Outcomes of Victorian 5-6 year old children with congenital hearing loss

Outcomes of Victorian 5-6 year old children with congenital hearing loss: The Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) Study

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Executive Summary

In order to improve educational outcomes for Victorian children who are deaf or hard of hearing (DHH), it is important that practitioners and policy-makers have a clear understanding of factors that influence language and academic achievement. This report draws on the data collected as part of the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study (Ching, Leigh, & Dillon, 2013) to describe demographic characteristics, educational intervention choices and outcomes of Victorian children at five years of age, compared with their peers in New South Wales and Queensland; and to determine factors influencing language outcomes.

The major findings were:

1. On average, LOCHI children in Victoria received hearing aids significantly later than did children from other states.
2. On average, LOCHI children in Victoria enrolled in early education later than did children from other states, although the difference was not significant.
3. A smaller proportion of Victorian children used spoken language (oral communication mode) as the primary mode of communication at home and during educational intervention than did children from other states.
4. A greater proportion of Victorian children changed their communication mode during educational intervention over the first three years of life than did children from other states.
5. Children with lesser hearing loss, no additional disability, and come from families with higher socio-economic status were more likely to use an oral-only mode of communication in early education.

6. On average, language outcomes for children in Victoria were poorer than for the other states. However, there were no significant differences between the states in these outcomes once we adjusted for the children in Victoria having a later age at amplification, lesser nonverbal cognitive ability, lower proportion of children engaged in oral-only educational intervention, greater proportion of additional disabilities, and lower proportion of mothers with post-secondary education.
7. The factors that significantly predicted language outcomes of DHH children at five years of age include: age at hearing-aid fitting or cochlear implantation, severity of hearing loss, presence of additional disabilities, nonverbal cognitive ability, communication mode, and the level of education of the child's mother.

The LOCHI findings provide strong evidence for the effectiveness of early detection and intervention in improving the language outcomes of DHH children at five years of age. However, a child whose mother has low educational level requires greater support, on average, than one whose mother completed university education. To take the benefits of UNHS forward, improvement in management is essential. This requires urgent action research that increases understanding of the processes underlying language learning, and controlled trials of different intervention methods regarding communication mode and parent support on a large scale to guide management. As the children enter formal schooling, the extent to which educational needs are met will be crucial for maximising their academic outcomes and life opportunities.

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Introduction

An extensive body of literature has demonstrated the developmental consequences of permanent childhood hearing loss for communication, language, cognitive, and educational outcomes (Joint Committee on Infant Hearing, 2007). In the US, the median reading level of DHH high-school graduates falls between the fourth and fifth grade level (Helfand et al., 2001; Qi & Mitchell, 2012). In a similar vein, a lag in reading performance by nearly ten months has been reported for Australian DHH children at seven to eight years of age (Wake et al., 2004).

In the late 1990s, several program-based studies first reported a retrospective association between early identification of hearing loss and better preschool language in DHH children (e.g. Yoshinaga-Itano et al., 1998; Moeller et al., 2000). These studies provided the driving force for widespread implementation of universal newborn hearing screening (UNHS) programs. In a systematic review conducted by the US Preventive Services Task Force (USPSTF), Thompson et al (2001) found good evidence that UNHS leads to earlier identification, but the evidence to determine whether earlier intervention (fitting hearing aids and providing educational support) leads to improvement in speech and language development is inconclusive due to methodological flaws. As most reports on the efficacy of UNHS have studied convenience samples rather than whole populations of DHH children, the USPSTF called for prospective studies that directly examine whether newborn hearing screening and earlier intervention result in improved speech, language, or educational development, at a population level.

Two published quasi-randomised trials in recent years have examined the efficacy of UNHS programs. The Wessex study compared language outcomes at seven to eight years of age of 61 children born during periods with UNHS to those of 57 children born during periods without UNHS in southern England. On average, there was a benefit of early detection for receptive language, but no clear benefits for either expressive language or speech production (Kennedy et al., 2006). A recent study in the Netherlands evaluated outcomes at three to five years of age of children who were born in regions with or without UNHS programs. The study reported better motor and social, but not language outcomes for children born in regions with UNHS (Korver et al., 2011). These studies had methodological limitations, including sample bias, variations and delays in post-diagnostic audiological intervention, and reliance on report tools for assessing outcomes. Therefore, whether UNHS is effective in achieving its goal of better outcomes, particularly language outcomes, for DHH children at a population level remains uncertain.

To address this evidence gap, we took advantage of a unique research environment in Australia during a narrow time window (Leigh, 2006) arising from the gradual implementation of UNHS programs in three Australian states to commence the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study in 2005. The LOCHI study was aimed to determine the speech, language, academic, and functional outcomes of children with congenital hearing loss. It also investigated the influence of age of intervention, together with a range of demographic factors, on children's outcomes (Ching, Leigh, & Dillon, 2013). All children born between 2002 and 2007 in New South Wales, Queensland, and Victoria with a hearing loss who accessed the national paediatric hearing services before three years of age were invited to participate in the study. Currently, 461 children are enrolled in the study. Evaluations of the participants' speech, language, and psychosocial outcomes were conducted at 6- and 12-months after initial hearing-aid fitting and/or cochlear implantation. Further evaluations occurred when the participants were three and five years of age. Information about a range of demographic characteristics was also collected at each assessment interval.

Ching et al. (2013) found that, on average, the LOCHI cohort at three years of age scored below the population norms (-1.5 standard deviation [SD]) on global language development (estimated by aggregating scores of nine speech and spoken language measures). Multiple regression analyses revealed that outcomes were significantly influenced by the child's severity of hearing loss, gender, the presence of additional disabilities, and the level of education of the child's mother (Ching et al., 2013). Age at amplification has only a weak effect on outcomes. However, children with severe or profound hearing loss who received a cochlear implant at an earlier age had better language outcomes.

The LOCHI data collected when the children were three years of age indicated that the majority (75 percent) used spoken language as the primary mode of communication at home, hereafter referred to as 'oral' communication. One percent used sign language only as the primary mode (e.g. Australian Sign Language; hereafter referred to as 'manual' only), and 24 percent used spoken language combined with some system of sign or symbol (hereafter referred to as 'combined' mode) as the primary mode of communication (Crowe, McLeod, & Ching, 2012).

The choice of communication mode at home and in early education environments is one of the decisions that parents or caregivers need to make after their child is diagnosed with hearing loss. Factors influencing decisions can be grouped according to whether they relate to the child or the family. Child-related factors include the child's degree of hearing loss (Li, Bain, & Steinberg, 2003), age of identification of hearing loss (Gravel & O'Gara, 2003), age at intervention (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998), type of hearing device used (Watson, Hardie, Archbold, & Wheeler, 2008), and the presence of additional disabilities (Crowe, Fordham, McLeod, & Ching, 2014). Family-related factors include the presence of parental hearing loss (Mitchell & Karchmer, 2004), the family's socioeconomic status, the parent's education level (Wheeler, Archbold, Hardie, & Watson, 2009; Young, Jones, Starmer, & Sutherland, 2005), and the parent's or caregiver's beliefs about how communication mode may influence their child's future (Li, et al., 2003).

Previous analyses of the LOCHI data collected when participants were three years of age by Crowe, McLeod, McKinnon, and Ching (2014) found that almost all children whose female parent/caregiver reported using oral-only communication at home, who had no additional disability, and who had a university-educated female parent/caregiver, were reported to use oral-only communication at home. The communication mode used by children at home was the best predictor of communication mode in early education. Ninety-three percent of children reported to use an oral-only mode at home used the same mode in early education, and seventy-five percent of children reported to use a combined mode at home used the same mode in early education. The use of communication modes other than oral-only in early education of children was associated with the presence of additional disability, and the child's father using a language other than English at home (Crowe, McKinnon, McLeod, & Ching, 2013). Children who used an oral-only mode of communication in early education had better language outcomes than those who used other modes.

It has been reported that the communication mode used by DHH children may change during their early years of development (Hyde & Punch, 2011; Watson, et al., 2008; Wheeler, et al., 2009). The reasons posited for these changes include the child's communication skills and individual's preferences (Hyde & Punch, 2011; Meadow-Orlans, Mertens, & Sass-Lehrer, 2003; Wheeler, et al., 2009). For example, a child may cease to use sign language after his/her spoken language skills improve following cochlear implantation (Wheeler, et al., 2009). Alternatively, a child who could not communicate effectively with spoken language may learn to use sign language. Further, professionals in early educational services may recommend changes in communication mode to parent/caregivers when planning for suitable school-age options for their children (Crowe, McLeod, & Ching, 2012).

State-wide comparison

All Australian children identified with a hearing loss that may require amplification are referred to Australian Hearing (AH). This organisation, funded by the federal government, is responsible for hearing assessment and fitting of hearing devices, at no cost to families. The service is available to eligible people up to the age of 26 years. Children residing in different states also have similar access to the full range of early educational intervention services. This includes centre- and home-based programs that offer oral, total communication or bilingual communication options. Children have similar access to cochlear implants and also to public health care, at no cost to families.

Despite these similarities, the situation that existed between 2002 and 2007 regarding detection of childhood hearing loss differed between Victoria and the other states in Australia. New South Wales (NSW) commenced its state-wide UNHS program in December 2002, and achieved more than 95 percent (>95%) coverage rates for screening, with follow-up rates for those infants referred for audiological assessments >95% by 2003. Queensland commenced its UNHS program in 2004, and achieved >95% coverage rates by 2006. Throughout 2002-05, Victoria newborns admitted to the state's four neonatal intensive care units and their associated special care nurseries (approximately four percent of Victoria's annual birth cohort) were offered hearing screening before discharge. The remaining newborns were eligible for systematic risk factor screening and referral. Those without a risk factor were offered a behavioural screen by their nurse at 8-12 months of age. Victoria commenced UNHS in 2005, with a population coverage for screening of 30 percent by 2007 (Ching, Leigh, Dillon, 2013). The differential rates of implementing UNHS programs across the three states between 2002 and 2007 provided for the LOCHI study a cohort of children who were naturally divided according to whether hearing loss was identified early via UNHS (NSW, many in Queensland, and a very small proportion of children in Victoria) or standard care (some children in Queensland and most children in Victoria).

The Current study

The purpose of this report is to describe the demographic characteristics and outcomes of 5-year-old children in the LOCHI study who reside in Victoria, compared to those of children who reside in NSW and Queensland (hereafter referred to as ‘other’ states). The specific characteristics of interest to educators include the children’s age at hearing-aid fitting, age at enrolment in early education, and choice of communication mode at home and during early educational intervention.

The demographic characteristics that are associated with the choice of communication mode and the language outcomes of children at five years of age will be examined, with specific reference to whether or not there were significant differences between children in Victoria and those in other states. Factors that influenced language outcomes at five years of age will be discussed.

In line with previous reports and findings from the LOCHI cohort at three years of age, we hypothesise that, at five years of age, any differences in global language outcomes between children in different states will be accountable for on the basis of differences in age of intervention between the states, and demographic differences between the children in the different states.

Methods

A. Participants

Participants were 461 children (254 boys, 207 girls) enrolled in the LOCHI study (Ching, Leigh, & Dillon, 2013). There were 130 children from Victoria and 331 children from other states.

B. Evaluation measures

A team of research speech pathologists directly assessed children's language ability in their homes or in early educational centres. During evaluations, children wore hearing devices at their personal settings. As far as possible, speech pathologists were blinded to the severity of hearing loss and the settings in the hearing devices of children. Formal assessments were audio-video recorded, and 10 percent were randomly selected for double scoring to check inter-rater reliability. The agreement was high (>97%) for all measures.

Standardised tests of language included the Pre-school Language Scale (PLS-4, Zimmermen et al., 2002), Peabody Picture Vocabulary Test (PPVT-4, Dunn & Dunn, 2007), Diagnostic Evaluation of Articulation and Phonology (DEAP, Dodd et al., 2002), Woodcock Diagnostic Reading Battery (WDRB, Woodcock et al., 2004). Parent-report tools included the Child Development Inventory (CDI, Ireton, 2005), the Parents' Evaluation of Aural/oral Performance of Children (PEACH, Ching & Hill, 2007), Strengths and Difficulties Questionnaire (SDQ, Hawes & Dadd, 2004), and Pediatric Quality of Life Questionnaire (Peds-QL, Varni et al., 2003). Researchers rated the overall speech intelligibility of the children using the Speech Intelligibility Rating Scale (SIR, Allen et al., 2001). Although there was some variation in age of testing (56 to 70 months), the majority of tests (95.8%) were completed with children when they were between 60 and 66 months of age.

A team of research audiologists directly assessed children's speech perception ability in AH hearing centres or early educational centres. In addition, a team of psychologists assessed the children's nonverbal cognitive ability using the Wechsler Nonverbal Scale of Ability (WNV, Wechsler & Naglieri, 2006) at their centres.

C. Demographic information

Information about children's hearing threshold levels and hearing device were obtained from clinical records, with permission from parents or caregivers. We also collected information about the child's gender, presence of auditory neuropathy (ANSD), age at diagnosis, age at first fitting of hearing aids, degree of hearing loss, hearing aid settings, and hearing devices used (e.g. hearing aids or cochlear implants). All hearing aids were fitted according to the Australian Hearing National Paediatric Amplification protocol (King, 2010) by AH audiologists. They also provided ongoing services for assessment of hearing and selection and verification of hearing aids for all children via the national service network. For children with cochlear implants, information about age at cochlear implant switch-on, implant type, speech processor, and processing strategy were collected from records held at cochlear implant service centres.

Parents or caregivers provided information about their family and their child by completing custom-designed questionnaires. The solicited information included the parents' ethnicity, hearing status, level of formal education, and employment status. In addition, parents or caregivers reported on the birth history of their child, any other disabilities experienced by their child, the communication mode they use with their child at home, language use at home, age at which their child enrolled in early educational programs, the communication mode used in those programs with their child, the hours of intervention per week received in each program with entry and exit dates (where applicable), and whether their child had changed educational programs during the first three years of life. Parents also reported on their child's use of hearing devices. Socioeconomic status was determined using the Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD), which represents attributes such as income, educational attainment, employment, occupation, housing cost, household over/under crowding, and internet access in Australia (Australian Bureau of Statistics, 2006). The IRSAD scores are standardized for the Australian population to a mean of 1000 ± SD of 100. Higher IRSAD deciles indicate geographical areas with relatively more financial, educational and infrastructure resources, and lower deciles indicate a relative disadvantage. The education level of parents or caregivers was specified on a four-point scale: 1 to 6 years of formal education, 7 to 12 years of formal education, diploma or certificate, and university qualification. The mode of communication used with the child at home and during educational intervention was categorized as oral only, combined (typically manually coded English or another augmentative communication system together with spoken English), and manual only (Australian Sign Language). For each of the educational programs named by parents or caregivers, information about the type of program their child attended and the communication mode used during the child's education was collected.

D. Data analysis

This report describes the demographic characteristics and language outcomes of the LOCHI cohort at five years of age. For analyses purposes, participants were grouped according to their state of residence into either Victoria (VIC) or states other than Victoria (Others). To analyse the changes in communication mode, data on communication mode used during educational intervention when the children were younger than 5 years of age were also extracted from the LOCHI dataset, if available.

1. Demographic characteristics

The demographic characteristics were summarized using descriptive statistics. Independent *t* tests were used to compare the differences between Victoria and the other states on age at diagnosis of hearing loss, age at first fitting of hearing aids, age at switch-on of first cochlear implant, four-frequency average hearing loss (4FA) at 0.5, 1, 2, and 4 kHz in the better ear in terms of decibels hearing level (dB HL), age at which the child commenced early educational intervention, total hours of intervention up to five years of age, and socioeconomic status. A Chi-square test was used to compare the differences between Victoria and the other states on gender, presence of additional disabilities, device usage, hearing screening, communication mode at home at five years of age, language used at home, the mother's level of education, communication mode at early intervention centers at five years of age, and the frequency of changes in communication mode during educational intervention. Logistic regression analyses were performed to investigate the factors influencing the choice of communication mode at home and during early education; as well as changes in communication mode over time.

The factors previously identified in the literature as potentially influencing children's communication mode (Allen & Anderson, 2010; Crowe, et al., 2014; Crowe, et al., 2013; Li, et al., 2003; Mitchell & Karchmer, 2004; Watson, et al., 2008; Wheeler, et al., 2009) were selected as predictor variables in analyses. These factors were: the presence of additional disability, age at first fitting of hearing aids, level of hearing loss (4FA), hearing device (hearing aids, cochlear implants, or unaided), socioeconomic status, the mother's level of education (1-6 years of schooling, 7-12 years of schooling, certificate or diploma, and university), parent's hearing status (presence or absence of hearing loss), and non-English speaking background (yes or no). The predictors for analysing the changes in communication mode included: presence of additional disability, age at first fitting of hearing aids, change in hearing loss, and whether there has been a change in hearing devices (yes or no).

2. Outcomes

The primary purpose of analyses was to examine whether or not the Victorian children in the LOCHI cohort achieved similarly to their interstate peers on measures of language and communication at five years of age. A factor analysis was first performed using all 22 test scores to derive a global language score. The multiple imputation method (Rubin, 1987) was applied to handle missing values. The use of a global language score aggregated from multiple test scores reduced measurement error and random variations in individual test scores. The global language scores were standardised such that, for normal hearing children, they would have a mean of 100 and a standard deviation of 15. Multiple regression analyses were used to investigate the effect of predicted variables on outcomes after controlling for the effects of other variables. Three models were fitted, each with the standardised global language score as the dependent variable. The first model included age at first fitting (months), hearing loss (4FA in dB HL), nonverbal cognitive ability (WNV standard score), and states (VIC vs others), and the interaction between hearing loss and age at fitting as predictor variables. The second model had the predictor variables in the first model as well as communication mode. The third model had the predictor variables in the second model plus the mother's level of education (university/diploma or less than university/diploma) and additional disabilities (presence or absence).

In line with standard practice, a Type I error rate of $\alpha = 0.05$ (two-tailed) was adopted for all statistical analyses. This testing was performed using Statistica 64, version 10 (StatSoft. Inc., 2011) and SPSS for Windows (version 16) software.

Results

A. Demographic characteristics

1. Characteristics at five years of age

Table 1 summarizes the demographic characteristics of participants.

Table 1. Demographic characteristics of participants from Victoria and other states. Asterisks denote significant differences between the two cohorts.

Characteristic	Victoria	Other states	Difference *p* value
Gender			
• Total number with available data	130	331	0.049*
• Male, n (%)	62 (48%)	192 (58%)	
Presence/Absence of additional disabilities			
• Total number with available data	118	282	0.023*
• Present, n (%)	54 (42%)	94 (28%)	
• Absent, n (%)	64 (49%)	188 (57%)	
• Not reported	12 (9%)	49 (15%)	
Hearing screening at birth status			
• Total number with available data	122	308	< 0.01*
• Not Screened, n (%)	56 (43%)	32 (10%)	
• Screened, n (%)	66 (51%)	276 (84%)	
• Not reported	8 (6%)	23 (7%)	
Age of diagnosis			
• Total number with available data	130	327	0.008*
• Age (months), Mean (SD)	7.5 (8.6)	5.2 (8.5)	
Age at first fitting of hearing aids			
• Total number with available data	130	331	0.03*
• Age (months), Mean (SD)	10.4 (9.6)	8.3 (9.1)	

Age at activation of cochlear implants			
• Total number with available data	42	120	0.08
• Age (months), Mean (SD)	24.8 (14.5)	20.3 (12.9)	
Hearing loss			
• Total number with available data	106	267	0.04*
• 4FA hearing loss in the better ear, Mean (SD)	53.8 (23.4)	59.5 (24.2)	
Device, n (%)			
• Total number with available data	130	330	0.14
• Cochlear implant	42 (32%)	120 (36%)	
• Hearing aid	85 (65%)	203 (61%)	
• Unaided	3 (2%)	7 (2%)	
• Not reported	0	1 (0.3%)	
Communication mode at home, n (%)			
• Total number with available data	118	276	0.01*
• Oral Only	83 (64%)	228 (69%)	
• Manual Only	0 (0%)	2 (1%)	
• Combined (oral and manual)	35 (27%)	46 (14%)	
• Not reported	12 (9%)	55 (17%)	
Language used at home, n (%)			
• Total number with available data	108	269	0.03*
• English	99 (76%)	261 (79%)	
• Other language	9 (7%)	8 (2%)	
• Not reported	22 (17%)	62 (19%)	
Maternal education level, n (%)			
• Total number with available data	116	270	0.008*
• University Qualification	40 (31%)	120 (36%)	
• Diploma / Certificate	23 (18%)	75 (23%)	
• 7-12 years formal education	51 (39%)	73 (22%)	
• 1-6 years formal education	2 (2%)	2 (1%)	
• Not reported	14 (11%)	61 (18%)	
Socioeconomic status			
• Total number with available data	119	277	0.15

• IRSAD decile, Mean (SD)	6.7 (2.6)	7.1 (2.6)	
Parent/Caregiver's hearing loss, n (%)			
• Total number with available data	130	331	0.045
• One parent has hearing loss	9 (7%)	42 (13%)	
• Both parents have hearing loss	1 (1%)	7 (2%)	
Age at enrolment in early education			
• Total number with available data	122	303	0.09
• Age (months), Mean (SD)	13.2 (10.8)	12.2 (12.4)	
Hours of educational intervention (over five years)			
• Total number with available data	124	307	0.5
• Hours, Mean (SD)	239.6 (369.6)	219.7 (162.5)	
Communication mode during intervention, n (%)			
• Total number with available data	112	284	< 0.01*
• Oral Only	65 (50%)	233 (70%)	
• Manual/Sign Only	1 (1%)	4 (1%)	
• Combined (oral and manual)	46 (35%)	46 (14%)	
• Not reported	18 (14%)	48 (15%)	

There was a significantly higher proportion of children (43 percent) not screened by a newborn hearing screening program in Victoria compared to that in other states (10 percent) ($\chi^2(1, N = 430) = 67.7$, $p < 0.01$). As expected, there were significant differences in age of diagnosis and age at first fitting between Victoria and the other states ($p < 0.05$). For the Victorian cohort, the mean age at diagnosis of hearing loss was 7.5 months (SD = 8.6) and the mean age at initial hearing-aid fitting was 10.4 months (SD = 9.6). Hearing aids were fitted on average within three months of diagnosis (SD = 4.4). The mean age of cochlear implant switch-on for children's first implant was 24 months (SD = 13.6). Nine out of the 42 (21.4 percent) children who had cochlear implants received their implant before 12 months of age. For the Victorian cohort at five years of age, 85 (65 percent) children used hearing aids, 42 (32 percent) children used a cochlear implant, and three (2 percent) children were unaided.

The communication mode at home was significantly different between Victoria and the other states ($\chi^2(2, N = 394) = 9.2$, $p = 0.01$). There were more children in Victoria than in other states who used a communication mode that combined both oral and manual methods than in other states.

As with at home, the communication mode used during educational intervention was significantly different between Victoria and the other states ($\chi^2(2, N = 396) = 28.1$, $p < 0.01$). More Victorian children used a communication mode that combined both oral and manual methods than in other states.

Further, there was a higher proportion of Victorian families (6.9 percent) that used languages other than English at home, compared to the other states (2.4 percent). The spoken languages reported were Vietnamese, Arabic, Turkish, Mandarin, and Cantonese.

On average, there were no significant differences in age at enrolment in early education or the number of hours of educational intervention received by children in Victoria compared to those in other states.

2. Changes of communication mode in early education

A total of 301 (89 from Victoria and 214 from other states) participants had information about communication mode during educational intervention at five years of age, and also at one or two assessment intervals at an earlier age. These data were used to examine changes in communication mode over time (see Table 2). During the first three years of life, there was a higher proportion of children in Victoria (n = 21) than in other states (n = 18) who changed communication mode ($\chi^2(1, N = 294) = 11.8$, $p < 0.01$). Seven children changed from oral only to a combined mode, and ten children changed from a combined mode to an oral only mode. Two children changed from a combined mode to a manual only mode. Two other children changed from a manual only to a combined mode. Between three and five years of age, however, there was no significant difference between states in the number of children who changed communication mode ($\chi^2(1, N = 303) = 3.0$, $p = 0.1$).

Table 2. Number of children who changed communication mode during early intervention in Victoria and other states. 'Early interval' refers to assessment intervals before three years of age. Percentages are shown within parentheses.

From zero to three years

Victoria (n = 89)

early interval	3 years of age: oral	manual	combined
oral	40 (45.5%)	0 (0%)	7 (8%)
manual	0 (0%)	0 (0%)	2 (2.3%)
combined	10 (11.4%)	2 (2.3%)	28 (31.5%)

Other states (n = 205)

early interval	3 years of age: oral	manual	combined
oral	169 (82.4%)	0 (0%)	13 (6.3%)
manual	0 (0%)	0 (0%)	0 (0%)
combined	5 (2.5%)	0 (0%)	18 (8.8%)

From three to five years

Victoria (n = 89)

3 years of age	5 years of age: oral	manual	combined
oral	46 (51.1%)	0 (0%)	5 (5.6%)
manual	0 (0%)	0 (0%)	2 (2.2%)
combined	7 (7.9%)	0 (0%)	29 (32.2%)

Other states (n = 214)

3 years of age	5 years of age: oral	manual	combined
oral	175 (79.5%)	2 (0.9%)	10 (4.5%)
manual	0 (0%)	0 (0%)	0 (0%)
combined	6 (2.7%)	1 (0.5%)	20 (9.1%)

3. Factors influencing the choice of communication mode

For purposes of statistical analyses, the small number of children who were reported to use a manual mode of communication at home or during early education were grouped together with children who used a combination of oral and manual methods. A Spearman rank-order correlation analysis revealed that on average, age at diagnosis, age at fitting, and age at enrolment in educational intervention were significantly correlated ($p < 0.01$).

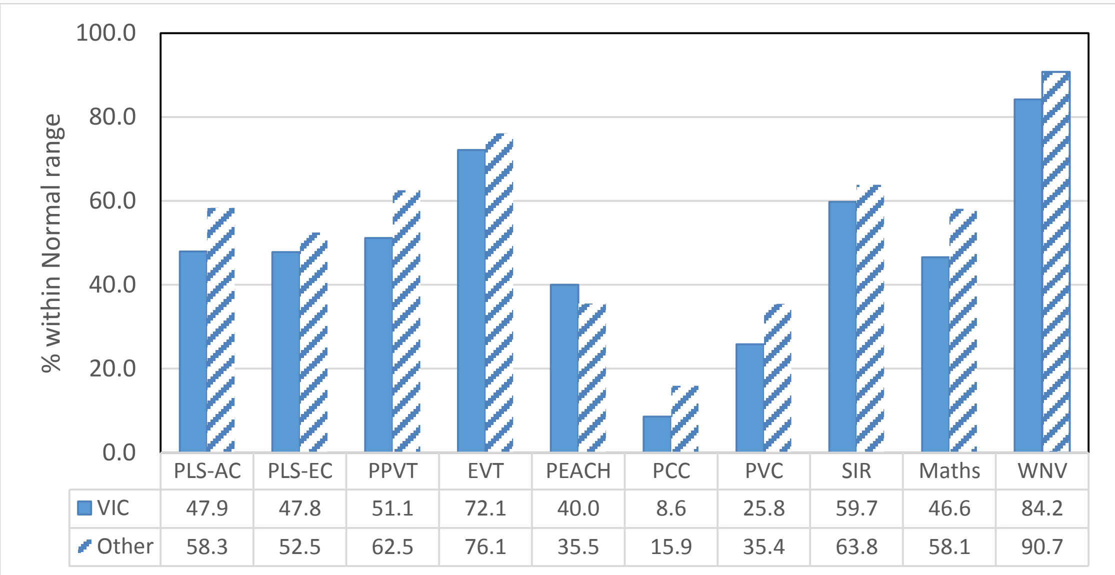
Logistic regression analyses revealed that children's communication mode during early education was related to the presence of additional disability (Beta = 2.0, $p < 0.01$), the severity of hearing loss (Beta = 0.02, $p < 0.05$), and socio-economic status (Beta = -0.01, $p < 0.01$). These factors also influenced children's communication mode at home (for the additional disability factor, Beta = 1.9, $p < 0.01$; for the severity of hearing loss factor, Beta = 0.04, $p < 0.01$; for socio-economic status, Beta = -0.01, $p < 0.01$). There was a significant correlation between communication mode used at home and that used during educational intervention ($r = 0.64$, $p < 0.01$). This suggests that the children tended to use the same communication mode in both settings, though exceptions are also common. There were also significant correlations between the presence of an additional disability and communication mode used at home ($p < 0.01$) and during educational intervention ($p < 0.01$). Children who have an additional disability are more likely to use a combined oral and manual mode of communication in both settings. There were also significant correlations between the severity of hearing loss on the one hand, and communication mode used at home $p < 0.01$) and during educational intervention on the other ($p < 0.01$). These findings imply that a greater severity of hearing loss was linked to an increased use of a combined oral and manual mode of communication in both settings. Also, a higher socioeconomic status was correlated significantly with an increased use of an oral communication mode in both settings ($p < 0.01$). In addition, a higher level of maternal education was significantly associated with higher socioeconomic status ($p < 0.01$), and the child's earlier enrolment in educational intervention ($p < 0.01$).

Logistic regression analyses were used to examine factors influencing changes in communication mode during educational intervention. Children with additional disability were more likely to change communication mode in early education during the first three year of life (Beta = 1.3 $p < 0.05$). There were no other significant factors influencing changes between three and five years of age ($p > 0.05$).

B. Language outcomes at five years of age

Figure 1 shows the percentage of the cohorts (VIC vs. Other) that scored within the normal range (standard scores between 85 and 115) for receptive and expressive language (PLS-AC, PLS-EC), receptive and expressive vocabulary (PPVT, EVT), functional performance in everyday life (PEACH), consonant and vowel production (PCC, PVC), speech intelligibility rating (SIR), Mathematical reasoning (Maths), and nonverbal cognitive ability (WNV).

Figure 1. Percentage of children who scored within the normal range by state.



Standard multiple regression analyses were used to examine factors that predicted language outcomes of children. Table 4 shows the correlations among child, family and intervention-related characteristics used in the analyses. The child’s age at fitting (Age Fit) and age at enrolment in educational intervention (Age EI) are in months. Hearing loss is represented by four-frequency average hearing level in the better ear (4FA). Presence of additional disabilities (ADisab) is a binary variable (yes or no). The level of education of the child’s mother or maternal education (MEdn) is a three-category variable (i.e., 1 = university; 2 = diploma or certificate; and 3 = less than or equal to 12 years of formal schooling). Socio-economic status is represented by IRSAD in deciles. Communication mode during educational intervention (CM_EI) is a three-category variable (i.e., 1 = oral only; 2 = combined oral and manual methods; and 3 = manual only). The same three categories were used to specify communication mode at home (CM_H). Significant coefficients are denoted by asterisks: ***<0.001; ** <0.01; * < 0.05.

Table 4. Spearman rank-order correlation coefficients among child, family and intervention characteristics of participants.

	Age Fit	Age EI	4FA	ADisab	MEdn	CM_H	CM_EI	WNV	SES
Age Fit	-								
Age EI	0.67***	-							
4FA	-0.24***	-0.15**	-						
ADisab	0.12*	0.03	-0.02	-					
MEdn	0.05	0.11*	0.02		-				
CM_H	0.002	-0.09	0.24***	0.37***	0.004	-			
CM_EI	0.009	-0.04	0.17**	0.27***	0.07	0.64***	-		
WNV	-0.09	-0.04	-0.09	-0.28***	-0.23***	-0.09	-0.13**	-	
SES	-0.07	-0.08	-0.02	-0.02	-0.32***	-0.16**	-0.17**	0.12*	-

On average, severity of hearing loss was negatively correlated with the child's age at hearing aid fitting (R = -0.24, $p < 0.0001$) and their age at enrolment in educational intervention (R = -0.15, $p < 0.001$). These findings suggest that children with more severe hearing loss were fitted earlier and also received educational intervention earlier. Children who were fitted with hearing aids early also received educational intervention at an early age (R = 0.67, $p < 0.0001$). Further, the communication mode used at home and early educational settings were highly correlated (R = 0.64, $p < 0.0001$). This suggests that the same communication mode was often used in both settings. Higher maternal education was significantly associated with higher socio-economic status (R = -0.32, $p < 0.0001$). Given these correlations, only one in each pair of correlated variables could validly be used as predictors in further multiple regression analyses. For this purpose, the child's age at first fitting, communication mode during early education, and maternal education level were each selected for use as predictor variables.

To determine the effects of a range of factors on language outcomes, three models were fitted to the data with the standardized global language score (aggregated from 22 test scores as indicated in the Method section) as the dependent variable (see Table 5).

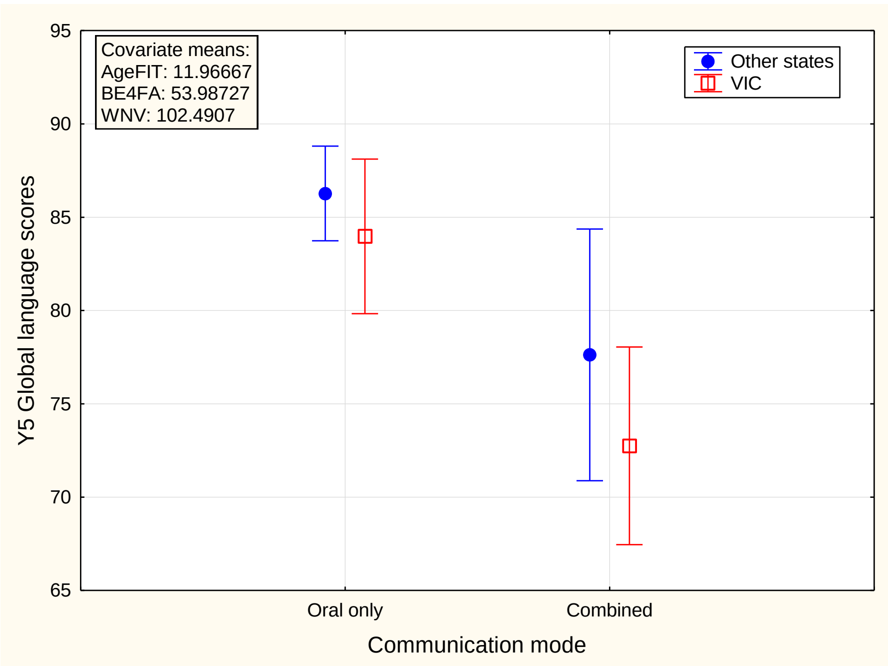
Table 5. Multiple regression summary table for three models. For each model, the estimates and 95% confidence intervals (CInt) of the regression coefficients are shown with the *p*-values.

Predictor	Model 1		Model 2		Model 3	
	Adjusted R^2 = 0.48		Adjusted R^2 = 0.51		Adjusted R^2 = 0.57	
	p	Effect (CInt)	*p*	Effect (CInt)	*p*	Effect (CInt)
Age FIT	<0.0001	-0.31 (-0.5,-0.14)	<0.001	-0.31 (-0.48,-0.13)	0.002	-0.27 (-0.44, -0.10)
4FA	<0.0001	-0.33 (-0.42,-0.24)	<0.0001	-0.29 (-0.38,-0.19)	<0.0001	-0.28 (-0.38, -0.19)
WNV	<0.0001	0.66 (0.54, 0.79)	<0.0001	0.62 (0.50, 0.74)	<0.0001	0.52 (0.39, 0.65)
State	0.008	2.85 (0.74, 4.97)	0.15	1.79 (-0.68,4.27)	0.66	0.62 (-2.19,3.42)
Communicat-ion mode	-		<0.001	4.97 (2.47, 7.47)	0.001	4.75 (1.92, 7.59)
Additional disabilities	-		-		0.005	4.20 (1.28, 7.12)
Maternal education	-		-		<0.0001	6.71 (3.85,9.56)

The first model showed that state (Victoria vs others) accounted for significant unique variance in language scores, after controlling for the variance associated with age at first hearing-aid fitting (Age FIT), severity of hearing loss (4FA), and nonverbal cognitive ability (WNV). The model explained 48 percent of total variance in scores.

In the second model, communication mode was added as a predictor because that was found to vary significantly between Victoria and other states (see Table 1). The model accounted for 51 percent of the total variance. The effects of age at first fitting, hearing loss, nonverbal cognitive ability, and communication mode were significant. The effect of the state variable on communication mode, however, was not significant. Figure 2 shows the mean global language scores of Victoria vs other states, separately for children whose primary mode of communication was either oral only or a combination of oral and manual methods.

Figure 2. Mean global language scores for children who used an oral only mode or a combined (oral and manual) mode of communication, by state. Open squares in red depict mean scores for children in Victoria, and filled circles in blue depict mean scores for children in other states. Scores were adjusted for age at first fitting (AgeFIT), severity of hearing loss (BE 4FA) and nonverbal cognitive ability (WNV). The vertical bars denote 95% confidence intervals.



The third regression model added the presence of additional disabilities and maternal education level to the predictors in previous models. The model accounted for 57 percent of the total variance. Significant predictors were age at first fitting, the severity of hearing loss, nonverbal cognitive ability, the choice of communication mode, maternal education and presence/absence of additional disability. The effect of state was not significant, and there were no significant interaction effects ($p > 0.05$).

Discussion

This report describes the demographic characteristics and the language outcomes of the LOCHI cohort in Victoria, compared to the cohort in other states.

A. Demographic characteristics

The first aim of this investigation was to describe the demographic characteristics of children who resided in Victoria, and to compare them with characteristics of children in other states. The present findings revealed that 51 percent of Victorian LOCHI children were identified by a hearing screening program compared to 84 percent of children in other states ($p < 0.01$). This reflects the gradual implementation of UNHS programs across Australia (Leigh, 2006), which commenced in NSW in 2002, in Queensland in 2004, and in Victoria in 2005. Consequently, the age of diagnosis and age at first fitting of hearing aids to DHH children were, on average, significantly later in Victoria than in other states ($p < 0.05$). There were no significant differences in the hearing device fitted to children, age at cochlear implant activation for children with implants, or the severity of hearing loss between Victoria and other states ($p > 0.05$). There was a higher proportion of children with additional disabilities, likely to be a consequence of the at-risk screening program in Victoria prior to the implementation of UNHS in 2005.

There were no significant state-wide differences in the age at commencement of early education and the amount of educational intervention ($p > 0.05$). However, more children in Victoria used a combined communication mode (oral plus manual) at home and during educational intervention than in other states ($p < 0.05$). The same results were found even after children with additional disabilities were excluded from the comparison, both for communication mode at home ($\chi^2[2, 240] = 12.32$, $p < 0.01$) and in early education ($\chi^2[2, 235] = 25.16$, $p < 0.01$).

This study analysed data collected from families on children during two intervals: firstly between a child's first diagnosis of hearing loss and three years of age, and secondly when the child was five years of age. At both intervals, the presence of additional disabilities, the level of hearing loss, and the communication mode used at home were highly correlated with the communication mode during educational intervention. Whereas the mother's education level, the language used by the father, and parental hearing loss were also significantly associated with the communication mode used during educational intervention for children at three years of age, these factors did not have a significant influence on choice of communication mode at five years of age. This may be explained by the children transitioning from a predominately home-based environment at three years of age to a more diverse speaking and listening environment at five years of age.

Table 6 summarizes the cases who changed communication mode during early educational intervention at the two intervals. The single factor that accounted for changes in communication mode during the first five years of life was the presence of additional disability.

Table 6. Number of children who changed communication mode during early educational intervention. In this table, the children who used sign language only were grouped together with children who used a combined mode of communication (designated Combined/Signed). The first column shows possible reasons for change in communication mode: change from hearing aids to cochlear implants (change in device), presence of additional disability or auditory neuropathy (AD/ANSD), and unknown (other reasons).

	From 0 to 3 years of age			
	Oral to Combined/Signed		Combined/Signed to Oral	
	Victoria	Other	Victoria	Other
Change in device	4	1	2	2
AD/ANSD	5#	9#	4#	4#
Other reasons	1	4	5	0
Total	7	13	10	5
	From 3 to 5 years of age			
	Oral to Combined/Signed		Combined/Signed to Oral	
	Victoria	Other	Victoria	Other
Change in device	0	3	0	0
AD/ANSD	3	7#	4	3
Other reasons	2	2	3	3
Total	5	10	7	6

 # Children who also changed their hearing devices.

Of the Victorian children who changed communication mode from an oral-only mode to a combined or manual mode, 67 percent were reported to have additional disabilities or ANSD, 33 percent changed their hearing device (i.e., hearing aids to cochlear implants). A chart review of the three children designated under 'other reasons' (one child between zero and three years of age, and two children between three and five years of age) revealed that two of them changed their early education agency, and one child was reported to be using mainly speech but would "use sign to communicate with some deaf peers and adults". Of the children who changed from a combined communication mode to an oral only mode, 47 percent had an additional disability or ANSD, 12 percent changed their hearing device. A chart review was conducted for the remaining eight children designated under 'other reasons'. Two children were learning English as a second language, and two had parents with a hearing loss. Another child was reported as "signing in English word order during a short period of time" although the reason for this is unclear. No information was available for the remaining three children.

Further insight was found in comments provided by the caregivers and teachers of Victorian participants at five years of age. It was evident that finding a communication mode that allowed the child an effective way to communicate was a priority. Most families desired an oral only communication mode for their child. However, the communication mode was altered if the child's speaking and listening skills were not sufficient for achieving effective communication. The qualitative data below explains the reasons given by three parents who decided to change their child's primary mode of communication.

> "*We introduced sign because he had no hearing, after he was implanted in April (we) dropped off signing by the end of the year, now the focus is on oral communication";*
>
> *"the oral only program was not meeting (our) needs as (he) wasn't learning communication*";

"*(using oral only approach) wasn't working for J as he hears nothing at all*".

These two different reasons highlight the importance of having educational services available that provide a range of communication options for families. It also emphasizes the need for services to flexibly respond to individual needs.

For some children, different communication modes were used at times in different situations. The comments from parents below provide insight into some reasons why:

"*K uses spoken language although on the odd occasion he may sign one or two words";*

"C uses primarily speech but we do use sign when he is bathing, sleeping or takes them (cochlear implants) off";

"… she communicates with speech but receptively can understand AUSLAN and uses it minimally with her peers";

"… on occasion when hearing aids can't be worn e.g. bath, swimming pool we use AUSLAN".

The reported changes in communication mode support previous research suggesting that such choices are not one singular decision. These choices are dynamic and reflect the changing communication needs of the child and family.

B. Outcomes

Our second aim was to compare the spoken language outcomes of Victorian children with those of children from other states. On average, language outcomes of Victorian children were significantly worse than those of children in other states. After the effects of age at hearing-aid fitting, degree of hearing loss, non-verbal cognitive ability, and communication mode in early education were included in the analyses, language outcomes for children in Victoria were not significantly different from other states. In the final model that accounted for 57 percent of the total variance in language scores at five years of age, six significant effects were evident:

1. Children fitted with hearing aids at an earlier age scored higher.
2. Children with less severe hearing loss scored higher.
3. Children with higher nonverbal cognitive skills scored higher.
4. Children who used an oral-only mode of communication (spoken language as the primary mode of communication) during educational intervention scored higher (up to 7.5 score points or 0.5 SD) than children who used other communication modes.
5. Children whose mothers had completed post-secondary education achieved higher language scores (up to 10 score points or 0.67 SD) than did children whose mothers had 12 years or less of formal schooling.
6. Children without additional disabilities scored higher (up to 7 score points or 0.47 SD) than children with additional disabilities.

These findings are consistent with earlier results from the same cohort at three years of age (Ching et al., 2013). The present study extended previous research by including nonverbal cognitive ability of children as a predictor of spoken language outcomes at five years of age. The benefit of early fitting and cochlear implantation to improving outcomes of children who would not receive it without UNHS is substantial. On average, a 6-month delay in amplification for children with moderate hearing loss reduces language scores by 0.3 SD. In a similar vein, delaying CI activation from 6 to 12 months of age for children with severe/ profound hearing loss leads to a reduction of 0.7 SD in language scores at five years of age (Ching et al, 2015). This study provides important evidence that early intervention, including amplification and educational intervention, is effective for improving language outcomes of children with congenital hearing loss, at a population level.

The significant effect of maternal education level on language outcomes of children with hearing loss in this study is consistent with results reported for children with normal hearing (Reilly et al., 2010). Parental education has been linked to knowledge and beliefs about child development (Benaisch & Brooks-Gunn, 1996; Tamis-LeMonda et al., 1998). It has also been linked to the quantity and diversity of speech input to infants and young children (Greenwood et al., 2010). Education (or knowledge), well-being, and empowerment have been identified as critical for supporting parents of children with hearing loss (Henderson et al., 2014). The level of maternal education likely determines the child's language environment, which influences the quality and quantity of spoken language input. Further research on this mediating factor is recommended to inform parental support in the future.

The present findings relate only to spoken language outcomes at five years of age. Having better spoken language ability has been associated with higher academic achievement in DHH secondary students (Marschark et al., 2015). As the LOCHI children progress from early educational intervention to formal schooling, the next phase of the study will assess their academic performance, language, and psycho-social development. This research will examine factors influencing a range of outcomes, and gauge the extent to which the educational needs of children with hearing loss are met.

Conclusions and Recommendations

The present study found that children who received early hearing-aid fitting (who also tended to have earlier educational intervention, and who also tended to receive cochlear implants earlier if they needed them), who had less severe hearing loss, no additional disabilities, higher cognitive abilities, and whose mother completed post-secondary education achieved better language outcomes at five years of age. The use of an oral-only communication mode during educational intervention was also significantly associated with better spoken language outcomes.

The language outcomes of Victorian children were significantly worse than the other two states. The average ages of hearing-aid fitting, cochlear implantation and enrolment in early education were later in Victoria than in other states. Early educational intervention using an oral-only mode of communication was more common in other states than in Victoria. There was a greater proportion of children with additional disability in Victoria than in other states. After allowing for the effects of degree of loss, communication mode in early education, non-verbal cognitive ability, presence of additional disabilities, and education level of the female parent, there were then no significant differences between Victoria and other states, on average, in language outcomes of children.

The LOCHI study showed that it is important to:

1. Streamline services to ensure early detection and intervention for children born with hearing loss; and,
2. Devise and implement better evidence-based management for children with hearing loss, especially those with parents of low education level or socio-economic status.

The benefits of early fitting and cochlear implantation to improving outcomes of children who would not receive it without UNHS is substantial. UNHS offers the opportunity that will lead to improved outcomes, as attested by the strong evidence shown in the LOCHI study. To take the benefits of early detection forward, better management is essential. This requires urgent action research that increases understanding of the neuro-physiological processes underlying language learning, and controlled trials of different intervention methods regarding communication mode and parent support on a large scale to guide management of DHH children.

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