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# Predicting Speech Sound Disorder Outcomes in School-Age Children with Hearing Loss: The VicCHILD Experience

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**Running head:** Speech Sound Disorder in Children with Hearing Loss

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**Keywords:** speech, speech sound disorder, hearing loss

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Abstract

*Background:* Congenital hearing loss is the most common birth anomaly, typically influencing speech and language development, with potential for later academic, social and

employment impacts. Yet surprisingly, the nuances of how speech is affected have not been well examined in regards to the subtypes of speech sound disorder. Nor have the predictors of speech outcome been investigated within a sizeable population cohort.

*Aims:* (1) To describe the subtypes and prevalence of speech sound disorder in children with hearing loss. (2) To determine which characteristics of hearing loss predict the presence of speech sound disorder.

*Methods & Procedures:* Ninety children (5 to 12 years of age) with permanent hearing loss were recruited from an Australian population cohort. Children completed a standardised speech assessment to determine the presence and subtype of speech sound disorder. Logistic regression was used to determine predictors of speech outcome. Demographic, developmental and hearing-related predictors were examined.

*Outcomes & Results:* The prevalence of speech disorder overall was 58%; with the most common subtype being phonological delay in 38% of the sample. Factors most predictive of speech disorder were being male, younger and a bimodal user (i.e. using both a hearing aid and cochlear implant).

*Conclusions & Implications:* This is the first study, in a sizeable cohort, to describe the prevalence, and predictive factors for, speech sound disorder associated with hearing loss. Clinically, it could be beneficial to implement earlier targeted phonological interventions for children with hearing loss.

**What this paper adds:**

*What is already known on this subject.* Speech issues are common in children with hearing loss, however the breakdown of subtypes of speech sound disorder (SSD) (e.g. articulation

versus phonological disorder) have not been previously described in a population cohort. This distinction is relevant, as each subtype calls for specific targeted intervention. Studies examining factors predictive of speech outcomes, across a range of hearing levels, are also lacking in a population cohort.

*What this study adds.* Data suggest the most common type of SSD in children with hearing loss is phonological delay. Males, younger children, and bimodal users were at greater risk of having a subtype of SSD.

*Clinical implications of this study.* Results are clinically pertinent as the speech diagnosis determines the targeted treatment. Phonological delay is responsive to treatment, and early targeted intervention may improve prognosis for speech outcomes for children with hearing loss (Dodd *et al*. 2018).



**Introduction**

Congenital hearing loss (HL) is the most common birth anomaly, occurring in 1-2 out of every 1000 births in developed countries (Mehra *et al*. 2009, Morton and Nance 2006). Prevalence increases after infancy, as some losses progress in severity, and others have later onset (Ching *et al*. 2006). HL impairs one's ability to perceive sound and impacts both speech and language learning (Moeller *et al*. 2007a, b). Consequently, academic achievement (e.g. Moeller *et al.* 2007a, Venail *et al.* 2010), psychosocial development (e.g. Lukomski 2007, Moeller 2007), and employment (e.g. Jung and Bhattacharyya 2012, Venail *et al.* 2010) may be hampered. It is known that HL impacts communication development, yet the specific clinical nuances of how speech is affected have not been well explored; and the outcomes relating to speech sound disorder (SSD) subtypes are unknown. Specifically, we refer to

subtypes of articulation errors (phonetic level impairment of speech movement/placement, e.g., lisp) and phonological errors (phonemic level impairment of the knowledge of speech patterns/contrasts, e.g., initial consonant deletion) (Dodd *et al*. 2018, Morgan *et al.* 2017). Phonological errors include phonological delay (use of patterns typical of younger children) and phonological disorder (use of non-developmental patterns or inconsistent pattern use). These distinctions are clinically relevant, as each require specific and targeted interventions (Dodd *et al*. 2018, Morgan *et al.* 2017). The first purpose of this study is to describe the SSD subtypes and proportions present in children with HL. The second purpose is to determine the outcomes for children's speech production based on a number of predictors.

A number of factors may account for speech outcomes. Namely, degree of HL (normal-profound), type of HL (conductive: of the outer/middle ear; sensorineural: of the inner ear and brain nerve pathways; mixed), laterality (unilateral; bilateral), input device (hearing aid (HA); cochlear implant (CI); both; none), and age of device fitting (Baudonck *et al.* 2010, Ching *et al.* 2013, Cupples *et al.* 2018, Fulcher *et al.* 2012, Lieu 2004, Tomblin *et al*. 2014).

Specific speech error forms of voicing, substitutions, nasality issues, misarticulation of consonant clusters, and initial/final consonant deletion have been found to be more common in children with HL, with some reporting phonological delay (e.g. Buhler *et al*. 2007, Huttunen 2001), phonological disorder (Osberger and McGarr 1982) or a combination (e.g. Asad *et al*. 2018, Flipsen and Parker 2008, Kral *et al.* 2014) but inconsistencies in methodology and small sample sizes (n=1 to n=33) make results difficult to generalise. A handful of earlier studies had examined SSD subtypes, at a time when the landscape of HL intervention was vastly different, i.e. prior to Universal Newborn Hearing Screening (UNHS) and early amplification techniques, and therefore comparisons to the current population of

children with HL are problematic. The largest study of children with HL that has included data on speech development (phonology only) included 133 children (Ching *et al.* 2010). The study was focused on language, rather than speech development, in 3 year old participants with bilateral hearing loss and fitted with HAs, and noted that delayed phonology was common across their cohort. The sample consisted of 3 year old participants with bilateral loss and fitted with only. Hence, we are yet to understand the broader spectrum of SSD subtypes in a contemporary cohort of school-aged children with HL.

In regards to input device used, two studies found articulation and phonological errors as common, but more so among HA than CI users (Baudonck *et al.* 2010, Van Lierde *et al.* 2005). Others have looked at communication outcomes for CI and HA users, yet they have only investigated language outcomes (e.g. Svirsky *et al.* 2000, Yoshinaga-Itano *et al.* 2010), used highly selected samples (i.e., only bilateral HL/only severe-profound HL) (Yoshinaga-Itano *et al*. 2010) or clinical samples (Baudonck *et al*. 2010), and/or only considered CIs or HAs in isolation (e.g. Svirsky *et al.* 2000, Tomblin *et al*. 2014, Yoshinaga-Itano *et al*. 2010) thus making comparisons difficult.

Effect of age of device fitting has also been investigated, although speech outcomes have been sparse and mixed. Some report speech production improves as age of fitting (either HA/CIs) decreases (e.g. Fulcher *et al.* 2012, Sevinc *et al.* 2009). Others report that earlier fitting does not play a significant role in predicting speech production in HA users (Ching *et al.* 2013). Although results are mixed, the central auditory system has maximum plasticity until roughly 3.5 years (see Kral and Sharma 2012) so it is reasonable to suspect that speech outcomes should be more favourable with earlier fitted devices. For children who did not achieve age appropriate speech across any of the above-mentioned studies, SSD subtypes were not discussed.

Other hearing factors have had much less investigation, or none at all. Namely, when comparing degrees of HL, speech outcomes have been investigated in only one study to date, and again with a limited age sample. Cupples *et al.* (2018) examined degree of loss as a predictor of a language and speech outcomes in a 5 year old sample. Although degree of loss was not a predictor across the whole sample, it was associated with speech outcomes when only those with HAs were examined. In regards to unilateral versus bilateral loss, speech outcomes have not been clearly characterised in children with unilateral HL in any studies (Lieu 2004), and as such, they have not been empirically compared to bilateral HL outcomes.

The aims for this study are twofold. The first aim is to describe the SSD subtypes and prevalence in children with HL. The second aim is to determine the outcomes for children's speech production based on 13 demographic, developmental and hearing-related predictors. Both quantitative standard scores (Goldman and Fristoe 2000) and qualitative (classification of SSD subtype) data will be analysed. Given the past literature, it was hypothesised that SSD presence would be predicted by greater degree of HL, bilateral HL, HA use, and later fitting of hearing device.

## Methods

### *Participants*

Fifty-three children aged 9 to 12 years old (9;0-12;1) and 40 children aged 5 to 8 years old (5;0-8;0) participated in this study. All children were participants in the Victorian Childhood Hearing Impairment Longitudinal Databank (VicCHILD) (https://www.rch.org.au/ccch/vic-child/). VicCHILD is a Victorian register and research databank of children born with permanent hearing loss. VicCHILD collects a large amount of various information from children and their families, at particular timepoints. Two children from non-English speaking

backgrounds in the 5 to 8 age group were excluded from the analysis due to low English proficiency. One child was excluded from the 9 to 12 group as they did not complete all items on the Goldman-Fristoe Test of Articulation (GFTA-2; Goldman and Fristoe 2000). All children were considered to have congenital hearing impairment, with all in the 5 to 8 year group detected via Universal Newborn Hearing Screening (UNHS). Of the 9 to 12 age group, 13 were identified as hearing impaired at birth, and the remainder (n=39) were identified at a mean age of 14 months. These children were born before universal hearing screening began in Victoria, and joined VicCHILD from a prior study: Statewide Comparison of Outcomes (SCOUT; Wake *et al.* 2016). See Table 1 for demographic information of the cohort. Ethics approval was obtained from the Royal Children's Hospital Human Research Ethics Committee (HREC#31225). Written consent was obtained from all parents.

*Measures*

Hearing data were provided by Australian Hearing. Australian Hearing is a service provider throughout Australia tasked with providing monitoring and rehabilitation services for children with hearing loss from birth through to 26 years of age. Data collected included information about each child's type of HL, laterality, degree of HL (unaided), device/s used, and age at which device/s were fitted, where available. Information was collected through VicCHILD about any comorbid diagnoses (developmental, neurological or communication related, including speech diagnoses such as dysarthria and Childhood Apraxia of Speech), as well as sex, household income, maternal education, gestation (full term or premature), and family history of speech or language issues. Participants' degree of loss was based on either 3 Frequency Average HL (3FAHL, measured at 500, 1000, 2000 Hz) or 4FAHL (measured at 500, 1000, 2000, 4000 Hz), depending on which was provided. In cases where data were available for both, 4FAHL was used, as this provided more accurate information about the

child's loss. Degree of HL was categorised based on the "better hearing ear" in those with bilateral HL and the affected ear in those with unilateral HL. Children were then classified according to degrees of HL set by Australian Hearing (Supplemental Table 1). It is important to emphasise here, that HL (dB HL) is averaged across multiple frequencies, and for those with bilateral loss it is customary for the "better hearing ear" to be used to classify loss. So, although it may appear unintuitive to classify HL as "Normal" (see Supplemental Table 1), it does not mean their hearing is normal, it simply falls within a very mild range of HL when averaged.

Trained research assistants assessed participants' speech production using the standardized GFTA-2 Sounds-in-Words subtest (Goldman and Fristoe 2000). The GFTA-2 has been one of the most commonly used standardised clinical assessments for speech production and was also selected because of its brief administration time and large normative sample (Dodd *et al*. 2018, Eadie *et al.* 2015, Goldman and Fristoe 2000, Morgan *et al.* 2017). Administration and scoring was completed in accordance with the GFTA-2 instruction manual. Research assistants were formally trained in these procedures by an experienced speech pathologist on the VicCHILD team and they followed a set protocol for administration. All assessments were audio recorded and cross-transcribed by a senior speech pathologist for reliability. The GFTA-2 requires children to name single words in response to picture stimuli and responses are recorded on the GFTA-2 record form. Participants' speech errors were also analysed and compared to local normative Australian data (Dodd *et al.* 2002). This was for the purpose of classifying participants' speech into the subtypes of articulation disorder, phonological delay and/or phonological disorder using approaches detailed elsewhere (Dodd *et al.* 2018). Articulation disorders were classified as phonetic level impairment of speech movement or placement, such as a lisp. We utilised the classification of

Dodd *et al* (2002) to delineate typical (developmental) versus atypical (non-developmental) error patterns in order to denote delayed versus disordered phonology, respectively; and 3 instances of an error were required to be classified as a pattern. Any further atypical (non-developmental) patterns observed, that were not previously described in Dodd's classification, were also recorded. Speech recordings were also examined for features of dysarthria and Childhood Apraxia of Speech (CAS), in addition to any evidence of these diagnoses from previous clinical reports. A speech inconsistency subtest was not completed due to testing time restrictions, however clinical reports were also examined for this. Dysarthria features were rated using the 'Mayo Clinic Motor Speech Characteristics Rating Scale' (Duffy 2013) while diagnostic criteria used to examine features of CAS were those in Fedorenko *et al* (2016), based on the three American Speech and Hearing Association (ASHA 2007) consensus-based criteria. The Wechsler Nonverbal Scale of Ability (WNV; Wechsler and Naglieri 2006) was also completed in accordance with testing instructions, in order to obtain a comparative measure of nonverbal IQ (NVIQ).

*Statistical Analysis*

The characteristics of the sample are summarised using means and standard deviations (SD) for quantitative variables and percentages for categorical variables. For the purpose of statistical analysis, the presence of speech difficulty was defined as having any one or more of the SSD subtypes, including articulation disorder, phonological delay or phonological disorder, CAS or dysarthria. Logistic regression analysis was used to investigate the effect of predictor variables on outcomes. The primary outcome measure was the presence or absence of SSD based on the definition discussed above. As this is a binary outcome measure, binary logistic regression was used as the statistical model.

Thirteen predictor variables were analysed, 12 of which were categorical and one continuous. Categorical variables included sex, household income, maternal education, gestation (full term or premature), and family history of speech or language issues, as well as degree of HL, type of HL, laterality, device/s used, age at which first device was fitted (categorised), presence or absence of additional disability, and a non-verbal IQ (NVIQ) standard score less than or greater than 80. The continuous variable was age (in months).

We first performed univariate (unadjusted) analyses; testing all potential variables individually for their association with the outcome variable, i.e., the presence of a SSD. Predictors for which there was a strong association at the 10% significance level were included in a backward elimination multivariable regression model. At this stage, an intentionally tolerant level (i.e., $p < 0.10$) was used so as to not miss any potentially significant variables. Variables were then entered hierarchically into the logistic regression model and removed stepwise with decreasing significance until only the significant predictors were retained in the model. We set statistical significance at $p < 0.05$ for the multivariate analysis. Statistical analysis was performed using Minitab 18 software (Minitab 18 Inc.).

**Results**

Demographic characteristics of the 90 participants who were eligible and who completed the GFTA-2 are seen in Table 1. For relevant hearing data see Table 2. As participants were recruited either through VicCHILD or SCOUT and the demographic data collected for each of these differed slightly, not all data elements were reported on or available (see Tables 1, 2).

The first aim was to describe the clinical diagnoses and proportions of SSD subtypes of the group. Proportions of SSD subtypes amongst the sample are seen in Figure I. Some

form of SSD was noted in 58% of our sample. The most common subtype was sole phonological delay (n=31, 34%), followed by articulation disorder (n=7, 8%) and both phonological delay and phonological disorder (n=7, 8%). No children had an isolated phonological disorder. Specific atypical error patterns noted in our sample can be found in Supplemental Table 2. No children displayed obvious characteristics consistent with a CAS or dysarthria diagnosis, or had these reported in past clinical reports. Although an inconsistency subtest was not able to be completed, there were also no instances of inconsistent phonological disorder described in any clinical reports. There was 100% reliability between two raters.

*- Table 1 -*

*- Table 2 –*

*- Figure 1 -*

For statistically significant predictors, the results of the univariable and multivariable logistic regression analyses are shown in Table 3. Variables which met the 10% criterion, which were entered into the adjusted regression model, included age, sex, maternal education, NVIQ, and the hearing device used (i.e., either HA, CI, both HA+CI or no device). The retained predictors in the final adjusted regression model were age, sex, and device used. Maternal education and NVIQ could not be included in the final multivariable regression analysis due to complete and quasi-complete separation of data points, respectively. The regression model found that males were six times more likely to have a SSD in comparison to females (OR 6.03; CI 1.99-18.24). While bimodal users with both HA and CI were significantly more likely to have a SSD in comparison to either HA (odds ratio [OR] 7.97;

confidence interval [CI] 0.70-90.97) or CI (OR 9.84; CI 0.75-129.57) alone. In addition, an increase in age indicated a slightly decreased association with SSD (OR 0.97; CI 0.94-0.99).

*- Table 3 –*



**Discussion**

This is the first study to examine the impact of a range of hearing loss variables directly on speech outcomes, across a sizeable population cohort. This research aims to expand the understanding of both the prevalence of various SSD subtypes in the school age HL population, but also to unravel the predictors of having an SSD in a child with HL.

*Prevalence of Speech Sound Disorder*

Addressing the first aim, to describe the prevalence and subtypes of SSD in children with HL, it was found that in this sample of children, aged 5 to 12 years old, the prevalence was 58%. In past studies, the prevalence of SSD has been estimated at 1.06% to 3.4%, amongst general paediatric populations in Australia (Eadie *et al.* 2015, McKinnon *et al.* 2007), therefore we have demonstrated that children with HL are at a considerably greater risk of SSD and its consequent implications for literacy and language disorder, than previously understood. This is not surprising, considering the intricate links between hearing and speech development (Eisenberg 2007). More specifically, and of particular importance, is that the most common SSD subtype within our sample was phonological delay; present in 34% of the group. The impact of hearing loss on speech development is regularly cited in the literature, however the specifics of prevalence and SSD subtypes are rarely made clear. Past literature investigating the links between HL and specific speech subtypes is sparse, and sample sizes have been

limited (max. of n=25, most n<10). Some describe delayed phonology (e.g. Buhler *et al*. 2007, Huttunen 2001), others describe disordered phonology (Osberger and McGarr 1982), or a combination of the two (e.g. Asad *et al*. 2018). Differences in the reported speech outcomes could relate to differences in a number of factors including study design, the participants investigated and their hearing characteristics (i.e., only CI users, only mild-moderate HL, Dutch speakers, etc.), and demographic differences. This paper is the first to provide an estimate of the population proportion of SSD subtypes in children with HL. Sole phonological delay was most common, with smaller proportions of articulation disorder, phonological disorder, or a combination of the three; while pure phonological disorder was rare. Instances of neither CAS, dysarthria, nor inconsistent phonological disorder were observed by experienced raters or within past history reports. The type of SSD subtype has significant clinical implications. In a recent population study by Morgan *et al.* (2017), using longitudinal data from the Early Language in Victoria Study (ELVS), it was determined that of all the predictors examined (including family history, socioeconomic status, sex, NVIQ, and the type of speech errors made) speech error subtype was only factor that significantly predicted speech outcomes. They found that children who made typical errors (i.e., phonological delay) were twice as likely to have their speech difficulty resolve in comparison to those making atypical errors (i.e., phonological disorder). These findings signpost the prognostic value of exploring specific SSD subtypes, as the current study has done. In relation to this cohort, the high percentage of phonological delay (as opposed to phonological disorder) may suggest a somewhat positive prognosis for children with HL. There are intervention implications in that phonological delay is highly amenable to treatment and hence earlier speech intervention could serve to speed up the progression towards typical speech production (Dodd *et al.* 2018). Ultimately speech outcomes may be improved via

many pathways. Intervention options (e.g. AV therapy) and timing were not explored in this study, but could also have an impact on successful speech outcomes and prognosis.

*Predictors of Speech Sound Disorder*

The second aim was to determine which factors relating to HL predicted speech outcomes. Of the 13 variables examined, age and sex were the demographic variables found to predict the presence of speech disorder. Specifically, males were more likely to have a SSD. This is consistent with previous findings which have found male sex to be a predictor of speech outcome (Eadie *et al.* 2015), and is seen commonly across most neurodevelopmental conditions. Older children were slightly less likely to have an SSD, which is not unexpected considering older children may have had more opportunity for speech intervention and improvement. Of the hearing related predictors, the device used was found to be the only significant predictor, in that those bimodal users (with dual HA and CI) were more likely to have an SSD in comparison to those using HA or CI alone. This is an interesting finding considering recent evidence recommending bimodal fitting (e.g. Mok *et al*. 2010). Although these studies report the benefits of bimodal use, they do not report on whether these benefits observed in speech recognition/perception necessarily relate to subsequent benefits in speech *production*. There are several plausible reasons why children within the current cohort have bimodal HA and CI. One may be that they were assessed at a point of transition between the two modes of amplification. Some children initially fitted with HAs progress to being CI users due to various reasons (e.g., poor outcomes, progression of hearing loss). It may be that some children within this cohort had begun this process at the point of assessment, and were hence bimodal at the time. Alternatively, bimodal users may have asymmetrical HL, which is not uncommon (Vila and Lieu 2015). These bimodal users have a complex integration task. Not only because their hearing ability is asymmetrical between the two ears; but also because

the nature of the auditory stimulus received in either ear is different. Hearing aids provide acoustic stimulation, whereas CIs provide electrical stimulation, and the combination of the two may prove difficult for the auditory system to integrate (Potts *et al.* 2009). The reasons why bimodal users in the current study were more likely to have an SSD are not entirely clear, although the integration difficulties discussed above may be a key factor. It is important to note that bimodal children comprise only 6% of the sample and that there is a wide OR (95%) confidence interval for this predictor (Table 3). Therefore, there is a degree of variation to be aware of whereby the odds of having an SSD in bimodal children could range from a low through to a high chance, compared to single modality users. Children with bimodal assistance are less commonly represented in the broader HI population and this subpopulation is less clearly understood. This finding is hypothesis-generating and further work is warranted to confirm whether this is a more vulnerable group of children, as findings indicate here.

Somewhat surprisingly, none of the other potential predictors (relating to HL) were found to predict the presence of SSD. Neither type of HL, degree of HL, laterality, or age of device fitting predicted the presence of speech disorder. No prior studies have investigated the effect of type of HL or laterality on speech outcomes. We provide an important novel finding here, in that within the context of all one's characteristics of HL, the type of HL or laterality does not predict their speech outcomes. Further, in the context of an individual's hearing, developmental and demographic factors, the degree of their HL did not prove to be a significant predictor of speech outcomes. This is an interesting finding, as intuitively one would assume degree of HL to have a clear impact on speech development. It appears that in context of the entire hearing and demographic profile on an individual, the degree of loss alone is not solely important, but rather is intimately intertwined with other factors. As is the

case with age of device fitting. Age of device fitting has shown mixed results in the past, with some studies finding this variable to be predictive of speech outcomes, while other have not (Ching *et al.* 2013, Sevinc *et al.* 2009, Tomblin *et al.* 2014). Although age of device fitting was not found to predict speech outcome in our study and has been equivocal across past research, a combination of unknown predictors may be impacting results. For example, it could be a combination of age of device fitting, *alongside* mode of communication and type of early intervention that influences the speech outcome. However, past work reviewing the impact of mode of communication on speech outcomes has described this area of research as limited with insufficient high quality evidence, so it is difficult to speculate on intervention options here (Fitzpatrick *et al.* 2016).

*Critical appraisal and novel contributions of our study*

This is the first study to delineate the proportions of SSD subtypes; utilising the largest sample of hearing impaired children recruited from a substantial Australian population cohort. Although past studies have been successful in describing common speech errors of children with HL (e.g., Moeller *et al.* 2007b), they have` not differentiated between phonetic (articulation) and phonemic (phonology) errors, which is a crucial distinction in terms of clinical decision making relating to intervention. Those that have reported on phonological development, have only assessed preschool samples (e.g. Kral *et al.* 2014), or have only recruited a subset of HL diagnoses (e.g. only those with bilateral SNHL; Ching *et al.* 2010). The current study is the first to describe the articulation and phonology in school aged children across all hearing diagnoses. Further we provided the first examination of a clinically meaningful subset of predictors of speech difficulty, namely across all degrees of HL, types of HL, hearing devices used, and both unilateral and bilateral HLs.

One limitation of this study (which is not uncommon amongst quantitative studies of speech production) is that estimates of SSD are derived from the production of single words only. If speech diagnoses had been classified based on the presentation of spontaneous speech, it can be postulated that the prevalence of SSD would be higher, as previously demonstrated (e.g. Wren *et al*. 2013). We also note that an inconsistency subtest was not included within our assessment due to testing time restrictions, however we examined past clinical data and there were no reports of this in clinical histories.

A further general limitation is that, for HA users, the frequency of use was not reported. Therefore, it is impossible to know whether those fitted with HA alone or bimodal users were using their aids at all times or only a portion of the time. Further, in regards to age of first fitting, this may correspond to HA fitting yet some children may move to CI/s when determined to be more appropriate. For some of the children in this study, the age of first fitting might not correlate with when their ultimate optimal modality was fitted (i.e. the age of first fitting corresponds to HA fitting, when the child was ultimately fitted with CI). However, it is important to emphasise that in the current landscape of hearing services in Australia, children fitted with HA are likely to be closely monitored and if results are not optimal, then they would hope to convert to CI relatively quickly if warranted. It is hypothesised that the time gap between HA and CI fitting (for those who switch from HA to CI or become bimodal users) is likely to be minimal.

A final limiting point relates to participants' mode of communication. Although all children within this study were oral, specific data was not available detailing their communication mode use, frequency and history. A systematic review found the research on communication mode to date as neither compelling nor unequivocal (Fitzpatrick *et al.* 2016),

therefore future investigation into communication mode and its effect on speech outcome is warranted.

## Conclusions

This is the first study, examining a population cohort, to describe the prevalence of SSD within paediatric hearing loss, and to examine which factors are predictive of speech outcome. In summary, the current findings suggest that SSD is considerably more common amongst children with HL in comparison to those with normal hearing, with more than half (58%) of children with HL affected. Phonological delay was the most common subtype of speech presentation found. As phonological delay is especially amenable to treatment. Hence the introduction of earlier phonological therapy should imply potential for more positive speech outcomes, albeit likely at a slower rate in comparison to children with typical hearing. Boys, younger children and those bimodal users fitted with a CI and HA were the most likely to present with an SSD. This group at increased risk for speech disorder may also benefit from earlier targeted therapy.

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**Table 1. Demographics of the Sample**

| Variable | 5-8yo (n=38) | 9-12yo (n=52) | Total (n=90) |
|---|---|---|---|
| Age (mnths), *n* (SD) | 77.3 (10.8) | 127.2 (10.6) | 102.8 (27.4) |
| Sex, *n* (%) | | | |
| Male | 17 (44.7) | 28 (53.8) | 45 (50.0) |
| Female | 21 (55.3) | 24 (46.2) | 45 (50.0) |
| Gestation, *n* (%) | | | |
| Full term | 33 (86.8) | 41 (78.8) | 74 (82.2) |
| Premature (<37wks) | 5 (13.2) | 10 (19.2) | 15 (16.7) |
| Not reported | 0 (0.0) | 1 (1.9) | 1 (1.1) |
| Family history of speech/language issues, *n* (%) | | | |
| Yes | 3 (7.9) | 7 (13.5) | 10 (11.1) |
| No | 21 (55.3) | 36 (69.2) | 57 (63.3) |
| Not reported | 14 (36.8) | 9 (17.3) | 23 (25.6) |
| Maternal education, *n* (%) | | | |
| < Year 12 | 4 (10.5) | 2 (3.8) | 6 (6.7) |
| Year 12 | 10 (26.3) | 4 (7.7) | 14 (15.6) |

| | | | |
|---|---|---|---|
| > Year 12 | 15 (39.5) | 5 (9.6) | 20 (22.2) |
| Not reported | 9 (23.7) | 41 (78.8) | 50 (55.6) |
| Household income (per year), *n* (%) | | | |
| <$31,199 | 3 (7.9) | 7 (13.5) | 10 (11.1) |
| $31,200-51,599 | 3 (7.9) | 9 (17.3) | 12 (13.3) |
| $52,000-77,999 | 6 (15.8) | 11 (21.2) | 17 (18.9) |
| $78,000-103,999 | 8 (21.1) | 4 (7.7) | 12 (13.3) |
| $104,000-155999 | 5 (13.2) | 9 (17.3) | 14 (15.6) |
| $156,000+ | 8 (21.1) | 7 (13.5) | 15 (16.7) |
| Not reported | 5 (13.2) | 5 (9.6) | 10 (11.1) |
| Presence of additional disability* | 3 (7.9) | 4 (7.7) | 7 (7.8) |

SD, Standard Deviation; NB. Due to rounding, some totals may not correspond with the sum of the separate figures. *Comorbid disabilities included Cerebral Palsy, Autism Spectrum Disorder, Intellectual Disability, Prader-Willi syndrome, and CHARGE syndrome.

**Table 2. Hearing Characteristics of the Sample**

| Variable | 5-8yo (n=38) | 9-12yo (n=52) | Total (n=90) |
|---|---|---|---|
| Age of first device fitting (mnths), *n* (SD) | 16.7 (19.1) | 17.4 (17.4) | 17.1 (18.0) |
| Degree of HL, *n* (%) | | | |
| Normal | 0 (0.0) | 3 (5.8) | 3 (3.3) |
| Mild | 10 (26.3) | 16 (30.8) | 26 (28.9) |
| Moderate | 10 (26.3) | 15 (28.8) | 25 (27.8) |
| Severe | 4 (10.5) | 8 (15.4) | 12 (13.3) |
| Profound | 14 (36.8) | 10 (19.2) | 24 (26.7) |
| HL type, *n* (%) | | | |
| SNHL | 34 (89.5) | 37 (71.2) | 71 (78.9) |
| Conductive | 1 (2.6) | 4 (7.7) | 5 (5.6) |

| | | | |
|---|---|---|---|
| Mixed | 3 (7.9) | 9 (17.3) | 12 (13.3) |
| Not reported | 0 (0.0) | 2 (3.8) | 2 (2.2) |
| Laterality, *n* (%) | | | |
| Unilateral | 10 (26.3) | 5 (9.6) | 15 (16.7) |
| Bilateral | 28 (73.7) | 47 (90.4) | 75 (83.3) |
| Device use, *n* (%) | | | |
| None | 7 (18.4) | 8 (15.4) | 15 (16.7) |
| Bilateral HA | 16 (42.1) | 31 (59.6) | 47 (52.2) |
| Bilateral CI | 9 (23.7) | 9 (17.3) | 18 (20.0) |
| Unilateral HA | 4 (10.5) | 0 (0.0) | 4 (4.4) |
| Unilateral CI | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| HA+CI | 2 (5.3) | 4 (7.7) | 6 (6.7) |
| Age of first device fitting, *n* (%) | | | |
| 0-12 months | 21 (55.3) | 26 (50.0) | 47 (52.2) |
| 13-24 months | 3 (7.9) | 9 (17.3) | 12 (13.3) |
| 25-36 months | 1 (2.6) | 6 (11.5) | 7 (7.8) |
| 37+ months | 7 (18.4) | 4 (7.7) | 11 (12.2) |
| Not applicable* | 6 (15.8) | 5 (9.6) | 11 (12.2) |
| Not reported | 0 (0.0) | 2 (3.8) | 2 (2.2) |

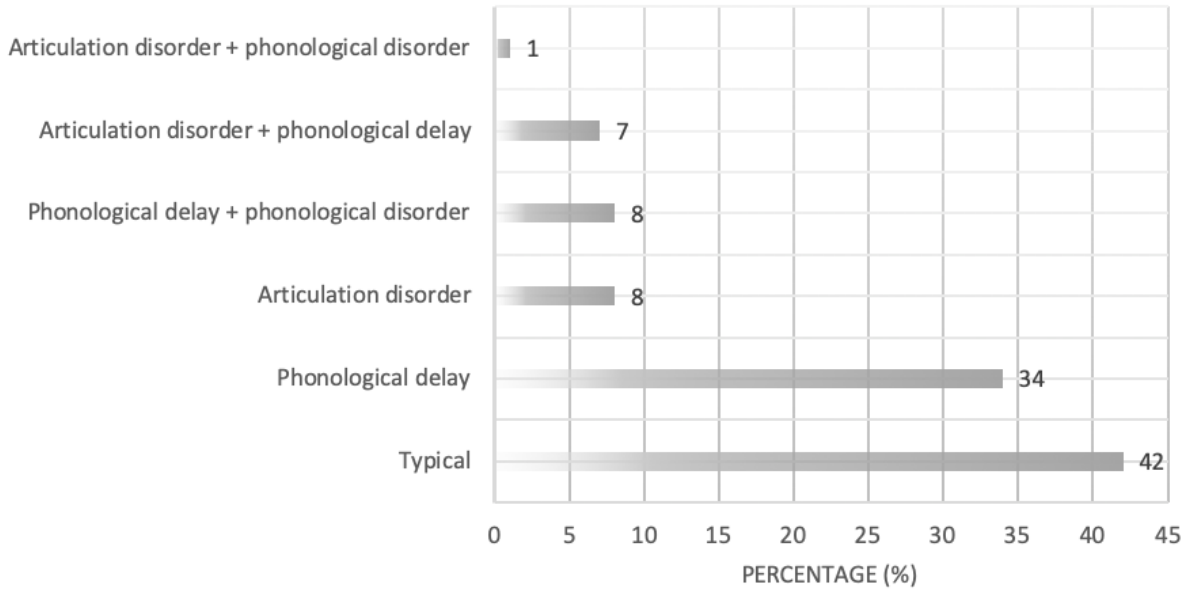
SD, Standard Deviation; HL, Hearing Loss; SNHL, Sensorineural Hearing Loss; HA, Hearing Aid/s; CI, Cochlear Implant/s. NB. Due to rounding, some totals may not correspond with the sum of the separate figures. *Not applicable to those who have never had a device.

**Table 3. Logistic regression of variables on SSD**

| | Unadjusted | | | | Adjusted | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **OR** | **95% ConfI** | **p-value** | | **OR** | **95% ConfI** | **p-value** |
| Age | 0.98 | 0.97-0.99 | 0.02 | | 0.97 | 0.94-0.99 | 0.000 |
| Male sex | 3.26 | 1.56-6.81 | 0.007 | | 6.03 | 1.99-18.24 | 0.001 |
| Device used | | | 0.04 | | | | 0.002 |
| CI v HA | 0.77 | 0.31-1.91 | | | 0.81 | 0.23-2.81 | |
| CI+HA v HA | 3.06 | 0.47-19.77 | | | 7.97 | 0.70-90.97 | |
| None v HA | 0.22 | 0.08-0.65 | | | 0.16 | 0.04-0.73 | |
| CI+HA v CI | 4.00 | 0.56-28.50 | | | 9.84 | 0.75-129.57 | |
| None v CI | 0.29 | 0.08-1.00 | | | 0.20 | 0.04-1.11 | |
| None v CI+HA | 0.07 | 0.01-0.56 | | | 0.02 | 0.00-0.33 | |
| Maternal education (ref: < Year 12) | | | 0.04 | | | | |
| Year 12 | 12.00 | 1.25-115.36 | | | | | |
| UG/PG degree | 2.44 | 0.36-16.55 | | | | | |
| NVIQ <80 | 6.19 | 0.71-54.31 | 0.05 | | | | |

OR, odds ratio; ConfI, confidence interval; CI, cochlear implant/s; HI, hearing aid/s; UG, undergraduate; PG, postgraduate; NVIQ <80, Nonverbal IQ full scaled score less than 80, indicating low average to extremely low NVIQ.

**Figure 1. Proportion of SSD subtypes**



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