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

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A longitudinal study reported positive speech and language outcomes for 29 children with hearing loss in an auditory-verbal therapy program (AVT group) (aged 2 to 6 years at start; mean PTA 79.39 dB HL) compared with a matched control group with typical hearing (TH group) at 9, 21, and 38 months after the start of the study. The current study investigates outcomes over 50 months for 19 of the original pairs of children matched for language age, receptive vocabulary, gender, and socioeconomic status. An assessment battery was used to measure speech and language over 50 months, and reading, mathematics, and self-esteem over the final 12 months of the study. Results showed no significant differences between the groups for speech, language, and self-esteem ($p > 0.05$). Reading and mathematics scores were comparable between the groups, although too few for statistical analysis. Auditory-verbal therapy has proved to be effective for this population of children with hearing loss.

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Introduction

This longitudinal study was designed to investigate the effectiveness of auditory-verbal therapy (AVT) for a group of children with hearing loss (AVT group). 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, including AVT, is minimal (Gravel & O'Gara, 2003; Sussman, et al., 2004). Existing research studies on AVT outcomes have been criticized as being few in number and lacking in rigor (Eriks-Brophy, 2004; Rhoades, 2006). These studies also had limited generalizability because of their retrospective nature, inconsistency in the use of standardized assessments, the possibility of self-selected populations, and lack of control groups.

A review of research findings on outcomes of AVT was conducted by Dornan, Hickson, Murdoch, and Houston (2008). In this review, several studies were found to demonstrate a typical rate of progress for the language development of children in AVT programs (Hogan, Stokes, White, Tyszkiewicz, & Woolgar, 2008; Rhoades, 2001; Rhoades & Chisolm, 2000). However, these findings needed substantiation with a controlled study. Such comparisons were undertaken in the earlier stages of this research where outcomes of the AVT group were compared with those for a matched group of children with typical hearing (TH group) (Dornan, Hickson, Murdoch, & Houston, 2007; 2009). At baseline, there were 29 children in the AVT group, between 2 and 6 years old (mean pure tone average of 76.17dB HL). The children were matched with the TH group for initial language age, receptive vocabulary, gender, and socioeconomic status (as measured by head of the household's education level). Both groups were assessed over time using a battery of assessments. Speech and language outcomes for the AVT group were compared with those for the TH group from a baseline measure (referred to as the pretest) to 9, 21, 38, and 50 months after the baseline tests (referred to as the posttests). Results of these earlier studies have been positive, with the AVT group showing significant progress for speech and language at the same rate as the TH group (Dornan, et al., 2007; 2009). An exception was receptive vocabulary, for which the AVT group achieved the same progress as the TH group at the 9 months posttest ($p > 0.05$) (Dornan, et al., 2007), but the TH group scored significantly higher than the children in the AVT group at the 21 and 38 months posttests ($p \leq 0.05$) (Dornan, et al., 2009). Despite this difference, the AVT children's mean age equivalent was within the typical range for their chronological age.

Further study on the outcomes of the AVT group is important because few controlled longitudinal studies of speech and language outcomes are available for children with hearing loss. In addition, an extension of the study time

allowed us to include measures of academic outcomes for the children. It is widely acknowledged that significant hearing loss in children also impacts academic achievement, which usually lags behind the norm for children with typical hearing (Powers, 2003). Academic success for a child with hearing loss in the mainstream has been linked with a number of factors, including education using listening and spoken language, a shorter period of hearing loss prior to amplification or cochlear implantation, and level of intelligence (Damen, van den Oever-Goltstein, Langereis, Chute, & Mylanus, 2006; Geers, et al., 2002). The fundamental academic skill of reading is often severely affected by significant hearing loss, with many children never achieving functional literacy skills (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). Traxler (2000) found that children with severe-to-profound hearing loss typically completed 12th grade with language levels of 9- to 10-year-old children who had typical hearing, and 50% of those students read at a 4th-grade reading level or less. Reports such as these are in contrast to two studies on the reading abilities of children in an AVT program (Robertson & Flexer, 1993; Wray, Flexer, & Vaccaro, 1997), which found that children were able to read at or above age-appropriate levels. However, as the previous research did not include control groups and used different assessments, interpretation of findings and close comparison of results are difficult.

Poor consistency has also been reported among studies on the reading development of children with hearing loss using a variety of education approaches (Marschark, Rhoten, & Fabich, 2007). Spencer and Oleson (2008) studied the reading abilities of 72 children with hearing loss who had used unspecified education approaches (after 48 months of cochlear implant use) and concluded that early access to sound helped build better phonological processing skills, one of the likely contributors to reading success (National Institute of Child Health & Human Development, 2000). Spencer and Oleson (2008) also found that 59% of variance in reading skills for these children could be explained by early speech perception and speech production performance. However, other researchers found that although early cochlear implantation had a long-term positive impact on listening and spoken language development, it did not result in age-appropriate reading levels in high school for the majority of students (Geers, Tobey, Moog, & Brenner, 2008).

Another important academic skill is mathematics and, as with reading, research on the mathematical achievements of children with hearing loss is generally inadequate because studies are rare and seldom use the same measures. Furthermore, no data is available on mathematics outcomes for children in AVT programs. However, mathematics skill levels below that of their peers with typical hearing are consistently reported for children with hearing loss (Kritzer, 2009). Mathematics ability for children with hearing loss has shown to be related to a child's skills in reading, language, and morphological knowledge regarding word segmentation and meaning (Kelly & Gaustad, 2007). Nunes and Moreno (2002) reported two aspects of the functioning ability of

children with hearing loss that place them at risk for underachievement in mathematics, over and above reduced access to hearing: (1) reduced opportunities for incidental learning and (2) difficulty in making inferences involving time sequences. Traxler (2000) found that the mathematics performance of school-aged students with hearing loss indicated only partial mastery of mathematical knowledge and skills. High school graduates were found to have computational skills comparable to 6th grade students with typical hearing, and mathematics problem solving skills comparable to 5th grade students with typical hearing (Traxler, 2000). Low academic attainments in mathematics, as well as reading, may have significant economic impact on the child's future because of the relationship that exists between education level and income (Nunes & Moreno, 2002).

In addition to reading, mathematics, and overall academic achievement, the way children with hearing loss perceive themselves and their abilities is an important outcome. No research on the self-esteem of children educated in AVT programs is available. Researchers have found that for children with significant hearing loss who do not develop language skills commensurate with their peers, self-esteem and emotional development are often severely affected (Bat-Chava, Martin, & Kosciw, 2005; Hintermair, 2006; Nicholas & Geers, 2003). Self-esteem measures usually take the form of either a child or a parent-reported questionnaire or survey, either oral or written (e.g., Percy-Smith, et al., 2006; Schorr, Roth, & Fox, 2009). During the 38 months posttest we added a self-esteem questionnaire in which parents responded to questions regarding their child's sense of self, sense of belonging, sense of personal power, and overall self-esteem. Results showed that self-esteem levels were not significantly different between groups. It was important to investigate whether these positive self-esteem results would continue as the group advanced through school. Hence, the self-esteem questionnaire was repeated at the 50 months posttest.

This entire study used a battery of assessments to investigate the effectiveness of AVT over a 50-month time period for a group of children with hearing loss. We studied whether the promising outcomes for listening and spoken language for the AVT group shown in earlier stages of this longitudinal study (Dornan, et al., 2007; 2009) were maintained over 50 months by 19 of the same children who remained in the study for the full 50 months. Reading, mathematics, and self-esteem were also investigated over the last 12 months of the study, by which time most of the 2 groups had reached school age. Outcomes for the AVT group were compared with those for the 19 matched children in the TH group over 50 months.

Method

This study employed a matched group, repeated measures design. At the start of the study, 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).

Participants

Auditory-Verbal Therapy Group (AVT Group)

Selection criteria for the participants 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-on-one, parent-based AVT for a minimum of 6 months; wore hearing devices consistently (hearing aids and/or cochlear implants) and aided hearing was 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; and both parents spoke only English to the child.

The children attended one of the five regional centers of an AVT 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 AG Bell Academy for Listening and Spoken Language, 2007). Even though a particular AVT program may adhere to all of these principals, programs may vary in the operational details. A description of the AVT program in this study can be found at http://www.hearandsaycenter.com.au/mission-delivery.html.

Of the 10 children who left the study between the 38-month and 50-month posttests, 2 had left the program because of diagnosis of additional disabilities, 6 had moved away or were unavailable for testing, and the departure of 2 TH group children from the study necessitated omitting their matched AVT group pair. The remaining AVT group participants had bilateral sensorineural hearing loss ranging from moderate to profound (mean PTA 79.39 dB HL; range = 45 dB to >110 dB). All children were fitted with hearing aids, commencing intervention within 3 months of diagnosis. Of these, 13 children received unilateral Cochlear Nucleus CI 24 implants and used an Advanced Combined Encoder (ACE) processing strategy. The median age for receiving a cochlear implant was 23.04 months (mean = 27.54 months, SD = 15.24). During the study, 6 of these children received a bilateral cochlear implant. All but 1 of the unilateral cochlear implant users in the study also wore a hearing aid in the contra-lateral ear. Both hearing devices were balanced by their audiologist according to the recommendation of Ching, Psarros, and Incerti (2003). All children wore their hearing devices consistently throughout the study. A battery of speech perception tests was administered by an audiologist to ensure that the children's listening skills were developing optimally. The mean age of the AVT group at the start of the study was 3.80 years

(SD = 1.15) and the mean age at the 50 month follow-up was 8.02 years (SD = 1.28) (Table 1).

Typical Hearing Group (TH group)

The TH group was recruited by families and staff of the AVT program, and their characteristics are also available in Table 1. Selection criteria for the participants 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; typical articulation as measured by the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 2001) and using Australian norms (Kilminster & Laird, 1978); no significant cognitive or physical disabilities (as evidenced by case history or parent report); and both parents spoke only English to the child.

Sixty four children were initially tested to ensure controlled matching with the AVT group. The TH group children who remained in the study were matched at the initial assessment with the AVT group for total language age (± 3 months) on the Preschool Language Scale (PLS-4) (Zimmerman, Steiner, & Pond, 2002) or the Clinical Evaluation of Language Fundamentals

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

	AVT Group	*TH Group*
N	19	19
Mean Age in months (SD)	96.26 (15.32)	87.84 (16.68)
Gender		
Male	14	14
Female	5	5
Age at identification in months	22.29 (11.82)	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, if applicable, in months (SD)	27 (5.8)	n/a
Time spent in AVT Program in months (SD)	70 (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%

CI = Cochlear Implant; HA = Hearing Aid

(CELF-3) (Semel, Wiig, & Secord, 1995), as well as for receptive vocabulary on the Peabody Picture Vocubulary Test (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. The rationale for matching for language age rather than chronological age has been discussed in an earlier paper (Dornan, et al., 2009). Had chronological age been used for matching (instead of language age), the children with typical hearing generally would have had a higher language level than the children with hearing loss, introducing the possibility that the children in the TH group might progress faster. 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). 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 highest level of education of the head of the household was used. As an added check, the occupations of both groups were placed in categories according to those developed by Jones (2003), as occupation category has been found to impact the vocabulary learning of a child with hearing loss (Hart & Risley, 1995) (see Table 1). It was concluded that both AVT group and TH group parents had a moderate to high socioeconomic status. The mean age of the TH group at the start of the study was 3.11 years (SD = 1.22) and the mean age at the 50 month follow-up was 7.32 years (SD = 1.39) (Table 1).

Materials

To assess total language, receptive vocabulary, speech, reading, mathematics, and self-esteem at pre- and posttest for participants in both the AVT and TH groups, a battery of assessments was used (Table 2). As some assessments are recorded differently, (i.e. standard scores, percentile ranks, and raw scores), this is also represented in Table 2. Additional information on the assessments for reading, mathematics, and self esteem is included in the Appendix.

Procedure

Appropriate ethical clearance and parent consent was gained for this study (Dornan, et al., 2007, 2009). Assessments of children in the AVT group took place at the child's program center. For the TH group, testing was performed either at the center, 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 and for convenience, available qualified staff performed the testing and, frequently, different speech-language pathologists

Table 2. Battery of assessments

Test	*Description of Test*	*Scoring*
Language		
Preschool Language Scale-Fourth Edition (PLS-4) (Zimmerman, et al., 2002).	Measures young child's receptive and expressive language from birth to 6 years, 11 months. Australian norms were not available. Used at pretest for all children but one pair. CELF-3 was used for this pair. Not used at 50 months posttest.	The scoring ceiling used was five consecutive items incorrect. Receptive language and oral expression were expressed as standard scores because the CELF-3 does not have age equivalents for comparison. Total language score is expressed as an age equivalent.
Clinical Evaluation of Language Fundamentals (CELF-3) (Semel, et al., 1995).	Measures child's receptive and expressive language from 6 years to 21 months. CELF-3 used for all children at posttest. 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. Australian norms were not available.	If a child scored the highest possible score on the PLS-4, the CELF-3 was administered. Receptive language and oral expression are expressed as standard scores (age equivalents are not available) and total language 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, and (d) jug for pitcher. Australian norms were not available.	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. Australian norms were not available.	Child's score is expressed as an age equivalent.

Reading		
Reading Progress Tests (RPT) (Vincent, Crumpler, & de la Mare, 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 were 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 rank.
Mathematics		
I Can Do Maths (Doig & de Lemnos, 2000).	This test assesses numeracy development in first 3 years of school. Australian norms are available.	One mark is awarded for each correct answer. Score is expressed as a percentile rank.
Progressive Achievement Tests in Mathematics (PATMaths) (Australian Council of Educational Research, 2005).	This test assesses mathematic achievement levels in school years 3 to 11. Australian norms are available.	One mark is awarded for each correct answer. Score is expressed as a percentile rank.
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, and the 36 questions were divided into 3 different areas, which included their child's sense of self, sense of belonging, and sense of personal power. Parents were asked to report whether the skill was evident "Most of the Time" (3 points), "Quite Often" (2 points), "Occasionally" (1 point), or "Almost Never" (0 points).	The sum of the scores for the 3 areas studied (sense of self, sense of belonging, and sense of personal power) were totalled (maximum possible score = 108) and then rated as "High," "Good," "Vulnerable," or "Very Low" according to score-based criteria: "High" = 87–108; "Confident and at ease with self, other people, and the world most of the time." "Good" = 64–86; "Feels good about self, but takes knocks now and again." "Vulnerable" = 40–63; "Tends not to feel very confident." "Very Low" = 0–39; "Depressed or very challenging behaviour to cover this up."

assessed the children at pre- and posttest. Tester reliability was not examined in the study; however, all tests were administered according to the standardized instructions in the test manuals. Language and speech tests were administered over two or three sessions according to the needs of each child with a rest break between assessments, and were discontinued if a child showed fatigue or distress. The children's responses to the GFTA-2 were judged to be correct or incorrect at the time of testing. The order of presentation of the standardized tests to the TH group was different than the AVT group to account first for screening, and then to establish a match with a child in the AVT group before the child was unnecessarily tested.

For the AVT group, assessments were performed in the best aided condition. For all children with cochlear implants, the optimally functioning MAP (assessed by the child's audiologist and auditory-verbal therapist) was used for assessments. 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 behaviorally and confirmed objectively. Optimal implant performance was verified by 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 frequencies widely used clinically to verify effectiveness of hearing aid fitting in children (Agung, Purdy, & Kitamura, 2005). The Ling Six Sound Test was developed for the North American population (Ling, 2002), and /o/ was added (seven sound test) to account for differences in production and spectral content of Australian vowels (Agung, et al., 2005). For the children with hearing aids, best aided condition was determined by the audiologist and auditory-verbal therapist, performance of the seven sound test, speech perception tests, and the child's aided audiogram.

For speech and language assessments, the mean time between the pretest and 50 months posttest was 51.16 months for the AVT group (SD = 1.12) and 51.37 months for the TH group (SD = 0.94), which was not significantly different ($t = –0.335$, $p = 0.742$). Similarly, mean times between pretest (38 months) and posttest (50 months) for reading, mathematics, and self-esteem assessments (M = 12.73 months, SD = 2.03 for the AVT group; M = 13.26 months, SD = 1.91 for the TH group) were also not significantly different for the two groups ($t = –1.398$, $p = 0.171$).

Results

Preliminary analysis was carried out to ensure the validity of matching 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. A Mann-Whitney

test showed that the total mean language ages of the AVT (M = 3.58 years; SD = 1.46) and TH groups (M = 3.5 years; SD = 1.52) were comparable (z = –0.307; p = 0.759). Similarly, there were no significant differences (z = –0.197; p = 0.844) for mean receptive vocabulary ages at pretest on the PPVT-3 between the AVT (M = 3.06 years; SD = 1.56) and TH groups (M = 2.97 years; SD = 1.46). Overall, both groups were found to be matched for total language age and receptive vocabulary at the pretest.

Speech and Language

Table 3 displays the pre- and posttest mean age equivalents, standard deviations, z and p values for total language, receptive vocabulary, and speech for the 19 children in the AVT and TH groups at pretest and at the 50 months posttest.

For total language age assessed using the PLS-4 or CELF-3, both groups made significant progress over 50 months and the change in scores over this period of time was not significantly different between the groups. Further comparisons of receptive and expressive language results were made using standard scores on the CELF-3 as age equivalence is not calculated on this assessment. For receptive language, no significant changes in standard scores were found from pretest to posttest for each group because standard scores

Table 3. Pre- and posttest mean age equivalents, standard deviations (in parentheses), and z and p values for total language, receptive vocabulary, and speech for 19 children in the AVT and TH groups at pretest and at 50 months posttest

Test	*Group*	*Pretest Mean Age Equivalent (months) (SD)*	*Posttest Mean Age Equivalent (months) (SD)*	*z*	*p*
PLS-4/CELF-3	AVT	42.95 (17.59)	94.26 (34.60)	–3.824	<0.001*
	TH	42.00 (18.27)	98.05 (12.37)	–3.825	<0.001*
Group Comparison				**1.550**	**0.121**
PPVT-3	AVT	36.74 (18.56)	93.95 (43.88)	–3.824	<0.001*
	TH	35.57 (17.55)	100 (19.01)	–3.825	<0.001*
Group Comparison				**–2.921**	**0.235**
GFTA-2	AVT	36.74 (17.38)	80.42 (15.76)	–3.824	<0.001*
	TH	42.11 (17.04)	86.00 (11.76)	–3.765	<0.001*
Group Comparison				**–0.336**	**0.737**

Note 1: * = significant difference (acceptable level of significance is ≤0.05); progress with time for each group analysed using the Wilcoxon Signed Rank Test; between group comparisons of progress analysed using the Mann-Whitney Test.
Note 2: AVT group chronological age at pretest was 45.6 months (SD = 13.8) and at posttest was 96.26 months (SD = 15.32).
TH group chronological age at pretest was 37.32 months (SD = 14.64) and at posttest was 87.84 months (SD = 16.68).

are age corrected ($z = –1.808$, $p = 0.071$ for the AVT group; $z = –1.7$, $p = 0.089$ for the TH group). Also, the amount of change displayed by both groups was not significantly different ($z = 0.599$, $p = 0.549$). Similarly, for expressive language, there was no significant change in standard scores between pre- and posttest for each group ($z = –1.002$, $p = 0.316$ for the AVT group; $z = –1.373$, $p = 0.170$ for the TH group) and no significant difference for amount of progress between the two groups ($z = –1.131$, $p = 0.895$).

Receptive Vocabulary

For receptive vocabulary, as assessed using the PPVT-3, both groups showed significant changes in age equivalents over the 50 months with no significant difference in the amount of change between the groups (Table 3). The mean age equivalent for the AVT group was within the typical range for their chronological age.

Speech

On the GFTA-2, significant increases in age equivalents were evident for both groups over 50 months with no significant differences in the changes between the two groups (Table 3). At the 50 months posttest, 42% of the AVT group and 63% of the TH group scored at the ceiling of 7 years, 8 months on this test.

Reading and Mathematics

For these assessments, a smaller sample of 7 pairs of children in each group was available for comparison. This is because a number of children in both groups had not yet entered school or begun formal reading and mathematics by the 50 months posttest (1 child in the AVT group; 3 children in the TH group) or had not reached this stage by the 38 months posttest (4 children in the AVT group; 13 children in the TH group children). Table 4 shows the pre- and posttest percentile ranks for reading and mathematics assessments for the 14 eligible children in the AVT group and TH group at 38 and 50 months posttest.

Table 4. Pre- and posttest percentile ranks for reading and mathematics for the 14 children in the AVT group and TH group at 38 and 50 months posttest

			Pretest Percentile			*Posttest Percentile*	
Name of Test	*Group*	*N*	*Rank (SD)*	*Range*	*N*	*Rank (SD)*	*Range*
Reading	AVT	7	83.57 (17.74)	51–98	7	88.14 (10.90)	46–99
	TH	7	88.14 (7.90)	75–98	7	90.14 (9.81)	79–99
Mathematics	AVT	7	60.43 (35.02)	23–98	7	77.57 (28.54)	32–99
	TH	7	81.28 (24.88)	67–96	7	80.86 (19.35)	77–92

The numbers of children in each group were considered too small for statistical comparison. For reading, the AVT group scores were in the 83rd percentile at the 38 months posttest and in the 88th percentile at the 50 months posttest. Similarly, for mathematics, the AVT group scores were in the 60th percentile at the 38 months posttest and in the 77th percentile at the 50 months posttest. The percentile ranks at the 50 months posttest for both groups were comparable (see Table 4).

Self-Esteem

Eighteen parents of the AVT group and 16 parents of the TH group responded to the self-esteem questionnaire at the 50 months posttest, and 10 matched pairs were identified with scores both at the 38 months posttest and the 50 months posttest. Table 5 shows the results for sense of self, sense of belonging, and sense of personal power subscales for both groups at 50 months, the highest possible score being 36 in each category.

Mann-Whitney tests showed no significant differences between the groups for sense of self, sense of belonging, and sense of personal power components of the questionnaire. Furthermore, at the 50 months posttest, the total self-esteem scores between the two groups were not significantly different. The majority of children in both participant groups (80% in the AVT group and 70% in the TH group) were rated as having "high" self-esteem while the remainder had "good" self-esteem. No children from either group were rated in the "vulnerable" or "very low" categories.

Discussion

This study reported speech perception outcomes for the AVT group from the 38 months to the 50 months posttests and also compared outcomes for the AVT group for receptive, expressive, and total language, receptive vocabulary, and speech over 50 months with outcomes of the matched TH group. In addition, the study also compared reading, mathematics, and self-esteem outcomes between the AVT and TH groups over the last 12 months of the study. The AVT group's promising earlier outcomes of typical rate of progress for total language and speech skills to those of hearing controls (Dornan, et al., 2007, 2009) has been maintained over the 50 months. Furthermore, receptive vocabulary progress, reported to be slower for the AVT group than for the TH group at earlier posttests (Dornan, et al., 2009), was found to have accelerated significantly at the 50 months posttest to develop at the same rate as the TH group. The AVT group maintained standard score levels for receptive and expressive language, which were similar to results for the TH group. Self-esteem levels were not significantly different between the groups, with predominantly high self-esteem reported for both groups. We will further discuss and compare these results with our previous research.

Table 5. Pre- and posttest raw scores for self-esteem for the AVT group and the TH group for primary Insight at 38 and 50 months posttests

		Sense of Self (SD)		*Sense of Belonging (SD)*		*Sense of Personal Power (SD)*		*TOTAL Self-esteem (SD)*	
		Mean 38 months (SD)	*Mean 50 months (SD)*	*Mean 38 months (SD)*	*Mean 50 months (SD)*	*Mean 38 months (SD)*	*Mean 50 months (SD)*	*Mean 38 months (SD)*	*Mean 50 months (SD)*
AVT Group		31.07 (3.93)	32.1 (3.11)	31.64 (2.98)	32.4 (3.09)	30.29 (3.79)	31.60 (3.72)	92.86 (9.46)	96.1 (9.22)
TH Group		31.93 (4.8)	32.94 (2.81)	29.92 (5.27)	33.8 (2.53)	27.36 (7.17)	31.5 (2.88)	89.93 (12.82)	98.4 (7.44)
Group Comparison	z	**–0.324**	**–0.609**	**–0.949**	**–0.996**	**–0.946**	**–0.229**	**–0.621**	**–0.417**
	p	**0.746**	**0.542**	**0.343**	**0.319**	**0.344**	**0.819**	**0.534**	**0.677**

Acceptable level of significance = ≤0.05. Progress with time for each group analysed using the Wilcoxon Signed Rank Test. Between group comparisons of progress analysed using the Mann-Whitney Test.

Total language growth for the AVT group was at a rate of 12.31 months per year, comparing favorably to a rate of 13.45 months for the TH group. The majority of the AVT group (79%) and the entire TH group scored within the typical range or above for language at the 50 months posttest. The AVT group achieved mean total language scores, which were 2.1 months less than their mean chronological age or within one standard deviation of the mean for their age. The only other studies that have indicated such positive language growth results have included children fitted with hearing aids at less than 6 months of age (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998) or children receiving cochlear implants before 18 months of age (Ching, et al., 2009; Dettman, Pinder, Briggs, Dowell, & Leigh, 2007; Svirsky, Teoh, & Neuburger, 2004). In the present study, 1 child had been fitted with hearing aids before 6 months and 2 children had been fitted with cochlear implants at less than 18 months. Nevertheless, the group as a whole achieved age appropriate language.

These positive results for language of the AVT group are similar to those obtained previously for children in AVT programs (e.g. Rhoades, 2001; Rhoades & Chisolm, 2000) in which the majority of children were reported to show no significant chronological age and language age gaps when entering mainstream school. Results obtained here are superior to a number of other studies of children with hearing loss educated using a range of different interventions (e.g. Blamey, Barry, et al., 2001; Geers, Nicholas, & Sedey, 2003; Sarant, Holt, Dowell, Rickards, & Blamey, 2008).

The AVT group progressed in receptive vocabulary development at a rate of 13.73 months per year over the 50 months of the study, compared to the TH group at 15.46 months, with no significant difference in progress between the two groups. For the AVT group, 68% had scores within the typical range or above for receptive vocabulary, compared to 100% of the TH group. At the 50 months posttest, the gap between chronological age and age equivalence for the AVT group for receptive vocabulary was 2.4 months. This suggests that the AVT group were functioning as expected for their age for receptive vocabulary. The receptive vocabulary results for the AVT group are superior to those found in the literature, which have reported levels of receptive vocabulary for children with hearing loss lower than children with typical hearing (e.g. Blamey, Sarant, et al., 2001; Eisenberg, Kirk, Martinez, Ying, & Miyamoto, 2004; Fagan & Pisoni, 2010; Hayes, Geers, Treiman, & Moog, 2009; Schorr, Roth, & Fox, 2008; Uziel, et al., 2007).

Similar to earlier stages of the study, the AVT group achieved intelligible speech with the same scores as the TH group (Dornan, et al., 2007, 2009). The rate of change in scores per year for correct articulation of consonants in words was 10.48 months for the AVT group and 10.53 months for the TH group. The lack of a significant difference between the changes in speech scores for the AVT and TH groups is surprising because children with hearing loss typically have difficulty with articulation of speech sounds (Marschark, Lang, & Albertini, 2002; Schorr, et al., 2008; Uziel, et al., 2007). An increase in accuracy of

consonant production for children with implants (like most of the AVT group in this study) has been reported, as well as an increasing ability with longer implant experience and use of oral communication (Tobey, Geers, Brenner, Altuna, & Gabbert, 2003). A high correlation between speech perception and speech production has also been reported for children with cochlear implants (Phillips, et al., 2009). It is likely that the combination of cochlear implant use and AVT may have positively influenced the level of speech skills achieved by the AVT group in this study.

In this paper we report preliminary results for reading and mathematics over a 12-month period for a small sample of children (n = 7). Over the last 12 months of this study, the AVT group results for reading improved from the 84th percentile to the 88th percentile (as compared to from the 88th percentile to the 90th percentile for the TH group). The AVT group results for mathematics improved from the 60th percentile to the 77th percentile (as compared with remaining around the 81st percentile for the TH group). Since percentile ranks are already normalized scores, the improvement in percentile ranks for the AVT group indicates that the children were progressing at a faster rate than is typical. The positive results for reading and mathematics, although for a very small group, show the potential for this group of children to be successful in the mainstream. As the AVT group was relatively young (8.02 years) at the 50 months posttest, it will be important to follow up this study, particularly for reading, over a longer term as it has been found that reading scores for a group of 85 adolescents with cochlear implants studied from ages 8–9 years did not keep pace with their language development at ages 15–18 years (Geers, et al., 2008). In addition, further large-scale studies are needed to investigate reading progress for children in AVT programs. Positive reading achievement for children with hearing loss educated using AVT has been reported in a number of studies (Durieux-Smith, et al., 1998; Goldberg & Flexer, 1993, 2001; Robertson & Flexer, 1993; Wray, et al., 1997), and has been related to speech perception and speech production performance (Spencer & Oleson, 2008). Together, these findings are in contrast to unfavorable reports on reading ability for children with hearing loss in some studies (e.g. Boothroyd & Boothroyd-Turner, 2002; Moeller, et al., 2007; Traxler, 2000; Vermeulen, et al., 2007). The good levels of speech perception and speech production achieved by the AVT group in this research (Dornan, et al., 2009) may have had an influence on their reading achievement. The addition of an assessment of phonological processing in future research may add to the information on reading skills for children in AVT programs.

In relation to mathematics, the same inherent problems of sample size made interpretation of the results difficult. At the 50 months posttest, however, the mean percentile rank for the AVT group for mathematics was high (78th percentile), as was the percentile rank for the TH group (81st percentile), which suggests that the results are relatively comparable for both groups. Since the mathematics assessment was both read by the AVT group and presented to them verbally, these outcomes represent positive skill levels for listening and

reading as well as mathematics for this group. The current AVT group performed better than the group studied by Traxler (2000), who found that the mathematics ability of high school students with hearing loss was at a "basic level" or below. The findings for the AVT group may be explained by their good reading and language skills, as Kelly and Gaustad (2007) found that levels of reading and language skills influenced the ability of a child with hearing loss to achieve in mathematics. In addition, the good listening ability of the AVT group may well have influenced their mathematics ability, as their listening ability allowed them opportunities for incidental learning of early mathematics concepts, unlike the study reported by Nunes and Moreno (2002). More studies on mathematics outcomes for children with hearing loss are needed to add to the body of knowledge in this area.

The self-esteem results for the AVT group are better than those obtained by a number of other researchers who reported adversely affected self-esteem (Nicholas & Geers, 2003), mental health (Laurenzi & Monteiro, 1997), and socio-emotional development (Prizant & Meyer, 1993) for children with significant hearing loss. In the present study, there was no significant difference between the AVT group and the TH group for self-esteem. These results are in agreement with those in a Danish parent survey of children with hearing loss (Percy-Smith, et al., 2006), which reported a satisfactory or very satisfactory level of well-being for children with cochlear implants. The AVT group results are also in agreement with those of Schorr et al. (2009) who found that 37 children (ages 5–14 years) who received a cochlear implant and used listening and spoken language reported improved quality of life; positive self-esteem was also related to receiving a cochlear implant at a younger age. The high results for self-esteem for the AVT group could be a factor of their good use of their hearing device(s), their good listening skills, and speech and language development, but their mean age of cochlear implantation was not particularly early (27 months). It is significant that these results for self-esteem were based on a parent rating, showing that at the 50 months posttest, the parents perceived that there was little detrimental impact on the child's self-esteem as a result of the hearing loss.

Although this study's findings are promising, the outcomes cannot be generalized for a number of reasons. First, both the AVT and TH groups were mainly from a moderate to high socioeconomic level. This may have caused a self selection of both groups of children, making some interpretation difficult. Similarly, a number of studies on outcomes of AVT have reported the predominance of well-educated parents (Dornan, et al., 2007, 2009; Easterbrooks, O'Rourke, & Todd, 2000; Rhoades & Chisolm, 2000). Socioeconomic status has been found to be a significant predictor of better speech perception performance for children with hearing loss (Hodges, Dolan Ash, Balkany, Schloffman, & Butts, 1999), and has also been associated with better language for children with TH (Hart & Risley, 1995; Hoff-Ginsberg, 1991). Higher socioeconomic levels have also been found to be associated with higher reading and writing scores and a

lower risk of academic delays (Geers, 2003; Martineau, Lamarche, Marcoux, & Bernard, 2001). Low socioeconomic status has been reported as being associated with reduced academic opportunity and underachievement (Connor & Zwolan, 2004). Therefore it is suggested that if only children from high socioeconomic groups attended an education program, better outcomes for speech perception, language, reading, and writing would possibly result. As AVT is becoming more available to diverse family groups, the limitations of the generalized outcomes of this study must be acknowledged. Another limitation of this research is the fact that even though one child with mild cerebral palsy was included, two children had left the program in the first 9 months of the study because of the diagnosis of additional disabilities. It is acknowledged that the outcomes for the AVT group may not be applicable to today's growing cohort of children newly diagnosed with hearing loss as a result of newborn hearing screening who also have other disabilities (Larroque, et al., 2008). In addition, similar comments are applicable to the generalizability of outcomes data for children who are not native English speakers, which is another increasing demographic group in the population of children with hearing loss.

Whether AVT is effective for children and families across a wide socioeconomic range remains an important empirical question for future research. A further study limitation included the relatively small numbers of participants, particularly for reading and mathematics comparisons. Despite these limitations, the research goes some way towards providing a benchmark for minimum rate of progress for children with hearing loss acquiring listening and spoken language.

Summary

The results described here provide evidence that AVT is an effective intervention option for the AVT group. Speech perception improved significantly with moderate to high levels at 50 months after the start of the study. Although the group was identified at a mean age of 22.29 months, much later than the current "international gold standard" of 6 months of age (Joint Committee on Infant Hearing, 2007; Yoshinaga-Itano, et al., 1998), their language and speech attainments have been the same as a matched control group of children with TH over a 50 month time period. Reading, mathematics, and self-esteem outcomes were also comparable for both groups over the last 12 months of the study period. This study has provided a research model, utilizing a control group matched for language age, which could also be replicated across different languages, cultures, and countries and with different education approaches.

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Appendix: Further Description of Reading, Mathematics and Self-Esteem Tests

Reading Tests

Reading Progress Tests (RPT) (Vincent, Crumpler, & de la Mare, 1997)

The Reading Progress Tests are a series of 7 British tests for ages 5 to 11. They comprise a Literacy Baseline Test of prereading and early literacy skills and 6 tests of reading comprehension (Reading Progress Test 1 to Reading Progress Test 6).

These tests provide individual or group measures of reading progress in two stages, Stage 1 (5–7 years) and Stage 2 (7–11 years) through the first 6 years of schooling. Tests are administered in a manner that ensures that children comprehend the nature of the task. Feedback is given when the method of response is incorrect, with time to correct their response. Feedback on whether the response is correct or incorrect is not given. Up to three repeats of a target word in instructions, plus practice items, are allowable. Children are reminded to refer back to the text to prevent relying on memory for their responses. There are no time limits but they usually take up to 45–50 minutes to administer. Australian norms were available and percentile ranks have been used to describe a child's level of ability.

The Literacy Baseline Test has three purposes: to provide a baseline from which to measure subsequent progress, as a screening procedure designed to identify a child likely to face difficulties in development of early reading skills, and as an appraisal of early literacy development. This test assesses existing reading and spelling ability, identification of initial sounds in spoken words and the identification of rhymes in spoken words (phonological awareness), familiarity with literacy concepts (such as knowing which words on the cover of a book are likely to be the name of the book, or which is the first word in a line of print), knowledge of letter names, and letter sounds. The child is asked to underline, or otherwise mark or point to, the correct response. This test was administered to Grade 1 children in the present study.

RPT1 and RPT2 are tests of reading comprehension that have two main purposes: to allow a standardized assessment of the child's reading comprehension and to monitor a child's progress in reading comprehension from one assessment point to the next in comparison with the progress made by other children in the same age-group. Both tests include three main types of comprehension question: (1) identifying the meaning of individual words, (2) selection of the correct answer from a number of choices after reading a short story, nonfiction passage or poem, and (3) choosing or supplying missing words in a short story or non-fiction passage. The majority of responses required consisted of marking one of a multiple choice selection. These tests were administered to Grade 2 and Grade 3 children in the present study.

RPT3, RPT4, RPT5, and RPT6 are similar to RPT1 and RPT2 in construction and administration, but are of a higher reading comprehension level. They were administered to Grade 4, 5, 6, and 7 children, respectively, in the present study.

Mathematics Tests

I Can Do Maths (Doig & de Lemnos, 2000)

I Can Do Maths is an Australian test of numeracy development in the early years of schooling. Children are requested to write, draw, count, and measure in response to the questions, which cover three main areas of numeracy (number, measurement, and space) and are ordered by increasing level of difficulty. The complete set of questions is covered in two books: Level A (30 questions), which was administered to children in Grade 1 in the present study, and Level B (33 questions), which was administered to a child in Grade 2. All questions are read to the children to avoid performance being affected by reading ability. The test is untimed but usually takes 30–40 minutes. A short break can be given. Australian norms were available and scores were expressed as a percentile rank.

Progressive Achievement Tests in Mathematics (PATMaths)
(Australian Council of Educational Research, 2005)

PATMaths is an Australian test of mathematics consisting of 8 tests (Test A and Tests 1 to 7), each in a separate book and each containing separate assessments of number, space, measurement, chance, and data with later tests containing questions on patterns and algebra. Test A required 20 minutes of testing time plus time for administration, and Tests 1 to 7 required 40 minutes of testing time. Test A was administered to children in Grade 3 while Test 1 was given to Grade 4 children, Test 2 to Grade 5, Test 3 to Grade 6, and Test 4 to Grade 7. Australian norms were available and scores were expressed as a percentile rank.

Self-Esteem Tests

Insight Preschool and Insight Primary (Morris, 2002)

Insight Preschool and Insight Primary are self-esteem indicators which can be used to explore the three key elements of a child's self-esteem: their sense of self, belonging, and personal power. Insight Pre-School covers ages 3–5 years and Insight Primary covers ages 5–11 years. Self-esteem is seen as a highly personal experience unique to each individual, which can mean how a person believes in themself, how they feel when they are with other people, or how

they feel when they tackle something new or difficult. Insight Preschool consists of 24 questions and Insight Primary consists of 36 questions that the parent reads and responds to in writing. This can also be answered by a teacher but in this study, the parent was asked to respond. The form of the test chosen was according to whether the child attended preschool or primary school. Examples of questions included "Is your child usually contented?" and "Does your child try something first before asking for help?" The scoring was according to categories of whether the behaviour was observed "Most of the time" (3 points), "Quite often" (2 points), "Occasionally" (1 point), or "Almost never" (0 points). Table 2 shows the categories for interpretation of these scores.