2.8	0.132
Consonant Score	11	73.36	21.09	36–98	22	80	11.56	64–96	1.96	0.05*
Word Score	11	54.64	29.06	36–98	22	61.18	22.66	16–92	1.96	0.008*
CNC Words Recorded 65dBA (Quiet)										
Phoneme Score	4	75.5	9.57	64–86	9	73.17	13.41	53–88	not tested	-
Vowel Score	4	80.85	24.90	44–87	9	86.67	10.00	76–100	not tested	-
Consonant Score	4	76.85	10.73	62–84	9	69	14.00	48–82	not tested	-
Word Score	4	58.98	25.07	36–92	9	48.77	20.74	25–76	not tested	-
BKB Sentences										
BKB Sentences Live Voice (Quiet)	10	64.5	26.30	26–94	24	79.71	19.82	33–100	1.05	0.293
BKB Sentences Recorded 65dBA (Quiet)	2	81	24.04	64–98	11	66.23	20.81	26–90	not tested	-

* = Acceptable level of significance is ≤ 0.05.

Table 5. Summary of changes in age-equivalent scores in years for AVT group and TH group over 21-month test period and results of statistical analysis of change scores over time

Test	Group	Pretest			Posttest			Statistical Result	
		N	Mean	SD	N	Mean	SD	*t*	*p*
Total Language (PLS-4/ CELF-3)	AVT	25	3.58	1.33	25	5.56	1.15	20.84	< 0.001*
	TH	25	3.46	1.39	25	5.47	1.19	13.74	< 0.001*
Receptive Vocabulary (PPVT-3)	AVT	25	2.79	1.29	25	4.77	1.21	12.26	< 0.001*
	TH	25	2.86	1.32	25	5.67	1.65	17.06	< 0.001*
Speech (GFTA-2)	AVT	25	3.02	1.33	25	4.58	1.17	8.10	< 0.001*
	TH	25	3.45	1.35	25	5.05	1.20	8.54	< 0.001*

* = significant difference

Table 6. Summary of CASALA scores (percentage) and statistical tests of change over time for AVT group consonants attempted and consonants correctly produced

	Attempts				Correct			
Consonant	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*
/m/	15.00 (9.52)	19.59 (7.16)	2.08	< **0.05**	96.3 (1.12)	95.9 (1.01)	0.89	0.377
/n/	26.00 (16.12)	36.73 (10.58)	2.84	< **0.006**	77.8 (2.16)	91.3 (0.79)	1.97	< **0.05**
/ŋ/	5.10 (3.05)	6.68 (5.09)	1.41	0.158	60.1 (2.47)	78.3 (1.06)	2.49	< **0.05**
/w/	10.50 (6.37)	13.73 (7.94)	1.24	0.215	94.3 (0.61)	95.4 (1.00)	0.56	0.577
/j/	5.64 (4.56)	12.00 (6.71)	3.82	< **0.006**	92.7 (1.93)	92.9 (1.03)	1.66	0.097
/p/	12.78 (10.78)	14.82 (6.39)	1.56	0.120	81.4 (3.30)	94.1 (1.12)	2.76	< **0.006**
/b/	13.61 (14.38)	12.18 (7.68)	0.93	0.354	90.4 (2.48)	97.6 (1.00)	2.24	< **0.05**
/t/	30.30 (17.03)	42.82 (15.76)	2.73	< **0.05**	40.7 (0.64)	49.1 (1.15)	0.57	0.564
/d/	13.96 (9.05)	19.14 (11.62)	1.78	0.078	73.5 (0.29)	78.0 (1.15)	-0.26	0.797
/k/	16.70 (9.04)	24.59 (10.91)	2.55	< **0.05**	64.6 (3.05)	89.6 (1.15)	2.74	< **0.006**

/g/	8.62 (6.25)	9.73 (6.73)	0.88	0.380	62.3 (7.81)	93.6 (1.15)	5.26	< **0.006**
/f/	6.11 (4.47)	6.90 (3.66)	2.03	< **0.05**	62.7 (2.50)	97.2 (0.99)	4.30	< **0.006**
/v/	4.59 (3.16)	5.70 (4.14)	1.75	0.081	63.9 (2.68)	82.8 (1.09)	2.11	< **0.05**
/θ/	2.65 (2.06)	3.68 (2.58)	1.93	0.054	49.9 (1.87)	76.8 (1.13)	1.43	0.154
/ð/	15.29 (11.65)	19.32 (12.31)	1.98	< **0.05**	35.3 (1.15)	64.7 (5.23)	1.87	0.626
/s/	15.69 (9.64)	24.91 (12.72)	3.23	< **0.006**	74.6 (1.12)	86.6 (1.04)	2.49	< **0.05**
/z/	8.00 (6.78)	11.14 (9.07)	2.17	< **0.05**	74.7 (1.17)	83.6 (1.02)	0.96	0.336
/ʃ/	2.56 (2.03)	4.85 (3.25)	2.86	< **0.006**	93.3 (1.32)	98.2 (1.04)	0.91	0.367
/tʃ/	3.53 (2.67)	3.40 (3.89)	0.29	0.774	62.9 (1.45)	90.8 (1.15)	2.15	< **0.05**
/dʒ/	2.31 (1.70)	2.71 (2.30)	0.45	0.656	47.9 (1.46)	75.1 (1.23)	0.22	0.830
/h/	7.70 (6.11)	8.55 (6.62)	0.87	0.384	88 (1.12)	94.3 (1.12)	1.75	0.080
/l/	14.42 (9.45)	21.86 (11.76)	2.90	< **0.006**	65.6 (65.6)	69.1 (1.19)	0.01	0.993

/r/	9.19 (7.20)	9.05 (4.40)	1.31	0.192	67.8 (1.13)	77.4 (1.02)	1.46	0.146

Note: Significant differences are highlighted in boldface type.

Is Auditory-Verbal Therapy Effective for Children with Hearing Loss?

A longitudinal controlled study of speech, language, reading, mathematics and self esteem outcomes

By

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Abstract

This longitudinal study aimed to investigate the effectiveness of Auditory-Verbal Therapy for a group of children with hearing loss. Their speech and language outcomes were compared with those for a matched control group of children with typical hearing over 50 months. Reading, mathematics and self-esteem outcomes were also investigated from the 38 months posttest to the 50 months posttest. Nineteen (19) children in an Auditory-Verbal Therapy program (mean hearing loss 79.39 dB) were initially matched with the control group for language age, receptive vocabulary, gender and socioeconomic level. Both groups made significant progress ($p = <0.001$) in speech and language over 50 months and there was no significant difference ($p = > 0.05$) between the change scores for speech and language for the two groups over 50 months. There was also no significant difference ($p = > 0.05$) between the change scores for reading, mathematics and self-esteem between both groups from the 38 months posttest to the 50 months posttest. Seventy nine (79%) percent of the children in the Auditory-Verbal Therapy program had language scores within the typical range and the group had a mean language age equivalent that was only 2.1 months lower than their mean chronological age at the 50 months posttest.

The treatment of hearing loss in children is a dynamic and fast-changing field. Since the introduction of universal newborn hearing screening, digital hearing aids and cochlear implants, there has been increased debate about educational options for children with hearing loss. Appropriate and timely information is needed in order to guide parent and professional decision-making. However, rigorous evidence for the outcomes of any of the educational approaches in use today is minimal (Gravel & O'Gara, 2003; Sussman, Duncan, Estabrooks, Hulme, Moog, McConkey Robbins, 2004). Auditory-Verbal Therapy is no exception, and this longitudinal study is designed for the purpose of investigating the effectiveness of Auditory-Verbal Therapy for a group of children with hearing loss. Their speech and language outcomes were compared with those for a matched group of children with typical hearing from the pretest to the 50 months posttest. Reading, mathematics and self esteem assessments were added at the 38 months posttest, as many of the group reached school age, and outcomes were studied from the 38 months posttest to the 50 months posttest.

Research on Auditory-Verbal Therapy has been criticised as sparse, incomplete and lacking in rigour (Eriks-Brophy, 2004; Rhoades, 2006). Research findings on outcomes of Auditory-Verbal Therapy to date are summarized here and a more complete review can be found in Dornan, Hickson, Murdoch and Houston (2008). Research on communication intervention has been classified into providing three levels of evidence (Eriks-Brophy, 2004, Fratalli, 2004; Fineberg, 1990; Holland, Fromm, De Ruyter, and Stein, 1996; Oxford Centre for Evidence-Based Medicine, 2001). Class 1 evidence consists of well designed experimentally controlled studies, usually randomized controlled trials involving large numbers of subjects assigned to random groups. These studies are not ethically feasible in outcomes research where clients or their parents have chosen one approach over another.

Consequently, Class 1 evidence is not possible in studies of Auditory-Verbal Therapy outcomes (Rhoades, 2006). Class 11 studies include quasi-experimental designs, often in the form of cohort studies or program evaluations. Cohort studies are prospective studies following a group of individuals over time to examine particular outcomes, which may involve a control group for comparison and may have limited generalisability. Class 111 studies are typically non-experimental research designs which are often retrospective, questionnaires or surveys, case studies, data base studies, group judgements or expert opinions of performance. Therefore, Class 11 evidence is the highest level of evidence typically available, and Class 11 and Class 111 classifications will be used to describe current evidence on outcomes of Auditory-Verbal Therapy for children for language, speech and reading. There is no current evidence available for Auditory-Verbal Therapy outcomes for mathematics or self esteem.

Much of the existing studies of Auditory-Verbal Therapy outcomes are Class 111 in nature and are retrospective surveys or case studies (e.g. Davis & Morrison, 2005; Duquette, Durieux-Smith, Olds, Fitzpatrick & Whittigham, 2002; Easterbrooks, O'Rourke and Todd, 2000; Goldberg & Flexer, 1993; 2001; McCaffrey, Davis, Macneilage, & von Hapsburg, 1999; Warner-Czyz, Davis & Morrison, 2005; Wray, Flexer and Vaccaro, 1997; Robertson & Flexer, 1993). These authors found a high degree of mainstreaming for children in Auditory-Verbal programs, and some evidence of reading and academic potential. However these studies have limited generalisability because of their retrospective nature, inconsistency in the use of standardised assessments, possibility of self selected populations and lack of control groups.

Two Class 11 studies on the same population, which did include a control group, investigated the length and complexity of utterance produced by preschool children with hearing loss compared with children who had typical hearing. These studies showed some evidence that Auditory-Verbal Therapy can provide an acceleration of development of language (Duncan, 1999; Duncan & Rochecouste, 1999). In two Class 11 studies on a different population, researchers used standardised assessments on a heterogeneous group of children with hearing loss in an Auditory-Verbal Therapy program (aged 6 – 40 months) over 1 to 4 years with language tests repeated yearly (Rhoades & Chisholm, 2000; Rhoades, 2001). No control group was used. They found that this group of children in an Auditory-Verbal Therapy program progressed at a rate of at least one year of language progress in one year of time. In another Class 11 study of 37 children in an Auditory-Verbal Therapy program (Hogan, Stokes, White, Tyszkiewicz, & Woolgar, 2008), data from assessments for spoken language was gathered at the start of the study and repeated every 6 months over a period ranging from 1 year to 4 years. Children's outcomes for language were extrapolated according to the expected typical rate of development. The authors report an accelerated spoken language development for this group of children with hearing loss beyond that expected for children with typical hearing. Once again, this study lacked a control group and is difficult to interpret because children do not necessarily progress at an even rate if developmental progress is extrapolated.

This typical rate of developmental progress for children with hearing loss in an Auditory-Verbal Therapy program was replicated in earlier stages of this current longitudinal study (Dornan, Hickson, Murdoch & Houston, 2007; 2009). There were initially 29 children aged 2 to 6 years with a mean pure tone average of 76.17dB HL in the study. Outcomes for speech and language skills were compared to those for a control group of children with typical hearing over 9 months (2007) and 21 months (2009) time span. The children with typical hearing were matched for language age, receptive vocabulary, gender and head of the household education level. Results showed that both groups of children made the same amount of progress for language and speech. Receptive vocabulary progress was the same for the two groups at the 9 months posttest but at the 21 months posttest, there was a significant advantage in this skill for the children with typical hearing. This longitudinal study has so far provided some Class 11 level evidence, and included a control group, but the short time span is a limiting factor.

When investigating effectiveness of an education option, the educational achievement of the group is important in addition to speech and language outcomes. Educational achievement typically lags behind the norm for children with typical hearing (Traxler, 2000; Powers, 2003). Academic success for a child with hearing loss in the mainstream has been found to be influenced by a number of factors, including an oral education, a shorter period of hearing loss prior to amplification or receiving an implant, duration of implant use, more recent cochlear implant processing strategies, number of working electrodes, level of intelligence and a more recent hearing loss (Damen, van den Oever-Goltstein, Langereis, Chute, & Mylanus, 2006; Geers, 2002; Geers, Brenner, Nicholas, Uchanski, Tye-Murray, & Tobey, 2002).

Reading is a fundamental academic skill which has been reported to be affected by significant hearing loss, with many children never achieving functional literacy (Geers, 2003; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). In a Class 11 study, Traxler (2000) found that children with severe to profound hearing loss typically completed 12th grade with language levels of a 9- to 10-year-old hearing child and a reading level equivalent of the 3rd- to 4th-grade. These outcomes are in contrast to those found in two Class 111 studies on the reading of children in an Auditory-Verbal Therapy program (Robertson & Flexer, 1993; Wray, Flexer, and Vaccaro, 1997), which found that children in an Auditory-Verbal Therapy program were able to read at or above age appropriate levels. Once again, these studies did not include control groups, so interpretation of results is difficult. Other Class 111 studies on children educated in Auditory-Verbal Therapy programs (Durieux-Smith et al., 1998; Goldberg & Flexer, 1993; 2001) have found that the majority of children in the studies had been mainstreamed at school, with adequate competence in reading ability.

Research on the mathematics achievements of children with hearing loss is generally inadequate. Furthermore, little data is available on mathematics outcomes for children educated in Auditory-Verbal Therapy programs. Mathematics ability for children with hearing loss has been shown to be related to children's skills in reading, language, and morphological knowledge regarding word segmentation and meaning (Kelly & Gaustad, 2007). As well as reduced access to hearing, two aspects of the functioning of children with hearing loss have been reported to place them at risk for underachievement in mathematics (Nunes & Moreno, 2002). These are, firstly, their reduced opportunities for incidental learning, and secondly, their difficulty in making inferences involving time sequences. As a result, constraints on academic attainments and consequent career opportunities may have significant economic impact because of the relationship between education level and income (Nunes, et al., 2002). The mathematics performance of school students with hearing loss reported by Traxler (2000) showed that results indicated only partial mastery of mathematical knowledge and skills. This author found that high school graduates typically had computational skills comparable to 6-th grade students with typical hearing, and problem solving skills in mathematics comparable to 5-th grade students with typical hearing.

In addition to reading, mathematics and overall academic achievement difficulties, the way children with hearing loss perceive themselves and their abilities are an important outcome measure. Researchers have found that for children with significant hearing loss who do not develop language skills commensurate with their peers, their self esteem and emotional development is often severely affected (Bat-Chava, Martin, & Kosciw, 2005; Crouch, 1997; Hintermair, 2006; Lane & Grodin, 1997; Nicholas & Geers, 2003). However no research to date is available for self esteem development for children in Auditory-Verbal Therapy programs.

This study aimed to investigate whether the promising outcomes for speech and language of children in an Auditory-Verbal Therapy program shown in earlier stages of this longitudinal controlled study (Dornan, Hickson, Murdoch and Houston, 2007; 2009) over 21 months were maintained over 50 months by 19 of the same children who remained in the study for the full 50 months. Outcomes for language, receptive vocabulary and speech for the Auditory-Verbal Therapy group (AVT group) were measured over the 50 months period. This study also aimed to investigate the same children's progress for reading, mathematics and self esteem from the 38 months posttest to the 50 months posttest. All outcomes for the AVT group were compared to those for their 19 matched pairs of children with typical hearing (TH group).

Method

This study employed a matched group repeated measures design. The TH group was individually matched to the AVT group for total language, receptive vocabulary, gender and socioeconomic level as measured by the education level of the head of the household. In this longitudinal study, participants in both groups were assessed at the start of the study (pretest) and at the 9-months, 21-months, 38-months and 50 months points after pretest using an assessment battery. These points of testing were determined by the availability of the children and staff performing the assessments, as tests needed to be carried out within two weeks of the due date, so this was a factor in planning the longitudinal study. Results for the first 9 month and 21 month posttests have previously reported (Dornan, Hickson, Murdoch, & Houston, 2007; 2009). The results for the progressive development of speech and language from the pretest to the 50 months posttest, and the additional tests for reading, mathematics and self esteem from the 38 months posttest to the 50 months posttest are reported in this study.

Participants

Auditory-Verbal Therapy Group (AVT Group)

In this stage of the longitudinal study, 19 children with a range of sensorineural hearing losses, with either hearing aids or cochlear implants, were initially matched with a group of 19 control children with typical hearing and assessed at the start of the study. The children attended one of five regional centres of an Auditory-Verbal Therapy program in Queensland, Australia, which offers a range of services including audiology, early intervention and a cochlear implant program. This program adheres to the Principles of Auditory-Verbal Therapy (Adapted from Pollack, 1970; endorsed by the Alexander Graham Bell Academy for Listening and Spoken Language, 2007). The operational model for this Auditory-Verbal Therapy program has been described on the Hear and Say Centre website (http://www.hearandsaycentre.com.au/mission-delivery.html). It is important to take into account the operational model because even though a particular Auditory-Verbal Therapy program may adhere to all of the principals of Auditory-Verbal Therapy, programs may vary in the operational details.

All children were receiving regular audiologic follow-up by qualified pediatric audiologists to ensure optimal amplification, and weekly individual Auditory-Verbal Therapy in which parents were guided and coached to be the primary language models for their child. Diagnostic teaching principles were also employed, and children were fully integrated into mainstream education at the earliest possible age. Potential participants at the start of the study included all of the 75 children in the program (aged 2 months to 6 years of age) who were in the early intervention program, satisfied the selection criteria, were geographically accessible and whose parents agreed to participate in the research. No parent refused to participate. Selection criteria were:

- Pure-Tone Average (PTA) at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz of ≥ 40dB hearing threshold levels in the better ear.

- Prelingually deafened (at ≤ 18 months old).
- Attended the educational program weekly for intensive one-to-one parent based Auditory-Verbal Therapy for a minimum of six months.
- Wore hearing devices consistently (hearing aids and/or cochlear implants).
- Had aided hearing within the speech range or had received a cochlear implant.
- No other significant cognitive or physical disabilities reported by parents or educators.
- 2 to 6 years of age at the first test session.
- Both parents spoke only English to the child**.**

At the 50 months posstest, there were 19 AVT group children remaining in the study (see Table 1).

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The AVT group's mean age at the pretest was 3.80 years (SD = 1.15) and at posttest was 8.02 years (SD = 1.32). Ten of the original 29 children were not included at the 50 months posttest. Of these, two were transferred to another program in the first 9 months of the study because of diagnosis of additional disabilities, four left the area and another two children were unavailable for family reasons. In addition, results for two children in the AVT group had to be eliminated because their matched control child from the TH group had left the study for family reasons. The mean age of the 19 remaining AVT group children at the 50 months posttest was 8.03 years (range = 6.17 - 10.66 years; S.D. = 1.26). The participants had bilateral sensorineural hearing loss ranging from moderate to profound, with a mean PTA of 79.39 dB HL (range = 45 dB to >110 dB; S.D. = 23.79). All children were fitted with hearing aids and commenced intervention within 3 months of diagnosis of the hearing loss. Three of the children had been diagnosed and commenced intervention before the critical age of 6 months identified by Yoshinaga-Itano, Sedey, Coulter, and Mehl (1998); all of these had a profound bilateral sensorineural loss, and subsequently received a cochlear implant before 19 months of age. All 13 implanted children in this study had received unilateral Cochlear Nucleus CI 24 implants and used an ACE processing strategy. The relatively late mean time of implant (27.54 months, SD = 15.24) was due to the fact that two children received a unilateral cochlear implant during the period from the pretest to the 9 months posttest because of plateauing of their speech and language development. The median age at implant was 23.04 months. During the study, six children received a bilateral cochlear implant, and another child had difficulties with ongoing electrode issues, which finally resulted in reimplantation with a unilateral cochlear implant. One had mild cerebral palsy in addition to hearing loss. All but two cochlear implant users in the study also wore a hearing aid in the contra-lateral ear. Both hearing devices were balanced by their Australian Hearing audiologist according to the recommendation of Ching, Psarros and Incerti (2003). All children wore their hearing aids consistently throughout the study. Speech perception tests were administered to ensure that the children's listening skills were developing optimally.

Typical Hearing Group (TH Group)

The children with typical hearing in the control group were recruited by families and staff of the Auditory-Verbal Therapy program (Table 1). It is acknowledged that this may be a limitation of the study. However, participants from other sources were not available. Because of the difficulty in matching both total language age and receptive vocabulary scores, 64 children with typical hearing were initially tested to ensure that matching of control children with the AVT group was possible. The 19 children with typical hearing finally selected were matched at the initial assessment (± 3 months) with the experimental group for total language age on the Preschool Language Scale (PLS-4) (Zimmerman, Steiner, & Pond, 2002) or the Clinical Evaluation of Language Fundamentals (CELF-3) (Semel, Wiig, & Secord, 1995), and also for receptive vocabulary on the PPVT-3 (Dunn &

Dunn, 1997). Matching criteria also included gender and socioeconomic level as assessed by highest education level of the head of the household. Selection criteria were:

- Hearing threshold levels within the range of 0 to 20 dB at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for both ears.
- No delay in phonetic development as assessed using the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 2001). Australian norms for articulation (Kilminster & Laird, 1978) were used and results within one standard deviation of the mean for age were required for inclusion.
- No significant cognitive or physical disabilities (as evidenced by case history or parent report).
- Both parents spoke only English to the child.

The mean age of the control group children at the start of the study was 3.11 years (S.D. = 1.22) and the mean age at the 50 month follow-up was 7.32 years (S.D. = 1.39). Had chronological age been used for matching (instead of language age), as was done in the study reported by Duncan (1999) and Duncan and Rochecouste (1999), the children with typical hearing typically would have had a higher language level than the children with hearing loss of the same chronological age (Blamey et al., 2001) introducing the possibility that the group of children with typical hearing might progress faster. The study was conducted in Queensland, Australia, and, at the time, the average age for diagnosis of a sensorineural hearing loss in Australia was over two years because newborn hearing screening programs were not yet in place (Wake, 2002). Thus, it was highly likely that, if we had matched children by chronological age, the children with typical hearing would have had a significant language age advantage over the children with hearing loss. It is also possible that matching children for language age could have resulted in the children with hearing loss being significantly older than the children with typical hearing (Blamey, et al., 2001), introducing the potential that they may progress faster because of their superior cognitive skills. However, it was considered that the potential cognitive “advantage” afforded to the children with hearing loss who were older was likely to be offset by the delays they often experience in speech and language development.

When matching the control group with the experimental group, it was difficult to achieve a complete match for each individual child for both the total language score (PLS-4 or CELF-3) and the receptive vocabulary score (PPVT-3) as the range of total language and receptive vocabulary scores was wide. However, both groups of children were initially matched for total language scores and then for receptive vocabulary. Deciding how to define socioeconomic level for matching purposes was difficult because there are many different perspectives and a number of different possible measures (Kumar, et al., 2007). Some factors which might have been measured include family income, education level of the parents, and parental occupation (Marschark & Spencer, 2003). However it was thought that questions about family income may deter parents from long term commitment to the longitudinal study before it had commenced. Consequently, the occupations of both groups were placed in categories according to those developed by Jones (2003) for parents in education programs, as occupation category has been found to impact on vocabulary learning of a child with hearing loss (Hart & Risley, 1995). The AVT group and the TH group parents were found to have a moderate to high socioeconomic status, which is acknowledged as a limitation of the study.

Materials

To assess receptive and expressive language, receptive vocabulary, speech, reading, mathematics and self esteem at pretest and posttest for participants in both the AVT and TH groups, a battery of assessments was used (see Table 2).

Put Table 2 near here

Procedure

Clearance for this project was sought from the Medical and Ethical Committee of the Auditory-Verbal program and was then referred to the program Board of Directors who approved the project. Ethical clearance was also obtained from the Behavioural and Social Sciences Ethical Review Committee, University of Queensland, Brisbane, Australia. After consent was obtained from the parents for each participant, arrangements were made to conduct the assessments. Assessments of children in the experimental group took place at the child's program centre. For the control group, testing was performed either at the centre, at the child's education setting in a quiet room, or at the child's home.

Speech, language, reading and mathematics testing was performed by experienced, qualified speech-language pathologists. Because of geographic constraints, the most convenient and available qualified staff performed the testing and, frequently, different testers assessed the children at pretest and posttest. Tester reliability was not examined in the study, however all tests were administered according to the standardised instructions in the test manuals. The language and speech tests were administered over two sessions if possible, however a number of children required three sessions because of age or attentional constraints. Children were given rest breaks between assessments, and the session was discontinued if a child showed evidence of fatigue or distress. The children's responses to the Goldman-Fristoe Test of Articulation were not transcribed and scored at a later date, but were judged to be correct or incorrect at the time of testing.

The order of presentation of the standardised tests used is summarised in Table 3.

Put Table 3 near here

The order of testing for the TH group was different to the AVT group in order to account firstly for screening and then to establish a match with a child in the AVT group before the child was unnecessarily tested.

All tests for the experimental group were performed in the best aided condition. For all children with cochlear implants, the child's optimally functioning MAP as assessed by the child's audiologist and Auditory-Verbal Therapist was used. Both "T" levels (threshold, or minimum amount of current causing sound to be detected) and "C" levels (maximum amount of current causing discomfort) for the child's MAP were measured behaviourally and confirmed objectively where necessary. Optimal implant performance was verified by the stability of the MAP, consistent identification by the child of the seven sound test (i.e. the Australian adaptation of Ling's Six Sound Test, Romanik, 1990), other speech perception tests and the cochlear implant assisted audiogram (a record of the child's cochlear implant aided thresholds for responses at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz). The 'Ling sounds' are a range of speech sounds encompassing the frequencies that are widely used clinically to verify the effectiveness of hearing aid fitting in children (Agung, Purdy & Kitamura, 2005). The Ling six sound test was originally developed for the North American population (Ling, 2002), and in the seven sound test, /ɔ/ was added to account for the differences in the production and spectral content of Australian vowels (Agung, et al., 2005).For the children who wore hearing aids, best aided condition was determined by the child's audiologist and Auditory-Verbal Therapist, performance of the seven sound test, speech perception tests, and the child's aided audiogram.

The mean time between pretests and posttests was 51.16 months for the AVT group and 51.37 months for the TH group, this time difference being largely due to geographical access to the children with hearing loss. A paired *t* test indicated that there was no significant difference between the pre-post test intervals for the two groups (t = -.335, df = 18, p = 0.742).

Results

In the first instance, preliminary analysis was carried out to ensure the validity of matching of participant groups at the pretest, that is, the matching of total language on the PLS-4 or CELF-3 and receptive vocabulary on the PPVT-3 . The 19 participants in the AVT group had a total language mean age equivalent of 3.58 years (SD = 1.46) and the mean for the control group was 3.5 years (SD = 1.52). A Mann-Whitney test showed no significant difference between these values ($z = -0.307$; $p = 0.759$). Similarly there was no significant difference between groups for the mean receptive vocabulary age equivalents on the pretest for the PPVT-3 ($z = -0.197$; $p = 0.844$). The mean age equivalent for the experimental group on the PPVT-3 was 3.06 years (SD = 1.56) while the mean for the control group was 2.97 years (SD = 1.46).

Language and Speech

Outcomes for the age equivalents for each group for language, receptive vocabulary and speech were analysed using Wilcoxon signed rank tests and the mean rate of change for both groups was compared using a Mann-Whitney Test (see Table 4).

Put Table 4 near here

For total language, there were significant changes in scores over time from the pretest to the 50 months posttest for both groups, and these were not significantly different for both groups. By the time of the 50 months posttest, all of the children had improved enough to be above the ceiling of the PLS-4 and were tested on the CELF-3, although all but one of the AVT group was tested on the PLS-4 at the pretest. As age equivalents were not available individually for auditory comprehension and expressive communication on the CELF-3, standard scores were reported (Table 5).

Put Table 5 near here

The pretest and posttest measures were compared using a Mann-Whitney test and significant change over time was unable to be shown for these measures using standard scores at the 50 months posttest because these scores are age-corrected (see Table 5). The mean increase in age equivalents for the AVT group and TH group for total language over 50 months and also the rate of change per year is shown in Table 6.

Put Table 6 near here

In looking at the individual total language scores at the 50 months posttest, there was much variability, especially for the AVT group. It was noted that 78.95% of the AVT group had scores that were within or above the age appropriate range for total language on the CELF-3, and the remaining 21.05% scored below the typical range. This is in comparison to the TH group in which 100% of the children had scores within the typical range or above.

For receptive vocabulary, the scores of both the AVT group and the TH group showed significant change in age equivalents over time from pretest to the 50 month post test, and the amount of change was not significantly different for both groups (Table 4). The mean increase in age equivalents for the AVT group and TH group for language over 50 months and also the rate of change per year is shown in Table 6. For the AVT group, 63% had age equivalents for receptive vocabulary that were within the typical range or above, while 89% of the TH group scores were within this range or above.

Results for speech skills showed that both the AVT group and the TH group showed significant change in age equivalents over time from pretest to the 50 month post test, and this change in age equivalents was not significantly different for both groups (Table 4). The mean increase in age equivalents for the AVT group and TH group for speech skills over 50 months and also the rate of change per year is shown in Table 6. Forty two percent (42%) of the AVT group had scored at the ceiling of 7 years and 8 months for the test, and 63.16% of the TH group had also reached the ceiling of the test by this time. For the AVT group, 79% had age equivalents for speech skills that were within the typical range or above and 89% of the TH group had scores that were within the typical range or above this range.

Reading and Mathematics

For the reading and mathematics results (see Table 4), the Wilcoxon signed ranks test showed that the progress made over the 12 months of the study was not significant ($p = \leq 0.05$) for either group of participants. Pretest and posttest data was available for 7 matched pairs of children, while 10 pairs of children had data for the posttest only. One of the AVT group and three of the TH group children had not yet entered school and begun formal reading by the time of the 50 months posttest, while a number had not reached this stage at the pretest at 38 months, which reduced the number of available pairs of scores. Analysis of the change in scores for reading from pretest to posttest using a Mann-Whitney test showed no significant difference between the change for the AVT group and the TH group (p = >0.05). When all of the 10 pairs of available reading and mathematics scores at the posttest were compared for the AVT group and the TH group, and analysed using Mann-Whitney tests, this also showed that there was no significant difference between the scores for the two groups for reading and mathematics at the 50 months posttest (Table 4) (p = >0.05).

Self Esteem

Eighteen of the AVT group parents and 16 of the TH group parents responded to the questionnaire. One of the AVT group and 3 of the TH group children used the Pre-school Insight, and 17 of the AVT group and 13 of the TH group used the Primary Insight. The mean of the AVT group for sense of self was 31.94 (SD = 3.86), for sense of belonging was 32.29 (SD = 3.44) and for sense of personal power was 31.35 (SD = 3.71). The mean of the TH group for sense of self was 32.38 (SD = 2.81), for sense of belonging was 33.14 (SD = 3.24) and for sense of personal power was 30.38 (SD = 9.37).

The mean total rating by parents of the AVT group for self esteem was 96.18 (SD = 9.30), while that for the TH group was 96.08 (SD = 9.38). The majority of children in both participant groups were rated by their parents as having “High” self esteem (78.9% in the AVT group and 68.42% in the TH group). The remaining children in both groups were all rated by their parents as having “Good” self esteem. There were no children from either the AVT group or the TH group in the “Vulnerable” and “Very Low” categories. Overall, the self esteem results for the AVT group and the TH group were very comparable.

Discussion

This study compared the progress of the AVT group for language, speech, receptive vocabulary, reading, mathematics and self esteem with those for a control group of children with typical hearing. The study has found that the promising earlier outcomes for the AVT group (Dornan, Hickson, Murdoch, & Houston, 2007; 2009) have been maintained for the whole 50 months of this study for total language, receptive vocabulary and speech skills. The AVT group made significant progress in language, receptive vocabulary and speech over a 50 month period. However they did not make significant progress in reading and mathematics skills from the 38 month posttest, when these assessments were added to the test battery, to the 50 months posttest. Nevertheless, the results showed that the developmental progress made by the AVT group for language, receptive vocabulary and speech skills from the 0 months pretest to the 50 months posttest and that the developmental progress made by the AVT group for reading, mathematics and self esteem from the 38 months pretest to the 50 months posttest was the same as for the TH group. These results will now be discussed under the headings of language, receptive vocabulary, speech, reading, mathematics and self esteem. This discussion will include the amount of progress made by each group, comparison of the rate of progress between the AVT group and the TH group, percentage of children within the typical range, and a comparison of the results with other studies.

Language

The mean language progress for the AVT group has been significant, and at the same rate as the TH group. Progress has also been the same as expected for children with typical hearing, with the AVT group developing language at a rate of 12.31 months per year. The TH group of children also made impressive progress for total language at a rate of 13.45 months per year. The majority of the AVT group (78.95%) scored within the typical range or above for language. This is in comparison to the 84.49% of the typical population expected to fall within this range.

The AVT group of children achieved mean total language scores which were only 2.1 months below their mean chronological age, which is within one standard deviation of the mean for their age. Therefore the AVT group no longer exhibited a gap between their chronological age and language age at the 50 months posttest. These results are similar to those obtained previously for children in Auditory-Verbal Therapy programs (e.g. Durieux-Smith, et al., 1998; Rhoades & Chisolm, 2000) in which the majority of children left the program to attend a regular school with no chronological age and language age gap.

The results for the AVT group are not in agreement with those of Geers, Nicholas and Sedey (2003) who found that only 30% of a group of 181 children with hearing loss scored at the age appropriate level for receptive language, and 47% were within the age appropriate range for expressive language. This is compared to the 84.2% of the AVT group for receptive language and 78.94% for oral expression whose scores fell within the typical range in this study. The children in the Geers, et al. (2003) study had all received cochlear implants, with 89 attending total communication programs and 92 using oral communication. The results for the AVT group are also not in agreement with those reported by Sarant, Holt, Dowell, Rickards and Blamey (2008), who found that over half of 57 children in an Auditory-Oral program with permanent sensorineural hearing loss (aged 1-6 years), and who were tested on a battery of tests, had “poor language outcomes overall”. These children had been identified at a mean age of 10 months, and fitted with hearing aids at 15 months. Their mean PTA hearing loss was 63dB. In comparison, they had been diagnosed earlier than the AVT group, and less hearing loss, but were tested at age of school entry (55-75 months) and were therefore at a younger age than the AVT group at the 50 months posttest. However, at the 21 months posttest of this current longitudinal study, when the children were of a comparable age, results showed that 84% of the AVT group had language in the age appropriate range (Dornan, Hickson, Murdoch & Houston, 2009).

The results for rate of development of language for the AVT group are supported by those of Rhoades and Chisolm (2000) who found that group performances for children in an Auditory-Verbal Therapy program showed at least one year of progress in one year of time. The results are also in agreement with those of Hogan, Stokes, White, Tyszkiewicz, and Woolgar (2008) who found that the language of children in an Auditory-Verbal Therapy program progressed at the same rate or faster than the predicted rate of language development for children with typical hearing. However the lack of control groups in both studies makes direct comparison indecisive.

This rate of developmental progress for children in an Auditory-Verbal Therapy program which was the same as for children with typical hearing which was found in this study has also been found in other studies (Dornan, Hickson, Murdoch, & Houston, 2007; 2009; Hogan, Stokes, White, Tyszkiewicz, & Woolgar, 2008; Rhoades, 2001; Rhoades & Chisolm, 2000). This can be compared to that found by Blamey, Barry, Bow, Sarant, Paatsch, and Wales (2001) for a group of children in an Auditory-Oral program (mean Pure Tone Average of 78 dB HL), in which the group progressed in language skills at half to two-thirds the rate expected for group with typical hearing. However, because it is difficult to match all of the variables between studies on cohorts of children with hearing loss, comparison of studies on education outcomes are iTHerently difficult, and must be interpreted with caution.

Only a few other studies on outcomes for children with hearing loss, in which a group of children with hearing loss achieved a rate of growth similar to children with typical hearing, have been reported. These were outcomes studies on children identified before 6 months of age (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998), or children receiving cochlear implants before 18 months of age (Ching, Dillon, Day, Crowe, Close, Chisolm, & Hopkins, 2009; Dettman, Pinder, Briggs, Dowell, & Leigh, 2007; Svirsky, Teoh, & Neuburger, 2004). The results of this type of research on children who are provided with early auditory brain access through early identification and early optimal amplification can be partly explained by the facilitation caused by synchrony of development facilitated by maximum plasticity of the developing auditory system (Cole & Flexer, 2007).

A wide variability in children's outcomes was noted in this current study particularly for the children with hearing loss, but also for the children with typical hearing. At the posttest, one AVT group child had a total language score in excess of two standard deviations above the mean, one child scored more than one standard deviation above the mean. Also one AVT group child had scores that were one deviation below the mean, and two children scored more than two standard deviations below the mean. Five TH group children had language scores more than one standard deviation above the mean, no TH group children had scores more than two deviations above the mean and no children in this group had scores below the mean. This variability of performance for children with hearing loss has been recorded by many authors, most notably for children with cochlear implants (Blamey, Sarant, Paatsch, Barry, Bow & Wales, et al., 2001; Oullet & Cohen, 1999; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000; Szagun, 1997). More than half of the AVT group were cochlear implant recipients. Better language and speech scores have been associated with earlier age of implant (Svirsky, Teoh, & Neuburger, 2004; Tye-Murray, Spencer, & Woodworth, 1995) but this group of children have not been implanted particularly early, with a mean age of implant of 27 months.

One criticism of studies on the language of children in Auditory-Verbal Therapy programs is that the typically higher socioeconomic status of the parents may result in a self-selected population. A number of studies on outcomes of Auditory-Verbal Therapy report that the parents of the children came from a well-educated group, and these parents would be likely to have access to private therapies like Auditory-Verbal Therapy (Dornan, Hickson, Murdoch and Houston, 2007; Easterbrooks, O'Rourke, and Todd, 2000; Rhoades

& Chisolm, 2000). This topic has been further investigated by Dornan, Hickson, Houston and Murdoch (2009). It is suggested by the authors that the AVT group were advantaged by information their parents received on opportunities about Auditory-Verbal Therapy, as well as having received post-school education. However, they were not as advantaged socioeconomically as the TH group, whose parents were four times more likely to have a professional occupation. Whether Auditory-Verbal Therapy is effective across a broader range of families is an important empirical question for future research.

Receptive Vocabulary

The AVT group made significant progress for receptive vocabulary development, at a rate of 13.73 months per year, which was better than expected for the typical population over the 50 months of the study. The TH group progressed at a rate of 15.46 months per year, and there was no significant difference between the progress for the two groups. There were 68.42% of the AVT group who had scores within the typical range or above compared to 100% of the TH group. One child in the AVT group had a receptive language score that exceeded 2 standard deviations above the mean. The gap between the chronological age and age equivalent for the AVT group for receptive language was 2.4 months and the scores at 50 months for receptive vocabulary for the children with hearing loss were within their age appropriate range. The results for the AVT group are in sharp contrast to some other studies which have reported levels of receptive language significantly lower than the population of children with typical hearing (e.g. Young & Killen, 2002; Dodd, McIntosh & Woodhouse, 1998). Past research has shown that children with cochlear implants have smaller vocabularies and achieve lower levels of vocabulary than their peers with typical hearing (Blamey, et al., 2001; Eisenberg, Kirk, Martinez, Ying, & Miyamoto, 2004). Furthermore, several authors have reported rates of vocabulary growth of less than one year of in one year of time (Blamey, Sarant, Paatsch, Barry, Bow, Wales, et al., 2001; El-Hakim, et al., 2001). Hayes, Geers, Treiman, and Moog (2009) studied the PPVT scores (tested repeatedly over time) for the receptive vocabulary of 65 children with cochlear implants who used oral communication and found that some children showed rates of progress of more than one year in one year of time, but this growth rate decelerated with time. They also found that children implanted before two years of age could achieve PPVT scores within the average range. This current group of children achieved mean scores within the average range but the children with cochlear implants were ,implanted at a mean age of two years and three months (median score of 23.04 months). The results for the AVT group are in contrast to those of Uziel, et al. (2007) who studied the language of a group of 82 French-speaking children who had consecutively received cochlear implants in the previous 10 years. They found that 76% of the children scored below the median value of their typically hearing peers for receptive vocabulary. The results are also in contrast to those of Schorr, Roth, and Fox (2008) who found a significant difference in PPVT scores for two groups of 39 children, one with hearing loss and one with typical hearing matched for age and gender. The children with hearing loss had received cochlear implants at between 1-8 years of age (aged 5-14 years at time of study, and mean age of 9 years) and had at least one year of listening experience with the implant. They all used oral communication and were educated in a range of programs. Fifty one (51%) scored within the average range on the PPVT compared to 97% of the control group. The authors concluded that significant receptive and expressive language differences existed in their "high functioning" group of children with cochlear implants compared to their matched controls with typical hearing. However their measurements are taken at one point in time only, instead of multiple points over longer time, which would have given a more accurate representation of the children's progressive development.

Speech

The AVT group children all achieved intelligible speech, with scores similar to children with typical hearing. The AVT group made significant progress in speech skills over the 50 months, and the progress was not significantly different to that for the TH group. These results replicate those for the AVT group at the 21 months point of the study, when both speech imitation and spontaneous speech were investigated (Dornan, Hickson, Murdoch & Houston, 2009). The AVT group have maintained the rate of progress for speech development over the full 50 months. The rate of developmental progress per year for articulation of consonants in words by the AVT group was 10.48 months in 12 months of time, while that for the TH group was 10.53 months. In explanation of the seemingly slower rate of speech progress per 12 months for both groups, slower than that expected for children with typical hearing, many of the children in both groups reached the ceiling score of the GFTA-2 during the test period. Specifically, 42% of the AVT group achieved top age equivalent scores of 7 years 8 months for the GFT-2 test at posttest, and their mean chronological age was 8 years. The progress rate for speech skills for the TH group was 10.53 months in 12 months of time with 63.16% reaching the ceiling of the GFTA-2. The chronological age of the TH group at the posttest was 7 years 5 months. This ceiling effect for a large number (52.58% of the total for both groups) at the 50 months posttest made results for speech skills difficult to interpret at this posttest, even though when these “topped out” scores were removed, there was no significant difference between the group scores. Dornan, Hickson, Houston and Murdoch (2009) have more fully described the results for the AVT group and the TH group for speech skills in an earlier publication at the 21 months posttest when fewer children had reached the ceiling of this test, and similar results have been found.

The fact that there were larger numbers of males in both groups (14 males and 5 females) may have adversely affected the speech results, as females are known to have a verbal advantage for speech over males (Fenson, et al., 2000). However, there was no significant difference between the progress for the two groups at the 50 months point. This is surprising, as children with significant hearing loss typically have difficulty with articulation of speech sounds (Marschark, Lang, & Albertini, 2002; Schorr, Roth, & Fox, 2008), which has been found to correlate with correct consonant production (Tobey, Geers, Brenner, Altuna, & Gabbert, 2003). For children who receive a cochlear implant, like most of the children in this study, an increase in accuracy of consonant sound production has been reported (Tobey, et al., 2003). These authors found that this ability increased with longer implant experience, and that use of oral communication (as in Auditory-Verbal Therapy) has been found to be an important variable for predicting better speech. It is likely that the cochlear implants for those who needed them plus Auditory-Verbal Therapy have influenced the level of speech skills achieved by the AVT group.

In a large multicentre study of 117 children with cochlear implants, a high correlation has been reported between speech perception and speech intelligibility (Phillips, Hassanzadeh, Kosaner, Martin, Deibl, & Anderson, 2009). The speech perception ability of the AVT group was reported in Dornan, Hickson, Murdoch and Houston (2008). It was found that significant progress was made for speech perception by the AVT group over 21 months by the group for live voice. The speech perception abilities for the TH group were not tested for comparison because of time restraints.

In another study of children with hearing loss, it was found that the development of speech sound production for 27 cochlear implant users stabilised after 6 years of implant use, and reached a plateau after 8 years of use (Tomblin, Peng, Spencer, & Lu, 2008). Although early rate of speech growth (before 4 years of device experience) did not predict later growth rates or levels of achievement, good predictions for speech ability could be made after 4 years of implant use. Consequently it might be expected that the AVT group will continue to progress favourably in speech development. The positive speech outcomes for children with a cochlear implant found for the AVT group are also similar to those of Schorr, Roth, & Fox (2008). They found that two groups of 39 children (one with cochlear implants with a mean age of 9 years and one with typical hearing matched for chronological age and gender) showed no difference between speech skills when measured on the GFTA-2 at least one year after implant. Eighty five percent (85%) scored within the typical range for speech on the GFTA-2, compared to 100% for the control group. However, in contrast, Uziel, et al. (2007) found that only 40% of a group of 82 French speaking children who had received cochlear implants over 10 consecutive years had speech that was intelligible to the average listener. In comparison, all of the children in the AVT group achieved intelligible speech.

Reading

Reading ability is a complex skill, and there are many factors that may contribute to a child's reading skills. Studies have consistently reported that reading deficiencies are dependent on a child's ability to use listening skills in order to process the phonological components of language (National Institute of Child Health and Human Development, 2000). Although neither the AVT group nor the TH group made significant progress over the 12 months of the study, the progress made by both the AVT and TH groups was not significantly different. Because the youngest children in the AVT group were just over two years of age at the start of the study, not all of the children had reached a level of reading that was able to be tested at both the 38 months pretest and the 50 months posttest. This meant that a number of pairs of children had to be omitted from the study. In addition, by the time of the posttest, the time involved for the reading and mathematics assessments meant that an additional test session was often required. Some parents from both groups were unable to make their children available for the extra time, causing more attrition from the pairs of children in the study. The lower numbers (7 pairs remaining) could explain why both the AVT group and the TH group did not make significant progress in reading and mathematics over the 12 months test period. It is also possible that the tests used were not sensitive to change over so short a period. Statistical analysis using an analysis appropriate for smaller numbers of scores (Mann-Whitney test) showed that the scores for the AVT group for reading from the 38 months posttest to the 50 months posttest was the same as that for the TH group of children. When all of the results for the 10 pairs who had available scores at the 50 months posttest were analysed, no significant difference was found between the scores for both the groups. Once again, the size of the groups may be problematic in making a comparison, and this is a limitation of this study. The mean percentile for reading was 88.14 for the AVT group, so the mean of the AVT group's reading scores was greater than the scores for the majority of their peers with typical hearing. The mean percentile for the TH group for reading was 90.14.

Potential for reading and academic achievement for children with hearing loss educated using Auditory-Verbal Therapy has been reported by a number of researchers (Durieux-Smith et al., 1998; Goldberg & Flexer, 1993; 2001; Robertson & Flexer, 1993; Wray, Flexer, & Vaccaro, 1997). In these studies, most of the children in Auditory-Verbal Therapy programs were found to be competing favourably with their peers with typical hearing for reading. This is in contrast to typically unfavourable reports on low reading ability for children with hearing loss (Geers & Moog, 1989, Traxler, 2000), many to the point of being "functionally illiterate (Waters and Doehring, 1990). One study focussing on early literacy skills showed that children with hearing loss achieved lower scores in reading than children with typical hearing when the difficulty of these tests increased (Boothroyd & Boothroyd-Turner, 2002). The AVT group have, thus far, shown their potential for reading at an age appropriate level, but further ongoing research will be needed to determine if the level of reading can be maintained by the group and leads to the same academic and career options as children with typical hearing over time.

A lack of consistency among studies on reading of children with hearing loss has been noted by Marschark, Rhoten, and Fabich (2007), making them difficult to interpret. Spencer and Oleson (2008) found that it was possible to explain 59% of the variance in a study of the reading of 72 children with hearing loss (after 48 months of cochlear implant use) by early speech perception and speech production performance. They concluded that early access to sound helped to build better phonological processing skills, which is one of the likely contributors to reading success. The AVT group in this longitudinal study has been found at the 9 months and 21 months posttests to have had the same speech perception and speech production performance as the TH group (Dornan, Hickson, Murdoch & Houston, 2007; 2009), which may have been a reason for comparable reading skills.

The results for reading for the AVT group are supported by evidence from the area of neuroscience, which has shown that the primary reading centres of the brain are located in the auditory cortex (Chermak & Musiek, 1997; Musiek & Berge, 1998). Reading skills have been found to depend on auditory brain development through meaningful listening experience. This allows for the development of a series of interdependent skills leading to the ability to read, the foundation of which is phonological processing (Werker & Tees, 2005). Better auditory skills and subsequent better phonological processing have been found to be the basis for achievement in reading, as the degree of phonological awareness has been found to be the single best predictor of reading success (Mody, 2003). Phonological processing has been defined as the segmental analysis of words for listening and speaking, as well as the metaphonological skills required for explicitly analysing the sound structure of speech into the phonemic components represented by the alphabet (Mody, 2003). This strong relationship between listening ability, phonological processing and reading has been illustrated by the AVT group who have been found to have speech comprehension skills which are not significantly different to the TH group. This level of listening ability may have contributed to the results of the same outcomes for reading skills as those for the TH group. The AVT group results are also supported by research on dyslexia, which has validated a critical role for phonological processing in literacy development and reading disorders (Lyon, Shaywitz, & Shaywitz, 2003). It is suggested by the current authors that, if auditory brain pathways are accessed by appropriate hearing technology, and intensively stimulated by Auditory-Verbal Therapy, then reading may have the chance to develop similarly to a child with typical hearing. However, this suggestion cannot be proved by the small amount of available data from this study. Validation through extension of this longitudinal study, plus other studies on reading outcomes, with greater numbers of children participating over longer periods are necessary.

The results for the AVT group are supported by those of Spencer, Barker and Tomblin (2003), who reported that language and reading levels are correlated. These authors tested a group of 16 children with cochlear implants and 16 age-matched children with typical hearing who were being educated in mainstream schools. They found that the children with cochlear implants scored for reading within one standard deviation of the scores for the children with typical hearing. Connor and Zwolan (2004) also studied the reading of 91 children with cochlear implants, and found that this could be predicted by better language skills, younger implant and higher socioeconomic status. Geers (2002) found that, 4-6 years after implant, the reading of children was most strongly associated with non-verbal IQ, implant functioning and use of an oral communication mode. This group of AVT children had the same language skills as the TH group, most of the children with a cochlear implant had been implanted around 2 years of age, had well functioning hearing devices, moderate to high socioeconomic status, and used an oral communication mode. It is likely that the interaction of a number of factors were responsible for their reading skills.

In contrast to the AVT group, Geers, Tobey, Moog, and Brenner (2008) found that, in a study of 181 children with cochlear implants (received before 5 years of age), cochlear implantation did not result in age appropriate reading levels at high school for the majority of the students. Consequently it will be important to continue following the reading levels of the AVT group as they become older, to ensure that the reading outcomes continue to be positive. It will also be of benefit to increase information regarding the relationship of reading and phonological processing skills for children in Auditory-Verbal Therapy programs by including assessments of these skills in future studies.

Mathematics

The same pairs of AVT and TH group children as provided data for the reading assessments also produced the data for the mathematics analysis. As for the reading outcomes, the results for mathematics show that the children in both groups did not make significant progress between the 38 months pretest and the 50 months posttest. Once again, this could have been because some of the children were too young at the pretest or posttest or were unavailable, leaving the sample short on numbers, or that the tests used were not sensitive to change. However, the outcomes for the AVT group for mathematics from the 38 months pretest to the 50 months posttest were the same as that for the TH group. The mean percentile for the AVT group for mathematics was 77.57 while that for the TH group was 80.86. As no mathematics studies for children in Auditory-Verbal Therapy programs are available, the results for the AVT group will be discussed with reference to the few available studies on mathematics of children with hearing loss. The AVT group results are in contrast to those of Wood, Wood, & Howarth (1983) who found that students with hearing loss were 3.4 years behind in mathematics achievements of children with typical hearing. The results are also not in agreement with the findings of Traxler (2000), who found that mathematics ability of high school students was at a “basic level” or below. The findings for the AVT group are, however, supported, by the findings of Kelly & Gaustad, (2007) who found that levels of reading and language skills influence the ability of a child with hearing loss to achieve in mathematics. The AVT group scored as well as the TH group in reading and language skills, which may have influenced their mathematics skills. Nunes and Moreno (1998) have suggested that hearing loss is not a cause but a risk factor for problems in mathematics, and therefore a lag in mathematics skills may be prevented. This AVT group does not show a difficulty in mathematics as compared to the TH group at this stage, and it is possible that being able to understand speech at age appropriate levels has assisted in the development of mathematics skills for the AVT group. More longitudinal research needs to be carried out with a number of different populations, but the results for mathematics for the AVT group show the importance of continuing this follow-up, and including larger numbers over a longer time span. In general, more studies are needed on mathematics outcomes for children with hearing loss, as Marschark, Rhoten, and Fabich (2007) have found that studies of academic achievement beyond reading are rare.

General academic success in a mainstream classroom is reported to be influenced by a number of audiological factors (e.g. type of listening device, length of hearing experience), level of intelligence and a focus on oral communication (Damen, van den Oever-Goltstein, Langereis, Chute, & Mylanus, 2006; Geers, Brenner, Nicholas, Uchanski, Tye-Murray, & Tobey, 2002). Children who learn in inclusive settings alongside children with typical hearing have been found to perform significantly better on tasks relating to reading, including phonological awareness, letter identification, general knowledge and vocabulary, than children who are not fully integrated in mainstream school (Most, Aram, & Andorn, 2006). Evidence is increasingly positive for speech and language benefits for children with hearing loss educated in settings which include children with typical hearing (Geers, Spehar & Sedey, 2002; Tobey, Rekart, Buckley & Geers, 2004). Regarding overall academic skills, Uziel and colleagues (2007) assessed 82 French-speaking children with cochlear implants who had 10 years of implant use. They found that many could achieve satisfactory academic competence on French language, foreign language, mathematics and academic/occupational status. Boothroyd & Boothroyd-Turner (2002) concluded that children with hearing loss may need additional support in a mainstream classroom, because as the difficulty of reading and vocabulary tests increased, children with hearing loss fitted with a cochlear implant performed at a significantly lower level than children with typical hearing. It will be critical to follow longitudinally the academic outcomes for different, larger cohorts of children educated in Auditory-Verbal Therapy programs and other programs before conclusions are made regarding their academic performance.

Self Esteem

Hearing loss can adversely affect self esteem (Bat-Chava, 1993; Nicholas & Geers, 2003) as well as mental health (Laurenzi & Monteiro, 1997), and socio-emotional development (Prizant & Meyer, 1993). However this group of children with hearing loss who have been educated in an Auditory-Verbal Therapy program have been found, on a parent rated assessment, to have very similar self esteem levels as their typical hearing controls. The results show that the majority of the AVT group (78.9%) were rated by their parents as having high self esteem. These ratings were comparable to those for their matched control group, for which 68.42% of parents rated their child's self esteem as "Good". The fact that there were no children from either group rated in the "Vulnerable" or "Very Low" categories illustrates the positive feelings that the parents had for their child's sense of self, sense of belonging and sense of personal power. These results show that the parents of the AVT group view the self esteem of their children as favourably as compared to the TH group.

These results agree with those of a parent survey of Danish children (Percy-Smith, Jensen, Josvassen, Jønsson, Andersen, Samar, et al. (2006). The authors found that 60 of the 61 parents of children of various ages who received cochlear implants at the clinic over a 10 year period reported a satisfactory or very satisfactory level of well-being for their child. This study is also in agreement with that of Schorr, Roth and Fox (2009). They found that, on a self-reported quality of life questionnaire for 37 children aged 5-14 years who received a cochlear implant and used spoken language, the children reported improved quality of life because of their implants. This improved quality of life was related to age of implant. In another study of 167 children with cochlear implants (Percy-Smith, Jensen, Cayé-Thomasen, Thomsen, Gudman, & Lopez, 2008), the authors asked parents to rate their child's level of social well-being regarding personal-social adjustment. They found that there was a statistically significant relationship between speech understanding, speech production, and vocabulary with level of social well-being. As the majority of children in this current study had cochlear implants and were good users of spoken language, it is possible that at least some of the improvement in how they felt about themselves was due to their cochlear implant and their Auditory-Verbal Therapy program which together have produced the higher levels of spoken communication skills they have exhibited.

This research is significant because it has provided a benchmark of a minimum of one year of progress in one year of time for rate of language development for children with hearing loss. This benchmark is more robust than suggestions for a similar benchmark made by previous authors (e.g Easterbrooks, 1987; Hogan, Stokes, White, Tyszkiewicz, & Woolgar, 2008; Rhoades & Chisolm, 2000) because of the inclusion of a control group in this study. This research model could potentially now be applied to populations of children in different Auditory-Verbal Therapy programs or programs using another education options. This study is also significant because the research model, utilizing a control group matched for language age, could also be replicated across different languages, cultures and countries. Research studies would need to be matched with this study in as many parameters as possible.

Summary

These results provide high level evidence in favour of Auditory-Verbal Therapy and show that it has indeed been an effective option for this particular group of children with hearing loss who have received early intervention in an Auditory-Verbal Therapy program. The group was identified at a mean age of 24.6 months, much later than the current “international gold standard” of 6 months of age (Joint Committee on Infant Hearing, 2007; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Their speech, language, reading, mathematics and self esteem attainments have been significantly the same as for a matched control group of children with typical hearing over 4 years 2 months of time. These results provide a robust benchmark for language progress against which other populations can be measured, and a model applicable to a variety of populations. This study will now be extended to include further follow-up of academic skills and will be applied to other types of populations using various education approaches. Provided control groups are sought from similar populations and matched for language age, this research model has potential global application to children with hearing loss using other languages or from different cultures.

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References

Agung, K. B., Purdy, S. C., & Kitamura, C. (2005). The Ling sound test revisited. *The Australian and New Zealand Journal of Audiology, 27*(1), 33-41.

Australian Council of Education Research (2005). *Progressive Achievement Tests in Mathematics (PAT Maths)* (3rd ed.) Melbourne, Australia: ACER Press.

Alexander Graham Bell Academy for Listening and Spoken Language (2007). Alexander Graham Bell Association for the Deaf and Hard of Hearing, 2007. Accessed 23 January, 2008 at http://www.agbellacademy.org.

Bat-Chava, Y. (1993). Antecedents of self-esteem in deaf people: A meta-analytic review. *Rehabilitation Psychology, 38*(4), 221–234.

Bat-Chava, Y., Martin, D., & Kosciw, J. (2005). Longitudinal improvements in communication and socialization of deaf children with cochlear implants and hearing aids: Evidence from parental reports. *The Journal of Child Psychology and Psychiatry, 46* (12), 1287 – 1296.

Blamey, P. J., Barry, J., Bow, C., Sarant, J., Paatsch, L. & Wales, R. (2001). The development of speech production following cochlear implantations. *Clinical Linguistics and Phonetics, 15 (5)*, 363 - 382.

Blamey, P.J., Sarant, J. Z., Paatsch, L. E., Barry, J. G., Bow, C. P., Wales, R. J., et al. (2001). Relationships among speech perception, production, language, hearing loss, and age in children with impaired hearing. *Journal of Speech, Language, and Hearing Research, 44*(2), 264-285.

Boothroyd, A., & Boothroyd-Turner, D. (2002). Postimplantation audition and educational attainment in children with prelingually acquired profound deafness. *Annals of Otology, Rhinology & Laryngology, 111*, 79-84.

Chermack, G.D., & Musiek, F.E. (1997). *Central Auditory Processing Disorders: New Perspectives.* San Diego, CA: Singular Publishing Group.

Ching, T., Dillon, H., Day, J., Crowe, K., Close, L., Chisolm, K., & Hopkins, T. (2009). Early language outcomes of children with cochlear implants: Interim findings of the NAL study on longitudinal outcomes of children with hearing impairment. *Cochlear Implants International, 10*(S1), 28-32.

Ching, T., Psarros, C., & Incerti, P. (2003). Management of children using cochlear implants and hearing aids. *Volta Review*, *103*(1), 39-57.

Cole, E. B., & Flexer, C. (2007). *Children with hearing loss: Developing listening and talking*. San Diego, US: Plural Publishing.

Connor, C.M., Craig, H.K., Raudenbush, S.W., Heavner, K., & Zwolan, T. (2006). The age at which young deaf children receive cochlear implants and their vocabulary and speech-production growth: Is there an added value for early implantation? *Ear and Hearing, 27*(6), 628-644.

Connor, C.M. & Zwolan, T.A. (2004). Examining multiple sources of influence on the reading comprehension skills of children who use cochlear implants. *Journal of Speech, Language and Hearing Research, 47*(3), 509-526.

Crouch, R.A. (1997). Letting the deaf be deaf. *Hastings Center Report, 27*(4), 14.

Damen, G.W., van den Oever-Goltstein, M.H., Langereis, M.C., Chute, P.M. & Mylanus, E.A. (2006). Classroom performance of children with cochlear implants in mainstream education. *Annals of Otology, Rhinology & Laryngology*, *115*(7), 542-552.

Dettman, S.J., Pinder, D., Briggs, R. J. S., Dowell, R. C., & Leigh, J.R. (2007). Communication development in children who receive the cochlear implant younger than 12 months: Risks versus benefits. *Ear & Hearing. 28*(2 Suppl), 11S-18S.

Dillon, C.M., Burkholder, R.A.M, Cleary, M. & Pisoni, D.B. (2004). Nonword repetition by children with cochlear implants: accuracy ratings from typical-hearing listeners. *Journal of Speech, Language and Hearing Research, 47*(5), 1103-1116.

Dodd, B., McIntosh, B., & Woodhouse, L. (1998). Early lipreading ability and speech and language development of hearing-impaired preschoolers. In R. Campbell, B. Dodd, & D. BurTHam (Eds.), *Hearing by Eye 11: Advances in the psychology of speechreading and auditory-visual speech,* 229-242. Hove: Psychology Press.

Doig, B., & de Lemnos, M. (2000). *I Can Do Maths.* Melbourne, Australia: ACER Press.

Dornan, D.A., Hickson, L., Murdoch, B., & Houston, T. (2007). Outcomes of an Auditory-Verbal Program for Children with Hearing Loss: A Comparative Study with a Matched Group of Children with Typical Hearing. *The Volta Review 107*(1), 37-54.

Dornan, D.A., Hickson, L., Murdoch, B., & Houston, T. (2008). Speech and language outcomes for children with hearing loss educated in Auditory-Verbal Therapy programs: A review of the evidence. *Communicative Disorders Review, 2*(3-4), 157-172.

Dornan, D.A., Hickson, L., Murdoch, B., & Houston, T. (2009). Longitudinal study of speech and language for children with hearing loss in Auditory-Verbal Therapy programs. *The Volta Review,* In press.

Duncan, J. (1999). Conversational skills of children with hearing loss and children with typical hearing in an integrated setting. *The Volta Review, 101*(4), 193-211.

Duncan, J. & Rochecouste, J. (1999). Length and complexity of utterances produced by kindergarten children with impaired hearing and their hearing peers. *Australian Journal of Education of the Deaf, 5,* 63-69.

Dunn, L. & Dunn, L. (1997). *Peabody Picture Vocabulary Test (*3rd ed*.)*. Circle Pines, MN: American Guidance Service.

Durieux-Smith, A., Olds, J., Fitzpatrick, E., Eriks-Brophy, A., Duquette, C., Cappelli, M., et al. (1998). Outcome of AVT: Results of a follow-up study. *American Speech and Hearing Association Leader, 3*, 99.

Duquette, C., Durieux-Smith, A., Olds, J., Fitzpatrick, E., Eriks-Brophy, A., & Whittingham, J. (2002). Parents' perspectives on their roles on facilitating the inclusion of their children with hearing impairment. *Exceptionality Education Canada*, *12*(1), 19-36.

Easterbrooks, S.R. (1987). Speech/language assessment and intervention with school-aged hearing-impaired children. In: Alpiner, J., Mc Carthy, P. (Eds). Rehabilitative Audiology: Children and Adults. Baltimore: Williams & Wilkins, 188-240.

Easterbrooks, S. R., O'Rourke, C.M., & Todd, N.W. (2000). Child and family factors associated with deaf children's success in auditory-verbal therapy. *The American Journal of Otology, 21*, 341-344.

Eisenberg, L.S., Kirk, K.I., Martinez, A.S., Ying, E., & Miyamoto, R.T. (2004). Communication abilities of children with aided residual hearing: Comparison with cochlear implant users. *Archives of Otolaryngology – Head & Neck Surgery, 130*, 563-569.

Eriks-Brophy, A. (2004). Outcomes of auditory-verbal therapy: A review of the evidence and a call for action. *The Volta Review, 104*(1), 21-35.

Fenson, L., Pethick, S., Renda, C., Cox, J., Dale, P., & Rezniek, J. (2000). Short-form versions of the MacArthur communicative inventories. *Applied Psycholinguistics,21*, 95-115.

Fineberg, H. (1990). The quest for causality in health services research. *Research Methodology: Strengthening causal interpretations of nonexperimental data.* Rockville, MD: Agency for Health Care Policy and Research, U.S. Department for Health and Human Services.

El-Hakim, H., Levasseur, J., Papsin, B. C., Panesar, J., Mount, R. J., Stevens, D., et al. (2001). Assessment of vocabulary development in children after cochlear implantation.
Archives of Otolaryngology, Head & Neck Surgery 127(9), 1053-1059.

Frattali, C. (2004). Developing evidence-based practice guidelines. *The ASHA Leader, 13 April*, 13-14.

Geers, A. E. (2002). Factors affecting the development of speech, language, and literacy in children with early cochlear implantation. *Language, Speech, and Hearing Services in Schools, 33* (3), 172 - 183.

Geers, A.E. (2003). Predictors of reading skill development in children with early cochlear implantation. *Ear and Hearing, 24* (1), 59s - 68s.

Geers, A.E., Brenner, C., Nicholas, J., Uchanski, R., Tye-Murray, N., & Tobey, E. (2002). Rehabilitation factors contributing to implant benefit in children. *Annals of Otology, Rhinology & Laryngology, Part 2 Supplement 189, 111*(5), 127-130.

Geers, A. & Moog, J. (1989). Factors predictive of the development of reading in profoundly hearing-impaired adolescents. *The Volta Review*, 91, 69-86.

Geers, A.E., Nicholas, J.G., & Sedey, A.L. (2003). Language skills of children with early cochlear implantation. *Ear and Hearing, 24*(1 Suppl), 46S-58S.

Geers, A.E., Spehar, .B.P., & Sedey, A.L. (2002). Use of speech by children from total communication programs who wear cochlear implants. *American Journal of Speech-Language Pathology*. *11,* 50-58.

Geers, A.E., Tobey, E., Moog, J., & Brenner, C. (2008). Longterm outcomes of cochlear implantation in the preschool years: From elementary grades to high school. *International Journal of Audiology, 47*(2 Suppl), 21S-30S.

Gilbertson, M., & Bramlett, R.K. (1998). Phonological awareness screening to identify at-risk readers: Implications for practitioners. *Language, Speech and Hearing Services in Schools, 29,* 10906.

Goldberg, D. M., & Flexer, C. (1993). Outcome survey of Auditory-Verbal graduates: Study of clinical efficacy. *Journal of the American Academy of Audiology, 4,* 189-200.

Goldberg, D. M., & Flexer, C. (2001). Auditory-Verbal graduates: An updated outcome survey of clinical efficacy. *Journal of the American Academy of Audiology, 12*(8), 406-414.

Goldman, R., & Fristoe, M. (2001). Goldman-Fristoe Test of Articulation. Shoreview, MN: American Guidance Service.

Gravel, J., & O'Gara, J. (2003). Communication options for children with hearing loss. *Mental Retardation and Developmental Disabilities Research Reviews, 9,* 243-251.

Hart, B., & Risley, T.R. (1995). *Meaningful differences in the everyday experience of young American children.* Baltimore: Paul H. Brooks.

Hayes, H., Geers, A.E., Treiman, R., & Moog, J.S. (2009). Receptive vocabulary development in deaf children with cochlear implants: achievement in an intensive auditory-oral educational setting. *Ear and Hearing, 30,* 128-135.

Hintermair, M. (2006). Parental resources, parental stress, and socioemotional development of deaf and hard of hearing children. *Journal of Deaf Studies & Deaf Education,* *11*(4), 493-513.

Hodges, A.V., Dolan Ash, A.M., Balkany, T.J., Schloffman, J.J., & Butts, S.L. (1999). Speech perception results in children with cochlear implants: Contributing factors. *Otolaryngology, Head and Neck Surgery, 121*, 31-34.

Hoff-Ginsberg, E. (1991). Mother-child conversation in different social classes and communicative settings. *Child Development*, *62*, 782-796.

Hogan, S., Stokes, J., White, C., Tyszkiewwicz, E., & Woolgar, A. (2008). An evaluation of auditory verbal therapy using rate of early language development as an outcome measure. *Deafness and Education International, 10*(3), 143-167.

Holland, A.L., Fromm, D.S., DeRuyter, F., Stein, M., (1996). Efficacy of treatment for aphasia: A brief synopsis. *Journal of Speech and Hearing Research, (39),* 5, 27S-36S.

Joint Committee on Infant Hearing (2007). Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention. *Pediatrics, 120*(4), 898-921.

Jones, R. (2003). Parental Occupation Coding. Report submitted to Performance Measurement and Reporting Taskforce, Ministerial Council on Education, Employment Training and Youth Affairs. Appendix 4, 33-34. Accessed 8 June 2009 from http://www.curriculum.edu.au/verve/_resources/parentaloccupation_file.pdf.

Kelly, R.R. & Gaustad, M.G. (2007). Deaf college students' mathematical skills relative to morphological knowledge, reading level and language proficiency. *Journal of Deaf Studies and Deaf Education, 12*(1), 25-37.

Kilminster, M. G. E., & Laird, E. M. (1978). Articulation development in children aged three to nine years. *Australian Journal of Human Communication Disorders, 6*(1), 23-30.

King, A.J. (2005). Auditory plasticity: Vocal output shapes the auditory cortex. *Current Biology, 15*(13), R503 - R505.

Kumar, S. et al. (2008). *Literature review of Current Best Practice in Early Intervention for Children with a Permanent Hearing Loss*. Technical report produced for Queensland Health. Retrieved June 7, 2009, from http://www.health.qld.gov.au/healthyhearing/pages/publications.asp.

Lane, H., & Grodin, M. (1997). Ethical issues in cochlear implant surgery: An exploration into disease, disability, and the best interests of the child. *Kennedy Institute of Ethics Journal, 7*(3), 231-251.

Laurenzi, C., & Monteiro, B. (1997). Mental health and deafness – the forgotten specialism? *ENT News, 6,* 22-24.

Ling, D. (2002). *Speech and the Hearing Impaired Child: Theory and Practice* (2nd ed.). Washington, DC: Alexander Graham Bell Association for the Deaf.

Lyon, G.R., Shaywitz, S.E., & Shaywitz, B.A. (2003). Defining dyslexia, comorbidity, teacher's knowledge of language and reading. *Annals of Dyslexia, 53,* 1-14.

Marshark, M., Lang, H.G., Albertini, J.A., (2002). *Educating deaf students: From research to practice.* New York: Oxford University Press.

Marschark, M. & Spencer, P. E. (2003). Oxford handbook of Deaf Studies, Language, and Education. New York: Oxford University Press.

Marshark, M., Rhoten, C., & Fabich, M. (2007). Effects of cochlear implants on children's reading and academic achievements. *Journals of Deaf Studies and Deaf Education, 12,* 269-282.

Martineau, G., Lamarche, P., Marcoux, S., & Bernard, P. (2001). The effect of early intervention on academic achievement of hearing-impaired children, *Early Education and Development, 12*(2), 275-289.

McCaffrey, H. A., Davis, B.L., Macneilage, P.F., & von Habsburg, D. (1999). Multichannel cochlear implantation and the organization of early speech. *The Volta Review, 101, 5-29.*

Mody, M. (2003). Phonological basis in reading disability: A review and analysis of the evidence. *Reading and Writing, 16*(1-2), 21-39.

Most, R., Aram, D. & Andorn, R. (2006). Early reading in children with hearing loss: A comparison between two educational systems. *The Volta Review, 106*(1), 5-28.

Morris, E. (2003). *Insight.* London: Nfer Nelson.

Musiek, F.E., & Berge, B.E. (1998). A Neuroscience view of auditory training/stimulation and central auditory processing disorders. In M.G. Masters, N.A. Stecker & J. Katz (Eds). *Central auditory processing disorders: Mostly management.* Boston: Allyn and Bacon.

National Institute of Child Health and Human Development. (2000). *Report of the National Reading Panel. Teaching children to read: an evidence-based assessment of the scientific research literature on reading and its implications for reading instruction.* Retrieved June16, 2007 from http://www.nichd.nih.gov/publications/nrp/smallbook.htm.

Nicholas, J.G. & Geers, A.E. (2003). Hearing status, language modality, and young children's communicative and linguistic behavior. *Journal of Deaf Studies and Deaf Education, 8*(4), 422-437.

Nunes, T., & Moreno, C. (1998). Is hearing loss a cause of difficulty in learning mathematics? In C. Conlan (Ed.). *The development of mathematical skills* (pp. 227-254). Hove, Britain: Psychology Press.

Nunes, T., & Moreno, C. (2002). An intervention program for promoting deaf pupil's achievement in mathematics. *Journal of Deaf Studies and Deaf Education,7*(2), 120-

133.

Ouellet, C. & Cohen, H. (1999). Speech and language development following cochlear implantation. *Journal of Neurolinguistics, 12*(3), 271-288.

Oxford Centre for Evidence Based Medicine (2001). Levels of evidence and grades of recommendation. Accessed 22 Dec 2008 at http://www.cebrn.net/levels_of_evidence.asp.

Percy-Smith, L., Jensen, J.H., Cayé-Thomasen, P., Thomsen, J., Gudman, M., Lopez, A.G. (2008). Factors that affect the social well-being of children with cochlear implants. *Cochlear Implants International, 9*(4), 199-214.

Percy-Smith, L., Jensen, J.H., Josvassen, J.L., Jønsson, M.H., Andersen, J., Samar, C.F., et al. (2006). Parent's perceptions of their children's speech, language and social outcome after cochlear implantation. *Ugeskrift for Laeger*, *168*(33), 2659-2664.

Phillips, L., Hassanzadeh, S., Kosaner, J., Martin, J., Deibl, M., & Anderson, I. (2009). Comparing auditory perception and speech production outcomes: non-language specific assessment of auditory perception and speech production in children with cochlear implants. Cochlear Implants International, 10(2), 92-102.

Pollack, D. (1970). *Educational audiology for the limited-hearing infant and preschooler.* Springfield, IL: Charles C. Thomas Publisher, Ltd.

Ponton, C.W., Don, M., Eggermont, J.J., Waring, M.D., Kwong, B., Masuda, A. (1996). Auditory system plasticity in children after long periods of complete deafness. *Neuroreport, 8*(1), 61-65.

Powers, S. (2003). Influences of student and family factors on academic outcomes of mainstream secondary school deaf students. *Journal of Deaf Studies and Deaf Education, 8*, 57-78.

Prizant, B.M., & Meyer, E.C. (1993). Socioemotional aspects of language and social-communication disorders in young children and their families. *American Journal of Speech-Language Pathology, 2,* 56-71.

Rhoades, E.A. (2001). Language progress with an auditory-verbal approach for young children with hearing loss. *International Pediatrics, 16*(1), 1-7.

Rhoades, E.A. (2006). Research outcomes of auditory-verbal intervention: Is the approach justified? *Deafness and Education International, 8*(3), 125-143.

Rhoades, E.A., & Chisholm, T.H. (2000). Global language progress with an auditory-verbal approach for children who are deaf and hard of hearing. *The Volta Review, 102*(1), 5-24.

Robertson, L., & Flexer, C. (1993). Reading development: A parent survey of children with hearing impairment who developed speech and language through the Auditory-Verbal method. *The Volta Review, 95*(3), 253-261.

Romanik, S. (1990). *Auditory Skills Curriculum*. Moorebank, Australia: New South Wales Department of Education and Training.

Sarant, J., Holt, C.M., Dowell, R.C., Rickards, F.W., & Blamey, P. (2008).Spoken language development in oral preschool children with permanent childhood deafness. *Journal of Deaf Studies and Deaf Education, 14*(2), 205-217.

Schorr, E.A., Roth, F.P., & Fox, N.A. (2008). A comparison of the speech and language skills of children with cochlear implants and children with typical hearing. *Communicative Disorders Quarterly, 29*(4), 195-210.

Schorr, E.A., Roth, F.P., & Fox, N.A. (2009). Quality of life for children with cochlear implants perceived benefits and problems and the perception of single words and emotional sounds. *Journal of Speech, Language and Hearing Research, 52,* 141-152.

Semel, E., Wiig, E. H., & Secord, W. A. (1995). *Clinical Evaluation of Language Fundamentals* (3rd ed.). San Antonio: The Psychological Corporation, Harcourt Brace & Company.

Sharma, A., Dorman, M.F., & Spahr, A.J. (2002). Rapid development of cortical auditory evoked potentials after early cochlear implantation. *Neuroreport, 13*(10), 1365-1368.

Spencer, P.E. (2004) Individual differences in language performance after cochlear implantation at one to three years of age: child, family and linguistic factors. *Journal of Deaf Studies and Deaf Education, 9,* 395-412.

Spencer, L.J., Barker, B.A., & Tomblin, J.B. (2003). Exploring the language and literacy outcomes of paediatric cochlear implant users. *Ear and Hearing, 24,* 236-247.

Spencer, L.J., & Oleson, J.J. (2008). Early listening and speaking skills predict later reading proficiency in pediatric cochlear implant users. *Ear and Hearing, 29*(2), 270-280.

Stacey, P.C., Fortnum, H.M., Barton, G.R., & Summerfield, A.Q. (2006). Hearing impaired children in the United Kingdom, 1: Auditory performance, communication skills, educational achievements, quality of life, and cochlear implantation. *Ear and Hearing, 27*(2), 161-186.

Sussman, K. D., Duncan, J., Estabrooks, W., Hulme, J., Moog, J. S., & McConkey Robbins, A. (2004, February 2004). *The Option of Spoken Communication.* 2004 Summit on Deafness Proceedings - Spoken Language Options in the 21st Century: Predicting Future Trends in Deafness, Washington, D.C.

Svirsky, R., Robbins, A. M., Kirk, Pisoni, & Miyamoto. (2000). Language development in profoundly deaf children with cochlear implants. *Psychological Science, II*(2), 153-158.

Szagun, G. (1997). Some aspects of language development in typical-hearing children with cochlear implants. *American Journal of Otology, 18,* 131S-134S.

Svirsky, M.A., Teoh, S.W., & Neuburger, H. (2004). Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation. *Audiology and Neuro-Otology*, *9*, 224-233.

Tobey, E., Geers, A., Brenner, C., Altuna, D., & Gabbert, G. (2003). Factors associated with development of speech production skills in children implanted by age five. *Ear and Hearing, 24*(1 Suppl), 36S-45S.

Tobey, E.A., Rekart, D., Buckley, K., Geers, A.E**.** (2004). Mode of communication and classroom placement: Impact on speech intelligibility**.** *Archives of Otolaryngology-Head and Neck Surgery 130,* 639–643**.**

Tomblin, J.B., Peng, S.G., Spencer, L.J., & Lu, N. (2008). Longterm trajections of the development of speech sound production and listening performance in paediatric cochlear implant recipients. *Journal of Speech, Language and Hearing Research, 51*(5), 1353-1368.

Traxler, C.B. (2000). The Stanford Achievement Test, 9th Edition: National Norming and Achievement Standards for Deaf and Hard-of-Hearing Students. *Journal of Deaf Studies and Deaf Education, 5*, 337-348.

Tye-Murray, N., Spencer, L., & Woodworth, G., (1995). Acquisition of speech by children who have prolonged cochlear implant experience. *Journal of Speech and Hearing Research, 38,* 327-337.

Uziel, A.S., Sillon, M., Vieu, A., Artieres, F., Piron, J.P., Daures, J.P., et al. (2007). Ten-year follow-up of a consecutive series of children with multichannel cochlear implants. *Otology and Neurotology, 28*(5), 615-628.

Vermeulen, A., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with cochlear implants. *The Journal of Deaf Studies and Deaf Education, 12* (3), 283 – 302.

Vincent, D., & Crumpler, M. (1997). *Reading Progress Tests*. UK: Nfer Nelson.

Wake, M., Poulakis, Z., Hughes, E.K., Carey-Sergeant, C., & Rickards, F.W. (2005). Hearing impairment: A population study of ade at diagnosis, severity and language outcomes at 7-8 years. *Archives of Diseases in Childhood, 90,* 238-244.

Waters, G.S. & Doehring, D.G. (1990). Reading acquisition in congenitally deaf children who communicate orally: Insights from an analysis of component reading, language, and memory skills (pp. 323-373). In T.H. Carr and B.A. Levy (Eds.), *Reading and its development.*San Diego, CA: Academic Press.

Warner-Czyz, A.D., Davis, B. L., & Morrison, H.M. (2005). Production accuracy in a young cochlear implant recipient. *The Volta Review, 105*(2), 151-173.

Werker, J. & Tees, (2005). Neurodevelopmental paper

Wood, D., Wood, H., & Howarth, P. (1983). The mathematical achievements of deaf children from different educational environments. *British Journal of Educational Psychology, 54,* 254-264.

Wray, D., Flexer, C., & Vaccaro, V. (1997). Classroom performance of children who are deaf or hard of hearing and who learned spoken communication through the auditory-verbal approach: An evaluation of treatment efficacy. *The Volta Review, 99*(2), 107-119.

Yoshinaga-Itano, C., Sedey, A.L., Coulter, D.K., & Mehl, A.L. (1998). Language of early and later identified children with hearing loss. *Pediatrics, 102,* 1161-1171.

Young, G. A., & Killen, D.H. (2002). Receptive and expressive language skills of children with five years of experience using a cochlear implant. *The Annals of Otology, Rhinology and Laryngology, 111,* 802-810.

Zimmerman, I. L., Steiner, V.G., & Pond, R.E. (2002). Preschool Language Scale - 4. San Antonio TX: The Psychological Corporation.

Table 1. Characteristics of AVT Group and TH Group at 50 months posttest

	Auditory-Verbal Therapy Group	Typical Hearing Group
N	19	19
Mean Age in months (SD)	96.32 (16.68)	87.89 (16.68)
Gender		
Male	14	14
Female	5	5
Age at identification in months	23.5	n/a
Mean PTA hearing loss in better ear in dB (SD)	79.39 (23.79)	n/a
Onset of Loss		
Congenital	17	n/a
Prelingual	2	n/a
Age at CI in months (SD)	27 (5.8)	n/a
Time spent in AVT Program in months (SD)	41 (16.34)	n/a
Hearing Device:		
Bilateral HA’s	5	n/a
Unilateral hearing aid	1	n/a
HA and CI in contra-lateral ears	6	n/a
Unilateral CI only	1	n/a
Bilateral CI’s	6	n/a
Parents educated beyond high school	18	18

Occupation category of head of household		
Professional	14%	65%
Manager	43%	15%
Trade/technical	29%	5%

Table 2. Battery of assessments.

Test	Description of Test	Scoring
Language		
Preschool Language Scale-Fourth Edition (PLS-4) (Zimmerman, Steiner, & Pond, 2002).	Measures young child's receptive and expressive language from birth to 6 years 11 months.	The scoring ceiling used was five consecutive items incorrect. Child's score is expressed as an age equivalent.
Clinical Evaluation of Language Fundamentals (CELF-3) (Semel, Wiig, & Secord, 1995).	Measures child's receptive and expressive language from 6 years to 21 months. Six subtests were administered only to children who achieved higher than the top score for the PLS-4. Subtests were Sentence Structure, Word Structure, Concepts and Directions, Formulated Sentences, Word Classes and Sentence Recalling.	If a child scored the highest possible score on the PLS-4, the CELF-3 was administered. Child's score is expressed as an age equivalent.

Receptive Vocabulary		
Peabody Picture Vocabulary Test (PPVT-3) (Dunn & Dunn, 1997).	Measures child's receptive vocabulary. Because this test was developed in the United States, Australian alternatives for some items were used by the testers: a) cupboard for closet, b) rubbish for garbage, c) biscuit for cookie, d) jug for pitcher.	Child's score is expressed as an age equivalent.
Speech		
Goldman-Fristoe Test of Articulation-2 (GFTA-2; Goldman & Fristoe, 2001).	Assesses articulation of consonants and was administered to participants in both AVT and TH groups.	Child's score is expressed as an age equivalent.
CASALA (Computer Aided Speech and Language Analysis) (Serry, Blamey, Spain & James, 1997).	This assessed articulation of consonants from a videotaped sample of spontaneous speech for children in the AVT group only. It was designed to transcribe and analyse phonetic aspects of speech samples. Broad transcription was chosen for reliability, (Bow, Blamey, Paatsch, & Sarant, 2002;	For a consonant to be scored as an attempted production, two well formed examples of phoneme required to be present in a sample, regardless of whether the produced phoneme had an identifiable target. For a consonant to be scored as correctly produced, it had to be

	Shriberg & Lof, 1991).	produced correctly at least twice within a sample, with a minimum of 50% of the phoneme targets to be correctly produced. Score is measured as Percent Consonants Attempted and Percent Correct Consonants.
Reading		
Reading Progress Tests (RPT). (Vincent & Crumpler, 1997).	Stage I is used in the first 3 years of school and assesses pre-reading and early reading skills in first year of school and reading comprehension in the second and third years of school. Stage 2 is used for school years 3 – 6 and assesses outcomes for reading by assessing a range of literal and inferential skills and reading vocabulary. Australian norms are available.	One mark is awarded for each correct answer. No marks are awarded for multiple choice questions where more than one choice has been selected. Score is expressed as a percentile.

Mathematics		
I Can Do Maths (Doig & de Lemnos, 2000)	This test assesses numeracy development in first 3 years of school using Australian norms.	One mark is awarded for each correct answer. Score is expressed as a percentile.
Progressive Achievement Tests in Mathematics (PATMaths) (Australian Council of Educational Research, 2005)	This test assesses mathematic achievement levels in school years 3 to 11 using Australian norms.	One mark is awarded for each correct answer. Score is expressed as a percentile.
Self Esteem		
INSIGHT (Morris, 2003)	This questionnaire assesses development of self esteem from 3 – 19 years of age (Preschool and Primary). Parents were asked to complete this questionnaire, which included topics regarding three areas, their child's sense of self, sense of belonging and sense of personal power.	Responses for the 3 areas studied were scored and the total score for self esteem was rated according to a rubric as "High", "Good", "Vulnerable", or "Very Low" according to below criteria. "High" = "Confident and at ease with self, other people and the world most of the time. Any

	knocks are quickly recovered from”. “Good” = “Feels good about self, but takes knocks now and again. Can take a bit of time to build back up again.” “Vulnerable” = “Tends not to feel very confident and many incidents make the pupil feel worse about self. Emotionally quite fragile. Hard to build confidence up”. “Very Low” = “Depressed or very challenging behaviour to cover this up. Needs support, encouragement and people with a strong belief in the pupil to change this behaviour/level of self esteem”.

Table 3. Order of Presentation for Standardised Assessments

Participants	Assessment
Pretest	
AVT Group	
	PLS-4 or CELF-3
	PPVT-3
	Goldman-Fristoe Test of Articulation-2
TH Group	
	Tests Used for Screening Purposes:
	Pure Tone Audiometry
	Goldman-Fristoe Test of Articulation-2
	Tests used for Matching Purposes:
	PLS-4 or CELF-3
	PPVT-3
Posttest	
Both Groups	
	PLS-4 or CELF-3
	PPVT-3
	Goldman-Fristoe Test of Articulation-2
	Reading Progress Test
	I Can Do Maths or PATMaths
	INSIGHT

Table 4. Summary of Changes in Scores for Language, Receptive Vocabulary, Speech, Reading and Mathematics for AVT Group and TH Group over 50 months Test Period and Results of Statistical Comparison of Changes in Scores Over Time

Name of Test	Group	N	Mean Age Equivalent Or Percentile	(SD)	N	Mean Age Equivalent (months)	(SD)	*z*	*p*
PLS-4/CELF-3	AVT	19	42.95	(17.59)	19	94.26	(34.60)	-3.824	<0.001*
(total language)	TH	19	42.00	(18.27)	19	98.05	(12.37)	-3.825	<0.001*
Group Comparison								-1.550	0.121
PPVT	AVT	19	36.74	(18.56)	19	93.95	(43.88)	-3.824	<0.001*
	TH	19	35.57	(17.55)	19	100	(19.01)	-3.825	<0.001*
Group Comparison								-2.921	0.003
GTTA-2	AVT	19	36.74	(17.38)	19	80.42	(15.76)	-3.824	<0.001*
	TH	19	42.11	(17.04)	19	86.00	(11.76)	-3.765	<0.001*
Group Comparison								-0.336	0.737
Reading	AVT	7	83.57 % ile	(17.74)	7	88.14 % ile	(10.90)	-0.210	0.833
	TH	7	88.14 % ile	(7.90)	7	90.14 % ile	(9.81)	-1.472	0.141

Group Comparison								-0.320	0.749
Mathematics	AVT	7	60.43 % ile	(35.02)	7	77.57% ile	(28.54)	-0.943	0.345
	TH	7	81.28 % ile	(24.88)	7	80.86 % ile	(19.35)	-0.405	0.686
Group Comparison								-0.963	0.336

Note: *= significant difference; Progress for each group was calculated using Wilcoxon Signed Rank Test; Group comparisons were calculated using Mann Whitney test. Reading and maths calculated from 38-50 months.

Table 5. Summary of Changes in Standard Scores for Auditory Comprehension and Expressive Communication for AVT Group and TH Group over 50 Months Test Period and Results of Statistical Comparison of Changes in Scores Over Time

Name of Test	Group	N	Standard Score (SD)		N	Standard Score (SD)		*z*	*p*
PLS-4/CELF-3									
Auditory	AVT	19	95.00	(17.47)	19	102.33	(19.44)	-1.808	0.071
Comprehension	TH	19	119.94	(11.27)	19	116.21	(10.37)	-1.7	0.089
Group Comparison								0.599	0.549
PLS-4/CELF-3									
Expressive	AVT	19	92.95	(13.86)	19	98.26	(20.57)	-1.002	0.316
Communication	TH	19	111.32	(9.15)	19	115.32	(10.43)	-1.373	0.170
Group Comparison								-0.131	0.895

Table 6. *Mean Increase in Age Equivalents for AVT Group and TH Group for Language and Speech Over 50 Months and Over 12 Months*

Test	AVT Group		TH Group	
	50 Months	*12 Months*	*50 Months*	*12 Months*
PLS-4 or CELF -3	51.31	12.31	56.05	13.45
PPVT	57.21	13.73	64.43	15.46
GFTA-2	43.68	10.48*	43.89	10.53^

Note * = 53% scored above ceiling of test; ^ = 68% scored above ceiling of test