Improving communication outcomes for children with hearing loss in their early years:

Tracking progress and guiding intervention

Aleisha Davis

A thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy

Department of Linguistics
Faculty of Medicine, Health and Human Sciences
Macquarie University

23rd December, 2020

Table of Contents

Abstract

Background

A growing number of studies have examined predictive factors to language outcomes for children with hearing loss (Ching, Dillon, Leigh, & Cupples, 2018; Geers & Sedey, 2011; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014). Findings from these studies have led to best practice position statements and universal shifts in clinical practice, including the introduction of newborn hearing screening, early access to appropriate audiological and educational intervention, and family-centered partnerships with integrated teams of professionals (Joint Committee on Infant Hearing, 2000, 2007, 2013). The level of evidence for effective intervention, therapy and training programs though, still needs to be understood (beyond the comparison of outcomes for children taught using different communication approaches).

Data on the use of communication approaches in published studies suggests the majority of child participants (52% to 98%) use a spoken component or oral communication system (Ching, Dillon, et al., 2013b; Gallaudet Research Institute, 2011; Niparko et al., 2010; Percy-Smith et al., 2013; Watson, Archbold, & Nikolopoulos, 2006; Yoshinaga-Itano, Sedey, Wiggin, & Chung, 2017). Despite considerable investment in research, design and development of hearing devices and coding strategies (Scollie et al., 2010; Vandali & van Hoesel, 2011; Wilson & Dorman, 2008), it is difficult to accurately evaluate the effect of device fitting and audibility levels over time in young children. Although there is a wide range of auditory measures available, in practice there are limitations to their use. These include a lack of versatility across age ranges, limited incorporation of real-world skills, minimal detail of how sound is used at a cognitive level, and the lack of ability to visually track progress and provide next steps.

How a child with hearing loss detects, uses, and processes linguistic input in their everyday settings, that is, their ‘functional listening skills’, is critical to understanding how well they are able to develop oral language. As such, the development of an outcome measure, the Functional Listening Index (FLI®) was considered. It was suggested that such a measure could track the acquisition of a child’s listening skills over time and provide a trajectory of developing listening competency. This information could be used by parents and caregivers to inform and guide early decisions, enabling and empowering choices regarding their child’s intervention. Similarly, such information could be used by professionals to monitor progress and optimise intervention through targeted listening, learning and language experiences in a child’s early and critical developmental years. Tracking functional listening acquisition through a tool such as the FLI may have the potential to improve a child’s language and communication outcomes through informed, timely decisions, and individually, appropriately targeted intervention.

Aim

To identify how communication outcomes for children with hearing loss can be improved, by:

1. Systematically evaluating the evidence for effective intervention, therapy and training programs that support the development of communications skills in children with hearing loss;
2. Identifying an effective way of furthering the communication development of children with hearing loss through a direct measure of functional listening and auditory development, to inform and support intervention decisions by parents and professionals; and
3. Reporting on the feasibility and viability of the use of a direct measure of functional listening and auditory development for young children with hearing loss.

Method

The evidence for effective intervention, therapy and training programs was established through a systematic review of the literature. Approaches were explored to improve communication options that would have the widest application across the population of children with hearing loss. Measures used to monitor progress and guide intervention for children with hearing loss in clinical practice by professionals in early intervention settings were reviewed, which led to the development of the FLI. Concurrent, construct and predictive validity levels of the FLI were analysed and its feasibility for use in an early intervention and cochlear implant program for children with hearing loss examined.

Results

The systematic review of the literature identified a small, yet growing, number of experimental studies that provided evidence of implementing specific therapies or training programs to improve language skills in children with hearing loss. The review indicated that well-designed single subject studies can provide valuable evidence whilst large-scale randomised control trials continue to be ethically and logistically challenging. The existing evidence base of intervention programs, factors supporting the development of language skills, and use of communication approaches reinforced the benefit of a functional listening measure to facilitate early intervention decisions. A review of functional listening and auditory tracking development measures identified a gap in current tools. The FLI was observed to be an effective measure of functional listening and its visual trajectories of progress provided valuable information to support development. FLI scores indicated the expected difference between known-groups and were found to be predictive of language outcomes. A feasibility study demonstrated the FLI could be used successfully with the entire population of children with hearing loss in a clinical setting. Individual scores showed expected changes over time, and a sensitivity to predictive factors known to impact listening development. Group data indicated expected differences and variations.

Conclusion

The FLI was found to be a valid, feasible, longitudinal measure of a child's functional listening acquisition. The functional listening information the FLI provides can bridge the gap between audiological measures of hearing and assessments of language skill and competency. Use of the FLI in clinical practice indicates the potential for therapeutic intervention programs for children with hearing loss developing spoken language to be optimally responsive, targeted and individualised. The sensitivity of a tool such as the FLI to predictive factors supports early decisions and facilitates collaborative partnerships between parents and professionals, with useful, meaningful information to track progress and guide intervention.

Declaration

I hereby declare that this thesis is my own work and that, to the best of my knowledge or belief, it does not contain any unattributed material previously published or written by any other person, apart from the published paper included in Chapter 2. As outlined in the Authorship Contribution Statement, for that paper I discussed the concept with the main author Dr Adam Smith and we collaborated on content for the workshop paper and subsequent publication. I provided all of the specialist corpus data for the study and was the subject matter expert in the key focus areas, contributing to the interpretation of results, the formation of the discussion and conclusions, and reviews of the manuscript and presentation.

I also declare that the work in this thesis has not previously been submitted to any other institution for, or as part of, a degree.

This study was granted approval by Macquarie University Ethics Review Committee (Human Research) (Reference 5201600650) and conducted in accordance with the stipulated guidelines (see Appendix A).

Name: Aleisha Davis

Signed:

Date: 21 December, 2020

Acknowledgements

There is an international community of parents and professionals dedicated to improving the lives and outcomes of children with hearing loss. It has been a true honour to be part of this field for many years, and hopefully for many more to come. The design and development of the FLI that is reported in this work, has only been possible thanks to the founding work of the pioneers who have paved the way with their learnings and insights about the development of listening in children with hearing loss. Helen Beebe, Norm Erber, Daniel Ling, Doreen Pollack, and the many more leaders and professionals around the globe passionate and committed to supporting communication development in children with hearing loss; it's been such a privilege to learn from you. Listening skills and behaviours have been brought into the lives of children with hearing loss through auditory hierarchies, which have proved to be the critical foundations on which children have been able to develop oral language. It's been an honour to be able to use such rich foundations, to continue to facilitate and improve the support we can provide to children with hearing loss and their families.

This research was inspired by wanting to support families with data and information about the individual rate of their child's listening development to guide their decisions at the earliest opportunity, in a partnership with professionals. Although independently led, this research was beyond the scope of an individual, and only possible through a true collaboration of clinicians, teachers, researchers, audiologists, child and family counsellors and the many parents who entrust their child's early intervention and language development in the hands of such professionals. I have been lucky enough to have been a part of such an incredible team of professionals for nearly 20 years now, and humbled and privileged to share the journey with so many families during that time.

The Shepherd Family had a different vision for children with hearing loss and their families, in supporting them to learn to listen and speak through appropriate aiding and early intervention. The family have worked tirelessly to support children in reaching their potential, through the incredible team at The Shepherd Centre. This team are the most amazing, high-performing, passionate group of individuals who continue to provide all-encompassing support for the families they work with. Anthea Green, who made this PhD possible; Jim Hungerford, who supported me in its completion; Alyshia Hansen, who has helped me bring the data to life; and the many, many clinicians and colleagues at The Shepherd Centre and in all the hearing health care and speech pathology organisations around the world that I have worked with, thank you for reminding me daily why we need to, and can, do better. To the families I've worked with, thank you, for opening up your lives, and sharing the highs, the lows, the trials and the tribulations of supporting a child with hearing loss to learn to listen and speak. I have learnt so much from walking the path next to you.

This research would not have been possible without the support of the HEARing Cooperative Research Centre, of which The Shepherd Centre was a member, for supporting this PhD and fostering the necessary collaboration across institutions to further these research findings into translation and industry application. This included the normative study referenced in Chapter 9 with the involvement of CRC Members Cochlear Ltd and Western Sydney University's MARCS Institute, which has been critical to the final development and application of the FLI-P.

My supervisors, Elisabeth Harrison and Bob Cowan, I have endless levels of gratitude for your mentorship, time, belief and genuine interest in keeping me on this path. It has been through your questions, encouragement, sage wisdom and insight that I have continued to learn and grow, in and out of each of the deep-dives of these chapters, culminating into this full body of work. At the outset, I never imagined this research journey would have the translatable impact that it has had. Thank you for supporting me in bringing this work to life, and truly change and improve clinical practice for children with hearing loss.

Finally, it's my own family that I am enormously grateful to for enabling this research work over the last 8 years. I will be forever thankful for your never-ending support, your understanding, your interest and the grace and patience you have shown over the countless evenings and weekends this has consumed. To my husband Nick, you've been my biggest fan in believing this could happen, my biggest enabler, and I couldn't have kept going without you. To my boys, Sam, Archie and Henry, I hope this inspires you to do great things with whatever you choose to do, and know that nothing is beyond your reach. To my Mum, the juggle has been real these last few years, and it wouldn't have been possible without you, and this PhD would have remained an idea. Finally, to my Dad, I wish you were here to read this. You have motivated me, encouraged me, educated me, and shaped who I am today. This one is for you. Thank you. From the bottom of my heart.

> *We are like dwarfs on the shoulders of giants, so that we can see more than they, and things at a greater distance, not by virtue of any sharpness of sight on our part, or any physical distinction, but because we are carried high and raised up by their giant size.*
>
> "Nanos gigantum humeris insidentes" (Merton, 1993)

Presentations and Publications arising from this research

This body of research work was supported by the HEARing CRC and The Shepherd Centre Early Intervention Program for children with hearing loss, with the aim of contributing to research that would benefit intervention for children with hearing loss and their families. The authors acknowledge the financial support of the HEARing CRC, established under the Australian Government's Cooperative Research Centres (CRC) Program. The CRC Program supports industry-led collaborations between industry, researchers and the community.

Material included in Chapter 2 was published as Smith and Davis (2018). It was written by the author with the assistance of Dr Adam Smith and was presented at an international workshop hosted by Fudan University in Shanghai from 7 to 8 November 2016. Dr Adam Smith and the author designed the study in 2016. Adam performed various statistical analyses to explore the corpus data provided by the systematic review reported in Chapter 3, and we collaborated on generation of the research questions, interpretation of results, and formation of the discussion and conclusion.

Preliminary data from the Chapter 6 and 7 studies was presented at two international conferences in 2019 (Davis, Fulcher, & Hopkins, 2019a; Davis, 2019b), and five international conferences in 2018 (Davis, Cowan, & Harrison, 2018a; Davis, Cowan, & Harrison, 2018d; Davis, Cowan, & Harrison, 2018e; Davis, Fulcher, Harrison, Dwyer & Cowan, 2018f; Davis, Cowan & Harrison 2018g). Davis, Cowan, & Harrison, (2018g) were awarded best oral presentation for this work at the World Congress of Audiology Conference in October 2018. Davis, Cowan, & Harrison, (2018b) & Davis, Cowan, & Harrison, (2018c) also presented the development work reported in the post script in Chapter 9 within a number of these presentations. Data and information from Chapter 3 was presented along with pilot data that informed the further work reported in Chapters 6 and 7 at four international conferences a few years prior (Davis, Abrahams, & Neal, 2015a; Davis, Abrahams, Neal, & Hansen 2015; Davis, Neal, & Abrahams, 2015b; Davis, Fulcher, Abrahams, Hansen, & Neal, 2015; Davis, Neal, Abrahams, & Hansen, 2015). Data for Chapters 6 and 7 were collected by clinical team members employed at The Shepherd Centre during the defined period, as part of clinical protocols. All children were clinically managed by staff under the author's clinical supervision.

Data in Chapters 6 and 7 were verified, checked and statistically analysed by Alyshia Hansen, Director of Information & Analysis and Dr Jim Hungerford, CEO at The Shepherd Centre. Work on the validation data presented in Chapter 7 was conducted as part of the Goodwill Analytics Data Science Charity event in October 2016, by a team of statisticians and data professionals, led by Yeeka Yau from The Shepherd Centre.

Davis, A., Fulcher, A., Hopkins, T. (2019a, June) *Language is caught not taught: Applying functional listening skills to guide communication development and intervention.* Paper presented at the International Society on early Intervention Conference: Research to Practice in Early Intervention; An International Perspective, Sydney, Australia, June 25 - 28 2019.

Davis, A. (2019b, November) *Clinical evidence and experience: Confidence in early decisions for parents and professionals.* Paper presented at the Asia Pacific Symposium on Children with Cochlear Implants, Tokyo, Japan, Nov 27 - 30, 2019.

Davis, A., Cowan, R. Harrison, E. (2018a, March) *Shifting focus: Using functional listening skills to guide paediatric cochlear implant evaluation.* Paper presented at the American Cochlear Implant Alliance ACI2018 Emerging Issues in Cochlear Implantation, Washington DC, March 7 - 10,2018.

Davis, A., Cowan, R. Harrison, E. (2018b, March) *Language is caught not taught: Supporting parents in monitoring and understanding their child's functional listening skills to guide implantation decisions, maximise listening and learning opportunities and its effect on outcomes.* Poster and Poster Highlight sessions presented at the American Cochlear Implant Alliance ACI2018 Emerging Issues in Cochlear Implantation, Washington DC, March 7 - 10, 2018.

Davis, A., Cowan, R. Harrison, E. (2018c, May) *Language is caught not taught: Applying functional listening skills to guide amplification decisions and intervention choices for children with hearing loss.* Workshop presented at the Audiology Australia Conference, Sydney, Australia, 21 - 23 May 2018.

Davis, A., Cowan, R. Harrison, E. (2018d, May) *Using functional listening skills to guide paediatric rehabilitation.* Paper presented at the Audiology Australia Conference, Sydney, Australia, 21 - 23 May 2018.

Davis, A., Cowan, R. Harrison, E. (2018e, June) *A shift of focus: Using functional listening skills to guide paediatric cochlear implant candidacy and measure outcomes*. Paper presented at the CI2018 15th International Conference on Cochlear Implants and other implantable Auditory Technology conference, Antwerp, Belgium, 27 - 30 June 2018.

Davis, A., Fulcher, A., Harrison, A., Dwyer, A., Cowan, R. (2018f, October) *The Functional Listening Skills Index (FLI-P) as a guide to paediatric rehabilitation.* Poster presented at the Asia-Pacific Babylab Constellation Conference, Singapore, 4 - 5 October 2018.

Davis, A., Cowan, R., Harrison, E. (2018g, October) *A shift of focus: Using functional listening skills to guide paediatric cochlear implant candidacy and measure outcomes*. Paper presented at the 34th World Congress of Audiology Conference, Cape Town, 28 - 31 October 2018.

Smith, A., & Davis, A. (2018). Disambiguating the use of common terms across related medical fields: the problem of intervention. *Lexicography, 4(1), 63-80*.

Smith, A., & Davis, A. (2016). *Disambiguating the use of common terms across related medical fields: The problem of intervention.* Paper presented at the 2016 Fudan University Medical Terminology and Lexicography in the E-Era conference, Shanghai, 23 August 2016.

Davis, A., Abrahams, Y. & Neal, K. (2015a. April) *Putting it all together: The role of functional listening in infant cochlear implant evaluation and service delivery*. Paper presented at the 10th Asia Pacific Symposium on Cochlear Implants and Related Sciences Beijing, 30 April – 4 May 2015.

Davis, A., Abrahams, Y., Neal, K. & Hansen, A. (2015, April) *Listening progress following pediatric cochlear implantation from 0 to 6 years: The Auditory Hierarchy*. Paper presented at the 10th Asia Pacific Symposium on Cochlear Implants and Related Sciences, Beijing, 30 April – 4 May 2015.

Davis, A., Neal, K. & Abrahams, Y. (2015b, June). *Putting it all together: The role of functional listening and objective testing for infants.* Paper presented at the 8th Australasian Newborn Hearing Screening Conference, Sydney, Australia 19 - 20 June 2015.

Davis, A., Fulcher, A., Abrahams, Y., Hansen, A. & Neal, K. (2015, July). *Tracking listening skills from 0-6 years: Changing progress, changing outcomes.* Paper presented at the AG Bell 2015 Listening & Spoken Language Symposium, Baltimore, July 9 - 11 2015.

Davis, A., Neal, K., Abrahams, Y. & Hansen, A. (2015, October). *Listening outcomes using the Functional Listening Index following cochlear implantation in young children: The precursor to speech and language.* Paper presented at the CI 2015 Symposium: Emerging Issues in Cochlear Implantation and ACI Alliance on the Hill, Washington DC, 15 - 17 October 2015.

Acronyms

The following acronyms are used throughout this thesis.

AUS	Australia
ASL	American Sign Language
BSL	British Sign Language
CDaCI	Childhood Development after Cochlear Implantation
DHH	Deaf and/or Hard of Hearing
EHDI	Early Hearing Detection and Intervention
EI	Early Intervention
FLI	Functional Listening Index
FLI-P v2.0	Functional Listening Index - Paediatric version 2.0
HL	Hearing loss
LOCHI	Longitudinal Outcomes of Children with Hearing Impairment
LSL	Listening and Spoken Language
Mod	Moderate
NH	Normal hearing
NZ	New Zealand
PI	Principal Investigator
Prof	Profound
RCT	Randomised controlled trial
Sev	Severe
SimCom	Simultaneous Communication
SLP/SLT	Speech Language Pathologist/Therapist
ToD	Teacher of the Deaf
SNHL	Sensorineural Hearing Loss
TC	Total Communication
TH	Typical hearing
TSC	The Shepherd Centre

Glossary

The following definitions are used throughout this thesis.

Audibility	Able to be heard; the degree to which something is audible.
Communication	Ability to impart and exchange information, encompassing all linguistic aspects (language, speech, pragmatics, vocabulary and literacy).
Communication Approach	Refers to the mode, method, philosophy or communication methodology.
D/HH	Deaf/Hard of Hearing (used when this has been specifically stated in an original text).
Deaf	Members of the signing Deaf community.
Detection	Ability to identify the presence or absence of a sound.
Discrimination	Ability to tell the difference between sounds.
Early Childhood	Birth to five to six years of age (Mashford-Scott, Church, & Tayler, 2012).
Functional Listening	Inclusive of detection, discrimination, identification and comprehension listening skills, in real-world language environments.
Hearing	Detection or discrimination of a sound.
Hearing loss	Hearing impairment, deafness, hard of hearing.
Language	Ability to understand what is heard or read, and how words are used.
Listening Competency	Ability to use listening skills and behaviour successfully.
Parent	Caregiver or direct family member that is or acts as a parent to a child.
Professional	Clinician; interventionist; health, education or disability professional working in hearing health care.
Speech	Sounds that make up words.
Therapeutic Intervention	The implementation of a specific therapy or training program.
Typical Hearing	Hearing within 0dBHL to 20dBHL (Clark, 1981; modified from Goodman 1965).
Vocabulary	Body of words used in a language.

List of Tables

List of Figures

Chapter 1

IMPROVING COMMUNICATION OUTCOMES FOR CHILDREN WITH HEARING LOSS IN THEIR EARLY YEARS: TRACKING PROGRESS AND GUIDING INTERVENTION

The language instinct that children develop is one of the most remarkable of human developmental processes. As a specialised and complex skill, it develops spontaneously without conscious effort or formal instruction, is deployed innately without awareness of its underlying logic, is qualitatively the same in all individuals, and is distinct from more general abilities to process information or behave intelligently (Pinker, 2003). For children with hearing loss, language development does not happen without specific and targeted intervention, and the detrimental impact on the development of language and communication skills has been well documented (Ching et al., 2018; Kennedy et al., 2006; Lederberg, Schick, & Spencer, 2013; Moeller, 2000; Yoshinaga-Itano, 2003a). Given the impact that language has on educational attainment, future earnings, life opportunities, the use of health care systems and life expectancy (Carvill, 2001; Mohr et al., 2000), improving communication outcomes is the primary focus of pediatric research across sectors.

Longitudinal evidence from studies led by researchers such as Christine Yoshinaga-Itano, Ann Geers and colleagues in the US, and the Longitudinal Outcomes for Children with Hearing Loss (LOCHI) led by Teresa Ching and colleagues in Australia born out of the HEARing CRC's program of research, demonstrate the positive impact of early diagnosis and device fitting on children's language outcomes (Ching et al., 2018; Ching, Dillon, et al., 2013a; Geers, 2002; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Consequently, worldwide health strategies in many countries now support the screening of newborns for hearing loss to facilitate early diagnosis to maximise auditory input in a child's critical early learning years (Mehl & Thomson, 2002; Sininger et al., 2009). Concurrently, advances in technology sectors have included the design and development of hearing devices and coding strategies to improve and increase children's audibility levels (Scollie et al., 2010; Vandali & van Hoesel, 2011; Wilson & Dorman, 2008).

Despite a growing understanding of these contributing factors, there remains significant variability in children's outcomes. Hearing health care professionals working with children with hearing loss and their families are keen to understand what they can do to further improve a child's language and communication skills. The motivation for the research in this thesis comes from this perspective—having been a clinician in the field for many years—and wanting to better objectively support outcomes and inform early intervention decisions. This was aligned with the primary focus of the research program of the HEARing CRC, to change and improve the way services were being delivered.

The initial chapter will introduce this thesis by providing an overview of typical language acquisition and the impact of reduced auditory input on a child's developing communication skills. The background, research and clinical context for children with hearing loss is reviewed, and the need for this research is identified. The value and intended knowledge contribution of outcomes are discussed and aim and research objectives of the project are defined. Subsequently, the research design employed throughout the project is described, and a brief precis of each chapter is provided in conclusion. There are eight thesis chapters, followed by a postscript that outlines the further developments, commercialisation opportunities and broader applications that have resulted from this work.

The Role of Listening in Children's Acquisition of Language

Many studies have demonstrated that listening behaviours and language development begin well before birth (Kuhl, 2004; McLean & McLean, 1999). Newborn babies already have preference for their mother's voice (DeCasper & Fifer, 1980) and demonstrate a perceptual predilection for their surrounding language (Mehler et al., 1988; Moon, Cooper, & Fifer, 1993). Such evidence indicates that unlike adults, newborn children are sensitive to acoustic changes from the time they are born, including even to those languages to which they have not been exposed (Eimas, 1975; Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Lasky, Syrdal-Lasky, & Klein, 1975). At this very early stage of development, infants apply a language-specific pattern of listening. As their ability to distinguish between sounds of familiar and unfamiliar languages reduces, their ability to discriminate between native-language phonetic units significantly increases (Kuhl, 2004; Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005; Werker & Tees, 1984). There is evidence that by 7 months of age, infants discriminate unfamiliar sentence structures through listening, and demonstrate the cognitive and linguistic capacity to abstract, use and extrapolate rules from language-like sounds (Marcus, Vijayan, Rao, & Vishton, 1999; Pinker, 1999). Their language instinct is developing and they can miraculously learn where one word ends and another begins in the stream of input around them. Each of these skills is reliant on a child's ability to hear, and listen to the acoustic environments of their world, and reflect their auditory development and growing linguistic competence[1].

Infants begin speech production (babble) from 6 months of age (Paul, 2007), and typically first words emerge between 8 and 12 months from the words and sounds they are exposed to (Bergelson & Swingley, 2015; Brown, 1973; Nott, Cowan, Brown, & Wigglesworth, 2009a, 2009b; Syrnyk & Meints, 2017). On average, children know up to 50 words by 15 to 18 months of age, and are understanding new words at twice the rate they produce them (Benedict, 1979). Learning capacity studies have revealed that an 18 month old child can learn one to two words each day, a 4 year old child up to a dozen words each day, and a 7 year old child can learn as many as 20 words each day (O'Grady, 2005). By the time children are 3 years of age, they have vocabularies of several thousand words and have developed complex knowledge of how each word is produced and can be combined with others to form sentences (Bloom & Lahey, 1978). Their foundation of language through use of their natural instinct is now well and truly established.

Language acquisition in terms of both pace and age depends on language exposure and linguistic experience (Hart & Risley, 1995; Weisleder & Fernald, 2013; Werker & Tees, 1984). Language exposure creates linguistic experiences in children's everyday

[1] Based on the development of spoken language.

environments, with everyone around them, and through everything they are experiencing. Naturally, where this exposure and/or experience is reduced, language acquisition is at risk. Hart and Risley (2003) famously demonstrated the impact of reduced language input and experience at 3 years of age. Reduced language input was found to be significantly predictive of language skills of children at 9 and 10 years of age in professional families (where the average child is exposed to 215,000 words of language experience), working class families (125,000 words of language experience), and welfare families (62,000 words).

The Impact of Hearing Loss on Language Acquisition

Globally, it is reported that there are approximately 32 million children with disabling hearing loss (World Health Organization, 2017). Permanent childhood hearing loss remains one of the most common disabilities in children (Davis, 1989; Fortnum et al., 2001; Morton & Nance, 2006). In comparison, congenital sensorineural hearing loss (SNHL) occurs three times more frequently than Down syndrome and six times more frequently than spina bifida in the USA (Alo & Howe, 1997; Stierman, 1994). Rates of hearing loss revealed by universal newborn screening programs are typically reported to be between 1 and 2 per 1000 live births in developed countries (Mason & Herrmann, 1998; Mehl & Thomson, 1998; Stevens et al., 2011). Rates have been reported to be a high 6 per 1000 live births (Bachmann & Arvedson, 1998), with a higher prevalence of hearing loss associated with lower levels of community and economic development (World Health Organization, 2019). Between 30% and 40% of children with congenital hearing loss are commonly reported to have additional developmental needs (Gallaudet Research Institute, 2011).

Hearing loss can also be acquired after birth and following exposure to language. Causes of acquired hearing loss include conductive hearing loss caused by acute otitis media or otitis media with effusion, or sensorineural hearing losses resulting from bacterial meningitis, ototoxic medications, late onset progressive hearing loss, syndromic hearing loss such as Usher's or Pendrid's syndrome, and noise induced hearing loss (Cunningham, Cox, Practice, & Medicine, 2003; Smith, Bale Jr, & White, 2005). Rates of hearing loss in school-age children indicate a growth in the prevalence of hearing loss with reported ranges from 11.3 % (Bess, Dodd-Murphy, & Parker, 1998), to 14.9% (Niskar et al., 1998) and 19.5% (Shargorodsky, Curhan, Curhan, & Eavey, 2010).

A child at any age, with any degree and type of hearing loss, will experience decreased auditory input. The language they are exposed to and their linguistic experience reduces, and impacts the development of their spoken language and communication skills (Sininger, Grimes, & Christensen, 2010). Although computational learning models show that infants can learn from being exposed to the right kind of auditory input in the laboratory (Saffran, Aslin, & Newport, 1996), Kuhl (2004) demonstrated that social interactions—a human interacting with a child—is what makes language meaningful for learning. This is evidence that language cannot be learnt in isolation, and must be meaningful. A complicating factor is that the everyday language learning settings and environments of a child's life—homes, playgrounds, parks, cars, shopping centres, playgroups, early education settings—are typically noisy and acoustically difficult. It becomes much more challenging for a child with hearing loss to receive necessary linguistic input and 'catch' the sounds, words, phrases and sentences around them in these noisy, real-world environments. Furthermore, they need to be acoustically sensitive to nuances and fine phonetic boundaries to discriminate where words end, where others begin, and to learn the rules of language as they are cognitively wired to do.

Background and Research Focus

A growing number of outcome studies have provided valuable information on children's longitudinal outcomes, and analyses have identified the predictive factors that impact these results (Ching et al., 2018; Geers & Sedey, 2011; Tomblin et al., 2014). This evidence has translated into universal shifts in clinical practice, including the introduction of newborn hearing screening, early access to appropriate audiological and educational intervention, and family-centered partnerships with integrated teams of health professionals across the health, education, and disability sectors. Despite considerable investment in research, design and development of hearing devices and coding strategies to improve audibility (Scollie et al., 2010; Vandali & van Hoesel, 2011; Wilson & Dorman, 2008), it is difficult to accurately evaluate the effect of device fitting and audibility levels over time in young children who are developing spoken language. Although there are a wide range of auditory measures available, in practice there are limitations to their use. Limitations include lack of versatility across age ranges, limited or no incorporation of real-world skills, no insight into how sound is used at a cognitive level, and the lack of ability to visually track progress and provide next steps. In addition to information at a general level (as provided by longitudinal outcome studies) data and monitoring at an individual child level can provide specific information to parents and professionals on what they really want to know and that is directly relevant to them, which is, understanding exactly how a child is progressing.

Research Value

Understanding how a child with hearing loss detects, uses and processes linguistic input in their everyday settings, that is, their functional listening skills, is critical to understanding how well they are able to develop oral language and communication. The research reported in this thesis was undertaken to improve the communication outcomes of children with hearing loss through the development of an outcome measure, the Functional Listening Index (FLI®) which can track the acquisition of a child's listening skills over time, provide a trajectory of developing listening competency and which parents and professionals could use to inform and guide early decisions. The first step in this research was to review the current evidence base for therapeutic interventions, use this to identify how an evidence-based measure could be developed and provide benefit, and determine levels of validity and clinical feasibility. Such a tool could enable and empower families to be more directly involved in decisions regarding their child's intervention, and guide professionals in how to optimise listening, learning and language development from linguistic exposure and experiences in a child's critical, early developmental years.

Aim and Research Objectives

The aim of this thesis is to identify how communication outcomes for children with hearing loss can be improved given the current evidence base. To do this, three research objectives were identified:

1. To systematically evaluate the evidence for effective intervention, therapy and training programs that support the development of communications skills by children with hearing loss;
2. To identify an effective way of furthering the communication development of children with hearing loss through development of a new direct measure of functional listening and auditory development to inform and support intervention decisions by parents and professionals; and
3. To explore the feasibility and viability of the use of a direct measure of functional listening and auditory development for young children with hearing loss.

Research Design and Dissertation Outline

The research reported in this thesis is underpinned by the need to understand the evidence that exists for interventions and therapies to improve communication outcomes for children with hearing loss across communication approaches. In order to do this, a clear definition of the term 'intervention' needs to be established due to the mixed usage this term has in clinical and research spheres. The ambiguity surrounding use of it is used is explored in Chapter 2 through an empirical analysis of both a general and a specific corpus. Results of this analysis provide a definition of 'intervention' that is used in the systematic review of therapeutic interventions that is reported in Chapter 3. The aim of this review was to systematically evaluate the evidence for effective intervention, therapy and training programs that support the development of communication skills for children with hearing loss, supporting the first research objective. The review identified a small yet growing number of experimental studies that provide evidence from results of implementations of specific therapies or training programs to develop communication skills in children with hearing loss. The review also highlighted the valuable evidence well-designed single subject designs can provide whilst large-scale randomised control trials continue to be ethically and logistically challenging.

The central principles and factors that contribute to the development of strong communication skills were explored in Chapter 4. To address the second research objective, available data on the use of communication approaches were reviewed to identify effective characteristics of measures used to quantify communication development of children with hearing loss. Data on the use of communication approaches suggest that the majority of child participants use a spoken communication system, or spoken and signing approach (incorporating an oral component) (Ching, Dillon, et al., 2013b; Gallaudet Research Institute, 2011; Niparko et al., 2010; Percy-Smith et al., 2013; Watson et al., 2006; Yoshinaga-Itano et al., 2017). Factors that predict the development of an effective oral language system are reviewed, and found to support the benefit of a functional listening measure to facilitate earlier intervention decisions.

In Chapter 5, a review of functional listening and auditory development tracking measures in current clinical use identified gaps due to limitations of their use, which include lack of versatility across age ranges, limited or no incorporation of real-world skills, no insight into how sound is used at a cognitive level, and the lack of ability to visually track progress and provide next steps.

Considerations in the design of a measure to suit the identified needs are discussed and the development process of the Functional Listening Index (FLI) are described. The validity of the FLI was examined in Chapter 6 in accordance with the third research objective, in order to assess whether the FLI measured what it was designed to measure. This was explored through investigations of concurrent validity (with existing tools), construct validity (the ability of the FLI as a measure to identify differences in known groups), and predictive validity (identifying if a child's FLI scores can predict a language skills). A clinical retrospective study is reported in Chapter 7 to explore the feasibility and viability of the FLI as a clinical measure for children with hearing loss enrolled in an early intervention and cochlear implant program. Results provided strong evidence to warrant further use and investment.

Future research directions are considered and recommended in Chapter 8 and contributions to knowledge in light of limitations within the research program as a whole are discussed. Dissemination of the results of this research program as detailed in the Presentation and Publications section generated a wider interest in the potential clinical applications and opportunities for use of the FLI, which have resulted in a number of industry and clinical collaborations and partnerships. Details of the ongoing development, commercialisation and broader applications of the FLI have been provided as a postscript in Chapter 9. Although these are outside the scope of the thesis, they provide information regarding the interest in, and need for a functional listening measure such as the FLI, the translational implications of this research and contributions that this work provides.

Chapter 2

THE PROBLEM WITH INTERVENTION

This chapter and the next will address the first research objective of this thesis: to identify and evaluate the evidence for effective intervention, therapy, and training programs that support the development of communication skills by children with hearing loss. Preliminary scoping for the systematic review in Chapter 3 quickly identified that the term *intervention* was used to refer to different concepts. For example, sometimes this referred to the intervention of fitting of a hearing device, and in others, to the provision of an intervention program. As this is a key term for this work, and fundamental to the first research objective and the systematic review, a preliminary analysis was needed to establish clarity for its use for the purpose of this thesis. Results from this analysis can support the development of a specialist vocabulary, or registry, which can become the referral point for concepts and understanding for the field, to avoid misinterpretation (Bell, 2001). This is widely evident in the medical field where complex and specialised terminology is used routinely and specific medical dictionaries have been developed to support understanding and use of such terminology. Without such sources of reference, terms and terminology can cause difficulties in communication between professionals and patients (Koch-Weser, Dejong, & Rudd, 2009; Lerner, Jehle, Janicke, & Moscati, 2000).

Along with discipline-specific terminology and jargon which can impede understanding, general terms that have a technical concept or use ('semi-technical' terms), for example, *procedure* or *cell* can also cause difficulties. *Intervention* is one of these semi-technical terms. In both practice and research, it can be used with reference to different technical concepts by clinical professionals and researchers from health, audiology, education, speech pathology, disability, and medical backgrounds. Given the diversity of backgrounds and context with which each professional group approaches the field, the likelihood of differences in usage of the term is high, matching the initial scoping findings of the systematic review.

The initial research into the ambiguity of use of the term intervention has been incorporated into a published manuscript, and provided in this chapter. This paper outlines the contexts in which the term intervention is used in a corpus data set to provide a real-world analysis and observation of how the term is used (Stubbs, 2001). The purpose of this analysis was to define a single understanding for the term for use throughout this thesis, and contribute suggestions for how professionals in the field can use the term in future without resulting in misunderstanding.

Pages 29-46 of this thesis have been removed as they contain published material. Please refer to the following citation for details of the article contained in these pages:

Smith, A., Davis, A. Disambiguating the use of common terms across related medical fields: the problem of *intervention*. *Lexicography ASIALEX* 4, 63–80 (2018). https://doi.org/10.1007/s40607-018-0038-x

Conclusion

The analysis of the term intervention by Smith and Davis (2018) provides evidence of its use as a semi-technical term. Contemporary corpora indicate a recent increase in the frequency of its use, predominately written in academic texts and in general/popular media. Usage of the term demonstrates issues with perception and understanding due to both its general and specialist uses. Findings indicate: a lack of awareness of the technical use of the term by the general public, variable use within discipline groups that leads to misunderstanding amongst professionals, and a negative perception of the term, that have the potential to impact discussions with clients. Use in a specialist corpus specifically relating to treatment for children with hearing loss demonstrated evidence of different uses across fields.[2] The use of common collocates with specific meanings indicated that the term is not clearly marked with a discipline-specific meaning. Identifying specific usage by the collocation of intervention with other technical and semi-technical terms indicated three meanings relevant to this research in the corpus. The first: audiological intervention (the fitting or surgical implant of a device); second, the implementation of a specific therapy (e.g., speech therapy); and, last, enrolment in an educational or curriculum program. Despite a frequent representation in the corpus of educational and specific therapy approaches, which may have been an unintended bias from the inclusion and exclusion criteria of the systematic review, all three meanings were demonstrated.

These results emphasise the need for clarity with how the term intervention is used, and provided a base from which to define its use. Considering the defined aim and research objectives, and work that already exists reporting on the impact of audiological and educational interventions as discussed in Chapter 1, the term intervention will be defined for the remainder of this work as *the implementation of a specific therapy or training program*. The findings from this study also identify an important consideration for researchers and professionals, suggesting the use of a specific categorisation to define how the term can be used to support joint understanding and improve clarity. This would provide benefit across research and clinical settings and avoid unintended misinterpretations.

In the next chapter, the systematic review of the literature of therapeutic training programs for children with hearing loss is reported. Consistent with the defined use of the term, the review considers only therapeutic not include audiological interventions (such as the fitting of hearing aids or devices), or reports and outcomes of educational intervention programs in which children are enrolled. This review aims to identify and evaluate the evidence for effective intervention, therapy, and training programs that support the development of communication skills of children with hearing loss.

[2] The audiological corpus referred to in Smith and Davis (2018) was an earlier version of the systematic review than that reported in Chapter 3.

Chapter 3

INTERVENTION AND TRAINING PROGRAMS TO IMPROVE THE COMMUNICATION SKILLS OF CHILDREN WITH HEARING LOSS: A SYSTEMATIC REVIEW

The previous chapter reviewed the ways in which the term *intervention* is used and understood, and identified the unintended misunderstanding that can arise from different interpretations. It was observed that intervention can refer to three types of intervention, specifically (1) audiological intervention, i.e., the fitting of a device, (2) educational intervention, i.e., enrolment in an educational program and (3) therapeutic intervention, i.e., the implementation of a specific therapy or training program. This review will deal specifically with only therapeutic intervention. The reason for this focus is the large number of published studies that report on the impact of audiological interventions (Ching, Dillon, et al., 2013b; Geers, 2002; Tomblin et al., 2014) and educational interventions (Allen, Letteri, Choi, & Dang, 2014; Antia, Jones, Reed, & Kreimeyer, 2009; Coryell, 2001; Dornan, Hickson, Murdoch, Houston, & Constantinescu, 2010; Easterbrooks & Beal-Alvarez, 2012). The evidence for interventions that implement specific therapy or training programs in the literature is less extensive and initial searches could not identify any existing reviews of the literature in this area.

The systematic review was designed to determine the evidence that exists for interventions pertaining to specific therapies and training programs, and their levels of efficacy and effectiveness in improving communication outcomes for children with hearing loss. The addition of a review of this nature follows the growing body of systematically designed literature reviews in allied health fields to evaluate the effectiveness of interventions across disciplines, and to build the evidence base within the respective field (Baker & McLeod, 2011; Dodd, Taylor, & Damiano, 2002; Lawlor & Hopker, 2001; Parsons, Cordier, Munro, Joosten, & Speyer, 2017; Yorkston, Hakel, Beukelman, & Fager, 2007).

Aim

The aim of this review is to identify and evaluate the evidence for effective intervention, therapy and training programs that support the development of communication skills by children with hearing loss. To be as applicable and informative as possible, this review was:

1. Conducted systematically, through a predefined search strategy and extraction protocol;
2. Analysed and evaluated using relevant and appropriate frameworks and criteria that provide information on the validity of the studies and corresponding strength of the results;
3. Extended across eight linguistic areas of development: 1) lexicon and vocabulary, 2) syntax and semantics, 3) morphology, 4) phonetics and phonology, 5) pragmatics and social communication, 6) reading and comprehension, 7) writing and spelling, and 8) narrative and discourse; and

4. Inclusive of all communication approaches for children with hearing loss (i.e., sign, spoken, Total Communication, and Cued Speech).

Method

The methodology and reporting for this systematic review was developed and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) (Moher, Liberati, Tetzlaff, & Altman, 2009). This framework provides the minimum set of items for undertaking and reporting systematic reviews in healthcare. Methodologically, the review followed the recognised steps of:

1. Preparation: review question formulated, previous systematic reviews scoped, protocol developed, and search strategy devised;
2. Retrieval: search and de-duplication;
3. Appraisal: abstracts screened, full texts obtained, full text screened, citations followed to find additional reports; and
4. Synthesis: data extracted, synthesised, literature re-checked, narrative/meta-analysis, and write up.

(Tsafnat et al., 2014)

Protocol Development: Inclusion/Exclusion Criteria

Inclusion and exclusion criteria were developed as per the Cochrane Protocol for Systematic Reviews (Higgins & Green, 2008). Along with search strategies and methods of data extraction and analysis, the inclusion and exclusion criteria were pre-specified and documented before data collection commenced. The Participants Intervention Control Outcomes and Study Design tool (PICOS) was used to define inclusion criteria (Methley, Campbell, Chew-Graham, McNally, & Cheraghi-Sohi, 2014).

Participants were defined as children under 16 years of age at commencement of the intervention, using any communication approach, from any cultural identity or linguistic background, with any degree and type of hearing loss (mild through to profound, unilateral and bilateral hearing loss, sensorineural, conductive, mixed, or Auditory Neuropathy Spectrum Disorder), any device configuration (including unaided) and device type/s. All communication approaches were included, as were participants with additional developmental needs to reflect the nature and diversity of children with hearing loss.

As per the results from the corpora analysis in Chapter 2, intervention was defined as any specific training or therapy program in any communication or educational approach, with appropriate detail for it to be reproducible. Control parameters were identified as either a comparative control group or studies that employed a pre- and post-training comparison.

Outcomes were defined to include one or more child-based standardised or criterion referenced communication assessment, or a parent/ teacher/clinician-based rating scale, checklist, questionnaire or survey that measured a change in one of the eight defined linguistic areas.

Eligible study designs were identified as prospective, experimental and quasi-experimental studies with the intervention introduced as an independent variable, including uncontrolled or controlled trials (both non-randomised and randomised). Although randomised controlled trials are often considered to be the level of evidence required for inclusion in a systematic review, as it is increasingly recognised that the results of well-designed studies with internal validation and controls can be particularly useful in heterogeneous fields like disability (in which it can be difficult to recruit large participant numbers) (Guyatt et al., 2000), lower level, well designed, controlled studies were included (Robey & Schultz, 1998). A minimum number was not set for participants, given the value methodologically robust studies with small participant numbers can provide. Full details of the inclusion criteria are provided in Table 1.

Table 1: PICOS Inclusion Criteria

Parameter	Inclusion Criteria
Participants	Children under 16 years at commencement of the intervention, - any degree and type of hearing loss, - any communication approach, linguistic or cultural identity, - any device configuration (including unaided) - any device type including assistive listening devices
Intervention	Specific intervention, training or therapy program in any communication or educational approach, with appropriate detail provided for the intervention to be reproducible
Control	Comparison with a control group or repeated measures (pre and post)
Outcomes	One or more child-based standardised or criterion referenced communication assessment, or parent/ teacher/clinician-based rating scale, checklist, questionnaire or survey measuring a change in any aspect of the eight linguistic areas including lexicon and vocabulary, syntax and semantics, morphology, phonetics and phonology, pragmatics and social communication, reading and comprehension, writing and spelling, and narrative and discourse
Study Designs	Prospective, experimental and quasi-experimental studies with an intervention introduced as an independent variable, including uncontrolled or controlled trials (both non-randomised and randomised controlled trials)

Exclusion criteria were identified for date, study design, peer-review and outcomes. Studies published before 2000 were excluded, as were observational designs such as cohort and case control studies. Studies published in non-peer reviewed publications (dissertations, conference papers and proceedings and reviews, editorials and opinion articles) were excluded for the purposes of maintaining a level of comparison. As discussed, studies reporting results of educational or communication approaches, or audiological (device fitting or programming interventions) were not considered. Indirect outcome measures such as attention, memory, cognitive and play skills were also excluded, as were subjective outcome measures (for example perceived levels of improvement). To reduce the risk of language bias, neither publication language nor language used by the participants was a defined criterion for exclusion and translations were sought for relevant studies in languages other than English. These included German, Japanese, Chinese, Polish, Afrikaans, Portuguese, Finnish, French, Spanish, Italian, Persian, Croatian, and Slavic texts. No exclusion criteria were set for the location of the intervention, frequency, length or duration of the intervention period. Exclusion criteria details are provided in Table 2.

Table 2: Exclusion Criteria

Parameter	Exclusion Criteria
Date	Published before 2000
Study Design	Observational study design (i.e., case-control, cohort, cross-sectional), reviews and editorials
Peer-reviewed	Not published in a peer-reviewed journal
Outcomes	Compared outcomes of communication approaches or outcomes of audiological interventions (device fitting, programming strategy change) Subjective outcome measures and outcomes measuring skills related indirectly to a child's communication skills e.g., executive function, attention, play skills, turn-taking, mental health, quality of life, parent behaviour, and parental input

Search Strategy, Retrieval and De-duplication

Data collection occurred between August and October 2017. Electronic databases were searched using all combinations of the terms *child, language* and *communication* in the title, subject, and user tags. The terms *hearing*, *hearing loss*, *hearing impairment*, *deafness*, *deaf*, *intervention*, and *therapy* were searched for in the subject tag. These search terms were not assumed to cover the full range of characteristics, identities, and terminology associated with children with hearing loss, instead, they were identified as key words that are commonly used in the research literature (Wendel, Cawthon, Ge, & Beretvas, 2015).

Databases and indexes searched were: the American Medical Association Journals, Aquatic Science Journals, Directory of Open Access Journals (DOAJ), CrossRef, Education Resources Information Centre (ERIC Institute of Education Sciences), Health Reference Centre-Academic (Gale), the JAMA Network (American Medical Association), JSTOR Archival Journals, Linguistics and Language Behavior Abstracts (LLBA), MEDLINE/PubMEd (NLM), Maney Online, Maney Publishing, Gale Academic OneFile, Oxford Academic (Oxford University Press), Project MUSE, ProQuest, Ovid (Wolters Kluwer), SAGE Journals, ScienceDirect, Scopus (Elsevier), Sociological Abstracts, SpringerLink, Taylor & Francis online (Informa), Thieme Journals, Web of Science: Science Citation Index Expanded, Web of Science: Social Sciences Citation Index, and Wiley Online Library.

All articles were saved in Endnote X8 0.1 and duplicates removed. Articles were screened by title and abstract against set criteria. In cases of uncertainty, articles were included for further investigation. An additional manual search was conducted of citations used in studies, and of a non-peer reviewed database (Google Scholar). Full papers were assessed for eligibility against defined PICOS parameters.

Reliability

A randomly allocated 10% of papers were checked for eligibility and consistency with defined criteria by two academic colleagues experienced in research design and methodology. Once differences in interpretation of the statements were clarified, the inter-rater reliability was 92% and 94%. Differences were resolved through discussion and agreement.

Data Extraction and Synthesis

Studies were analysed by design development stage in accordance with the five phase modified model for development of child language interventions proposed by Finestack and Fey (2017). This framework describes the levels of efficacy (in which causal relationships between the intervention and outcomes are measured in controlled conditions), and effectiveness (where previously established efficacious interventions are examined in real-world conditions). Traditional efficacy development stage frameworks can be problematic when applied, because language intervention studies rarely follow the organised evolution hierarchy (Baker & McLeod, 2011). Many language interventions are designed and used in generalised clinical settings at a much earlier stage, than, for example, medical or pharmaceutical interventions, because the potential for harm by the intervention is much lower. The addition of translational research steps in models such as that by Finestack and Fey (2017) supports how language intervention studies typically develop, and can facilitate a quicker transfer of knowledge to implementation of evidence-based treatments. This often is possible due to the high levels of external validity evidenced by their early use with the population for which they are intended. The studies in this review were categorised according to the Finestack and Fey (2017) model by both their phase of development and translational research level.

To determine methodological quality, criteria fields were set according to the Standard Quality Assessment for evaluating primary research papers (Kmet, Cook, & Lee, 2004). The Kmet quality assessment tool provides criteria for study designs other than randomised controlled trials (RCTs). Criteria ratings ranged from two (*yes*), one (*partial*) to zero (*no*). Despite clear differences in ratings of controls and external validity levels, scores on the other criteria for all studies were very similar. To better explore the impact of methodological design on levels of internal validity and risk of bias, the Study Quality Assessment Tool developed jointly by the National Heart Lung and Blood Institute and Research Triangle Institute International (2018) was used. The two sub assessments relevant for use were The Quality Assessment of Controlled Intervention studies, and The Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group.

Data Analysis

Despite a meta-analysis being the ideal outcome of a systematic review, it was not feasible in this context due to the large degree of heterogeneity in each aspect of the review criteria. Participants varied in age, communication approach, device use, age at device fitting, presence of additional developmental needs, and level of hearing loss. Interventions varied by type, across linguistic areas, and by control/pre-post measurement. There were extensive differences in outcome measures (dependent variables) and study designs, including both experimental and quasi-experimental designs, that were controlled (randomised and non-randomised) and non-controlled (before/after, time-series, single subject). Results were instead reviewed in a thorough narrative analysis.

Results

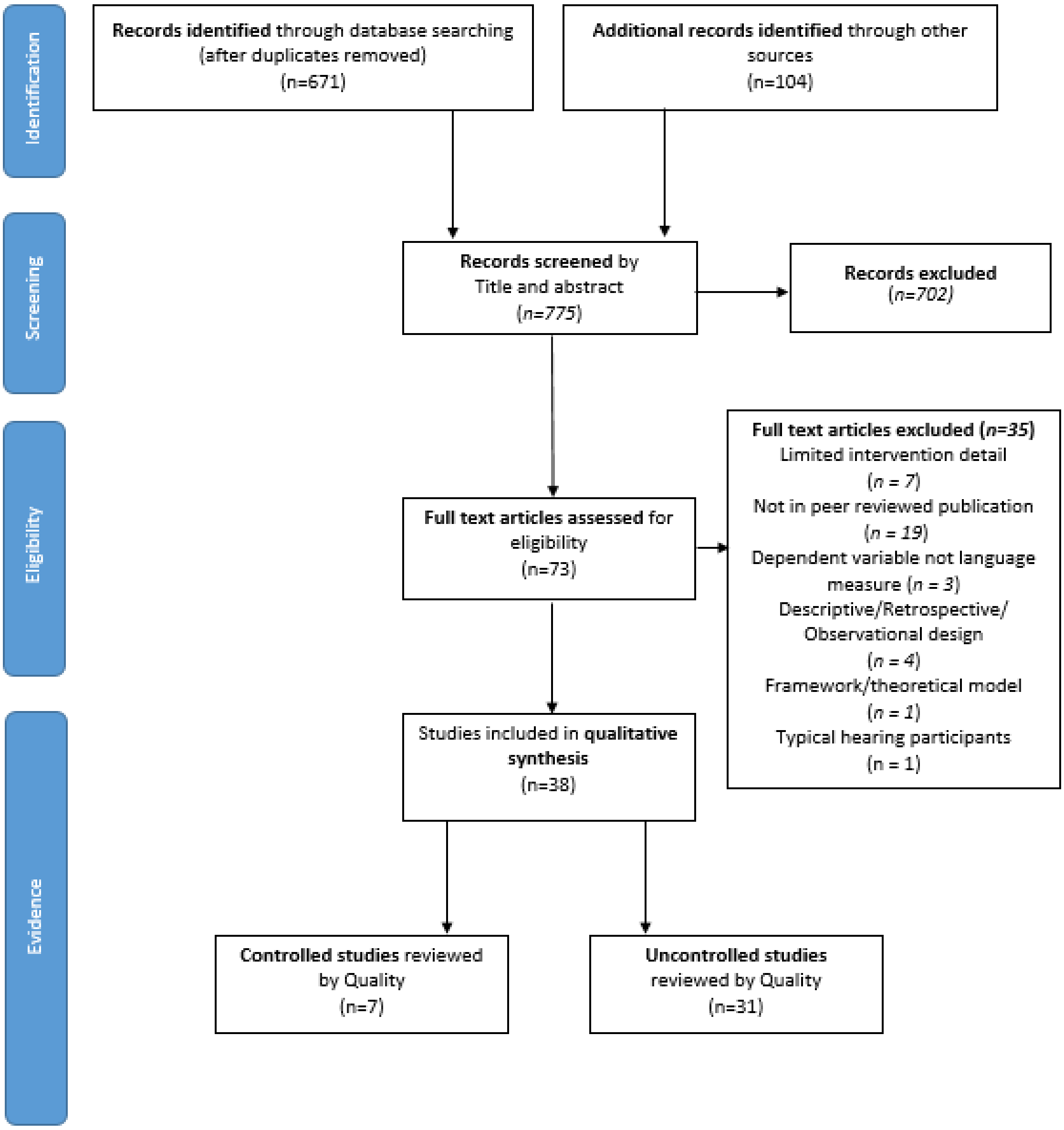
A total of 671 studies were identified through the initial database search after duplicates were removed. An additional 104 studies were added through additional sources including manual searches. These 775 studies were screened by title and abstract. From this, 702 were excluded based on the identified criteria. From the remaining 73 studies which were reviewed in full text, 35 further articles were excluded. Of these: 7 were excluded for limited intervention detail; 19 were published in non-peer-reviewed publications; 3 employed a non-linguistic dependent variable; 4 were descriptive, retrospective or observational in design; 1 was a theoretical model; and another used typical hearing participants. See Table 3 for numbers and reasons for exclusion; full details are provided in Appendix B.

Table 3: Excluded Studies

Parameter	Reason	Number
Intervention	Limited intervention detail	7
Peer-reviewed	Not in peer reviewed publication	19
Outcomes	Dependent variable not language measure	3
Study design	Descriptive/ retrospective/ observational design	4
	Framework/ theoretical model	1
Participants	Typical hearing participants	1

The remaining 38 studies that met inclusion criteria formed the basis of the eligible data set for review. The flow diagram of study selection through the identification, screening, eligibility and evidence process is detailed in Figure 3.1.

Figure 1: Flow diagram of study identification, screening, eligibility and evidence process



Study Characteristics

A summary of the study characteristic data extracted from each of the final studies is provided in Table 4. Single publications that reported results on more than one intervention program have been reported and presented separately.

Table 4: Characteristics of eligible studies

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
1	Alton, Herman, and Pring (2011)	n = 16 Location: UK Age: 7.2 - 11.0 HL sev or prof Device/s: not stated	BSL, English, sign supported English	Inclusion: normal cognitive function, grades 3-6, received school dinners, no previous therapy	SmiLE approach	Pragmatics and social communication	The impact of SmiLE therapy, whether deaf pupils spontaneously generalise specific skills learnt to another school communication situation	11-week block, within school, 2 x 25 min structured sessions per week, groups of 4 – 6 children	Specialist speech language therapist and specialist Teacher of the Deaf
2	Asad, Hand, Fairgray, and Purdy (2013)	n = 3 Location: NZ Age: 7 - 13 HL: mod - prof Device/s: HA/CI	NZ sign language, spoken English	Not stated. Participants recruited from a named clinic and not known to researcher	Use of dynamic assessment to evaluate narrative language learning	Narrative and discourse	Whether dynamic assessment is a useful alternative approach to traditional assessment of fictional narrative skills; Can it differentiate between normal versus poor language learning ability	Individual 2 x mediated learning sessions over 1 week	Speech language pathologist
3	Bergeron, Lederberg, Easterbrooks, Miller, and Connor (2009)	(STUDY 1): n = 5 Location: USA Age: 3;10 - 7;10 HL: mod - prof Device/s: HA/CI	Auditory oral, SimCom, ASL	Inclusion: HL 55dB+, PreK, K or G1 across 2 schools, no additional disabilities, not known to the CE, Score 3-4 on the Early Speech Perception Test. Exclusion: anxious on leaving classroom, knowledge of targeted phoneme-grapheme correspondences	Semantic association strategy embedded in early intervention program	Reading and comprehension	The effectiveness of a semantic association strategy for teaching phoneme-grapheme correspondences	35 mins x 4 days per week, 8 - 9 weeks, small group (2-3) pull out model of instruction	Research teachers
4	Bergeron et al. (2009) (S2)	STUDY 2: n = 5 *different participants to S1	Auditory oral, SimCom, ASL	As in study 1. No exclusion based on knowledge of phoneme	Semantic association strategy embedded in early literacy curriculum	Reading and comprehension	The effectiveness of a semantic association strategy for teaching phoneme-grapheme correspondences	1-hour pullout group sessions (5 children), 4 days per week x 6 weeks	Research teacher

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
		Location: USA Age: 3;10 - 4;5 HL = mod - prof Device/s: HA/ CI		grapheme correspondences.	(Foundations for Literacy)				
5	Bernhardt, Loyst, Pichora-Fuller, and Williams (2000)	n = 4 Location: USA Age: 4.0 - 5.2 HL: unilateral, bilateral prof Device/s: HA/ CI	TC	Not stated	Palatometry treatment program	Phonetics and phonology	To evaluate results of speech intervention in terms of body (impairment) and of activity level	Individual 15 x 30 – 45-min SLP therapy sessions, 20 x 40 - 50min palatometry sessions in 2 blocks over 5mths	Researcher speech language pathologist
6	Bobzien, Richels, Schwartz, Raver, and Morin (2015)	n= 4; Location: USA Age: 3;5 - 5;1 HL: mild - prof Device/s: HA/ CI	Spoken English	Weaknesses in expressive language, vocabulary, below age narration skills	Repeated storybook reading paired with explicit teacher instruction to teach novel vocabulary	Lexicon and vocab	The effectiveness of using four explicit teaching strategies during repeated reading group sessions to increase in-context verbal identification of targeted, or instructional, vocabulary	Small group (1 - 5), 15 - 33 mins, 3 - 8 sessions depending on time taken to reach mastery	Classroom teacher
7	Bow, Blamey, Paatsch, and Sarant (2004)	n = 17 Location: Aust Age: 5.3 - 11.10 HL: mod - prof Device/s: HA/ CI	Spoken English	Inclusion: selected from 29 students based on analyses of recorded conversations for lower phonological and morphological skills	Phonological and morphological training	Morphology; Phonology	The effects of phonological and morphological training on speech production, morphological knowledge, and speech perception	15 - 20mins daily, 1 - 3 students, 2 x 9-week blocks	Teachers
8	Bowers and Schwarz (2013)	n = 4 Location: USA	SimCom	Inclusion: enrolled in identified school. Exclusion: diagnosed	Basic concept instruction	Lexicon and vocabulary	Whether an experimental basic concept–curriculum based measure was	15-min group sessions, 2-week x 8 weeks	Principal investigator and speech

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
		Age: 4.0 - 5.2 HL: unilateral & bilateral prof Device/s: HA/ CI		cognitive impairments, behaviour interfered with ability to participate			able to accurately assess and monitor progress in basic concept acquisition		language pathologist
9	Brady and Bashinski (2008)	n = 9 Location: USA Age: 3.0 - 7.0 HL: mild - prof Device/s: HA/ CI/ unaided	Prelinguistic	Inclusion: concurrent vision & hearing loss; cognitive disability; adequate upper extremity mobility and control for independently performing gestures	Adapted version of prelinguistic milieu teaching	Lexicon and vocabulary	Describe the adapted version of prelinguistic milieu teaching and report preliminary responses by a group of children with complex communication needs, including concurrent vision and hearing losses	Individual 30 - 60min session, 4 days per week over several months	Project team members
10	Chan, Chan, Kwok, and Yu (2000)	n = 6 Location: Hong Kong Age: 3 - 11;6 HL: not stated Device/s: CI	Cantonese	Not stated	Intensive tone perception training	Phonetics and phonology	The effect of intensive tone perception training on tone production performance	Individual weekly intensive training x 8 weeks	Not stated
11	Charlesworth, Charlesworth, Raban, and Rickards (2006)	n = 12 (HL) n = 12 (TH) Location: Aust Age: 5.9 - 9.2 (HL); 6.4 - 8.8 (TH) HL: 8 prof, 4 not stated Device/s: not stated	Sign, spoken English	Inclusion: attended identified school; required intervention for language and communication skills	Reading recovery	Reading and comprehensi on	Can literacy achievement be improved by reading recovery? How will teachers of the deaf use reading recovery teaching procedures? Can special teaching procedures that support literacy learning be identified? Is the application of the literacy processing theory used as Reading Recovery in hearing contexts the same or different in	Withdrawn for 1 - 1 instructions; 35 – 39-min sessions, 3 - 4 per week, 12 - 21 weeks, 46 - 64 sessions in total	Teachers

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
							contexts for children with hearing loss?		
12	Clendon, Flynn, and Coombes (2003)	n = 5 Location = NZ Age range = 10.5 - 15.1 HL = Prof Device/s = CI	Spoken English	Inclusion: no cognitive or learning difficulties, profound HL, cochlear implant users	Earobics and SpeechViewer III software	Phonetics and phonology	Improvements in speech production, phonological awareness skills, speech perception and literacy skills.	Individual 30 min sessions twice weekly, 15-min programs, 2 x 4-month periods	Software program
13	Dwyer, Robb, O'Beirne, and Gilbert (2009)	n = 11 Location: NZ Age: 12 - 18 HL: sev - prof Device/s: HA/ CI	Spoken English or sign and spoken	Sev-Prof bilateral HL, congenital or pre-lingual HL, oral or signed NZ English as primary mode of communication, HA or CI users, no cognitive or physical impairments other than communication difficulties	Training to increase speaking rate	Phonetics and phonology	Do F1 and F2 frequencies change as a function of increased speaking rate? Do the 1st and 2nd formant bandwidths significantly decrease as a function of increased speaking rate? Are speakers rated as significantly less nasal as a function of increased speaking rate?	3 training sessions within 1week	Software program
14	Encinas and Plante (2016)	n = 3 Location: USA Age: 4.8 - 5.4 HL: prof Device: CI	Spoken English; ASL; spoken Spanish; spoken Arabic	Not stated	Enhanced conversational recast and auditory bombardment	Morphology	Feasibility of a language treatment method combining enhanced conversational recast treatment with auditory bombardment	Individual sessions 30mins per day, 5 days per week, 5 - 7 weeks.	Author
15	Golos and Moses (2011)	n = 31 (children) n = 7 (teachers) Location: USA and Canada Age: 3 - 6.0	ASL, oral, combination	Convenience sample	Video from an educational video series in ASL	Lexicon and vocabulary	Does viewing an educational video positively impact deaf preschoolers' acquisition of vocabulary, printed English and story elements? Does the impact of the video vary by	40-min video x 2 occasions to groups of 3-5 children over 1 week	Teachers and research assistants

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
		HL: mild - prof Device/s: HA/ CI/ unaided					children's baseline skills?		
16	Herman et al. (2015)	n = 4 Location: UK Age: 0.0 - 11.0 HL: sev - prof Device: HA/ CI	TC (signed supported English & BSL)	Not stated	Core vocabulary therapy	Lexicon and vocabulary	Can core vocabulary therapy increase the accuracy of sounds in words in order to enhance speech intelligibility?	16 individual 45-min sessions twice per week	Student therapists
17	Higgins, McCleary, and Schulte (2000)	n = 2; Location: USA Age: 4.10 - 5.5 HL: prof Device/s: CI	TC environment using signing exact English (SEE2) plus AO	Not stated	Visual feedback to treat negative intraoral air pressure	Phonetics and phonology	Can visual feedback teach production of +Po rather than –Po? Is there indirect evidence of improved phonatory physiology when phonatory goals are incorporated with treatment of –Po? Are other aspects of speech/voice production mis-learnt when visual feedback is used to remediate –Po or to change phonation?	2 alternated forms in 3 sessions of 20-30-min intervals within 2 - 3 weeks	Not stated
18	Ingber and Eden (2011)	n = 34 Location: Israel Age: 4.0 - 6.5 HL: mod - prof Device/s: HA/ CI	Oral & signed Hebrew	Enrollment in individual or group integration program, spoken-language gap is less than 1 year below age norms	Sequential time perception and storytelling	Narrative and discourse	Improve concept of sequential time and storytelling ability	Individual weekly 20-min meets in quiet room in kindergarten over 3 months	Clinicians
19	James, Wadnerkar-Kamble, and Lam-	n = 3 Location: UK Age: 0.9 - 3.10	Spoken English	First come, first recruited	Video Interaction Guidance	Pragmatics and social communication	Explore the efficacy of a psychological intervention that has a strong evidence-base	Goal setting session, 2 - 3 intervention sessions and	Accredited provider

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
	Cassettari (2013)	HL: prof Device/s: HA/ CI					in the psychological literature with capacity to produce effects on all aspects of child development	shared review session over 8 - 12 weeks	
20	Justice, Swanson, and Buehler (2008)	n = 3 Location: USA Age: 5.4 - 8.0 HL: sev - prof Device/s: CI	Spoken English	Inclusion: minimum 2yrs CI experience, deficits in narrative quality, language impairments, syntactic deficits and passed oral mechanism screening	Narrative-based language intervention	Narrative and discourse	Whether a production-based intervention approach focusing on production of grammatical structure, narrative content and form produces similar results in children with CIs as previously shown in children with SLI.	6 weeks of intervention sessions	Clinician
21	Klieve and Jeanes (2001)	n = 6; Location: Aust Age: 7.0 - 11.11 HL: prof Device/s: CI	Spoken English	Not stated	Meaning differences conveyed by prosody	Narrative and discourse	Whether children with cochlear implants understand the meaning differences conveyed by the prosodic features of intensity, duration and pitch, or require specific intervention to help them develop this understanding	Twice weekly x 10 weeks, 40-min individual sessions	Teacher
22	Lam-Cassettari, Wadnerkar-Kamble, and James (2015)	n = 14 Location: UK Age: 0.6 - 6.2 (Intervention Group) 0.9 - 3.2 (Waitlist Group) HL: mod - sev - prof Device/s: HA/ CI	Sign & spoken English	Above prelinguistic stage of development, & 50+ words	Video Interaction Guidance	Pragmatics and social communicati on	The effect of a family-focused psychosocial video intervention program on parent–child communication	3 x filming sessions, 3 x shared review sessions over 8 - 12 weeks	Interventionist
23	Lew, Purcell, Doble, and Lim (2014)	n = 3 Location: Singapore	Spoken English	Inclusion: 2:6 - 4:0, bilateral mod+ permanent SNHL, consistent	Speech Perception Education and Assessment Kit	Lexicon and vocabulary	To determine whether speech perception intervention for preschool children	3 sessions per week for 6 weeks or until	Therapist

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
		Age: 2.6 - 3.1 HL: mod - prof Device/s: HA/CI		HA/CI users, score below highest category on low verbal version of the Early Speech Perception Test, English as main home language Exclusion: diagnosis of other impairments	(SPEAK) programme		with hearing loss is effective in the development of speech perception skills and has a positive impact on vocabulary and speech development	ceiling reached	
24	Lund and Douglas (2016)	n = 9 Location: USA Age: 53 - 68mths HL: mild - prof Device/s: HA/CI	Spoken English and languages in addition to English	Inclusion: HL, amplification used; Exclusion: unable to sit and participate; unable to name pictures	Vocabulary Instruction	Lexicon and vocabulary	Do preschool children with hearing loss learn more vocabulary words as a result of direct instruction, follow-in labeling, or incidental exposure?	4 days per week, 15 mins x all 3 conditions each day for 6 weeks	Teachers of the deaf
25	Massaro and Light (2004)	n = 8 Location: USA Age: 6.11 - 11.0 HL: mild - prof; Device/s: HA/ CI	Spoken English	Inclusion: in day class for language arts & needed help with vocabulary building skills	Language player software training program with animated computer tutor	Lexicon and vocabulary	To test the effectiveness of a language wizard/player with Baldi, a computer-animated tutor	20 - 30 minutes per day x 2 days per week over 10 weeks	Digital device
26	Miller, Lederberg, and Easterbrooks (2013)	n = 5 Location: USA Age: 3.9 - 5.1 HL: mod - prof Device/s: HA/ CI	SimCom, conceptually accurate signed English; spoken English	Inclusion: unaided PTA 50dB+ in better ear, no additional disabilities, understand some spoken words, 3;8 - 5;11	Phonological awareness instruction	Reading and comprehension	Can DHH preschoolers with functional hearing learn to segment spoken words into syllables; discriminate words that rhyme; learn to isolate the beginning phoneme in words, and if so, do they use their alphabetic knowledge to do so	1hr, 4 days per week, group (3 children), 4 - 6 weeks into school year to 1 - 2 weeks to end of year	Research teachers

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
27	Nakeva von Mentzer et al. (2013)	n = 32 *DHH group n = 16 *NH group Location: Sweden Age: 5.0 - 7.11 HL: mild - prof Device/s: HA/ CI	Spoken Swedish	Inclusion: *DHH group -mild -prof bilateral SNHL, full time CI and/or HA users, no other disability, Swedish speakers. *NH group-normal hearing, speak Swedish, no disability affecting speech and language	Phoneme–grapheme training	Reading and comprehensi on	To examine the effects of phoneme–grapheme correspondence training in DHH children compared with age matched group of NH children	10 mins per day x 4 weeks	Digital device
28	Paatsch, Blamey, and Sarant (2001)	n = 12 Location: Aust Age: 5.11 - 10.5 HL: mod - prof Device/s: HA/ CI	Spoken English	Not stated	Effects of phonetic and phonological training methods	Phonetics and phonology	Drill and practice of articulation of phonemes at a phonetic level in repeated nonsense syllables will improve articulation of those phonemes but not in words or conversations; practice of articulation of phonemes at a phonological level in words, sentences & running speech will improve articulation of those phonemes; the articulation of untrained phonemes will not improve	Daily 15- 20-min individual or small group sessions over 8-week term	Teachers of the deaf
29	Paatsch, Blamey, Sarant, and Bow (2006)	n = 14 and 7 Location: Aust Age: 5.9 - 12.2 HL: sev - prof Device/s: HA/ CI	Spoken English	Inclusion: no sensory dyslexia or uncorrected visual impairment	Speech production and vocabulary training	Phonetics and phonology	To measure the effect of specific training in speech production and lexical knowledge on lexical knowledge and speech production; and to measure the effects of specific types of training on speech perception score	Daily 20-min individual or group session (2-3), 2 x 15-min session week blocks over 4 school terms	Spoken English

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
30	Pakulski and Kaderavek (2012)	n = 7 Location: USA Age: 9;4-11;1 HL: mild - prof Device/s: HA/ CI	Spoken English	Not stated	Cross-age reading program with manipulatives	Reading and comprehension	How does the narrative quality of school-age students with HL differ in response to two cross-age reading conditions: Does the narrative comprehension vary, and does participation in a cross-age reading intervention improve reading motivation and interest	Individual and group sessions over 4 days	Teacher and child 'reading buddies'
31	Pantelemidou, Herman, and Thomas (2003)	n = 1 Location: UK Age: 8;9 HL: prof Device: CI	Spoken English	Not stated	Electropalatography	Phonetics and phonology	To investigate the efficacy of electropalatography intervention	12 x 45min twice per week sessions	Clinician
32	Schirmer, Schaffer, Therrien, and Schirmer (2012)	n = 13 Location: USA Age: 9.2 - 12.5 HL: mild - prof Device: not stated	ASL, spoken English	Inclusion: convenience sample, Exclusion: below 1st grade reading level	Reread-Adapt and Answer-Comprehend Intervention	Reading and comprehension	To investigate the effect of the Reread-Adapt and Answer-Comprehend intervention on reading fluency and achievement	Individual session 2 - 3 per week x 8 weeks	Teachers of the DHH; grade teachers
33	Schopmeyer, Mellon, Dobaj, Grant, and Niparko (2000)	n = 11 Location: USA Age: 4.10 - 11.5 HL: prof Device/s: CI	TC, cued speech, Spoken English	Inclusion: attention and cognitive abilities necessary to understand intervention tasks	Fast ForWord™	Language	Do children with cochlear implants have the auditory capability to perform the fine discrimination, memory, and comprehension tasks presented through computer-generated, temporally altered signals, and will intense training and incremental increases in processing demand	5 x 20min games per day 5 days per week until criterion reached (about 8 weeks)	Digital device

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
							produce benefits in real-time language and auditory skills for the cochlear implant population?		
34	Silvestre and Valero (2005)	n = 5 (Exp) 28 (Control) Location: Spain Age: 4.4 - 5.10 (Exp) + 3.0 - 6 (Control) HL: prof Device/s: HA	Spoken Spanish	Inclusion: Prelinguistic HL, part of a larger population in transversal study	Musical Education	Language	The effect of music education on the development of oral language	2 x 45-min group sessions per week by class over 4 years	Teachers & clinicians
35	Smith and Wang (2010)	n = 1 Location: USA Age: 4 years HL: prof Device: CI	TC	Not stated	Visual Phonics in conjunction with a modified version of the Fountas and Pinnell Kindergarten Phonics Curriculum	Reading and comprehensi on	Does the use of Visual Phonics in conjunction with a phonics curriculum improve the phonological awareness and speech production? And if so, to what degree does the intervention improve phonemic awareness and phonics skills, word-learning skills, and representation of sounds in expressive language	15 - 20mins per day individual sessions; 4 days per week, over 7 weeks	Teacher and speech pathologist
36	Sugaya et al. (2014)	n = 60 (Intervention) + 30 (Control) + 628 (Baseline) Location: Japan Age: 4 - 12years HL: sev - prof	Sign and spoken Japanese	6-12 years of age, language delay > − 2SD in vocabulary, syntax, or communication/ discourse	Domain-based training	Language	To demonstrate the effectiveness of domain-based language training	12 x 40-min individual sessions over 6 months, face-to-face	Speech–language–hearing therapists

	Reference	Participants	Language	Inclusion/ Exclusion criteria	Type	Category	Research Aims/ Questions	Procedure	Provided by
		Device/s: HA/CI							
37	van Staden (2013)	n = 64 Location: South Africa Age: 6;03 - 11;08 HL: sev - prof Device/s: not stated	South African sign language and written English	Inclusion: reading two+ years behind grade level	Balanced reading	Reading and comprehension	Whether balanced reading intervention has a beneficial effect on deaf children's reading and vocabulary skills and knowledge	45-min sessions, small group instruction, 2-3 days per week over 9 months	Teachers
38	Wang, Spychala, Harris, and Oetting (2013)	n = 3 Location: USA Age: 3;11 - 4;7 HL: mod – prof/ central Device/s: HA/ CI/ unaided	ASL; signed and spoken English;	Convenience sample otherwise not stated	Visual phonics with phonics-based group reading instruction with smart board technology; phonics-based individual reading instruction	Reading and comprehension	Will a phonics based early intervention affect the early reading skills of preschool DHH students; and will DHH and hard of hearing students who have been given phonics-based early intervention in preschool sustain phonemic awareness and phonics skills and improve their reading skills, regardless of their instructional experiences in reading in early elementary school	20-min group sessions per day over 40 - 50 weeks, in classrooms, individual reading instruction in separate therapy rooms 1 x hour per week	Classroom teachers & graduate clinicians

Participants

Participants in the 38 studies ranged in age from 9 months to 18 years.[3] Hearing levels were reported for 37 of the studies (mild through to profound), and included both unilateral and bilateral hearing loss. Chan et al. (2000) did not report levels of hearing loss in their study, although all participants were cochlear implant users which would indicate that they were at a severe or profound level. Participants in all studies were either unaided, aided with hearing aids, aided with cochlear implants or used a combination of devices. Ten studies had cochlear implant users only, one study had a child with hearing aids only, and four studies did not state whether devices were used (Alton et al., 2011; Charlesworth et al., 2006; Schirmer et al., 2012; van Staden, 2013).

Different communication approaches were used across the 38 studies. These included spoken language approaches (16 studies), Total Communication (TC) (3 studies), Simultaneous Communication (SimCom) (1 study), and sign language (1 study). There were 16 interventions used across different communication approaches, and one conducted at a prelinguistic level. Sign and spoken languages were ASL, BSL, NZ Sign Language, South African Sign Language, Signing Exact English, Conceptually Accurate Signed English, Cued Speech, Japanese, Cantonese, Hebrew, Arabic, Spanish, Swedish and English. Participant sample sizes ranged from one child (4 studies) through to 90 children, with a median sample size of six children (mean= 13.8, SD=18.5).

Intervention and training programs were identified in six of the eight linguistic areas. The three linguistic areas with the highest number of interventions were reading and comprehension (10 studies), phonetic and phonology (10 studies), and lexicon and vocabulary (9 studies). Interventions to improve narrative and discourse skills were reported by four studies, pragmatic and social communication training programs (3 studies), and morphological interventions (2 studies). A further three interventions reported training programs to improve a child's total language skills. No interventions were identified for syntax and semantics, or writing and spelling.

Concerning the professions involved in delivery of interventions, the majority of interventions (21) were delivered by individual professionals who were either speech pathologists, teachers of the deaf, teachers, research assistants or project team members (unspecified). Interventions were delivered by classroom teachers (6 studies), teachers and clinicians working together (5 studies), and via digital device or computer software program (5 studies). Intervention providers were not identified in two studies (Chan et al., 2000; Higgins et al., 2000). Intervention mode was stated in all studies, and modes varied from individual one-to-one training (24 studies), small group (8 studies), to classroom-based

---

[3] Although this is older than the identified age criteria for studies, children within the same study were under the criteria age of 16 years.

interventions (1 study) and a combination of individual, small group and/or classroom-based approach (5 studies).

Interventions varied in frequency (number of sessions per day or week), duration (time period over which program was provided), and setting (where the intervention took place). Asad et al. (2013); Dwyer et al. (2009); Golos and Moses (2013); Pakulski and Kaderavek (2012) reported on interventions which took place over the shortest time period (over the course of one week) (Use of Dynamic Assessment, Training to Increase Speaking Rate, educational ASL video use and a Cross-age reading program). The majority of interventions took place over a 2 to 3-month period (17 studies) and between a 1- and 8-week period (11 studies). There were three interventions provided over a 5 to 6-month period, 3 studies over the course of a year. The longest intervention program was reported by Silvestre and Valero (2005), a musical intervention program, over the period of 4 years. All studies reported the timeframes within which the interventions were delivered, and inclusion and or exclusion criteria were reported for 26 of the 38 studies.

Controls

In total, seven of the 38 intervention studies that met inclusion criteria incorporated a control group in the study design. Control groups consisted of typical hearing participants (Charlesworth et al., 2006), waiting groups for intervention (Lam-Cassettari et al., 2015), groups receiving a reverse block of intervention (Bow et al., 2004; Paatsch et al., 2006; Sugaya et al., 2014), a comparison group from a wider study (Silvestre & Valero, 2005), and a group who received regular classroom instruction (van Staden, 2013). The remaining 31 intervention studies that did not incorporate specific control groups were repeated-measures studies with pre- and post-intervention comparisons.

Outcome Measures

The independent and dependent variables of eligible studies are detailed in Table 5 along with significance levels for reported outcomes. A statistically significant outcome was reported in 20 of the 38 studies (52%). An additional two studies reported a partially significant outcome (Higgins et al., 2000; Ingber & Eden, 2011). Referenced outcome measures were used by 11 studies, non-referenced tools and measures (14 studies), and a combination of tools (10 studies). Higgins et al. (2000) was the only study to use only an acoustic objective measure, whilst Dwyer et al. (2009) and Pantelemidou et al. (2003) used a combination of acoustic objective measures and rating scales. There was little similarity between the referenced outcome measures used, apart from those across studies investigating the same interventions, and those using recognised language analysis tools such as the Computer Aided Speech and Language Analysis (CASALA) (Serry, Blamey, Spain, & James, 1997) and the Systematic Analysis of Language Transcripts (SALT) (Miller & Chapman, 1985).

Table 5: Study design, independent variables, dependent variables and reportable significant outcomes

Reference		Study design	Independent variable (Intervention)	Dependent variables (Outcome measures)	Significant outcome reported
1	Alton et al. (2011)	Uncontrolled before/after; single subject	SmiLE therapy. Provided within a group context, as a ready-made social situation and opportunities to practice and extend communication skills into a social setting	- Pragmatic and functional communication skills measuring three aspects of interaction (entering, requesting, leaving) using designed criterion referenced measure - Clarity of communication	Y
2	Asad et al. (2013)	Uncontrolled before/after; single subject	Use of Dynamic Assessment to provide information to the SLP about the difficulties a child encounters by teaching an appropriate target using a specific teaching method (mediated learning), and assessing their learning, in terms of what they learn and the strategies they show in the process, in order to help build an appropriate intervention. Intervention was delivered through Mediated Learning Experience	- Test of Narrative Language (narrative production and comprehension subtests) (Gillam & Pearson, 2004) - Mediated Learning Experience Rating Scale, (mediator quality of mediation during sessions) - Modifiability Scale (child's ability to learn) - Response to Mediation Scale (a child is scored based on observation of the joint activity between the mediator and the child)	N
3	Bergeron et al. (2009)	Time-series; single subject	Semantic association strategy used to explicitly teach phoneme-grapheme correspondences embedded in the literacy intervention (enhanced Children's Early Intervention curriculum)	- Acquisition of phoneme-grapheme correspondences through a spoken-production assessment of ability to say the phoneme when shown the corresponding grapheme	N
4	Bergeron et al. (2009) (S2	Time-series; single subject	Semantic association strategy used to explicitly teach phoneme-grapheme correspondences embedded in the literacy intervention 'Foundations Curriculum'	- Acquisition of phoneme-grapheme correspondences through a spoken-production assessment of phoneme when shown corresponding grapheme - Phoneme-grapheme correspondence assessment - Alphabetic knowledge test - Decodable words test	N
5	Bernhardt et al. (2000)	Single subject	Palatometry treatment program	- Body (impairment) level: word structure & consonant accuracy in single word and connected speech of treatment and non-treatment targets - Activity level: judgement task 'ease to understand'	N
6	Bobzien et al. (2015)	Time-series; single subject	Repeated storybook reading; teacher's use of four explicit strategies employed during the direct instruction intervention sessions in which repeated reading occurred	- Frequency of correct expressive responses to verbal probes given immediately after the book was read	N
7	Bow et al. (2004)	Controlled before/after	Phonological training, Morphological training	- Production of trained and untrained phonemes in final position - Single Word Articulation Test (Paatsch, 1997) - Computer Aided Speech and Language Analysis (Serry et al., 1997) - Judgement of morphologically correct/incorrect sentences - Sentence test containing key words ending in targeted phonemes and morphological structures	Y

Reference		Study design	Independent variable (Intervention)	Dependent variables (Outcome measures)	Significant outcome reported
8	Bowers and Schwarz (2013)	Time-series; single subject	Direct instruction and child-directed intervention of new concepts	- Wiig Assessment of Basic Concepts (Wiig, Secord, & Semel, 2004) - Basic Concept–Curriculum-Based Measure	Y
9	Brady and Bashinski (2008)	Time-series; single subject	Adapted version of prelinguistic Milieu teaching	- Intentional communication acts coded by conversational type (initial, response to a question, response to a prompt), form (gestures, vocalisations, verbalisations, distal points, signs) and function (behavior regulation, joint attention, or social interaction) from videoed sessions	N
10	Chan et al. (2000)	Uncontrolled before/after; single subject	Intensive tone perception training	- Tone perception and production	N
11	Charlesworth et al. (2006)	Controlled before/after	Reading Recovery Intervention	- An Observation Survey of Literacy Achievement (Clay, 1993)	Y
12	Clendon et al. (2003)	Time-series	Earobics and SpeechViewer III intervention software	- Phonological Profile for the Hearing Impaired (Vardi, 1991) - Sentence structure subtest of the Clinical Evaluation of - Language Fundamentals (Semel, Wiig, & Secord, 1995) - Burt Word Reading Test – New Zealand Revision (Gilmore, Croft, & Reid, 1981) - Speech Perception BKB/A Speech Perception Test (Bench, Kowal, & Bamford, 1979) - Phonological awareness: subtests of the Queensland University Inventory of Literacy (Dodd, Holm, Oerlemans, & McCormick, 1996)	Y
13	Dwyer et al. (2009)	Uncontrolled before/after	Training to increase speaking rate	- Acoustic variables: speaking rate; formant frequency; formant bandwidth - Perceptual variables: Nasality ratings (comparison and degree)	Y
14	Encinas and Plante (2016)	Time-series; single subject	Enhanced conversational recast and auditory bombardment	- Responses to generalization probes (targeted and controlled grammatical forms) - Spontaneous use of target morphemes	N
15	Golos and Moses (2013)	Uncontrolled before/after	Educational video in ASL (with no sound) targeting key early ASL and literacy skills (i.e., vocabulary, letter recognition, concepts of print, comprehension, and grammatical features of ASL)	- ASL receptive skills test (Enns & Herman, 2011) - Vocabulary words and knowledge of story elements (research-developed assessment tool)	Y
16	Herman et al. (2015)	Time-series; single subject	Core vocabulary intervention	- Percentage consonants correct - Percentage vowels correct - Targeted and non-targeted words - Consistency of production - Intelligibility of speech (single words and sentences)	Y

Reference		Study design	Independent variable (Intervention)	Dependent variables (Outcome measures)	Significant outcome reported
17	Higgins et al. (2000)	Time-series; single subject	Visual feedback 1. Display of Po signal on oscilloscope, and 2. Movement of cellophane streamers	- Fundamental frequency - Electroglottographic cycle width - Po magnitude	P
18	Ingber and Eden (2011)	Uncontrolled before/after	Arranging and verbally describing pictorial scenarios	- Kaufman Assessment Battery for Children (picture series subtest) (Kaufman & Kaufman, 2013) - Guralnik's language screening test for Hebrew-speaking children (storytelling subtest) (Guralnik & Room, 1993)	P
19	James et al. (2013)	Time-series; single subject	Video Interaction Guidance	- Emotional Availability Scales Infancy/Early Childhood version, 4th edition (Biringen, Derscheid, Vliegen, Closson, & Easterbrooks, 2014) - The Tait framework (Tait & Lutman, 1997) - Frequency, onset, offset and duration of each mother– child dyads' vocal behaviours - Vineland Adaptive Behavior Scales (Sparrow, Balla, Cicchetti, Harrison, & Doll, 1984)	N
20	Justice et al. (2008)	Time-series; single subject	Narrative-based language intervention	- Quick Narrative Assessment (Miller, Gillam, & Peña, 2001) - Percentage of grammatically correct sentences, Systematic Analysis of Language Transcripts (Miller & Chapman, 1985)	N
21	Klieve and Jeanes (2001)	Time-series; single subject	The meaning differences that prosody conveys (questions, statements and commands, affect, intensity, stress, compound versus abutting words and grammatical class)	- Perception of Prosody Assessment Tool - Fundamental Speech Skills Test (Levitt, Youdelman, & Head, 1990)	N
22	Lam-Cassettari et al. (2015)	Randomised-patient	Video feedback of spontaneous parent–child interactions to increase appropriate responsiveness to a child's communicative cues and promote attuned behavior between parent and child	- Emotional Availability Scales, Infancy/Early Childhood version (Biringen et al., 2014) - Rosenberg Self-Esteem Scale (Rosenberg, 2015)	Y
23	Lew et al. (2014)	Time-series; single subject	Speech Perception Education and Assessment Kit (SPEAK)-Intervention Programme	- Early Speech Perception Test (Moog, Popelka, Geers, & Russo, 1990) - Peabody Picture Vocabulary Test (Dunn & Dunn, 2007) - 2500+ Words List - Goldman Fristoe Test of Articulation (Goldman & Fristoe, 2001) - Computer Aided Speech and Language Analysis (Serry et al., 1997)	N
24	Lund and Douglas (2016)	Time-series	Vocabulary instruction in 3 conditions a) explicit, direct instruction; b) follow-in-labelling; and c) incidental exposure	- Correct vocabulary words produced	N
25	Massaro and Light (2004)	Time-series	Language Wizard/Player for teaching new vocabulary	- Number of words identified and produced	Y
26	Miller et al. (2013)	Time-series; single subject	Explicit instruction of phonological awareness components (syllable segmentation, initial phoneme isolation, and rhyme recognition)	- Syllable segmentation, initial phoneme isolation and rhyme recognition measures - Early Speech Perception Test (Moog et al., 1990)	N

Reference		Study design	Independent variable (Intervention)	Dependent variables (Outcome measures)	Significant outcome reported
			embedded within Foundations for Literacy Curriculum	- Expressive One Word Picture Vocabulary Test (Brownell, 2000) - Peabody Picture Vocabulary Test (Dunn & Dunn, 2007) - Phonological Awareness Test (Webb, Schwanenflugel, & Kim, 2004) - Rhyme Recognition Test (Byrne & Fielding-Barnsley, 1991)	
27	Nakeva von Mentzer et al. (2013)	Time-series	Computer assisted intervention on phoneme-grapheme correspondences	- Sound Information Processing System Nonword Repetition test - Phonological Representation test - Nonword Discrimination test - Phoneme Identification test (Wass et al., 2008) - Phoneme test/Naming test (Hellquist, 1995) - Letter knowledge of sounds and names (Clay, 1979) - Letter naming	Y
28	Paatsch et al. (2001)	Uncontrolled before/after; single subject	Phonetic level training (nonsense syllable) Phonological level training (word training) No training	- Phonetic Level Evaluation (Ling, 1976) - 108 Single Word Articulation Test (Paatsch, 1997) - Computer Aided Speech and Language Analysis (Serry et al., 1997)	Y
29	Paatsch et al. (2006)	Controlled before/after	Training speech production skills (method A), training specific words (method B)	- Speech perception - Reading-aloud and word knowledge measure (designed list of 109 monosyllabic consonant–vowel–consonant words; - Sensory abilities measure (auditory-alone speech perception score divided by the reading-aloud score (Paatsch, Blamey, Sarant, Martin, & Bow, 2004) - 108 Single-Word Articulation Test (Paatsch, 1997) - Computer Aided Speech and Language Analysis (Serry et al., 1997)	Y
30	Pakulski and Kaderavek (2012)	Uncontrolled before/after; single subject	Cross-age reading intervention (Reading Only; Reading and Manipulative)	- SNAP Narrative Assessment Procedure (Strong, Mayer, & Mayer, 1998) - Systematic Analysis of Language Transcripts (Miller & Chapman, 1985) - Story Grammar Analysis Protocol (Pakulski & Kaderavek, 2001) - Faces Rating Scale of Literacy Motivation and Interest questionnaire	Y
31	Pantelemidou et al. (2003)	Single subject design	Electropalatography	- Linguapalatal contact patterns - Perceived intelligibility ratings	Y
32	Schirmer et al. (2012)	Uncontrolled before/after; single subject	Reread-adapt and answer-comprehend intervention	- Running Records assessment (Clay, 2001) - Woodcock-Johnson III Achievement Tests (Woodcock, McGrew, Mather, & Schrank, 2001) - Readings to reach criterion - Word reading errors per session - Reading time per passage per session - Comprehension questions correct	Y
33	Schopmeyer et al. (2000)	Uncontrolled before/after; single subject	Computer-based language-auditory skill training protocol (Fast ForWord™)	- Clinical Evaluation of Language Fundamentals Preschool (Wiig et al., 2004) - Clinical Evaluation of Language Fundamentals-3 (Semel et al., 1995) - Test of Auditory Perceptual Skills-Revised (Gardner, 1985)	Y

Reference		Study design	Independent variable (Intervention)	Dependent variables (Outcome measures)	Significant outcome reported
				- Token Test for Children (McGhee, Ehrler, & DiSimoni, 2007) - Assessment of Children's Language Comprehension (Foster, Giddan, & Stark, 1973) - Phonological Awareness Test (Robertson & Salter, 1997)	
34	Silvestre and Valero (2005)	Controlled before/after	Program of musical training	- Oral language production through explanation of comic strip - Judgements of speech intelligibility - Functional hearing (discrimination & identification of sounds, supra-segmental and segmental aspects of speech) - Acoustic voice analysis	Y
35	Smith and Wang (2010)	Single subject design	Visual phonics as a reading instructional tool	- Hear and produce /i/, /u/, /a/ - Identification and production of beginning consonant sounds and letters in words	N
36	Sugaya et al. (2014)	Controlled before/after	Domain-based language training	- Assessment package for language development in Japanese hearing-impaired children (Fukushima et al., 2012) - Test of Query-Answering Relationship (Satake, Higachie, & Chinen, 1996) - Word Fluency Test (Koren, Kofman, & Berger, 2005) - Picture Vocabulary Test–Revised (Ueno, Nagoshi, & Konuki, 2008) - Syntactic Processing Test for Aphasia (Nakajima, Horai, Sugita, Tatsumi, & Hamanaka, 1997) - Raven’s Coloured Progressive Matrices (Uno, Shinya, Haruhara, & Kaneko, 2005) - Pervasive Developmental Disorders Autism Society of Japan Rating Scale (Yamada et al., 2007)	Y
37	van Staden (2013)	Randomised - patient	Balanced reading approach of applying multi-sensory coding and scaffolding	- Raven’s Colored Progressive Matrices-non-verbal intelligence (Raven, 1990) - ESSI reading tests-word recognition (Esterhuyse, 1997) - Sight word knowledge - Receptive and expressive vocabulary knowledge - Reading comprehension test	Y
38	Wang et al. (2013)	Uncontrolled before/after; single subject	Visual phonics with phonics-based group reading instruction with smart board technology; phonics-based group reading instruction with smart board technology	- Test of Preschool Early Literacy (Lonigan, Wagner, Torgesen, & Rashotte, 2007) - Phonological Awareness Literacy Screening (Invernizzi, Sullivan, Meier, & Swank, 2004) - Woodcock-Johnson III Tests of Achievement (letter word identification, spelling; passage comprehension; word attack) (Woodcock et al., 2001)	N

Study Designs

As detailed in Table 5, of the 31 before/after (pre-post) studies with no control groups, 20 were single-subject designs. Of these, 17 studies were a time-series design, whereby repeated baseline measures were followed by an intervention period and subsequent follow up measures. Of the seven controlled intervention studies, participants were randomised in two studies, and five studies were non-randomised participant designs.

Study Quality and Risk of Bias

A description of the methodological quality and quality assessment ratings for before/after (pre-post) studies with *no control group* using the NIH Study Quality Assessment tool (National Heart Lung and Blood Institute and Research Triangle Institute International, 2018) is provided in Table 6. Of studies with no control group, six studies reported on eight or more of the 12 defined areas, 19 studies provided detail on six or seven areas, and a further six studies reported on five or fewer areas. All 38 intervention studies reported:

- a clear question or objective;
- pre-specified eligibility criteria;
- a representative participant sample;
- clear description of the intervention procedure;
- outcome measures that were defined, valid, reliable and consistently assessed; and
- a loss of participants to follow up rate of less than 20%.

Table 6: Methodological quality and quality assessment ratings for before/after (pre/post) studies with no control group

(Y=Yes, N=No, NS=Not Stated, CD=Cannot Determine)

	Reference	Kmet rating	Study question/ objective clearly stated	Eligibility criteria prespecified and clear	Participants representative	All eligible participants enrolled	Sample size sufficiently large to provide confidence	Intervention clearly described and delivered consistently	Outcome measures prespecified, defined, valid, reliable, and assessed consistently	Assessors blinded	Loss to follow-up 20% or less and accounted for	Statistical methods examine change	Interrupted time series design	Individual-level data considered if analysis at group level	
1	Alton et al. (2011)	5	Y	Y	Y	NS	N	Y	Y	Y	Y	Y	N	N/a	8
2	Asad et al. (2013)	5	Y	Y	Y	N	N	Y	Y	Y	Y	N	N	N/a	7
3	Bergeron et al. (2009)	5	Y	Y	Y	Y	N	Y	Y	N	Y	N	P	N/a	7
4	Bergeron et al. (2009) (S2	5	Y	Y	Y	Y	N	Y	Y	N	Y	N	Pl	N/a	7
5	Bernhardt et al. (2000)	5	Y	N	Y	N	N	Y	Y	Y	Y	N	P	N/a	6
6	Bobzien et al. (2015)	5	Y	Y	Y	NS	N	Y	Y	N	Y	N	Y	N/a	7
8	Bowers & Schwarz (2013)	6	Y	N	Y	NS	N	Y	Y	N	Y	N	Y	N/a	6
9	Brady and Bashinski (2008)	6	Y	N	Y	CD	N	Y	Y	Y	Y	N	N	N/a	6
10	Chan et al. (2000)	1	Y	N	CD	CD	N	CD	Y	CD	Y	N	N	N/a	3
12	Clendon et al. (2003)	6	Y	N	Y	CD	N	Y	Y	N	Y	Y	N	N/a	6
13	Dwyer et al. (2009)	6	Y	Y	Y	CD	N	Y	Y	Y	Y	Y	N	N/a	8
14	Encinas & Plante (2016)	6	Y	N	Y	CD	N	Y	Y	N	Y	N	P	N/a	5
15	Golos & Moses (2013)	5	Y	Y	Y	N	N	Y	Y	N	Y	Y	N	N/a	7
16	Herman et al. (2015)	5	Y	N	Y	CD	N	Y	Y	N	Y	Y	P	N/a	6
17	Higgins et al. (2000)	5	Y	N	Y	CD	N	Y	Y	N	Y	Y	Y	N/a	7
18	Ingber & Eden (2011)	5	Y	Y	Y	CD	N	Y	Y	N	Y	Y	N	N/a	7
19	James et al. (2013)	5	Y	Y	Y	N/a	N	Y	Y	Y	Y	N	Y	N/a	8
20	Justice et al. (2008)	5	Y	N	Y	CD	N	Y	Y	CD	Y	N	N	N/a	5
21	Klieve & Jeanes (2001)	5	Y	N	Y	CD	N	Y	Y	CD	Y	N	N	N/a	5
23	Lew et al. (2014)	5	Y	Y	Y	Y	N	Y	Y	NS	Y	N	Y	N/a	8
24	Lund & Douglas (2016)	5	Y	Y	Y	CD	N	Y	Y	CD	Y	N	N	N/a	6

	Reference	Kmet rating	Study question/ objective clearly stated	Eligibility criteria prespecified and clear	Participants representative	All eligible participants enrolled	Sample size sufficiently large to provide confidence	Intervention clearly described and delivered consistently	Outcome measures prespecified, defined, valid, reliable, and assessed consistently	Assessors blinded	Loss to follow-up 20% or less and accounted for	Statistical methods examine change	Interrupted time series design	Individual-level data considered if analysis at group level	
25	Massaro & Light (2004)	4	Y	CD	N	CD	N	Y	Y	N	Y	Y	Y	N/a	6
26	Miller et al. (2013)	6	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	N/a	8
27	Nakeva von Mentzer et al. (2013)	10	Y	Y	Y	N	N	Y	Y	NS	Y	Y	Y	N/a	8
28	Paatsch et al. (2001)	5	Y	NS	Y	CD	N	Y	Y	NS	Y	Y	N	N/a	6
30	Pakulski and Kaderavek (2012)	4	Y	NS	Y	CD	N	Y	Y	NS	Y	Y	N	N/a	6
31	Pantelemidou et al. (2003)	5	Y	N	Y	CD	N	Y	Y	NS	Y	Y	N	N/a	6
32	Schirmer et al. (2012)	5	Y	Y	Y	NS	N	Y	Y	No	Y	Y	N	N/a	7
33	Schopmeyer et al. (2000)	5	Y	N	Y	CD	N	Y	Y	NS	Y	Y	P	N/a	6
35	Smith & Wang (2010)	4	Y	N	Y	CD	N	Y	Y	N	Y	N	N	N/a	5
38	Wang et al. (2013)	5	Y	N	Y	CD	N	Y	Y	N	Y	N	N	N/a	5

Multiple measures taken before and/or after the intervention (i.e., an interrupted time-series design) was used in 13 of the intervention studies, increasing the confidence in intervention effects. A total of 16 studies reported inter-rater reliability measures, and fidelity measures of adherence to treatment protocols was reported in eight studies. It was not clear in 21 studies if all eligible participants were enrolled. All of the studies were limited in their statistical power due to the number of available or recruited participants. All studies had some risk of bias. Although blinding was often cited as a consideration, particularly in the discussion of limitations, assessor blinding was only included in the design in seven studies. These used either video recordings or transcriptions, and scorers who were blind to the goals, timings and/or treatment, or untrained listeners of speech intelligibility tasks blinded to the timing of recording (pre/post intervention).

A description of the methodological quality and quality assessment ratings for studies with a *control group* are detailed in Table 7. Of these controlled studies, Lam-Cassettari et al. (2015) reported on 12 of the 14 areas on the Video Interaction Guidance intervention study. As a result, this study had the lowest risk of bias across all studies. The remaining six controlled intervention studies reported on six to eight areas. Control groups reported in Charlesworth et al. (2006) and Lam-Cassettari et al. (2015) were similar at baseline measures, however, Silvestre and Valero (2005) and Paatsch et al. (2006) reported differences at baseline. Levels of similarity were not stated for the remaining control groups. Only two interventions employed a randomised control group design (Lam-Cassettari et al., 2015; van Staden, 2013).

Phase of Research Intervention Design

According to the framework model of Finestack and Fey (2017), the majority of studies that met methodological criteria for this review were early efficacy studies (quasi-experimental in nature), and past the feasibility stage that assesses value in moving into a trial stage. The two intervention studies that met the criteria for later efficacy studies were those that employed an experimental randomised design (Lam-Cassettari et al., 2015; van Staden, 2013) as they provided information on cause-effect relationships of the interventions in generalisable conditions. Neither of these studies had the sample size required for sufficient statistical power.

Table 7: Methodological quality and quality assessment ratings for studies with a control group

(Y=Yes, N=No, NS=Not Stated, CD=Cannot Determine)

Reference		Kmet rating	Randomised/ trial/clinical trial/ RCT	Method of randomisation adequate	Treatment allocation concealed	Participants and providers blinded	Assessors blinded	Groups similar at baseline	Overall drop-out rate 20% or lower at endpoint	Differential drop-out 15%age points or lower at end point	High adherence to intervention protocols	Other interventions avoided	Valid and reliable outcome measures implemented consistently	Sample size was sufficiently large for 80% power	Pre-specified outcomes reported or subgroups analysed	Use of intention-to-treat analysis	
7	Bow et al. (2004)	6	N	N/a	N/a	N	N	NS	Y	Y	Y	Y	Y	N	Y	Ye	7
11	Charlesworth et al. (2006)	9	N	N/a	N/a	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	8
22	Lam-Cassettari et al. (2015)	12	Y	Ye	Y	N/a	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	12
29	Paatsch et al. (2006)	9	N	N	N	N	NS	N	Y	Y	Y	Y	Y	N	Y	Y	7
34	Silvestre and Valero (2005)	6	N	N/a	N/a	N	N	N	Y	Y	Y	Y	Y	N	Y	N/a	6
36	Sugaya et al. (2014)	8	N	N/a	N	N/a	N	NS	Y	Y	Y	Y	Y	N	Y	N/a	6
37	Van Staden (2013)	8	Y	NS	CD	N	N	NS	Y	Y	Y	y	Y	N	Y	Y	8

Effects of Intervention

The following results section outlines the evidence of the effects of intervention across the range of outcome measures reported in the 38 studies. This discussion is grouped by linguistic area and a list of studies by area is provided in Appendix C.

Reading and Comprehension

Following the implementation of a Reading Recovery intervention program Charlesworth et al. (2006) reported a significant increase in scores on all tasks (apart from letter identification) across both Deaf and hearing groups. Changes in scores from beginning to completion of lessons were significant at either $p \leq .001$ or $p \leq .005$ level (2-tailed). Nakeva von Mentzer et al. (2013) reported all participating children improved their accuracy in phoneme–grapheme correspondence and output phonology after computer assisted intervention on phoneme-grapheme correspondences, with a moderate to strong effect ($p < .01$, $\eta_p^2 = .42$). Pakulski and Kaderavek (2012) demonstrated a significant result ($p = .026$) in narrative production and comprehension when manipulatives were used as part of cross age reading intervention. A significant improvement was reported in students' self-ratings of literacy motivation and interest to read ($z = -2.38$, $p = .017$).

Schirmer et al. (2012) reported significant results for all but the passage comprehension measure with reread-adapt and answer-comprehend intervention. A small effect size was reported for reading fluency ($p = .003$, Cohen's $d = .33$) and a moderate effect size for running records ($p = 0.000$, Cohen's $d = .43$), letter-word identification ($p = .001$, Cohen's $d = .46$), and reading vocabulary ($p = .005$, Cohen's $d = .51$). van Staden (2013) reported on a balanced reading approach of applying multi-sensory coding and scaffolding intervention, and found significant differences in post-intervention scores between the experimental and control groups in sight word reading ($t = 32.53$, $df = 62$; $p < .0001$); word recognition (ESSI) ($t = 28.17$, $df = 62$; $p < .0001$); receptive and expressive vocabulary knowledge ($t = 20.58$, $df = 62$; $p < .0001$); and reading comprehension ($t = 16.49$, $df = 62$; $p < .0001$).

Bergeron et al. (2009) reported that all children reached criteria for all correspondences following the use of semantic association strategy intervention (embedded in an enhanced children's early intervention curriculum), with no errors after reaching criterion. In the second part of the study, semantic association strategy was embedded in an early literacy intervention ('Foundations curriculum'). As a result of the intervention children reached criteria for unknown trained correspondences, maintaining 100% accuracy. Miller et al. (2013) also embedded an intervention (explicit instruction of phonological awareness components) within the Foundations for Literacy Curriculum. Of the 5 children, 4 were able to segment words consistently after the intervention, with an effective and clear functional relationship between rhyme instruction and initial sound isolation. Smith and Wang (2010) demonstrated improvements in children identifying target first letters, sounds in words, matching consonant letters and sounds following visual phonics intervention. Wang et al. (2013) reported on visual phonics training, with phonics-based group reading instruction with smart board technology. Improvements were demonstrated in early reading skills and all 3 children were able to sustain phonemic awareness and phonics skills at the follow up assessment point over a year later.

Phonetics and Phonology

A number of interventions focused on improving children's speech clarity and production. Bernhardt et al. (2000) reported a palatometry treatment program[4] following a period of traditional speech therapy. Results indicated word shape accuracy improved with changes in word shape and consonant accuracy occurring during the palatometry period, and an increase in accurate judgements of identifications of single words and words in sentences (from 12% to 50% accuracy). Chan et al. (2000) reported that 3 children showed improvements in tone perception training, and 1 child improved in both tone perception and production following training. Dwyer et al. (2009) reported both productive and perceptual aspects of speech nasality decreased following training to increase speaking rate, with significant values for a narrower F2 bandwidth post-intervention ($t\,(10) = 2.61$, $p = .02$, $\triangle = 1.03$), and less perceived nasality ($t\,(20) = 2.23$, $p = .03$, $\triangle = 0.95$).

Higgins et al. (2000) reviewed results of visual feedback intervention to treat negative intraoral air pressure. The production of both participants in the study changed in ways that were consistent with their phonatory goals, although changes were not all statistically significant. Pantelemidou et al. (2003) reported a significant effect in both taught and untaught words following electropalatography treatment. This effect was maintained after completion of intervention on two post intervention measures, words $F(2, 27) = 105.59$, $p < .0001$, and time $F(2, 54) = 472.67$, $p < .0001$).

Paatsch et al. (2001) reported results of phonetic level training (nonsense syllable) and phonological level training (words). Participants demonstrated significant improvements in the production of trained phonemes (phonological level mean improvement = 17.3%; $F = 31.22$; $df = 1.\ 55$; $p < .001$; phonetic level mean improvement = 11.6%; $F = 9.38$; $df = 1, 55$; $p = .003$). Slight improvements were observed for untrained vowels 6.4% ($F = 10.64$; $df = 1, 55$; $p = .02$) and untrained consonants 5.1% ($F = 12.01$; $df = 1, 55$; $p = .001$). Bow et al. (2004) reported on phonological and morphological training in a comparison study of the impact of both types of training on speech perception and grammatical judgements. Children in the study demonstrated significant improvement in their morphological skills after phonological training ($t = 2.45$, $p = .01$), but no significant improvement in phonological skills for either trained or untrained phonemes after either type of training.

[4] A computerised visual-auditory feedback tool that provides on-line dynamic display of the tongue's contact on the hard palate (Bernhardt et al., 2000).

A number of studies assessed speech production and perception. Clendon et al. (2003) reported speech, language and early literacy measures following use of the Earobics and SpeechViewer III intervention software programs. Speech production outcomes were significant following training ($F(2, 8) = 57.277$, $p < .001$), and a significant group effect was observed for sentence structure ($F(2, 8) = 5.725$, $p = .029$). No significant group effects were observed for reading, speech perception, or phonological awareness. A significant treatment effect was found for syllable identification ($F(2,8) = 8.523$, $p < .01$), syllable segmentation ($F(2,8) = 5.180$, $p = .036$), phoneme segmentation ($F(2,8) = 11.541$, $p = .004$) phoneme manipulation ($F(2,8) = 4.844$, $p = 0.042$) and non-word reading ($F(2,8) = 8.526$, $p = .01$).

Paatsch et al. (2006) compared speech production intervention training (method A), with training specific words (vocabulary training - method B). The two groups were trained in both methods in opposite order (AB/BA) to balance any effects of order of intervention. Significant improvements were observed in the word knowledge of children in the study after both speech production training (t [20] = 3.93, $p < .001$) and vocabulary training (mean improvement = 16.0%, $t[20] = 5.62$, p < .001). Both method A ($t[20] = 4.07$, $p < .001$) and B ($t[20] = 5.09$, $p < .001$) contributed to increases in overall group performances in speech perception scores, and reading aloud scores ($t[20] = 3.14$, p < .005) and ($t[20] = 2.98$, p < .007). No studies were identified in the review to improve the shape of sign, cued speech or total communication articulations or productions.

Lexicon and Vocabulary

Vocabulary intervention outcomes were reported in 4 studies. Bobzien et al. (2015) demonstrated all children in the study improved in vocabulary use from baseline to post-intervention, following reported storybook reading paired with explicit teacher instruction to teach novel vocabulary. Improvements generalised to a novel situation and vocabulary change was maintained for up to 4 weeks. Golos and Moses (2013) reported results following the use of an educational video series in American Sign Language (ASL). Significant differences were observed in pre and post test scores for participants ($F(1, 28) = 23.32$, $p < .001$, $\eta\rho^2 = .454$) regardless of the baseline score. Herman et al. (2015) observed a significant increase in vocabulary as well as targeted story elements following core vocabulary intervention. All children demonstrated positive changes post therapy, with a mean difference for consonants of +10.3% and vowels +10.8%. Mean positive difference scores at the maintenance datapoint 6 weeks after the completion of the therapy was +4.2% (consonants) and +5.5% (vowels), indicating that improved speech accuracy was maintained.

Lew et al. (2014) reported an increase in speech perception and speech development skills following the use of the Speech Perception Education and Assessment Kit intervention program (SPEAK), with 2 participants showing a significant growth in receptive vocabulary. The evaluation of a digital training program by Massaro and Light (2004) indicated that learning occurred for trained words, with an average accuracy across identification and production improving from .173 to .681 (F(l, 7) = 127.54, p < .001). Lund and Douglas (2016) reported on vocabulary instruction intervention across three conditions: explicit instruction, follow-in labelling, and incidental exposure. All 9 participants learned the most vocabulary in the explicit instruction condition (average 4.93 words) compared to follow-in labelling (2.86 words) and incidental exposure (0.24 words). Between-case effect size was calculated compared to baseline at g = 2.74 for explicit instruction, g = 2.01 follow-in labelling, and g = 0.54 for incidental exposure.

Bowers and Schwarz (2013) measured basic concept instruction intervention, using the Basic Concept–Curriculum-Based Measure. Although the intervention and communication outcomes were by-products of the main aim of this study (to determine if the measure was able to accurately assess and monitor progress), scores of concept knowledge improved for all participants during the intervention phase and changes in pre to post intervention scores were all positive. Brady and Bashinski (2008) demonstrated positive improvements in pre-linguistic outcomes from the adapted version of Prelinguistic Milieu Teaching. All participants increased initiated communication over the course of the intervention and demonstrated increases in the use of behaviour regulation communication acts. The number of prompted communication acts decreased as participants became more independent in their communication, and as new communication acts increased.

Narrative and Discourse

Asad et al. (2013) used dynamic assessment to evaluate narrative language learning. Of the 3 participants, 2 improved their oral narrative skills (3rd to 84th percentile, and > 99th percentile). Ingber and Eden (2011) demonstrated a clear improvement in performance following sequential time perception and storytelling intervention across all 34 participants, with the most significant improvement in sequential time ability as a mean score of 2.18 (SD = 2.12) at pre-test to a mean of 4.71 (SD = 3.35) post-test, t(33) = 6.08, p < .001. There was a smaller but significant improvement in storytelling ability, improving from a mean score of 7.94 (SD = 6.13) pre-test to a mean of 9.44 (SD = 6.57) post-test, t(33) = 2.51, p < .05. No significant differences were observed in progress rates for children with lesser versus greater language delays.

Justice et al. (2008) reported a narrative-based language intervention program in which 2 of the 3 participants made gains in narrative quality following the intervention period. All 3 participants demonstrated generalisation of syntactic targets into conversational speech over the course of intervention. The participants' percentage of grammatically correct utterances increased by an average of 30% (mean final score 57%). Klieve and Jeanes (2001) reported that all participants improved on their combined perception scores for variations in intensity, duration and pitch (86.8% to 98%) following an intervention program focused on improving perception and understanding of prosodic cues in different linguistic contexts. Combined production results of pitch and supra-segmental sounds indicated an overall improvement by all participants (442.4-588.2 of a possible 600).

Morphology

In a comparison study of morphological and phonological training Bow et al. (2004) reported that after morphological training, participants demonstrated significantly improved morphological skills (t=2.13, p=0.02). A significant improvement in speech perception scores was found after both morphological and phonological training (final scores and all previous scores for both words and phonemes $t \geq 2.72$, $p \leq .032$). Encinas and Plante (2016) also reported all 3 participants demonstrated increases in target morpheme use relative to the pre-treatment baseline (d = 2.7, 1.9, 1.8) after enhanced conversational recast treatment followed by a period of auditory bombardment. Two participants made significant gains in spontaneous use of the trained morpheme (d = 24.2, 19.6), with 1 participant making gains on a control grammatical form (d =1.1).

Pragmatics and Social Communication

Of the 3 studies analysing the effectiveness of pragmatic interventions, 2 studies examined the effect of Video Interaction Guidance on communication, and both measured communication outcomes in combination with parental involvement and sensitivity levels in interactions. James et al. (2013) used the Tait Framework (Tait & Lutman, 1997) to assess pre-verbal vocalisations, and the Emotional Availability Scales (Biringen et al., 2014) to score the quality of interactive congruence of 3 parent-child dyads. Results indicated an eradication of non-responses after the intervention, maintained at follow up for all cases. Lam-Cassettari et al. (2015) reported on child responsiveness and child involvement in communicative interactions between 14 hearing parents with a prelingual child with hearing loss, and on 4 dimensions of the Emotional Availability Scales (Biringen et al., 2014). Child responsiveness increased following the intervention assessment visit ($F(1, 12) = 20.757$, p = < .01, $\eta p^2 = .63$) with an increase from pre-intervention (M = 4.79) to post-intervention (M = 5.36). Child involvement scores increased ($F(1, 12) = 41.354$, p = < .01, $\eta p^2 = .78$) with significantly lower scores pre-intervention (M = 4.79) to post-intervention (M = 5.38). Alton et al. (2011) evaluated the use of SmiLE therapy (strategies and measurable interaction in live English). Participants' abilities to make successful requests in communication situations were measured using 3 pragmatic aspects of interactions. Scores after treatment were observed to be significantly higher than those before treatment ($F(1, 15) = 23.51$, $p < .001$) and no effect was observed in untreated situations.

Total Language

Schopmeyer et al. (2000) used standardised language assessments to measure the impact of Fast ForWord™, a computer-based language-auditory skill training system. All 11 children demonstrated significant improvement on all tests ($p < .05$) after 8 weeks of training. Sugaya et al. (2014) assessed language scores after a 6-month domain-based language training program across an intervention and control group and compared these with a larger baseline study group. Results indicated language growth in the intervention group (60 children) was significantly better than that in the control group (30 children) ($P < .05$). Mean monthly improvements in language scores in the intervention group were significantly higher than those in the larger baseline study group (628 children) ($P < .001$). Silvestre and Valero (2005) evaluated communication outcomes following a music education intervention program using an oral language measure, speech intelligibility, sound discrimination/ identification assessment, and acoustic voice analysis in an experimental group (5 children) and control group (28 children). Although the study did not provide evidence to support the initial objective of improving linguistic dimensions such as discourse organisation and syntactic structure, positive effects were seen in sentence structure and improved growth from 2-word sentences (in the control group) to simple sentences (the experimental group).

Discussion

Summary of Main Findings

The aim of this systematic review was to identify and evaluate the evidence for effective intervention, therapy and training programs that support the development of communication skills by children with hearing loss. Within the defined criteria, 38 experimental and quasi-experimental studies were identified for analysis. The largest number of interventions were literacy-based, consistent with the extensive number of approaches to literacy development, and the reported difficulties children with hearing loss have in developing proficient reading and writing skills (Carney & Moeller, 1998; Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008). Overall, the review highlights the very small number of therapeutic intervention studies that have been published in the last 16 years. More than half of these studies were published in the last 6 years, indicating that this number is growing in response to the need for evidence by health and education professionals.

Research Designs and Levels of Evidence

A number of challenges exist in establishing a meaningful evidence-base for therapeutic interventions for children with hearing loss (Wendel et al., 2015). These challenges include the social and demographic diversity of children, and hearing loss; differences in educational, home and communicative settings; lack of clinical resource and funding required to conduct high level clinical studies; ethical and logistical difficulties of groups receiving different treatments or programs, or lack thereof; and the complexity in reliably reproducing findings due to inherent differences in each child's hearing levels (Luckner, 2006; Luckner, Sebald, Cooney, Young III, & Muir, 2005). Due to these recognised and accepted difficulties, few studies are able to incorporate a randomised design, especially with large, matched control groups (Kazdin, 2011). This review of the literature indicates that although challenging, it is not impossible to design and implement a randomised control design to determine the efficacy of a therapeutic intervention.

Another outcome of this systematic review has been the exemplification of how a particular intervention can develop progressively through phases of design, providing increasing evidence of efficacy. This was demonstrated in the case of Video Intervention Guidance. A single case study published by Pilnick and James (2013) was initially identified for this review but excluded because it was a descriptive feasibility study with no communication measure. This study was the precursor for James et al. (2013)'s early efficacy study on the intervention program (which met inclusion criteria). The outcomes of the 2013 study provided the base for the later efficacy study (also identified in this review) by Lam-Cassettari et al. (2015). The 2015 study builds methodologically in design from the earlier studies, providing stronger and more compelling levels of efficacy evidence for the results achieved using the intervention (Finestack & Fey, 2017).

As health professionals delivered 95% of the interventions in this review, it could be proposed that these fit the final stage of 'effectiveness studies' as proposed in Finestack and Fey (2017)'s clinical research development model. That is, they are undertaken with typical populations, under real-world conditions. The problem though, is that they do not have the efficacy levels typically regarded necessary for translation to real-world applications through the progression of evidence-based intervention research. One solution to this dilemma of 'effectiveness without efficacy' has been the suggestion of blocks of translational and implementational research (Enna & Williams, 2009; Seely & Grinspoon, 2009; Sung et al., 2003). It is also worth considering that a different evidence based model of development for clinical interventions is necessary. Green (2008) advocates for this in the practice-based production of research and discusses the fallacy of the one-way pipeline of transferring research to practice. A framework that can guide the growth and development of early efficacy level intervention studies, based and trialled in clinical and education settings, could have the potential for wide-spread application of practice-based research in this context and support professionals in their use of evidence to guide their practice. The uptake of results from randomised controlled trials can be limited due to barriers in dissemination and/or implementation beyond academic settings, and clinicians and educators can find it difficult to generalise results to their own circumstances (Grol & Wensing, 2004; O'Connor & Pettigrew, 2009). Given the clinical desire to improve children's outcomes through intervention, and the professional demands for evidence-based practice guidance, the inclusion of evidence from different levels of well-designed intervention studies seems critical (Carey & Stiles, 2016; Howard, Best, & Nickels, 2015).

In addition to the possibility of randomised controlled designs despite the difficulties involved, this review highlights the growing body of well designed, single subject designs that can provide supplementary and valuable evidence. Of the studies in this review, 52% (n = 20) used a single subject experimental design. This proportion is slightly higher than the prevalence of single subject designs in systematic reviews conducted in parallel fields. Tate et al. (2004) reported 39% of studies in their review of language interventions for patients with head injury were single subject designs, Beeson and Robey (2006) reported 41% for aphasiology interventions, and Baker and McLeod (2011) reported 29.6% single subject designs in their reviews of interventions for speech sound disorders. As single subject experimental designs enable a child to serve as their own control, change is measured only in comparison to the individual and not across a group. In this context where the relationship between the intervention and outcomes can be more diverse than in biomedical sciences and trials in treatment laboratories, single subject designs can demonstrate clear causal relationships between intervention and change (Nock, 2007). With the existing challenges to the establishment of a strong and valid knowledge base, the accumulation of evidence on specific interventions through single subject designs has potential to provide information that educators and clinicians are seeking. Following similar recommendations in allied health and education fields, developing a series of robust single case studies provides the opportunity for collaboration between clinical researchers and health and education professionals to build the necessary and meaningful evidence base (Baker & McLeod, 2011; Green, 2008; Grol & Grimshaw, 2003).

The strong internal validity demonstrated in many of the studies identified in this review provide examples for clinicians and researchers to consider when designing experimental methodologies. These include additional time point measures (Herman et al., 2015; Higgins et al., 2000; James et al., 2013; Justice et al., 2008), blinding considerations (Alton et al., 2011; Bernhardt et al., 2000; James et al., 2013), reversal and alternating designs (Bow et al., 2004; Higgins et al., 2000; Lund & Douglas, 2016; Paatsch et al., 2006), multiple baseline designs (Bobzien et al., 2015; Lew et al., 2014), inter-rater reliability (Asad et al., 2013; Dwyer et al., 2009) and fidelity measures (Ingber & Eden, 2011; Schirmer et al., 2012).

Reporting Outcomes

All studies included in this review reported at least some positive effects of intervention, with statistically significant intervention effects in 22 of the 38 studies. Although a meta-analysis was not possible due to differences between interventions, research designs, heterogeneity and risks in pooling different outcome measures, a narrative analysis was able to provide a valuable overview of the current evidence. For interpretation and application of these findings, it is important for professionals to access the individual studies to understand the findings in relation to their own clinical questions, rather than relying solely on the results reported here given the varying degrees of bias and methodological quality. This can also support understanding of the measures used, how the interventions were implemented, and the relationship between the intervention and outcomes reported.

In reviewing how outcomes were reported throughout the studies, two themes emerged. Firstly, an increase in the number of experimental intervention-based studies. As discussed in Chapter 1 and further in Chapter 4, non-experimental outcome reporting studies have been fundamental for educators, clinicians, government/support bodies and organisations to guide and develop services based on best practice positions. The application though, does not provide information on how to improve, change or adapt intervention and training practices and programs for an individual child in ways that experimental intervention-based studies can. Secondly, it was revealed that specific outcome measures can provide greater levels of detail of a child's linguistic strengths and weaknesses that are not evident through total language or literacy scores. This information can be used inform and support intervention decisions for appropriate targets, goals, and intervention programs from which a child is likely to gain the greatest benefit. Relying on broader outcome measures may mean smaller incremental changes in specific parameters are not detected, and relying solely on specific measures may not provide information on the generalisability or impact of a child's skills at a communication level. A useful frame of reference for both research and clinical contexts may be to consider measuring skills across both activity and participation levels of the World Health Organization's International Classification of Functioning, Disability and Health (2001). A number of studies in this review applied this consideration in setting research objectives and choosing outcome measures (Bernhardt et al., 2000; James et al., 2013; Justice et al., 2008; Paatsch et al., 2006).

Carding and Hillman (2001) discuss the need for a multidimensional assessment for the evaluation of a complex intervention, because of the absence of a single standard outcome measure that can encompass the complexity of the disorder. Analysis of outcome measures used in the studies in this review reflect this need. There was very little similarity in the 131 outcome measures used across the 38 intervention and training programs, and within similar interventions in linguistic areas. Outcome measures necessarily varied across languages and communication modes (Golos & Moses, 2013; Ingber & Eden, 2011; Sugaya et al., 2014), children's age and communication level (Brady & Bashinski, 2008; Herman et al., 2015) and to enable measures of specific targets (Bobzien et al., 2015; Lund & Douglas, 2016; Massaro & Light, 2004). Whilst making a pooled analysis problematic (even within similar interventions/linguistic areas) and limiting the ability to determine trends or patterns across interventions, the measures used provide an overview of the range of outcome measures available and that could be considered for use in clinical application of further research studies.

Parental factors such as engagement, involvement, level of education, use of language and communicative behaviours in language development is well recognised as impacting factors on a child's language development (Boons et al., 2012; Calderon, 2000; Dickinson & Tabors, 2001; Hart & Risley, 2003; Moeller, 2000; Sacks et al., 2014; Yoshinaga-Itano et al., 1998). As the measures in this review were limited to child outcomes, a further study that systematically investigates interventions impacting such parental factors is recommended as a supplement to this review (Moeller, Carr, Seaver, Stredler-Brown, & Holzinger, 2013). Additionally, outcome measures that include satisfaction ratings, experiences, perceptions, preferences, and perceived benefit of interventions by parents and caregivers are also worth considering in future reviews of the literature.

Applications and Implications

The findings from this this systematic review provide a base from which to understand the extent of the efficacy and effectiveness evidence for intervention and training programs for children with hearing loss. Results indicate further evidence on therapeutic interventions are much needed across communication approaches to best guide development programs to improve the outcomes for children with hearing loss. Non-experimental outcome studies can be used to inform researchers and clinicians in specific areas for development, from which methodologically robust studies can be designed to trial therapeutic interventions to add to the current evidence base. If results from this review are applied, it is recommended that clinicians and educators complement the findings with their own searches as it is possible that not every study was identified using the specific methodology applied.

Limitations

There were a number of limitations with this systematic review of the literature. The variability and lack of homogeneity in the identified studies was evident across participants, interventions, mode of delivery, participant recruitment, methodological criteria, areas of focus and outcome measures which made comparisons problematic. The intervention effects and results of each study need to be interpreted with caution due to weaknesses in study designs as noted in the discussion. These are particularly in relation to external validity, small and convenient samples, varying measures of fidelity, a lack of strict inclusion and exclusion criteria and the methodological challenges in blinding of participants, those administering the interventions provided, and those generating outcome data (Gluud, 2006). All of the reviewed studies made appropriate efficacy and effectiveness claims given the levels of confidence that could be assumed from the design. The methodological design, systematic review protocols and inclusion/exclusion criteria for this review were developed in collaboration with the supervisors of this work. An inter-rater reliability check on the criteria ratings was performed by both supervisors on a random 10% of identified studies to support the consistency of the analysis. Initial data searches, database extraction and abstract reviews were conducted independently by the author.

As noted as a common limitation of systematic reviews with a predefined methodology, it is possible some studies were not included due to difficulty in discerning the intervention and experimental component of the study, or if the defined terminology did not appear in searches (Fitzpatrick et al., 2015; Marshall, Goldbart, Pickstone, & Roulstone, 2011). It should also be noted that the predefined inclusion and exclusion criteria resulted in the exclusion of a number of other intervention studies. For example, 13 intervention studies were excluded that provided limited detail, as were 19 studies published in non-peer reviewed publications. These studies, such as those by Cutler (2001), Hong (2013), Montgomery (2013) and Soukup (2005), warrant further consideration and investigation beyond the scope of this review given the subsequent value and benefit they could provide to future intervention development. Consideration also should be given to therapeutic interventions that develop skills known to support communication development such as attention, engagement, play, and executive function skills (Dashash, 2004; Kronenberger, Pisoni, Henning, Colson, & Hazzard, 2011; Pataki, Metz, & Pakulski, 2014).

As noted in the previous chapter, the broad application of the term intervention in clinical, medical and educational contexts opens up the possibility of misunderstanding. The way intervention has been defined in this context may mean that interventions as considered by some were not included in this review. These include studies reporting changes to device fitting, amplification, amplification strategies or introduction of AAC devices (Lee, Jeong, & Kim, 2013; Svirsky, Chute, Green, Bollard, & Miyamoto, 2002; Walker et al., 2015); outcomes pre and/or post cochlear implantation (Bobsin, 2011; Eisenberg, Kirk, Martinez, Ying, & Miyamoto, 2004; Tomblin, Barker, Spencer, Zhang, & Gantz, 2005); and predictive factors (e.g. family-centered, early age of commencement) (Holzinger, Fellinger, & Beitel, 2011; Lin et al., 2011). Although studies published in languages other than English were considered and translations sought, as the search strategy was restricted to English databases, a language bias in the search should be noted. Studies were not excluded based on the report of a significant outcome to reduce the risk of publication bias, but it cannot be dismissed that publication bias exists with regards to studies progressing to the point of publication (Easterbrook, Gopalan, Berlin, & Matthews, 1991).

Conclusion

This systematic review of the literature identified 38 experimental studies that examine the effectiveness of therapeutic interventions and training programs to improve the communication outcomes of children with hearing loss. Positive results were reported from all interventions, although not for all participants in each study, in all expected areas, nor were skills all generalised and/or maintained. Findings from these studies provide valuable information for clinicians and educators working with children with hearing loss to guide and plan individualised and appropriate intervention programs. Whilst large-scale randomised controlled trials are possible, they often remain ethically and logistically challenging. Robust, well-designed studies with considered methodologies, such as single subject designs, can contribute valuable information to build a useful and meaningful evidence-base.

The discussion in the next chapter considers approaches for how communication outcomes can be improved for children with hearing loss through their early years. This includes reviewing how an approach can have the widest application across the population of children with hearing loss, and the central principles for the development of strong communication systems. Published reports on the use of communication approaches suggest the majority of child participants use an oral component, and consequently predictive factors to the development of an effective oral language system are reviewed. These findings support the benefit of a functional listening measure to facilitate earlier intervention decisions.

Chapter 4

APPROACHES TO IMPROVING COMMUNICATION OUTCOMES THROUGH INTERVENTION

Chapter 3 identified the small yet growing number of experimental studies that have examined the efficacy and effectiveness of interventions that implement specific therapies or training programs to support the development of communication skills in children with hearing loss. This chapter considers approaches for improving communication outcomes beyond the previously reported therapeutic interventions. In doing so the discussion explores how an approach to improving outcomes could be most widely applicable, by reviewing data on the use of communication modes by children with hearing loss, and the complexity of individual factors that influence parent and caregiver decisions in this choice. At the outset of this discussion, it should be noted that the aim of this chapter, and this wider research, is not to promote the benefits of one communication approach over another, nor provide opinion on choices made by families or educators using a specific communication mode. The local and contextual factors pertinent to individual children, families and their learning environments that result in these choices are best made with knowledge of that context, coupled with the relevant outcomes evidence. The discussion does highlight the necessity for parents, clinicians and researchers to have access to information and evidence to support their decisions. Given the wide use of oral language, the central principles and predictive factors for the development of strong oral communication systems are reviewed. These considerations support the benefit of using a measure that is sensitive and adaptable to an individual child and family's changing contexts and where each child can serve as their own control over time. In doing so, individual intervention targets can best be guided in the earliest possible timeframe, earlier decisions facilitated, and improved language and communication outcomes supported, positively impacting future outcomes.

Choosing a Communication Approach

Human society and people's lives are largely organised, lived and maintained through communicative interactions with others (Barnes & Bloch, 2018). The success of these communicative interactions relies on language. Communicative interactions create and support relationships, participation, inclusion, education, employment and a sense of community belonging. In situations where the development of language is compromised, such as for a child with hearing loss, these aspects of social interaction are also at risk. It follows then, that the development of strong language systems that start in children's earliest days is of primary importance to support communicative interactions across their lifespan.

The choice of communication approach for a child with hearing loss is typically made by a child's parents and influenced by factors that are both intrinsic and extrinsic to each child and family (Borum, 2012; Crowe, Fordham, McLeod, & Ching, 2014; Crowe & McLeod, 2014; Guiberson, 2013; Wheeler, Archbold, Hardie, & Watson, 2009). A number of studies have examined factors impacting such choices, including a recent, large-scale Australian study, in which researchers investigated the Longitudinal Outcomes of Children with Hearing

Impairment (LOCHI) (Ching, Dillon, et al., 2013b). Information that influenced decision-making about choice of a communication approach was collected using a survey methodology, and analysed quantitatively. Questionnaires were returned from 177 parents of 157 children participating in the wider LOCHI study (34.8% of the total LOCHI cohort). Researchers examined caregivers' ratings of the importance of potential influences on their decisions. Responses indicated parents were most heavily influenced by their child's future opportunities ("My child's future access to rewarding employment"), and audiological and intervention characteristics ("The age at which my child first received hearing aids"). Additional influences were family (communication with close relatives), location (access to intervention and education services), community (participation) and advice from others, in particular speech-language pathologists, audiologists, and specialist teachers.

In a corresponding qualitative analysis Crowe et al. (2014) explored the perspective of 175 of these parent responses for 155 children (34.4% of the total LOCHI cohort). Parents were asked open-ended questions in interviews about influences on their decision making. Results identified 4 primary themes: 1) sources of information (including advice as well as parents/caregivers own research and preferences); 2) practicalities of a communication approach within the individual family and community; 3) the influence of individual child characteristics; and 4) parent and caregiver hopes for their child's future life.

Borum (2012) used a qualitative exploratory design to explore the sociocultural aspects of communication choice and language use of 14 African-American hearing parents of children who were deaf and hard of hearing. Participants identified a strong preference for their child to have access to their African-American oral tradition through speech, and a preference for voice and sign so as to interact and communicate with the d/Deaf and hard of hearing and hearing communities. Respondents also indicated that they wanted their children to have access to written language, and racial, ethnic, and cultural heritage.

Guiberson (2013) reported on the factors that influenced communication modality choice for 71 Spanish parents of children who were deaf or hard of hearing. Factors investigated included family involvement and support, professional involvement, accessibility of information, available services, bilingual background, and beliefs about bilingualism. Results indicated that those most supportive and most involved in the decision-making process were spouses/partners and the child's grandparents, along with speech-language pathologists, audiologists and deaf educators/special educators. Of parents in the study, 49% percent indicated they had to work hard to obtain information about communication options, and 54% wished professionals provided more options. In making decisions on a communication approach, 71% indicated the type of services in school settings was an important factor, and 40% indicated the importance of services close to home. Other issues that influenced decisions included resource availability, attitudes and beliefs about hearing loss, personal goals and values, and cost of intervention services.

Li, Bain, and Steinberg (2003) assessed 83 parental preferences for hypothetical functional outcomes in children with hearing loss, against four domains derived from considerations in developing family-centered interventions. These four domains were the child's academic performance; ability to communicate with hearing and deaf people; social experience; and emotional well-being. The extent of a child's hearing loss was the most influential factor in this study, with the assessment of parental beliefs, attitudes about deafness and parental valuation of the child's future ability to speak and sign all impacting family choices.

Together these studies highlight the complex interplay of factors that influence the choice of communication approach for each family and identify the role health professionals have in providing information. With the vast differences in clinical practices between and within countries, local professionals need to be familiar with the relevant environment and context, coupled with the current evidence base, to provide appropriate and accurate information to support parents decision making (Pappas & McLeod, 2008). Professionals also need to be able to recognise and respect the range of factors that can be present for any given family that is likely to impact their choice, beyond the extent of a child's hearing loss.

The added pressure in this context is the now substantial evidence that the earlier decisions can be made, the earlier intervention can be commenced, reducing the impact of later developmental consequences (Decker, Vallotton, & Johnson, 2012), and improving potential outcomes (Ching et al., 2018). Gravel and O'Gara (2003) suggest that due to the importance of family participation in a child's outcomes (discussed further in Chapter 5), a communication approach and an ongoing process that empowers parents, considers family dynamics, and continually evaluates changing needs can lead to the development of optimal communication skills for a child with hearing loss. This adds to the pressure on parents to make life impacting decisions at a time when they are still adjusting through the stages of having a child with hearing loss, and often with all that comes with a newborn child. Families find themselves in a position of information imbalance between their knowledge of the impact of hearing loss and how to deal with it versus that of a professional or early intervention specialist. Resources and tools that parents can use to assess how their child may be progressing with the intervention approach that they choose – e.g., hearing aids for a child with a severe hearing loss and determining whether a decision to move to an implant is warranted, becomes highly beneficial in guiding informed, empowered choices.

The International Context of Communication Approaches

The accessibility of vast quantities of material through the internet has made the gathering of information on communication approaches quicker, and has provided a wider platform on which to locate and access resources. Although online information may be more available, easier to access, and be representative of a range of perspectives, it brings with it necessary considerations about quality, relevance and accuracy that families may not be aware of when using this material to inform their decisions. For example, information on the internet does not require verification, nor does it need to reflect current practice, research or understanding. It can be subjective and based on opinion rather than evidence and may include erroneous or misleading information because there is no quality filter on what is available. Much also needs to be understood about the local context and accessibility of resources to support a communication choice which is not always represented online, due to the substantial variation in local intervention and education options for children with hearing loss. Parents who rely solely on such material as true and correct are at risk of making misinformed decisions.

Intervention options and communication approaches can differ within a country, but also within a state, region, and city. For example, the Total Communication (TC) approach (Lowenbraun, Appelman, & Callahan, 1980) is a communication philosophy that uses any and all means of communication—sign language, voice, fingerspelling, lip reading, amplification, writing, gesture and visual imagery—that fits best for the child to support language use and understanding. Total Communication can, and has been, confused with Simultaneous Communication (SimCom) (Maxwell, 1990) in which sign and spoken communication are used simultaneously. It is easy to find information online on the advantages and disadvantages of a TC approach, where the terms SimCom and TC are used interchangeably, and websites that state how TC is used and taught in the local context (for example, that the majority of educational programs use a TC approach "Using sign language and voice for total communication" 2018). This may indeed be the case in, for example, areas of the United States, or the United Kingdom, but it is not the case in Australia. Similarly, bilingual/bicultural education programs may be strong in some areas or used extensively in programs where the sign language of a particular country is taught and used as a child’s first language. The availability of bilingual/bicultural education programs may also be dependent upon and influenced by the history and context of that area, region or program.

Confusingly for parents, there is no clear uniformity with distribution of services in different geographical areas, for example regional differences in the accessibility of intervention approaches. There are also metropolitan and rural/remote considerations for families. Although telehealth models have assisted greatly with the provision of services in non-metropolitan areas, determining whether a teleintervention program will work for a family is a separate consideration. Funding considerations also become an issue, because not all intervention approaches and programs are available through government funding systems and this can restrict and limit access. A number of summaries discuss the factors considered above including geographical location, practicalities, education/intervention options, funding considerations and sources of information ("Choosing a communication approach," 2019; "Decisions...Decisions," 2015; Lenihan, 2017, Chapter 2).

Use of Communication Approaches by Children with Hearing Loss

Longitudinal, multisite research projects seeking to investigate outcomes of children with hearing loss often routinely collect information on communication mode. Information is also available from surveys conducted in educational settings of children with hearing loss. A sample of the current available data is presented in Table 8. One of the largest surveys that reported data on communication mode was the 2009-2010 Gallaudet Annual Survey of Deaf Children and Youth (Gallaudet Research Institute, 2011). Based on data from 37,251 elementary and secondary students across North America—which represents approximately half of the students who are D/HH in the US (Lenihan, 2017)— 53% (19,805 students) were taught using spoken language only. A further 27.4% (10,228 students) were taught using sign language only, 12.1% (4,514 students) used sign-supported spoken language (SimCom), 5.0% (1,872 students) used spoken language with cues, and 2.5% (932) were taught in another approach. This survey also reported that 23% of families regularly signed in their homes, and less than 6% used ASL. The "BEGINNINGS report: Change in communication choice over 10 years" (cited in Lenihan (2017)) reported data gathered in North Carolina from families choosing a listening and spoken language approach for infants and toddlers who were D/HH. In 2001, 69% of families chose a listening and spoken language approach; by 2011 this had increased to 90% of families.

The Childhood Development after Cochlear Implantation Study (CDaCI) was one of the first studies to use a national cohort to systematically evaluate early cochlear implant outcomes in children across the United States (Fink et al., 2007; Niparko et al., 2010). The study compared 188 children with cochlear implants from six implanting clinics with 97 similarly aged hearing peers, enrolled between 2002 and 2004. Children were assessed across multiple domains including oral language development, auditory performance, psychosocial and behavioural functioning, and quality of life. Parents of children with cochlear implants reported that they were using multiple communication modes at baseline, with 52% reported use of an oral communication, 32% using sign language, and 23% using total communication.

In a later study, Yoshinaga-Itano et al. (2017) reported a cross-sectional study of 448 children with bilateral, prelingual hearing loss aged between 8 and 39 months. Participants were children in the National Early Childhood Assessment Project who met the American Academy of Pediatrics Early Hearing Detection and Intervention Guidelines[5] across 12 states in the United States. Of the participants in this study, 83% were born to hearing parents, 74% used primarily spoken language (30% spoken language only and 44% spoken language with occasional use of sign language). A further 22% used a combination of sign and spoken language, and 4% sign language only.

[5] Early Hearing Detection and Intervention Guidelines recommend hearing screening by one month of age, diagnosis of hearing loss by three months of age, and fitting/intervention by six months of age (White, 2014, Chapter 1)

The LOCHI study in Australia reported the communication mode of all participants at their 3-year assessment data collection. At this point, 67% of children were using an aural/oral only approach (n=303), 22% used a combination of oral and sign (n=101) and mode was not reported for 10% (n=47) (Ching, Dillon, et al., 2013b). The group that used a combination of oral and sign included children who used manually coded English (Signed English), other augmentative alternative communication systems including gestures, symbols or signs to support speech, and 3 children who used sign language only.

Percy-Smith et al. (2013) reported outcomes of all children born in Demark between January 2005 and 2011 who received a cochlear implant. Of the 83 children in the study, 84% (n=70) used spoken language, 14% used both spoken and sign language (n=12), and for one child it was not reported.

Watson et al. (2006) followed 176 children who had received cochlear implants at one centre in the United Kingdom and were followed up 5 years post implant to track changes in communication mode over time. For children who were implanted under 3 years of age, 83% reported using an oral communication system. Of children implanted between 3 and 5 years, 63.5% were communicating orally, as were 45.1% of those implanted over 5 years of age. Children who were most likely to use oral communication 5 years after implantation were those who were implanted earlier than 3 years of age. The study concluded that the rollout of universal newborn hearing screening led to much earlier identification of hearing loss and referral for cochlear implantation evaluation and, as such, a greater proportion of children with hearing loss at levels suitable for cochlear implant candidacy were now using an oral mode of communication.

It should be acknowledged that studies reporting outcomes of cochlear implantation are likely to report outcomes of children using spoken language due to the nature of the device, and therefore are not necessarily representative of the communication mode of the total population of children with severe and profound hearing loss. Studies reporting on the outcomes of children with less significant levels of hearing loss (minimal, mild and moderate hearing loss) are also likely to report on predominately children using spoken language due to the access to sound children have with these levels of loss, unless there are influencing local or family factors.

Table 8: Reported communication approach by study

Study	Size	Location	Communication Approach as reported by study (%)
Ching, Dillon, et al. (2013b)	n = 451	Australia	67% aural/oral only
			22% combination oral and sign language
			10% not reported
Gallaudet Research Institute (2011)	n = 37,251	North America	53% spoken language only
			27.4% sign language only
			12.1% sign-supported spoken language
			5% spoken language with cues
			2.5% other approach
Niparko et al. (2010)	n = 188	North America	52% oral communication
			32% sign language
			23% total communication
Percy-Smith et al. (2013)	n = 83	Denmark	84% spoken language
			14% spoken and sign language
			2% not reported
Watson et al. (2006)	n = 176 (with CI)	United Kingdom	Implant < 3years 83% Implant 3-5years 63.5% Implant > 5years 45.1%
Yoshinaga-Itano et al. (2017)	n = 448	North America	30% spoken language only
			44% spoken language and occasional use of sign
			22% sign language and spoken language
			4% sign language only

Improving Intervention

In returning to the current research objective—to identify an effective way to further the communication development of children with hearing loss through intervention—the systematic review in Chapter 3 demonstrated that more evidence is required on the efficacy and effectiveness of interventions that implement specific therapy and/or training programs. Given that such evidence is necessary across the range of communication modes, and interventions and training programs differ according to the communication system in which they are based, it would seem relevant to consider an approach to this objective that has the broadest applicability and builds on the current evidence base.

One possibility would be to select an intervention in any one of the linguistic domains that underpin communication and build its evidence base as used in the framework for reviewing interventions as presented in Chapter 3 (lexicon and vocabulary, syntax and semantics, morphology, phonetics and phonology, pragmatics and social communication, reading and comprehension, writing and spelling, or narrative and discourse). Examples of this reported in Chapter 3 are Video Interaction Guidance, by James et al. (2013); Lam-Cassettari et al. (2015) or the Semantic Association Strategy Intervention reported by Bergeron et al. (2009). Such an approach could benefit language development in specific linguistic areas.

A different possibility would be to consider the outcome measures used to track progress for children with hearing loss. An empirical rationale for this approach is the large range of outcome measures used across the studies in the systematic review reported in Chapter 3. These measures differed to match the specific foci of the targets of the intervention, as well as for linguistic area, language, communication mode, and ability level. The large range of such measures make comparisons across interventions difficult, if not impossible. As also identified in the systematic review, specific and discrete outcome measures are needed to supplement generalised language scores to provide information on a child's linguistics skill profile and consequently to guide intervention. A measure that could be used to track an individual's progress and measure outcomes over time would provide specific information to guide intervention, and indicate the rate of acquisition of communication skills. Such a measure would enable each child to serve as their own benchmark and control. Thus, a possibility to improving outcomes through intervention could be to focus on the development of a measure to track outcomes and guide intervention targets, that is non-subjective and relevant across a child's early intervention years (0 – 6 years of age). Measures that span the mental and cognitive developmental stages covered in these years, such as standardised assessments, can provide valuable information through progression from baseline comparisons.

Data on the use of communication approaches in published studies and surveys suggests the majority of child participants (52% to 98%) use a spoken communication system, or spoken and sign approach, incorporating an oral component (as detailed in Table 8). Given the growing body of literature demonstrating age-appropriate communication outcomes for children with hearing loss using an oral approach, and technological advances to facilitate auditory development for oral language, these figures could be expected to continue to increase (Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011; Fulcher, Purcell, Baker, & Munro, 2012a; Geers et al., 2000). Following this argument, the development of an outcome measure that tracks progress and development, and provides individual guidance for intervention targets for children with hearing loss who are using either a part or full oral approach could have the potential to make a substantive and positive impact on a large number of children with hearing loss. A development such as this would be compelling in the Australian context, in which the Longitudinal Outcomes of Children with Hearing Impairment study indicated that the proportion of children using sign alone is less than 1%. In saying this though, it is important to recognise that the use of part or full oral language by children with hearing loss differs greatly within and across communities worldwide. There will always be contexts in which a spoken language only approach might not be the best approach for a child/family for all the reasons provided earlier in this discussion. Additionally, there will always be instances in which families will need to shift between communication approaches. This can be due to changing context, or a greater understanding of a child's needs over time. An outcome measure that tracks development could provide valuable early information to support and guide these choices and facilitate them happening at the earliest opportunity.

To develop an outcome measure for this purpose, the successful factors for developing strong oral communication systems need to be understood. The subsequent discussion in this chapter explores these factors and the evidence base supporting them. They include the critical period of auditory development, the importance of early detection and intervention, access to the acoustic properties of speech, and considerations regarding the real-world environments in which children with hearing loss learn language.

Evidence-Based Factors for Success in Developing a Strong Oral Communication System

Development of an oral communication system is reliant on the capacity of the auditory channel to receive and transmit information to the central nervous system early during development (Sininger et al., 2010). In a deprived auditory condition, like hearing loss, the input provided to and transmitted by the auditory channel is reduced. The negative impact that long periods of auditory deprivation can have on a child's language outcomes has been extensively reported (Boons et al., 2013; Ching, Dillon, et al., 2013b; Yoshinaga-Itano, 2004). For example, Ching et al. (2018) reported in a population-based study of Australian children that earlier device fitting (HA or CI)—and consequent shorter periods of unaided severe-to-profound deafness limiting access to auditory input—were associated with higher global language scores at 5 years of age. Sininger et al. (2010) reported that age of access to auditory stimulation was the overall dominant factor in determining auditory based outcomes in children with congenital hearing loss.

Neurophysiological studies have also addressed the question of a sensitive period for auditory development in children with hearing loss. Sharma, Dorman, and Kral (2005) reported on the longitudinal development of cortical evoked potentials in 21 children fitted with unilateral and bilateral cochlear implants. Results indicated that children who received cochlear implants at a younger age (before 3.5 years) showed rapid development in cortical waveform morphology and P1 latency of the cortical response generated within the auditory cortex. These results contrasted with later-implanted children (above 7 years of age) with aberrant waveform morphology and significantly slower decreases in P1 latency after cochlear implantation. Furthermore, Sharma et al. (2007) reported that P1 latencies return to normal limits within 3.5 months of implantation, indicating the degree of plasticity that the developing central auditory nervous system has available in these early, critical periods.

This neurophysiological evidence has led to widespread changes in national and international guidelines, the development of position statements on infant hearing and universally accepted Principles and Guidelines for Early Hearing Detection and Intervention Programs (Evelyn, 2000; Joint Committee on Infant Hearing, 2000, 2007; Joint Committee on Infant Hearing et al., 2013; White, Forsman, Eichwald, & Munoz, 2010; Yoshinaga-Itano, 2004). These guidelines are the foundations for the development and implementation of the 1-3-6 Early Hearing Detection and Intervention Plan (EHDI) (Joint Committee on Infant

Hearing, 2007) to maximise the linguistic competence and literacy development of infants and young children with hearing loss.

This plan states, *inter alia*:

1: All infants should have access to hearing screening at no later than 1 month of age;

...

3: All infants who do not pass the initial hearing screening and subsequent rescreening should have appropriate audiological and medical evaluations to confirm the presence of hearing loss at no later than 3 months of age; and

...

6: All infants with confirmed permanent hearing loss should receive early intervention services as soon as possible after diagnosis but at no later than 6 months of age (Joint Committee on Infant Hearing (2007)

Impacts of the Shift towards Early Hearing Detection and Intervention

The EHDI framework has provided the baseline of minimum accepted standards in the field of paediatric hearing loss and has become the globally recognised best practice, evidence-based position statement for screening, diagnosis and intervention guidelines (Joint Committee on Infant Hearing, 2000). Following the Principles of Early Disease Detection (Wilson, Jungner, & Organization, 1968) there has been a significant review of efficient and effective hearing screening models to guide the design, development and implementation of hearing screening programs appropriate to local contexts. Researchers and health economists have sought to find the balance of programs that are audiologically and clinically reliable, geographically and culturally relevant across populations, and are placed within existing child-healthcare structures and thus financially practical and sustainable (Davis, Smith, Ferguson, Stephens, & Gianopoulos, 2007; Mehl & Thomson, 2002; Vohr et al., 2001).

There have been similar advances in technology to support the achievement of the EHDI guidelines (Joint Committee on Infant Hearing et al., 2013). This has included technology for screening and diagnostic equipment, improvements in the functionality and capability of devices (hearing aids, cochlear implants, bone anchored devices), and the design and development of equipment to determine the access to sound that such devices provide. A reliable means of estimating a child's access to, and use of sound through this technology is vital. This is particularly relevant, yet challenging, for very young children who are unable to identify what they can and cannot hear or indicate changes in their hearing (for example as a result of middle ear pathology).

Beyond the Sounds of Speech

Speech sounds are made up of complex acoustic components. In determining access to speech sounds, consideration must be given to the acoustic and phonetic components that differentiate and characterise each sound. Vowels are differentiated by patterns of acoustic energies at each frequency (formants), whereas consonants are produced by varying manner, place and voicing features (Ladefoged, 1996). To learn to understand and use words, a child needs to be able to detect, discriminate and identify the phonetic features of each sound in order to recognise how each differs from all others. This requires detection of each discrete part or unit of the sounds (ability to hear its presence), discrimination of that feature from others (i.e. telling the difference between features) and identifying it as a component of an individual sound. Only when all of these steps can be achieved, can a child hear a sound, know how it is different to other sounds, and start to begin to learn how to associate the sound with a meaningful concept.

Moreover, sounds do not exist in isolation. In speech they run together, and it is not at all obvious where one sound ends and the next begins. In the continuous, connected flow of sounds that make speech, the characteristics of a preceding sound can influence the features of the following sound (Fromkin, Rodman, & Hyams, 2015; Hillenbrand, Clark, & Nearey, 2001). Similarly, not all words exist in isolation, with both single and true word combinations. (Nott et al., 2009a). Children learn single word combinations like 'thank you' or 'tooth brush' that in reality are single idea. True word combinations on the other hand are those in which a child puts together two separate ideas into a single phrase, for example 'more ball' or 'mum here'. Sound segments of words are also impacted by a language's assimilation rules and their neighbouring sound segments in a word or sentence. That is, they become more similar to the neighbouring sound by duplication of phonetic properties of that adjacent sound. Assimilation, for the most part, arises from routine processes to ease articulation. These assimilation rules reflect coarticulation—the spreading of phonetic features through gestural overlap in either the anticipation of, or in the preservation of, articulatory processes (Fromkin et al., 2015). Similarly, some languages also have dissimilation rules, whereby a sound segment becomes less similar to another segment, and feature addition rules, whereby a phonetic feature is added to a sound (such as aspiration of a voiceless stop in English at the beginning of a syllable).

From an acoustic perspective, not only do assimilation and dissimilation processes change the features used in the production of individual sounds, they influence those that are heard. To learn to use and produce these fine phonetic features of speech correctly and apply them in everyday connected speech, a child needs to be able to detect, discriminate, and identify these features in use. In doing so, children access and learn the phonology of their language and acquire its rules. If a child with a hearing loss hears a distorted signal, they will produce a distorted sound. Equally, if a child does not have auditory access to a certain frequency or component of speech, sounds with formants or articulatory features that rely on identification at this frequency are not possible, nor will the child be able to learn the correct feature rules of the language applied in production. Although individual sounds can be taught using visual cues, teaching the rule-governed acoustic properties of feature-changing phonological rules of speech through visual cues is impossible. The ability to listen, learn and apply this knowledge of sound patterns across a spoken language is fundamental to successful oral language production.

Language Learning Environments

A further consideration for children with hearing loss is where and how they learn language. As discussed in Chapter 1, language acquisition is reliant on linguistic exposure and experience in everyday settings, during everyday interactions and in meaningful contexts (Konishi, Kanero, Freeman, Golinkoff, & Hirsh-Pasek, 2014). These settings are children's real-world environments, which are often noisy and uncontrolled and can include: childcare, preschool, and early education settings; playgrounds; shopping centres; homes; and moving about in prams, strollers, trains, buses and cars. Linguistic input comes from different directions, distances, and people. It comes at varying volumes, and with changing amounts of background noise. Children with hearing loss face much greater difficulties perceiving speech in challenging acoustic settings than their hearing peers (Cole & Flexer, 2015; Crandell & Smaldino, 2000; Flexer, 2004). To support language development, children need to be able to hear sounds in quiet as well as in noise, similar to their everyday settings, when input can come from a distance and in the presence of background noise. Understanding how a child with hearing loss detects, uses and processes linguistic input in their everyday settings, that is, their *functional listening skills*, is critical to understanding how well they are able to develop oral language.

Aiding Considerations for Young and Very Young Children

Traditionally it has been accepted that appropriate access to sound is determined by a child's ability to detect sounds in either behavioural or objective audiological assessments. Behavioural audiological assessments of hearing thresholds require a child to hear a pure tone produced at a certain frequency (between 125 to 8000 Hz, typically 250 Hz, 500Hz, 1000 Hz, 2000 Hz and 4000 Hz) at a specified volume (which can span a 100dB range) (Bess & Humes, 2003). This is assessed either through behavioural reinforcement audiometry (i.e., in which the child's response to sound can be monitored) or through subjective audiometry (i.e., in which the child subjectively acknowledges that they have heard a sound stimulus). A child's frequency thresholds (that is, the lowest pure tone volume they can hear) are plotted on an audiogram. An audiogram is used to classify the extent of a child's hearing loss across the frequency range. Conversational speech is typically reported to be between 50 and 65dBSPL, with whispered speech from 30-50dB(Katz, Chasin, English, Hood, & Tillery, 1978). Appropriate access for young and very young children requires detection above 30dB across the speech spectrum of 250Hz –

4000Hz (Cole & Flexer, 2015). Auditory access at this level enables detection of speech sound formants necessary for oral language development (Madell, 1998; Madell & Flexer, 2008).

Speech sounds naturally have different intensity levels. Vowel and nasal sounds, such as /a/ and /m/, are naturally produced at louder intensities than fricative and affricate sounds such as /s/ and /ʃ/ due to their phonetic characteristics (voicing). Softer unvoiced fricatives and affricates can often be drowned out by louder sounds of speech, and by the presence of background noise in real world environments (Johnson, 2011). A substantial proportion of sensorineural hearing loss impacts the high frequency components of the auditory spectrum, rendering it more difficult to perceive consonant information (Killion & Fikret-Pasa, 1993; Ling, 1989). The lower frequency components provide valuable vowel information and conveys the time/intensity envelope of spoken language, whereas the consonant information and 2nd and 3rd vowel formant information contained in the higher frequencies carriers markers for inflections, word meaning, place and manner discrimination (Kewley-Port, Burkle, & Lee, 2007).

The methodology by which a young child's responses to sound are determined in an audiological assessment will vary with age. Very young infants will reflexively respond with eye widening, quieting, arousal from sleep, or a sucking response. Older infants will turn their head toward a stimulus, particularly if it is paired with a visual reinforcer. Toddlers will often cooperate in a play activity in response to the presentation of a sound they can detect. As sounds approach a child's threshold levels, the reliability and clarity of responses are likely to reduce. As there is a direct correlation between increasing age and children's reliability in detecting softer sounds, older children's threshold levels can be determined with greater levels of confidence (Northern & Downs, 2014). As the pure-tone sounds presented in behavioural observation audiometry are not representative of the complex acoustic nature of speech, speech perception testing can provide useful speech-based information. Once children are capable of repeating what they hear, speech perception testing can provide discrimination information on specific sounds, words, and sentences, which typically becomes reliable from 5-6 years of age (Dawson, Nott, Clark, & Cowan, 1998).

Behavioural audiological assessments are critical in understanding a child's threshold levels for detection of sounds at individual frequencies as this guides decision about the type and level of amplification best suited to develop oral communication. In conjunction with information from behavioural assessments, speech perception tests provide information on a child's ability to discriminate sounds, words and sentences in the sound-field (Bess & Humes, 2003). As with any test, audiological assessments have limitations. In particular, they are limited by the reliability and clarity of young children's responses, the time and attention required (to obtain thresholds in each ear or complete a speech perception battery), and a child's ability to tolerate bone conduction measures (to determine the type of hearing loss). They do not provide information on what a child does with sounds they hear (attaching meaning to sounds), nor a true indication of how a very young child is using their listening skills in real world environments[6].

To address the limitations of behavioural audiological assessment in infants and young children, objective measures such as immittance and electrophysiological assessments can provide objective information about a child's hearing. Otoacoustic emissions (sounds produced by the cochlea evoked by an auditory stimulus), auditory brainstem responses (electrical waveforms that appear in response to the presentation of a click or tone burst), cortical evoked auditory potentials (electrical signals produced by the hearing pathways in the brain in response to an auditory stimulus), and tympanometry (the mobility of the middle ear structures in response to changing air pressure in the external canal) are commonly used measures (Roeser, Valente, & Hosford-Dunn, 2000). The type of assessment chosen will depend on a child's cognitive level and ability to perform the task, and if they are not able to respond appropriately (due to a physical or cognitive impairment for example), objective assessments can provide useful additional information on their hearing levels. Objective assessments provide further essential information on the type and nature of a child's hearing loss, such as specifics of frequency responses which can assist with the fitting of hearing aids and/or decisions on a cochlear implant, but they too have limitations. Immittance testing is diagnostic in nature, does not provide frequency specific information, nor measure hearing sensitivity. Electrophysiological results can be difficult to obtain with young and very young children (due to moving, crying, talking or the need for sedation), and neither is able to provide an indication of a child's real-world listening abilities.

The combination of information from behavioural and objective assessments of young and very young children provides fundamental information to guide device fittings (Bess & Humes, 2003; Van Dun, 2017). As infants and young children have a limited attention span, information often needs to be built up over time. Results need to be used in combination with clinical and parental observations of how a child is responding to sounds in their everyday environments. Determining access to sound levels as accurately as possible, and as early as possible is critical in maximising a child's exposure to sound and therefore the linguistic input around them.

Objective, technological developments resulting from clinical research such as The HEARLab® system (Martin, Villasenor, Dillon, Carter, & Purdy, 2008) can assist in the process of determining a child's optimal audibility levels. HEARLab enables aided cortical assessment and cortical threshold estimation for very young children (Carter, Golding, Dillon, & Seymour, 2010; Chang, Dillon, Carter, van Dun, & Young, 2012; Dillon, 2005). Aided cortical assessments record cortical auditory evoked potentials in response to low,

[6] Speech perception tests designed with specific considerations for young children (vocabulary, attention span, closed/open set) were not designed for particular use in noise (Schafer, 2010)

mid and high frequency speech sounds and audiologists can determine if a response is present or absent. Using such an assessment, often referral for further electrophysiological testing is not required, and the cortical assessment can be completed in a clinic setting that is local to the child and family. Outcomes of the use of HEARLab in clinics have resulted in young children's hearing aids being adjusted more confidently within the first few months of fitting, compared to children with the same first hearing aid fitting for the first 9 months of life (Van Dun, 2017). Evidence of the usefulness of this system has been demonstrated by Mehta et al. (2017), who reported on 2 sequential cohort groups, one of which used unaided and aided cortical auditory evoked potentials to guide fitting levels. Results indicated a decrease in the median age of hearing aid fitting of over 5 months, particularly for children with milder hearing losses, and significantly earlier referral for cochlear implant assessment following the introduction of cortical testing.

In addition to objective measures, experienced pediatric audiologists and clinical team members are well-trained and practiced in aided behavioural assessments in response to the presence of auditory stimuli in very young children. A team-based approach, with professionals familiar with working in partnership with a child and family over time can provide accurate and reliable information on each child's individual and preferred response to sound. This information can provide further functional guidance on a child's levels of access to speech sounds.

Understanding a child's access to sound is critical for all children, but in particular, in children for whom hearing aids may not provide sufficient access to speech sounds, and so may benefit from cochlear implantation. Evidence demonstrates that children with greater degrees of hearing loss are more likely to benefit from a cochlear implant than a hearing aid (Ching, King, & Dillon, 2013; Leigh, Dettman, Dowell, & Sarant, 2011). This has been used to facilitate early referral guidelines and cochlear implant candidacy criteria. Supporting appropriate access to sounds across the speech range at the earliest opportunity is demonstrated by the strong relationship found between early implantation and communication outcomes (Geers, 2004; Govaerts et al., 2002; Robbins, 2003; Svirsky, Teoh, & Neuburger, 2004). Information to support these early decisions for families and professionals is key in optimising a child's later language outcomes.

More than Detection and Discrimination

Despite early device fitting, hearing loss impacts lexical acquisition and the emergence of language, such as that demonstrated by Nott et al. (2009b). As such, understanding how children use and integrate the sounds that they hear is critical. Historically, this has not been routinely considered. Focus has been on determining a child's levels of hearing and identifying whether or not appropriate access is provided by their devices at individual frequencies. Understanding how a child integrates and uses the sounds they have access to, is as important as detecting or hearing the sounds themselves. Access and detection do not automatically imply an ability to cognitively identify a sound, understand how it is being used, and subsequently produce it in the correct manner and context. A child needs to be able to link and process the information received in the auditory cortex, through the temporal lobe, in which sounds are associated with meaning.

Auditory development is widely recognised to follow four distinct stages (Erber, 1982). The stages are categorised by:

Detection: respond to the presence or absence of a sound;

Discrimination*:* perceive similarities and differences between sounds;

Identification*:* attach meaning to a sound; and

Comprehension*:* understand the meaning of speech and discourse.

These four stages are hierarchical, whereby each stage must precede the next. For example, discrimination of sounds is not possible without the ability to detect them. Within each stage there are also levels of skills. For example, there are easier detection skills (hearing loud sounds) and harder detection skills (hearing soft sounds). Many auditory checklists are based on these stages, such as the Auditory Skills Curriculum (Tuohy, Brown, & Mercer-Moseley, 2005) and the Auditory Learning Guide (Simser, 2011). Further to the detection and discrimination information provided by hearing tests, a child needs to be able to make use of their listening and cognitive skills to identify and comprehend sounds, so they can successfully attach meaning, and subsequently understand and use words, sentences, and discourse. This can be defined as the difference between hearing (detecting sounds) and listening (using sounds). Tracking how a child’s hearing and listening skills develop through each of these four stages is critical to the success of a strong oral communication system.

As mentioned, it also cannot be assumed that good hearing skills equate to good listening skills, as it is possible to have good detection skills yet poor identification and comprehension skills. This is exemplified by children with Auditory Neuropathy Spectrum Disorder (ANSD), a specific hearing disorder characterised by the abnormal function of the auditory pathway in the presence of normal cochlear outer hair function (Gardner-Berry, Hou, & Ching, 2017). Children with ANSD often demonstrate poorer speech understanding than expected for their measured level of hearing loss. Starr et al. (1991) and Starr, Picton, Sininger, Hood, and Berlin (1996) first reported on a group of adults and children with poor speech discrimination abilities that did not match performance levels expected from their hearing loss. Rance (2005) further reported that in almost 50% of children with ANSD, speech discrimination scores were lower than the lowest score expected on the basis of their behavioural audiogram. This indicates that although children with ANSD may show access or detection of sounds in a behavioural audiogram, their functional performance is mismatched to this, indicating they have difficulty using or integrating these sounds. In cases of ANSD, this is most often reported to be due to the processing of timing information, resulting in temporal processing deficits particularly evident in noise (Gardner-

Berry et al., 2017). Given the complexities of language acquisition for children with hearing loss discussed in this chapter, information on a child's developing use of sound is essential to optimise development of a strong oral communication system.

The Need for Information Between Early Objective Audiological Assessments and Language Outcomes

Spoken language skills are typically measured by standardised language assessments. Between birth and 3 years of age these assessments are often criterion-referenced checklists of receptive and expressive language, such as that used in the Rossetti Infant-Toddler Language Scale (Rossetti, 2006). In older children, language assessment results become more reliable with the use of standardised and norm referenced assessments completed by the child, such as the Preschool Language Scale 5 (Zimmerman, Steiner, & Pond, 2002) and the Clinical Evaluation of Language Fundamentals Preschool-2 (Wiig et al., 2004; Zimmerman et al., 2002). Current clinical practises rely heavily on standardised assessment results for information to guide intervention decisions with families. These decisions may be regarding amplification, or to address family context or educational factors that may be impacting outcomes. Often, changes or decisions are prompted when standardised assessment results show poorer than expected progress in comparison to typical hearing peers. When this is the case, it is common practice to wait for another language assessment to provide further information to support decision making. As these assessments have a test/retest time frame, often this will be a further 6 months away. When a child with hearing loss is attempting to 'close the gap' to catch up to the progress of typical hearing peers due to reduced auditory input, the timeframe in making decisions is critical.

Often the rationale for intervention changes comes when a child's language results progressively decline, and fall well below age-appropriate levels of typical hearing peers. The longer they are left to fall, the longer it takes for progress to be made up and the larger the impact will be on later outcomes. The EHDI framework (Joint Committee on Infant Hearing et al., 2013) highlights the impact of timing in the communication development of children with hearing loss, supporting the need for decisions at the earliest opportunity. For parents and professionals to feel confident in making early decisions (as opposed to waiting for further results) they need meaningful, and interpretable information specific to the child.

Conclusion: Identifying the Need: Information to Support Earlier Decisions and Improve Later Language Outcomes

The information provided by audiological measures to determine hearing and device fitting levels needs to be combined with measures of how a child uses, integrates and understands sounds to best support their oral language development. Additionally, this knowledge must be reflective of their listening skills in real-world auditory environments and language learning settings and within the milieu of their specific family environment. The existing evidence base of intervention programs, factors supporting the development of communication skills, and communication approaches used were considered in exploring how to identify an effective way to improve outcomes for children with hearing loss. The discussion thus far has considered the benefit of a measure that is sensitive and adaptable to an individual child and family's changing contexts, where each child can serve as their own control over time, and support and guide individual intervention targets. Specifically, by tracking listening development, such a measure could provide parents and professionals with valuable and meaningful information to guide and support decisions at the earliest opportunity, reinforcing best practice guidelines for early action.

The following chapter reviews some of the major language and listening measures currently used in clinical practice for children with hearing loss. Measures to evaluate listening are reviewed in accordance with the identified elements that are necessary to support the development of strong oral communication systems, including a child's ability to use and attach meaning to sound in their real-world environments (functional listening). Additional usage considerations are examined including the need for interpretable information to support parents in decisions in the context of family-centred intervention models, and to provide professionals with detailed, effective and efficient means to document of listening skill development to appropriately set therapy targets and track progress. As no existing measure could be identified that met the necessary criteria, the research design program to develop such a measure, the Functional Listening Index (FLI), is described.

Chapter 5

A REVIEW OF EXISTING MEASURES AND CONSIDERATIONS FOR DEVELOPMENT

The previous chapter considered the current evidence base for interventions that implement specific therapy or training programs aimed at enabling oral communication. The purpose of this was to explore and identify how communication outcomes for children with hearing loss could be improved. These considerations highlighted that whilst individual measures of detection and discrimination could establish the level of access a child has to auditory information, they could not necessarily ascertain whether this information would result in the development of a relationship between individual sounds and their meaning (i.e. functional listening). The discussion indicated that a measure that could track a child's functional listening progress could provide early evidence to guide intervention targets for professionals and inform parents' decisions. Such a measure would fill two current gaps in knowledge and information for parents and professionals to support the communication outcomes of children with hearing loss. The first, as identified in Chapter 4, would be the ability to link a child's listening skills to their language outcomes. The second, the focus of the current chapter, is the information that could support early decisions, by an easily interpretable visual measure of the acquisition of listening development.

This chapter will describe the substantial range of tools already available to support the evaluation of a child's auditory and listening skills. These tools will be classified by what they measure, who they can be used with, how they can be used, and the information they provide. This classification indicates the opportunity to consider how a tool can cover the areas of need, provide the clinical value required and be of benefit to all children with hearing loss developing listening. The chapter proceeds to describe the development of the Functional Listening Index (FLI®). The discussion details how the FLI was designed to meet the identified needs. The elements and criteria integral to the design are examined and include the ability of the measure to provide a longitudinal trajectory of a child's listening acquisition over their early learning years, be used so that a child can serve as their own control, guide a child's next steps for listening development, and provide information in a meaningful and visually interpretable way. The chapter concludes by identifying how the vision of a single tool that can be used across the wide population of children with hearing loss to meet all the identified needs can be fulfilled with the FLI. The subsequent chapters report on the feasibility, viability and validity of use of the FLI in a clinical setting.

Measures of Auditory and Listening Development

Given the fundamental impact hearing has on language and communication development, it is necessary to understand how a child's auditory and listening skills are typically evaluated. The measures used in clinical practice by professionals working in early intervention settings with children with hearing loss are described in detail below. For specific reference, Table 9 provides a summary of the content of each measure, children who the measure can be used with, how each measure can be used and the information each measure provides.

As discussed in the previous chapter, aided and unaided audiograms in a sound field are used routinely to provide a measure of a child's hearing levels with and without device/s, and to determine access to sounds across the range of speech frequencies. In addition to soundfield testing, speech perception testing is used in both research and clinical practice to provide an indication of a child's ability to discriminate and identify the sounds of speech (Miyamoto, Kirk, Robbins, Todd, & Riley, 1996; Svirsky et al., 2004; Werker & Tees, 2005). Speech perception testing also provides information on a child's ability to recognise various components of speech. These components can be sounds in isolation, words or sentences, and testing can be done in quiet and in the presence of background noise to assess performance in different environments to provide valuable and predictive information on a child's real-world auditory skills. Such tests for young children include the Early Speech Perception Test (Moog et al., 1990) and the Northwestern University Children's Perception of Speech (Elliott & Katz, 1980). As the items are purposely presented without any context, (i.e., often as monosyllables), children use either their top-down or bottom-up processing skills to identify the word or sentence. They are not required to attach meaning or use higher level auditory identification and comprehension listening skills.

Aside from speech perception and soundfield testing, there are many widely available tools to assess a child's hearing and listening skills. There is great variation with the use of these measures across and within clinics, intervention programs and educational settings. These measures include the Auditory Learning Guide developed by Walker (2009) based on Simser (1993), the Auditory Skills Checklist (Anderson, 2004) adapted from Caleffe-Schenck and Stredler-Brown (1992), the Auditory Skills Checklist (Meinzen-Derr, Wiley, Creighton, & Choo, 2007), the Developmental Index of Audition and Listening (Palmer & Mormer, 1999), and the Functional Auditory Performance Indicators (Stredler-Brown & Johnson, 2001), all of which closely follow the auditory stages outlined by Erber (1982). Similar measures are the Auditory Development Scale 0-6 years (Rhoades, 2011), Auditory Verbal Hierarchies (Simser, 2011), Early Listening Function (Anderson, 2002), and the Listening Skills Scale for Kids with Cochlear Implants (Estabrooks, 1998). Other listening assessments include the Categories of Auditory Performance (Archbold, Lutman, & Marshall, 1995), the Infant-Toddler Meaningful Auditory Integration Scale and the Meaningful Auditory Integration Scale (Robbins & Estabrooks, 1998; Zimmerman-Phillips, Osberger, & Robbins, 2001), and the LittlEARS Auditory Questionnaire (Tsiakpini et al., 2004). Specific measures, such as the Child Home Inventory of Listening Difficulties, have been developed to understand the communication needs of children within the context of their home (Anderson & Smaldino, 2000). The Functional Listening Evaluation (Johnson & Von Almen, 1997) is used to identify how a child's listening abilities are affected by noise, distance, and visual access in everyday listening environments.

A number of measures are specifically focused to provide information on parent and teacher perceptions of auditory benefit and behaviour. These include the Auditory Behavior in Everyday Life Parental Questionnaire by Purdy, Farrington, Moran, Chard, and Hodgson (2002), and the Parents Evaluation of Aural/Oral Performance of Children (Ching & Hill, 2007). The Children's Outcome Worksheets (Williams, 2004)is a questionnaire for professionals to quantify the degree of change and measure hearing improvements in identified areas of goals/needs in everyday settings. They were designed to apply the Client Oriented Scale of Improvement for Children to paediatric clients (National Acoustics Laboratory, 2016). The Children's Auditory Performance Scale (Smoski, Brunt, & Tannahill, 1998) was developed and designed mainly for educators to collect and quantify listening behaviours in children age 7 years and older.

In addition to specific listening-only measures, there are a number of auditory checklists used as part of general development scales, such as the Integrated Scales of Development (Cochlear Ltd, 2010), St Gabriel's Curriculum (Tuohy et al., 2005) and the Cottage Acquisition Scales for Listening, Language and Speech (Wilkes, 2001). Tools such as the Speech Perception Instructional Curriculum and Evaluation (Moog, Biedenstein, & Davidson, 1995) provide both a speech perception evaluation component and resource component to plan, guide, measure and report auditory skill instruction and intervention. Curriculum guides such as the Auditory Skills Program for school age children with hearing loss (Romanik, 1993) and the Sound Foundation for Babies (Cochlear Ltd, n.d.-a) and Sound Foundation for Toddlers (Cochlear Ltd, n.d.-b) provide therapy outlines for auditory intervention. Many of these measures differentiate discrete auditory and listening skills along the detection to comprehension hierarchy. Some provide very general high-level information, whereas others provide much more focused detail for specific ages/groups of children and/or stages of development.

A critical review of subjective audiological outcome evaluation measures was undertaken by Bagatto, Moodie, Seewald, Bartlett, and Scollie (2011) to assist in establishing an evidence-based outcome evaluation guideline for children with permanent childhood hearing loss impairment (PCHI). Bagatto et al. (2011) found as follows:

> "The development of spoken language depends on the reception and transmission of information through the auditory channel. For a child with PCHI, this channel is impaired; therefore, the function of the auditory system with acoustic input should be monitored closely. There is little research related to what a typical outcome might be for an infant who wears hearing aids or how to track the child's auditory development and performance over time. This is in part due to the lack of well-developed outcome measures available for use with infants and children who wear hearing aids" (Bagatto et al., 2011).

In this review by Bagatto and Moodie (2016), 12 subjective measures were selected using criteria designed to evaluate the assessments for the purpose of the study. The selection criteria were tools that met the needs of the population identified by the Network of Pediatric Audiologists of Canada, for children birth to 6 years of age who wore hearing aids. These measures were evaluated according to 13 psychometric and feasibility characteristics for incorporation into an evidence-based guideline: conceptual clarity, norms and standard values, measurement model, item/instrument bias, respondent burden, administrative burden, reliability, discriminant validity, convergent validity, ecological validity, responsiveness, alternate/accessible forms, and culture/language adaptations. Although four tools were rated highly across the majority of areas, only two tools were considered clinically feasible; The Parents Evaluation of Aural/Oral Performance of Children and the LittlEARS Auditory Questionnaire.

This evidence provides valuable guidance according to the identified appraisal criteria, as it applies specifically to paediatric audiology. For a listening measure to provide clinical value in guiding intervention decisions to aid and support language outcomes, different criteria than that related specifically to paediatric audiology should be applied. Primarily a measure needs to be able to track a child's functional listening and real-world listening skills, and be universally applicable to the widest possible range of children with hearing loss who enter early intervention programs (from birth to 6 years, with needs in addition to hearing loss, of any language background, and any type/level of hearing loss and device configuration). In addition, it should ideally be able to be used throughout their early intervention program as their language develops, and as such be able to provide a measure of listening development where a child can serve as their own control, guide next steps for development, be used regularly and according to need, provide a comparison with children with typical hearing, demonstrate evidence of reliability and validity, and be displayed in a meaningful and useable format for interpretation by parents and professionals. Table 9 reviews each current listening evaluation measure by these criteria. Hearing threshold measures (such as aided and unaided assessments) have not been included. To maximise consistency classifications in this table were rated by a second reviewer and inconsistencies discussed and agreed.

Table 9: Listening evaluation measures

(Y=Yes, N=No, P=Partially/to some extent)

Measure[7]	Functional listening skills	Real-world listening skills	Aged 0 - 6yrs	Needs in addition to hearing	All languages	All levels, type of HL and device/s	Listening development over time	Steps for development	Typical hearing comparison	Evidence of reliability, validity	Regularly and according to need	Visual and meaningful format	Completed by
1. Speech Perception Testing	N	P	N	Y	N	Y	N	N	Y	Y	Y	P	Clinician
2. Auditory Learning Guide (Walker, 2009)	Y	Y	N	Y	Y	Y	Y	Y	N	N	Y	P	Clinician
3. Auditory Skills Checklist (Anderson, 2004)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	P	Clinician
4. Auditory Skills Checklist (Meinzen-Derr et al., 2007)	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	N	Parent
5. Developmental Index of Audition and Listening (Palmer & Mormer, 1999)	Y	Y	Y	Y	Y	Y	N	N	P	Y	Y	N	Parent, clinician
6. Functional Auditory Performance Indicators (Stredler-Brown & Johnson, 2001)	Y	Y	Y	Y	Y	Y	P	Y	N	P	Y	P	Parent, clinician
7. Auditory Development Scale (Rhoades, 2011)	Y	Y	Y	Y	Y	Y	Y	Y	P	N	Y	N	Parent, clinician
8. Auditory Verbal Hierarchies (Simser, 2011)	Y	Y	N	Y	Y	Y	N	Y	P	N	Y	N	Clinician
9. Early Listening Function (Anderson, 2002)	N	P	N	Y	Y	Y	N	N	N	N	Y	N	Parent

[7] Functional Listening: Measures skills beyond detection and discrimination
Real world listening: Listening tasks reflect things the child would do in everyday life
Aged 0-6yrs: Appropriate for use with children from birth to 6 years of age
Needs in addition to hearing: Appropriate for use with children with additional needs
All languages: Appropriate for use with children whose primary language is not English, items easily translated and not complex or hierarchical in a way that would change difficulty depending on language
All hearing losses and device/s: Appropriate for use for children with all levels of HL, all devices
Listening development over time: Provides a hierarchical organisation of listening development
Steps for development: Provides the next listening skills and stages
Typical hearing comparison: A normative sample or comparative measures of the listening skills of typically hearing peers
Evidence of reliability/validity: Peer-reviewed journal article or other published evidence
Regularly and according to need: Can be used often and when needed, not a one-off administration
Visual & meaningful format: Results are clear, user-friendly language, easy interpretation

Measure[7]	Functional listening skills	Real-world listening skills	Aged 0 - 6yrs	Needs in addition to hearing	All languages	All levels, type of HL and device/s	Listening development over time	Steps for development	Typical hearing comparison	Evidence of reliability, validity	Regularly and according to need	Visual and meaningful format	Completed by
10. Listening Skills Scale Kids with Cochlear Implants (Estabrooks, 1998)	Y	Y	Y	Y	Y	Y	P	Y	N	N	Y	N	Clinician
11. Categories of Auditory Performance (Archbold et al., 1995)	Y	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Clinician
12. Infant-Toddler Meaningful Auditory Integration Scale (Zimmerman-Phillips, Osberger, & Robbins, 1997)	P	P	N	Y	Y	Y	N	N	Y	Y	Y	N	Clinician
13. Meaningful Auditory Integration Scale (Robbins & Estabrooks, 1998)	P	P	N	Y	Y	Y	N	N	Y	Y	Y	N	Teacher/ parent
14. LittlEARS Auditory Questionnaire (Tsiakpini et al., 2004)	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Parent
15. Child Home Inventory of Listening Difficulty (Anderson & Smaldino, 2000)	Y	Y	N	Y	Y	Y	N	N	N	N	Y	N	Parent
16. Functional Listening Evaluation (Johnson & Von Almen, 1997)	N	Y	N	Y	N	Y	N	N	N	N	Y	N	Clinician
17. Auditory Behavior in Everyday Life (Purdy et al., 2002)	Y	N	N	Y	Y	Y	N	N	N	Y	Y	N	Parent
18. Parents Evaluation of Aural/Oral Performance of Children (Ching & Hill, 2007)	Y	Y	N	Y	Y	Y	N	N	Y	Y	Y	N	Parent
19. Children's Outcome Worksheets (Williams, 2004)	Y	Y	N	Y	Y	Y	N	N	N	N	Y	P	Child, parent, teacher
20. Client Oriented Scale of Improvement for Children (National Acoustics Laboratory, 2016)	P	P	Y	Y	Y	Y	N	N	N	Y	Y	Y	Parent, clinician
21. Children's Auditory Performance Scale (Smoski et al., 1998)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Teacher
22. Integrated Scales of Development (Cochlear Ltd, 2010)	Y	Y	Y	Y	Y	Y	Y	Y	P	N	Y	N	Clinician
23. St. Gabriel's Curriculum (Tuohy et al., 2005)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Clinician
24. Cottage Acquisition Scales (Wilkes, 2001)	Y	Y	Y	Y	Y	Y	Y	Y	P	N	Y	N	Clinician

Measure[7]	Functional listening skills	Real-world listening skills	Aged 0 - 6yrs	Needs in addition to hearing	All languages	All levels, type of HL and device/s	Listening development over time	Steps for development	Typical hearing comparison	Evidence of reliability, validity	Regularly and according to need	Visual and meaningful format	Completed by
25. Speech Perception Instructional Curriculum & Evaluation (Moog et al., 1995)	N	N	Y	Y	N	Y	Y	Y	N	P	Y	N	Clinician
26. Auditory Skills program (Romanik, 1993)	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Clinician
27. Sound Foundation for Babies/Toddlers (Cochlear Ltd, n.d.-a, n.d.-b)	Y	Y	N	Y	Y	Y	N	Y	N	N	Y	N	Parent, clinician
Y scores	*20*	*19*	*11*	*26*	*24*	*27*	*11*	*14*	*6*	*11*	*26*	*4*	
P scores	*3*	*5*	*0*	*0*	*0*	*0*	*2*	*0*	*5*	*2*	*0*	*5*	
Y + P scores	*23*	*24*	*11*	*26*	*24*	*27*	*13*	*14*	*11*	*13*	*26*	*9*	

The categorisation in Table 9 indicates the substantial number of tools available to support the evaluation of a child's auditory and listening skills (n=27). Many provide a measure of functional listening beyond detection and discrimination (23) and real-world listening skills (24). The vast majority are appropriate for use in any language (24), with children with all levels and types of hearing loss (27)[8], with children with additional developmental needs (26), and can be used regularly and according to need (26). Fewer of the measures are applicable for children from birth all the way through to 6 years of age (11), provide a hierarchical order of listening development (11), and detail the next steps of listening skills for goal setting (14). A small number provide an indication of comparative listening skills of typical hearing peers (6), and in a visual, meaningful and easily interpretable format (4). This classification also indicates the LittlEARS Auditory Questionnaire addresses all the needs for a measure except that is designed specifically for children implanted under 3 years of age[9]. The Functional Auditory Performance Indicators also covered 11 of the 12 areas to some extent, partially addressing the need for measuring listening development over time, evidence for reliability/validity of use, and a visual and meaningful results format. The range of tools indicate the importance of listening measures in supporting children with hearing loss. The subsequent discussion highlights key considerations in how a single tool could be further developed to meet these needs and be of maximum benefit.

Usability and Practical Considerations

Documentation and Tracking Listening Skills

In clinical practice, tracking auditory development often falls within the scope of professionals such as early interventionists, speech language pathologists, and/or teachers of the deaf. These professionals typically track a child's developing listening skills in regular intervention sessions or as part of an educational program. A child's current listening skill level is used to identify next developing skills as future therapy goals, in line with the best practice guidelines for providing appropriately targeted intervention for children with hearing loss (Joint Committee on Infant Hearing et al., 2013). The listening tools and measures detailed in Table 9 are used in many countries around the world for this purpose, although there seems to be a wide range of variability in tools used by professionals within and between programs and education settings. Information on a child's listening development is most often documented and updated as part of child's medical/educational record, either on a paper form or as part of session notes. Finding and tracking information within a child's session notes and file history can be notoriously time consuming. One of the

[8] Although some measures have been specifically designed for certain populations e.g., children with cochlear implants, they have been classified as appropriate for use by children who use other hearing devices or with other levels of hearing loss if clinically relevant

[9] The Evaluation of Auditory Responses to Speech (EARS®) for cochlear implant recipients is available for children implanted 3 years and older (Esser-Leyding & Anderson, 2012)

challenges working within health and education settings is the lack of time available to devote to high quality and adequately detailed notes. Although documentation is understood as an ethical requirement, clinical time with children, teachers and families is prioritised. This can leave minimal time for recording session notes, thorough tracking and monitoring of progress, and often much of the detail of a child's auditory level remains undocumented despite being known by the professional. It can be challenging for an educator or clinician to quickly and accurately determine a child's level of listening achievement to plan and implement optimally targeted intervention. The level of detail provided in a child's session notes/records can also be highly variable and subjective.

Use in Partnership with Families

As identified in the United States' Individuals with Disabilities Education Act (IDEA) and the Australian Disability Standards for Education (2005) there is increasing emphasis on family-centered care for young children with disabilities (Turnbull, Huerta, Stowe, Weldon, & Schrandt, 2009). A substantial body of evidence demonstrates the benefits of family-centred practice and the importance of family and professional partnerships (Bruder, 2000; Espe-Sherwindt, 2008; Spoth, Kavanagh, & Dishion, 2002). Within this model, families are key decision makers. They are central to, and experts in, the needs and wants of their child, and the development of a collaborative partnership between parents and professionals is paramount (Dodd, Saggers, & Wildy, 2009; Law et al., 2003). A family-centred care model that supports informed choice for parents in all aspects of screening, diagnosis, communication and intervention is supported by the Joint Committee on Infant Hearing Position Statements (Joint Committee on Infant Hearing, 2000; Joint Committee on Infant Hearing et al., 2013). Involving parents as key decision makers and establishing successful collaborative parent-professional partnerships can support early intervention systems by addressing individual contexts, facilitating engagement and empowerment (Blue-Banning, Summers, Frankland, Nelson, & Beegle, 2004; Dunst & Paget, 1991).

Central to both family-centered practice and informed choice is the provision of accessible information to support family-made decisions. Professionals have a responsibility to provide information to families in meaningful, contextual, interpretable ways, recognising and respecting that each family, and each member of the family, may differ in how they understand, best receive and process information. Providing understandable information can empower parents as key decision makers, build family knowledge and capacity, and strengthen engagement and partnerships.

Interpreting Progress

Children's developmental trajectories are used internationally in research and clinical settings to provide person-specific, longitudinal data to identify factors that either promote or negatively impact health and development. Factors critical to early child development and indicators of overall progress are tracked from birth during routine early childhood checks (Hagan, Shaw, & Duncan, 2007; Krogman, 1972). These indicators include the World Health Organization Growth Standards (2006) for length/height, weight and head circumference for age, that enable comparison between an individual child and population-based data on typical development. Similar value can be gained from tracking a child's language growth over time to provide information on progress compared to normative rates of development.

As outlined in the systematic review presented in Chapter 3, there are many tools used to assess a child's language, which are usually language-specific. In practice, a clinic or intervention/education setting will typically use a particular assessment on a regular basis with each child. Standard scores provide a means of determining if a child's skills are above, within or below the average range for their age. Although a child's standard score is often used at given assessment intervals, plotting their standard scores over time can provide an indication of the rate of a child's acquisition of language. A visual and longitudinal representation of a child's rising, falling, or stable standard language scores can provide valuable information to guide intervention decisions for parents and professionals.

Tracking a child's acquisition of listening skills through a developmental trajectory could provide similar benefits. The information it would provide could inform and support an understanding of the factors impacting a child's listening acquisition, such as device compliance, middle ear pathology, functional access, language input, and linguistic exposure. In doing so, each child's progress could be measured whilst acting as their own control.

In the same way that an individual data point provides little meaning without surrounding context, an individual child's trajectory requires comparison, whether it be to other children with hearing loss, or to those without hearing loss. Both can indeed provide useful comparisons for professionals and parents. First, understanding a child's progress relative to children with hearing loss can include comparisons of children with similar levels of hearing loss, devices, hearing ages, fitting or implant ages, language levels, or hearing loss etiology. Second, the comparison of a child's progress to listening skills of children without hearing loss can indicate progress as compared to age equivalent norms. A longitudinal measure of listening acquisition with appropriate comparisons then, has the capacity to track an individual child's progress over time, and the capability to compare across groups, and to typical hearing peers.

Background context to development of the FLI

In 2012, I was working clinically as a speech language pathologist and managing a team of clinicians in a family-centered early intervention and cochlear implant program for children with hearing loss in Australia. The team of professionals included teachers of the deaf, paediatric audiologists, speech language pathologists, early educators and child and family counsellors. My responsibility for the team and outcomes for over 500 children and families necessitated the use of clinically effective and efficient measures. We faced the challenges described earlier in this chapter (differences in the use of tools, effectiveness of documentation, and a lack of meaningful and interpretable information to guide and support decisions). As part of this research work, I led an audit of measures in clinical use within the program. This audit identified 10 different listening tools were being used routinely by the team.

Choice of tool varied according to a child's age, needs, language skills, and individual preference. The measures in use included: the Auditory Verbal Hierarchies (Simser, 2011); Listening Skills Scale Kids with Cochlear Implants (Estabrooks, 1998); the Parents Evaluation of Aural/Oral Performance of Children (Ching & Hill, 2005); the Auditory Skills program (Romanik, 1993); the Categories of Auditory Performance (Archbold et al., 1995); the Integrated Scales of Development (Cochlear Ltd, 2010); St Gabriel's Curriculum (Tuohy et al., 2005); Speech Perception testing; the Cottage Acquisition Scales (Wilkes, 2001); and the Auditory Learning Guide (Walker, 2009). An audit of session notes indicated significant variation in the documentation of children's auditory skills. Some files contained 1 or 2 sentences per entry, while others reported detailed paragraphs. The type and number of listening skills evaluated and targeted in sessions varied depending on clinician experience and knowledge, with experienced clinicians measuring and focusing on a far greater range of auditory skills than less experienced colleagues. When gaining an understanding of a child's capacities, it became evident that clinicians could require up to an hour to read through an individual child's session notes and client file to determine a child's current listening level in order to plan a session appropriately. There was no standard listening information or minimum set of items routinely recorded in all files, no means to track a child's individual progress of listening development over time, and no standard for comparison of an individual child's listening progress.

An example of the range of auditory detail that can be provided and recorded for each child can be demonstrated using a typical auditory task such as the detection of the Ling 6 sounds (Ling, 1976). A child's performance on this task provides information on their ability to access the sounds of speech across the spectrum. While correct/incorrect responses provide this most basic level of information, experienced professionals can use a child's responses to further identify specifics of a child's listening skills. For example, understanding if and when a child:

- requires additional auditory information (duration or pitch change) to respond through audition alone
- responds to acoustically easier sounds (vowels, nasals) as compared to harder sounds (fricatives)
- can discriminate between two similar sounds (e.g., 'ss' and 'sh'),
- starts to imitate one or two sounds (identification)
- detects and imitates sounds at greater distances, and
- detects and imitates sounds in the presence of background noise.

These types of specific auditory information provide valuable insight into a child's developing skills and can be used to guide therapy targets and goals for intervention. Through the audit, it was clear that new clinicians to the program were missing this important level of detail from a child's session notes, and consequently therapy and program goals were mismatched to a child's skill level. At this point, I led the team to: a) identify the required and ideal information on a child's listening development across their early years to guide intervention; and b) determine the information parents needed to inform their choices and decisions. Into this I integrated considerations with regards to efficiency, ease of use and standardisation. The outcome identified the need for a universal measure that could:

- evaluate a child's use and integration of sound for meaning over a clinically significant time span;
- be appropriate for children from birth to 6 years of age;
- measure real-world listening skills (in background noise, from distances, to digital signals);
- facilitate the accurate identification of a child's current listening development status;
- provide information on a child's developmental 'listening path' or 'listening trajectory', similar to a child's language trajectory (e.g., using standard scores or mean length of utterance);
- provide an indication of rate of listening skill acquisition and a sensitivity to impacting and contextual factors;
- be appropriate for children with all levels and types of hearing loss, using any device configuration;
- provide comparisons to the listening skills of children with both hearing loss and typical hearing;
- be used with children with additional developmental needs and language backgrounds;
- provide guidance on the next listening steps and stages for an individual child;
- be quick and easy to use, and able to be administered regularly and according to need;
- be used standardly and objectively across team members; and
- provide meaningful information in a visual format that is easy to interpret by family members and support parent-professional partnerships.

The Development of the FLI®

Having considered the outcomes of the audit, as described above, the next challenge lay in deciding whether to use a 'best fit' existing universal listening measure that could achieve the identified goals or to develop a new measure. Options were to either: 1) modify a current scale/measure to meet as many of the requirements as possible or 2) develop a new tool/measure that fully met these requirements. As no single available tool met the criteria for elements and functionality considerations, the decision was made to progress through development of a new stand-alone measure of listening development. An additional consideration in this choice was the program's concurrent transition to a new clinical database at the time to support service delivery and capability that would involve transferring all client paper files to electronic records. This included all client notes, reports, session plans, goal tracking and progress information. In addition, all electronic records were to be combined, which required combining spreadsheets, Microsoft Word and PDF documents and Microsoft Access database records. Integral to the design of this database was the ability to track each child's development and progress. This included listening, language, speech, and cognitive measures. Appropriate measures to track progress were identified for all areas except listening, due to all the reasons described above.

Recognised evidence on listening skill acquisition and auditory stages were used to guide design and development of the new measure. Items were identified from commonly used auditory tasks that covered all stages of listening development associated with skills from birth to 6 years of age. These 60 items were grouped in six phases and named accordingly (see Table 10). Items in each phase were ordered according to expected order of acquisition, from earliest to latest. An extract of one of the full phases with items (Phase 1) is provided in Table 11, and a full version of the FLI for reference in Appendix D.

Table 10: Phases of the FLI

Phase	Phase name (number of items)
Phase 1	Sound awareness (9)
Phase 2	Associating sound with meaning (11)
Phase 3	Comprehending simple spoken language (11)
Phase 4	Comprehending language in different listening conditions (8)
Phase 5	Listening through discourse and narratives (13)
Phase 6	Advanced open set listening (8)

Table 11: FLI Phase 1: Sound Awareness

Phase 1 Sound Awareness
1.1 To wear hearing devices all waking hours
1.2 To show an involuntary response to sound
1.3 To search for the source of a sound
1.4 To attend to voice with interest
1.5 To begin to localise sound, although may be inconsistent
1.6 To attend to talking/singing for a couple of minutes
1.7 To consistently detect all the Seven Sounds at close range
1.8 To show a detection response to a range of Learning to Listen Sounds through listening alone
1.9 To respond to a whispered voiceless phoneme (e.g., 'p….p…' and 'h….h….') through listening alone

The FLI was developed as a checklist, so that it could be used regularly, in collaboration with families, and acquired skills checked off during each use. To facilitate a visual interpretation of progress over time, a score of 1 was given for each acquired item. The total number of acquired items could then be charted against a child's chronological age. This enabled a child's listening development to be longitudinally monitored.

Chronological age was chosen in the design rather than hearing age for two reasons. First, to align the child's development with the use of typical hearing development in other language assessment measures. Second, the inherent difficulty in accurately establishing a child's hearing age. Even when a child is fitted with a device/s, this date can be misrepresentative. Often device/s are not worn initially for all waking hours, nor is the fitting date representative if a child has some level of residual hearing. If a child receives cochlear implants, hearing age becomes more complex, because it cannot be determined if (nor how much) a child had usable hearing prior to implantation, and when the implant was programmed optimally (which is often sometime after activation).

Throughout initial design and development, the measure was known as the Auditory Hierarchy. The term hierarchy became problematic because it implied an inherent order, because children often acquired items and developed skills in different orders, and not all skills were necessary pre-requisites for those that followed. It became apparent that the name of the measure needed to identify that the tool was focused on the acquisition of listening skills in everyday environments, and what children do with sounds they have heard. It needed to reflect the cognitive component of listening, as opposed to the auditory/sensory skills of hearing. Due to these factors, the measure became known as the Functional Listening Index. Following feedback and pilot use within the program team, development was completed in July 2012 and the FLI was integrated into the new clinical database for use with all children across the early intervention and cochlear implant program in August 2012.

Conclusion

There is a wide range of auditory measures developed, and in use, across educational and clinical settings to measure the development of listening skills of children with hearing loss. These assessments provide critical information on how a child uses their hearing to develop language. In practice, there are limitations to use of each of these tools. These include their versatility across age ranges, incorporation of real-world skills acquisition of how sound is used, and ability to visually document and provide detailed next steps of listening development. This chapter has described the identification of an opportunity to design and develop a measure, the FLI, that could be used efficiently and effectively by professionals to accurately determine a child's listening skill level. Such a tool could be used in collaboration with families, for their children through their early years (from birth through to 6 years of age), to provide meaningful information in the form a visual trajectory of progress to support decisions. This chapter has outlined how this need was addressed in the initial development of the Functional Listening Index.

The next chapter presents the results of a validation study to understand and establish the levels of confidence in the application of the FLI when used to track outcomes and progress for children with hearing loss. The chapter reports three key measures of internal validity. First, the levels to which the FLI measures listening skill acquisition in comparison with current tools (concurrent validity), second, the extent to which it demonstrates the expected differences between groups (convergent validity), and third, to what extent listening scores on the FLI are predictive of a child’s language outcomes (predictive validity).

Chapter 6

VALIDITY OF THE FLI®

The need for a measure of functional listening for children with hearing loss was explored in Chapter 5. Challenges with the available auditory tracking tools were identified and the design process described that was used in the development of a tool to meet the existing need. Primary drivers for the development were: (1) meaningful information that parents could use to support decisions at the earliest opportunity; and (2) information to guide professionals to maximise a child's auditory development. A review of the current tools indicated there was no existing measure that met all requirements for content and use, and an audit of the existing measures in use in a clinical setting identified the challenges faced. Consequently, the Functional Listening Index (FLI) was designed and developed to provide the necessary information for parents and professionals to guide decisions and practice.

For the FLI to be a useful clinical tool and for users to be confident it is an accurate measure of listening development, it needs to be both valid and feasible. This chapter will report on a validation study that was undertaken in order to assess whether the FLI measured what it was designed to measure (a child's listening skill development over time). The study reported in this chapter explores three types of internal validity for the FLI as a measure of a child's listening. First, the extent to which the FLI measures listening skill acquisition in children in comparison with existing tools (concurrent validity). Second, if the FLI demonstrates the expected differences between groups (construct/known groups validity) and, last, if a child's listening scores on the FLI are predictive of language outcomes (predictive validity). Results of a clinical feasibility study examining use of the FLI across the population of children with hearing loss within an early intervention centre are reported in Chapter 7, and reliability and standardisation of administration and scoring is discussed in the postscript in Chapter 9 as part of ongoing research and development of the tool.

Aim

The aim of this study was to examine the internal validity of the FLI in terms of:

a) concurrent validity with similar assessments,

b) construct validity by differences in known groups, and

c) predictive validity of a child's language skills.

Method

Participants

Participants were children enrolled in an integrated Early Intervention and Cochlear Implant program for children with hearing loss and their families. This program focused on the development of listening and spoken language skills and provided services in three Australian states-New South Wales, the Australian Capital Territory and Tasmania. Following the clinical audit of listening measures described in the Chapter 5, the FLI was incorporated as the measure of listening for all children up to 6 years of age as part of the program's routine assessment and monitoring protocol. All children enrolled in the program who had a recorded FLI score between August 2014 and September 2016 were included as participants (n=450). There were an additional 16 children with no recorded FLI score during this period who were excluded. There were no further exclusion criteria.

Definitions

Participant age was measured at the point of data extraction.

A developmental need was determined by a written diagnosis of a disability or condition in addition to hearing loss that impacted on learning or language development.

Levels of hearing loss were defined as either mild = 26 - 40 dB, moderate = 41 - 55 dB, moderately severe = 56 – 70 dB, severe = 71 - 80 dB or profound = > 91 dB (Clark, 1981; modified from Goodman 1965).

Symmetry, type and degree of hearing loss was reported from the time of diagnosis.

Device used was reported as the device the child was using at the time of data extraction.

Age of implant was determined by date at surgery.

Activation was typically within 1 week of surgery.

Unknown indicates this field was not complete in the clinical database record at the time of data extraction.

Characteristics

The audiological characteristics of participants are detailed in Table 12 by newborn hearing screening result, age at diagnosis, age at activation and age at entry to the early intervention services. The majority of participants (76%) were referred for diagnostic testing following screening of their hearing as newborns. The average age of diagnosis was 6.8 months (SD13, 0 – 79) and the mean age of device fitting was 14 months (SD18, 0 – 152). Of the children with cochlear implants, 15 children had implant surgery under 6 months of age, 32 children between 6 and 11 months, 37 children between 12 and 23 months and 62 children were over 24 months of age. The mean age of entry to the early intervention service was 15 months, with a standard deviation of 18 months.

Table 12: Audiological characteristics by newborn hearing screen result, age at diagnosis, age at device fitting, age at activation and age at entry to the early intervention service

	Number	Percentage
Newborn hearing screen result		
Pass	50	11%
Refer	343	76%
Not tested	16	4%
Unknown	41	9%
TOTAL	450	
Age at diagnosis		
0 - 3 months	310	69%
3 - 5 months	20	4%
6 - 11 months	14	3%
12 - 23 months	35	8%
24 - 35 months	20	4%
> 36 months	29	6%
Unknown	22	5%
TOTAL	450	
Age at first device fitting		
0 - 3 months	137	30%
3 - 6 months	59	13%
7 - 11 months	39	9%
12 - 23 months	73	16%
24 - 35 months	35	8%
> 36 months	47	10%
Unknown	60	13%
TOTAL	450	
Age at cochlear implant surgery		Of children with a cochlear implant
Under 6mths	15	10%
6 - 11mths	32	22%
12 - 23mths	37	25%
> 24mths	62	42%
TOTAL	146	100%
Age at entry to EI		
0 - 3 months	121	27%
3 - 5 months	83	18%
6 - 11 months	62	14%
12 - 23 months	78	17%
24 - 35 months	42	9%
> 36 months	64	14%
TOTAL	450	

Participant audiological characteristics are further detailed in Table 13 by type and degree of hearing loss, symmetry and device used. Sensorineural hearing loss was reported for 279 participants (62%) left ear, 271 participants (60%) right ear. Conductive hearing loss was reported for 31 participants (7%) left ear, 49 participants (11%) right ear. A mixed hearing loss was reported for 28 participants (6%) left ear, and 28 participants (6%) right ear. Auditory Neuropathy Spectrum Disorder (ANSD) was reported for 18 participants (4%) left ear, 16 participants (4%) right ear. Symmetry was not recorded in the database for 33 participants (7%) left ear, 33 participants (7%) right ear.

Children in the dataset had hearing loss from mild through to profound levels at diagnosis, and normal hearing levels in the other ear with unilateral hearing loss. Participants used a range of devices and configurations at the time of data extraction (hearing aid, cochlear implant, bone conduction device, unaided). Full details of levels of hearing loss and devices used by participants are provided in Table 13. In regards to the symmetry of hearing loss, 264 children (59%) had a symmetrical bilateral hearing loss; 43 children (10%) had an asymmetrical bilateral loss; 88 children (19%) had a unilateral loss (38 left sided loss, 50 right sided loss); symmetry was not recorded in the database for 55 children (12%).

Table 13: Audiological characteristics by symmetry, type and level of hearing loss at diagnosis and device worn by ear at the time of data extraction

	Number	Percentage
Symmetry of hearing loss		
Asymmetrical	43	10%
Bilateral	264	59%
Unilateral left	38	8%
Unilateral right	50	11%
Unknown*	55	12%
TOTAL	450	
Type of hearing loss (left ear)		
Sensorineural	279	62%
Conductive	31	7%
Normal	61	14%
Mixed	28	6%
ANSD	18	4%
Unknown*	33	7%
TOTAL	450	
Type of hearing loss (right ear)		
Sensorineural	271	60%
Conductive	49	11%
Normal	53	12%
Mixed	28	6%
ANSD	16	4%
Unknown*	33	7%
TOTAL	450	
Degree of hearing loss (left ear)		
High frequency (mild - profound)	9	2%
Mild	45	10%
Mild - moderate to profound	85	19%
Moderate - moderate/ severe to profound	105	23%
Severe, severe to profound	52	12%
Profound	56	12%
Normal	61	14%

	Number	Percentage
Unknown*	37	8%
TOTAL	450	
Degree of hearing loss (right ear)		
High frequency (mild - profound)	8	2%
Mild	47	10%
Mild - moderate to profound	91	20%
Moderate - moderate/ severe to profound	99	22%
Severe, severe to profound	54	12%
Profound	60	13%
Normal	54	12%
Unknown*	37	8%
TOTAL	450	
Device (left ear)		
Hearing aid	202	45%
Cochlear implant	119	26%
Bone conduction device	25	6%
None	58	13%
Unaided	17	4%
Unknown*	29	6%
TOTAL	450	
Device (right ear)		
Hearing aid	195	43%
Cochlear implant	129	29%
Bone conduction device	28	6%
None	51	11%
Unaided	22	5%
Unknown*	25	6%
TOTAL	450	

*Fields recorded as unknown were either because information was yet to be obtained or it was stored elsewhere in the clinical database and not in extractable fields (e.g. attached in an audiogram). Some fields were more likely to be filled in than others due to their clinical need (such as degree vs symmetry) which led to discrepancies in numbers across fields.

Procedure

Demographic and audiological data were extracted retrospectively from the clinical database for all participants with each child's standardised language scores. Demographic data were date of birth, gender, presence of a diagnosed developmental need, language background, cultural heritage, postcode and date of enrolment to early intervention. Audiological data were newborn hearing screen result, date of diagnosis, date of device fitting, level of hearing loss (left and right), type of hearing loss (left and right), device type (left and right), and age at implant (if applicable). Language scores were recorded from standardised language assessments conducted as part of routine clinical assessments which were either the Preschool Language Scales 4 or 5 (PLS4/PLS5) (Zimmerman et al., 2002) or the Clinical Evaluation of Language Fundamentals – Preschool (CELF-P) (Wiig et al., 2004). Language assessments were conducted annually according to the service's protocol using one of these assessments per child, within a three-month window of their birthday. Each child's language score was their total language score on either of these assessments.

FLI scores for participants with a data point recorded between August 2014 and September 2016 were retrospectively extracted from the database in October 2016. This included previous FLI data points before August 2014 as well as those collected during the time period of the study. The FLI was typically completed quarterly by a child's clinical case manager (speech pathologist, teacher of the deaf, or audiologist) but administration points varied according to clinical need and individual progress. Case managers were routinely trained in the administration of the FLI and followed standard guidelines. Items were marked as acquired at the date of administration. An item was considered to be acquired when a child demonstrated the skills regularly and consistently. The majority of children in the dataset were accessing early intervention services and were aged under 72 months when the FLI was administered. There were 19 children at older ages who had delayed listening skills for whom the FLI was used, thus were over 72 months at point of FLI measure.

Overall raw scores on The Parents' Evaluation of Aural/Oral performance of Children (PEACH+) (Ching & Hill, 2005) and total scores on the LittlEARS Auditory Questionnaire (LEAQ) (Tsiakpini et al., 2004) were collected from as many children as possible that attended the early intervention service for a routine clinical session with their audiologist during a four week period in September 2016. All audiologists were familiar with both assessments and followed the standard protocols for administration. Although the LEAQ was developed for use by children under 2 years of age, it was used clinically in the setting for older children with listening skills in the range covered by the tool.

Statistical Tests

a) Concurrent validity: Participants FLI scores were compared with PEACH+ and LEAQ scores where they were taken within 4 weeks of each other (to represent scores at similar points in time). Data were analyzed to determine the presence of linear relationships and the strength of correlation coefficients.

b) Known-groups validity: To determine if the expected differences between groups were seen in FLI scores, two groups of listening scores were compared. First, FLI scores of children with a diagnosed developmental need in addition to hearing loss were compared to the FLI scores of children with hearing loss alone (no additional developmental needs). As developmental needs are not often formally diagnosed until 2 to 3 years of age unless a syndrome is present, only children older than 36 months were included in the comparison. Second, FLI scores of children who began early intervention services within three months of their hearing loss being diagnosed, compared with FLI scores of children who began intervention services 3 months or more after diagnosis. As differences between groups were determined using non-parametric analyses due to the lack of normal distribution of participants' FLI scores, the median FLI score of each group was the better measure of central tendency than the mean. Median FLI scores of each group were compared using

Moods Median test (Brown & Mood, 1951) and the Mann-Whitney U test (Mann & Whitney, 1947) due to the low statistical power of the median test.

c) Predictive validity: Sample sizes, intercept values, coefficients, p-values (of the coefficient), $\boldsymbol{R}^2$ values and correlation coefficients were analyzed using regression models of participants standard language scores from 36 months of age and accumulated FLI scores in three-month intervals.

Parents of all children enrolled in the study consented to participate in de-identified research conducted as part of assessments used in routine clinical practice. Data integrity checks were undertaken during analysis to maximise data quality. This study was approved by the Macquarie University Human Research Ethics Committee (Reference No: 5201600650).

Results

Participant characteristics by gender, the presence of a diagnosed additional developmental need, language background and socioeconomic status are provided in Table 14. Participants were 53% male and 47% female. There were 81 children (18%) in the dataset who had a diagnosed developmental disability in addition to hearing loss. English was the only language spoken by 247 children and their families (55%) and was reported to be spoken the majority of the time for 87 children and their families (19%). There were 48 children and their families (11%) who reported speaking primarily a language other than English and 20 children and their families (4%) reported only speaking another language.

Participants were from all socioeconomic levels as determined by the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) through the Socio-Economic Indexes for Area (SEIFA) (ABS 2011). There were 128 children and their families with a SEIFA ranking of 1 – 5 (28%), 46 families with a SEIFA ranking of 6 or 7 (10%), and 272 families with SEIFA ranking of 8 – 10 (60%)[10]. At point of data extraction, participants were aged between 3 months and 13 years with a median age of 55 months (SD = 28) (Table 15).

Table 14: Subject characteristics by gender, presence of additional developmental needs, language background and socioeconomic status

	Number	Percentage
Gender		
Male	239	53%
Female	211	47%
Additional developmental needs		
Presence of additional developmental need	81	18%
No additional developmental need	369	82%
Language background		
English only	247	55%
Majority English	87	19%

[10] A low score indicates relatively greater disadvantage and a lack of advantage in general, whereas a high score indicates a relative lack of disadvantage and greater advantage (Australian Bureau of Statistics, 2018).

	Number	Percentage
Majority other language	48	11%
Unknown	48	11%
Other language only	20	4%
Socioeconomic status indicator		
SEIFA 1 - 5	128	28%
SEIFA 6 - 7	46	10%
SEIFA 8 - 10	272	60%
SEIFA Unknown	4	< 0.1%

Table 15: Subject characteristics by age group at point of data extraction

Age at data extraction (months)	Number	Percentage
0 - 12	22	5%
13 - 24	46	10%
25 - 36	55	12%
37 - 48	63	14%
49 - 60	66	15%
61 - 72	75	17%
> 72	123	27%

FLI scores were collected for 450 participants (2,003 scores, mean = 4.45 scores per participant, SD = 3.00). A PEACH+ score was collected for 40 participants, and a LEAQ score for 23 participants. Language assessment scores were extracted for 421 participants during the period of the study (157 scores for children who were 3 years of age, 154 scores for children 4 years of age and 110 scores for children 5 years of age (Table 16).

Table 16: Language and auditory assessments by age

	Number
Language assessments	421
3 years	157
4 years	154
5 years	110
Auditory assessments	514
FLI	450 (2003 FLI scores)
FLI administrations per participant Mean = 4.45 SD 3.00	
PEACH+	41
LEAQ	23

Concurrent Validity

There were 40 participants identified who had FLI and PEACH+ scores within the identified timeframe (Table 17). The majority of these children were aged between 25 and 72 months. Raw scores on the PEACH+ ranged between 12 and 44, with a median of 36 (SD = 6.5). Statistical analysis indicated no evidence of a linear relationship between scores on the PEACH+ and the FLI (Figure 2).

Table 17: PEACH+ descriptive statistics

Age Group (months)	Count	Mean	SD	min	25% percentile	50% percentile	75% percentile	Max
0 - 12	--							
13 - 24	1	12	--	12	12	12	12	12
25 - 36	9	37.7	4.9	30	32.0	40.0	41.0	42
37 - 48	8	36.4	7.1	23	33.3	37.5	41.0	44
49 - 60	10	37.2	5.5	25	35.5	37.0	40.8	44
61 - 72	8	36.6	4.9	28	34.3	37.5	39.5	43
> 72	4	36	3.3	32	35.0	36.0	37.0	40

Figure 2: PEACH+ and FLI score linear regression analysis

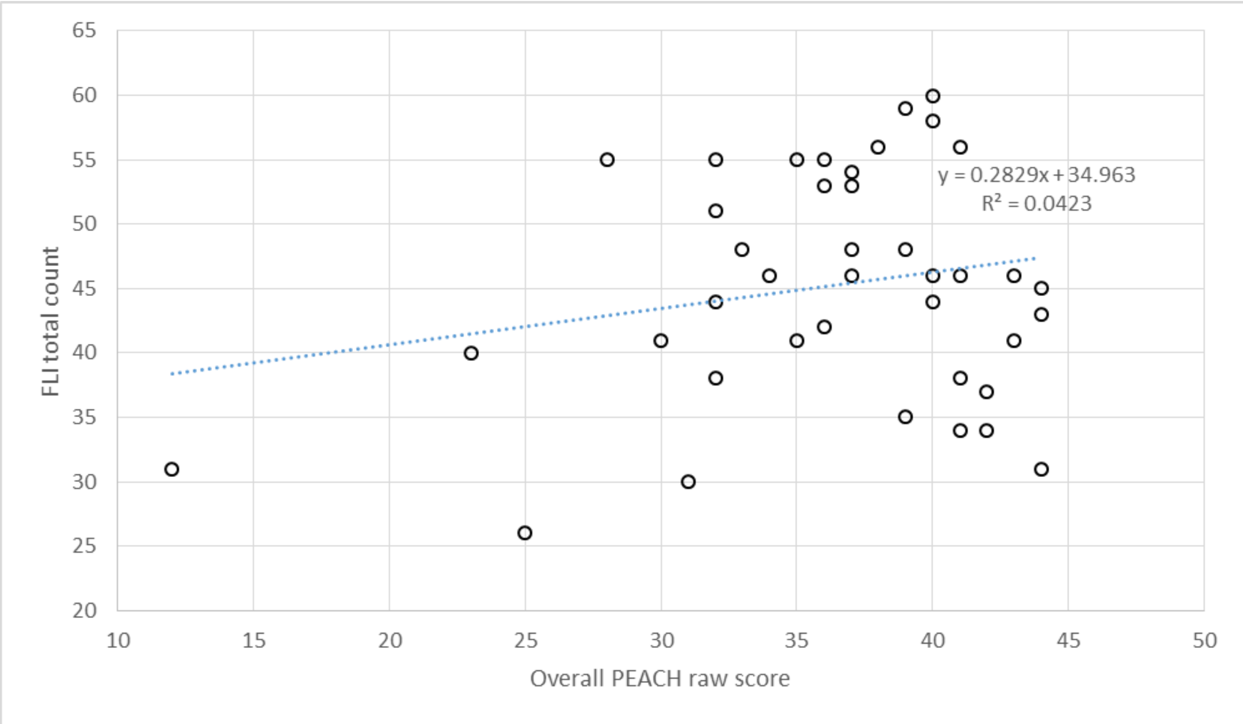


Figure 2. PEACH+ and FLI scores indicated no evidence of a linear relationship

Of the 28 participants in the study with a LEAQ score and a corresponding FLI score (Table 18), nine children were less than 12 months of age, 14 children were aged between 13 and 24 months, and five children were over 24 months of age. The mean LittlEARS score for children under 12 months of age was 15.77 (SD 6.37), with a range of 9 – 29. For children between 13 – 24 months of age, the mean LittlEARS score was 25.35 (SD 8.66) with a range of 6 – 35. Analysis established LittlEARS coefficients at 0.94 (1 unit increase in a child's LEAQ score = 0.94 increase in total FLI items achieved). A linear model using the least squares regression method yielded a correlation coefficient of 0.72 between the LEAQ and FLI scores, resulting in a relatively strong coefficient of determination ($\boldsymbol{R^2}$) of 0.52 (Figure 3). The two outlying very high FLI scores of above 50 were older children aged between 61 – 72 months of age. A plot of residuals indicated random errors and a relatively symmetrical distribution indicating appropriate use of a linear model (Figure 4). Results indicate significant relationships between the two measures.

Table 18: LEAQ descriptive statistics

Age Group (months)	Count	Mean	SD	min	25% percentile	50% percentile	75% percentile	Max
0 - 12	9	15.8	6.4	9	11.0	15.0	18.0	29
13 - 24	14	25.4	8.7	6	22.3	26.0	32.8	35
25 - 36	2	34.5	0.7	34	34.3	34.5	34.8	35
37 - 48	1	31.0	--	31	31	31	31	31
49 - 60	--	--	--	--	--	--	--	--
61 - 72	2	32.5	2.1	31	31.8	32.5	33.3	34
> 72	--	--	--	--	--	--	--	--

Figure 3: Linear regression and correlation co-efficient of FLI and LEAQ scores

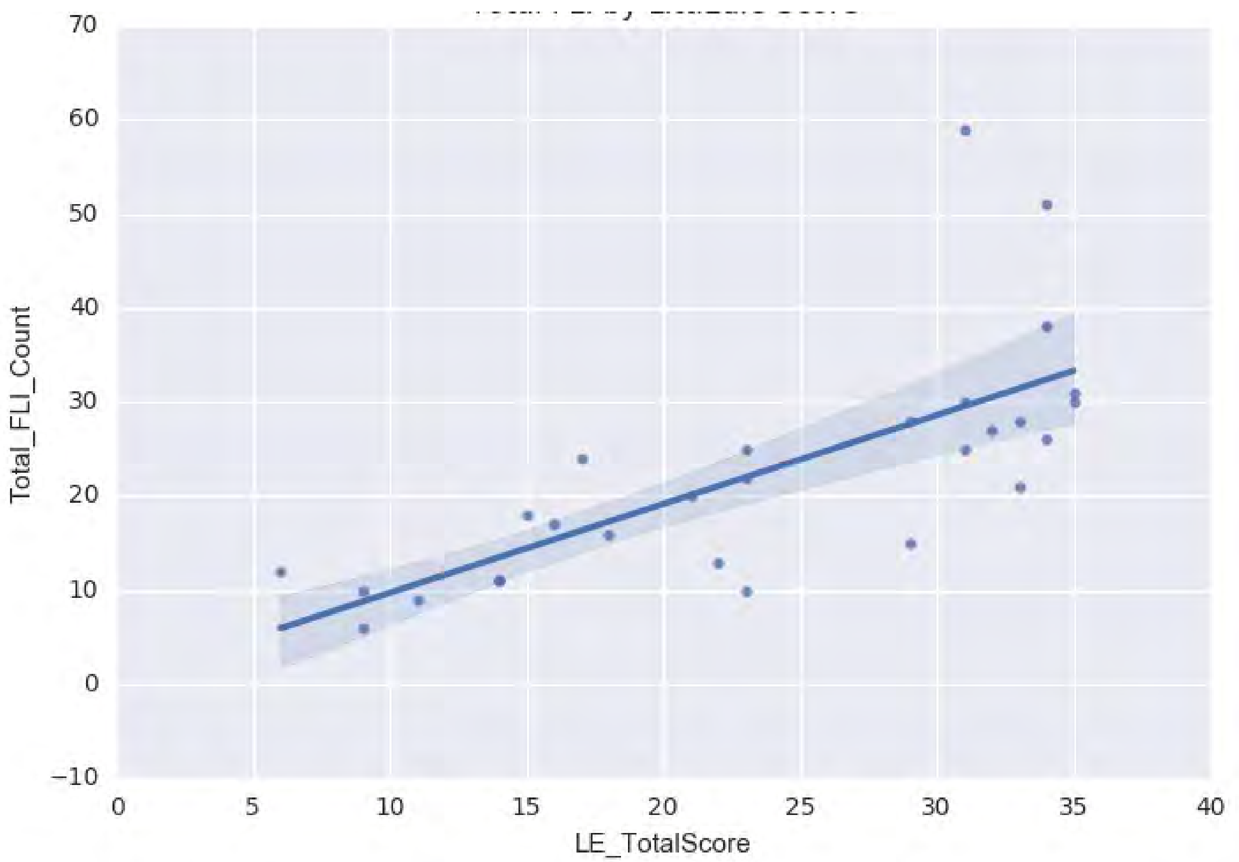


Figure 3. Coefficients were established at 0.94 (1 unit increase in a child's LEAQ score = 0.94 increase in total FLI items achieved). The two very high outlying FLI scores of 51 and 59 were the two children aged 71 and 70 months respectively and demonstrate the additional listening skills they are capable of at this age.

Figure 4: Plot of residuals: LEAQ predicting total FLI scores

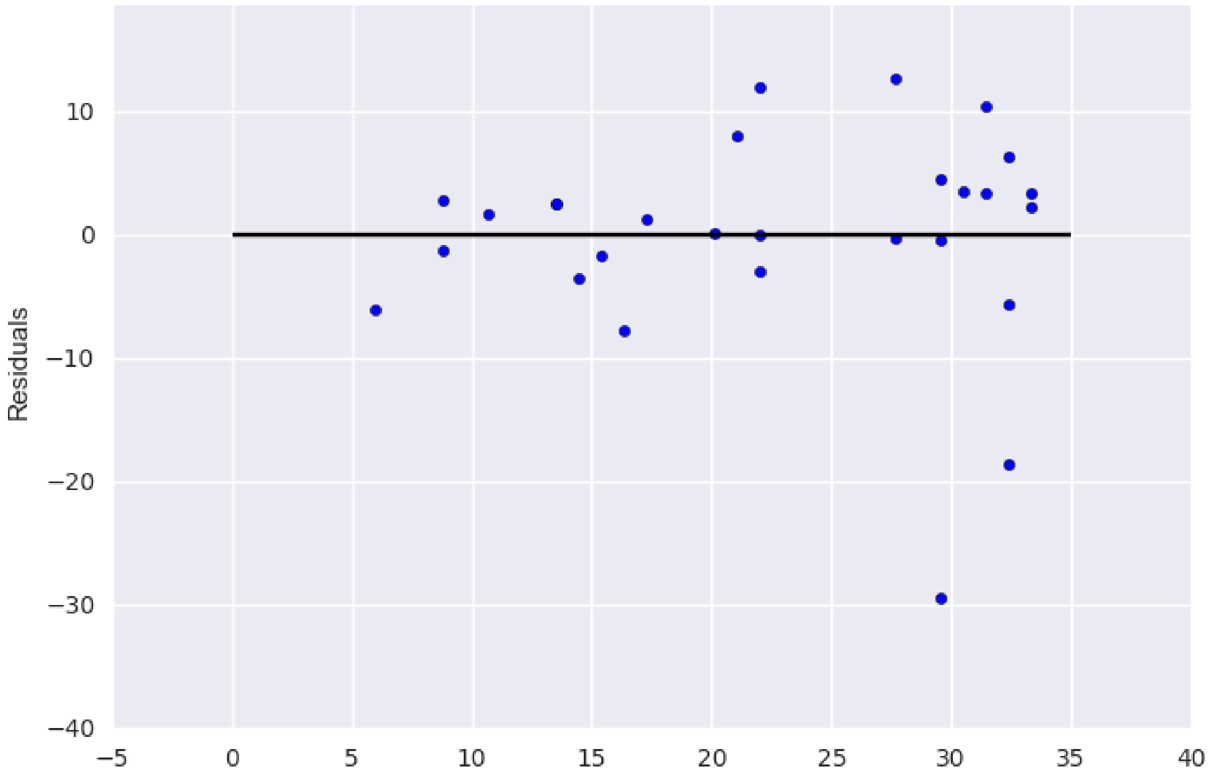


Figure 4. Random errors and a relatively symmetrical distribution indicate appropriate use of a linear model analysis.

Construct Validity

Known-groups validity is a recognised way to measure construct validity in fields where there is no gold-standard method of measurement (Davidson, 2014). To establish known groups in this context, it would be expected that the functional listening scores on the FLI for children diagnosed with a developmental need in addition to hearing loss would be lower than for children with hearing loss alone. Similarly, children entering an educational intervention program sooner after the diagnosis of a hearing loss may have a higher functional listening score than those enrolling later.

To establish a measure of known-groups validity, the functional listening scores of children above 3 years of age were grouped by the presence of a diagnosed additional developmental need. Of the 327 children aged 3 years and older in the study, 50 children had a developmental need in addition to hearing loss (277 children with hearing loss only). Of children aged 37 to 48 months, 13 children had a diagnosed additional developmental need (50 children hearing loss alone), 13 children aged 49 to 60 months had a diagnosed developmental need (53 children hearing loss alone), 10 children with a diagnosed additional need in the 61 to 72-month age group (65 hearing loss alone) and 14 children had a diagnosed additional need who were over 72 months of age (109 with hearing loss alone) (Table 19).

Table 19: Descriptive statistics of FLI scores for children with a diagnosed developmental need in addition to hearing loss

Age Group (months)	Additional needs	Count	Mean	SD	min	25%	50% (median)	75%	Max
37 – 48	No	50	38.3	11.9	2	34.3	41.0	46.0	56
37 – 48	Yes	13	25.3	9.9	12	18.0	25.0	31.0	45
49 – 60	No	53	39.9	14.1	1	32.0	44.0	51.0	59
49 – 60	Yes	13	36.2	15.4	9	27.0	44.0	46.0	52
61 – 72	No	65	47.9	10.4	2	45.0	50.0	55.0	60
61 – 72	Yes	10	34.6	13.9	10	27.3	39.0	42.8	50
> 72	No	109	48.7	10.8	15	45.0	53.0	56.0	60
> 72	Yes	14	42.6	10.1	27	38.3	43.0	50.8	58

FLI scores were lower for children with an additional need across all age groups (Figure 5). The Mann-Whitney U test was used to determine differences in the distribution of the known groups by comparing the mean ranks of each distribution (Table 20). Results indicate significant p-values for three of the four groups (where p = < 0.000 for the 37 – 48-month group, p = < 0.001 for the 61 – 72-month group, and p = < 0.009 for the over 72-month group) with significantly higher FLI scores for children with hearing loss alone.

Table 20: Mann Whitney U function results for children with and without developmental needs in addition to hearing loss

Age group (months)	p-value for U statistic from Mann-Whitney U (using normal approximation)
37 – 48	*0.000
49 – 60	0.195
61 - 72	*0.001
> 72	*0.009

A further analysis using Moods Median Test indicated significant differences in median of FLI scores for two of the four age groups. Significant p-values were observed for the 37 - 48-month group (p = 0.007) and the 61 - 72-month group (p = 0.009) (Table 21). For the 37 – 48-month group, 27 children with hearing loss alone were above the combined group median (compared to 1 child with additional needs). In the 61 – 72-month age group, 32 children with hearing loss alone were above the combined group median (compared to no children with an additional disability) (Table 22).

Table 21: Mann Whitney U function results for children with and without developmental needs in addition to hearing loss

Age group (months)	p-value for Mood's median test
37 – 48	*0.007
49 – 60	0.800
61 – 72	*0.009
> 72	0.058

Table 22: Mood's Median test descriptive statistics for children with and without a developmental need in addition to hearing loss

Number of children	No additional needs	additional needs
37 - 48-month age group		
Above combined group median	27	1
Equal or below combined group median	23	12
49 - 60-month age group		
Above combined group median	25	6
Equal or below combined group median	28	7
61 - 72-month age group		
Above combined group median	32	0
Equal or below combined group median	33	10
> 72-month age group		
Above combined group median	57	3
Equal or below combined group median	52	11

Figure 5: FLI scores for children by age group with hearing loss alone and with an additional developmental need

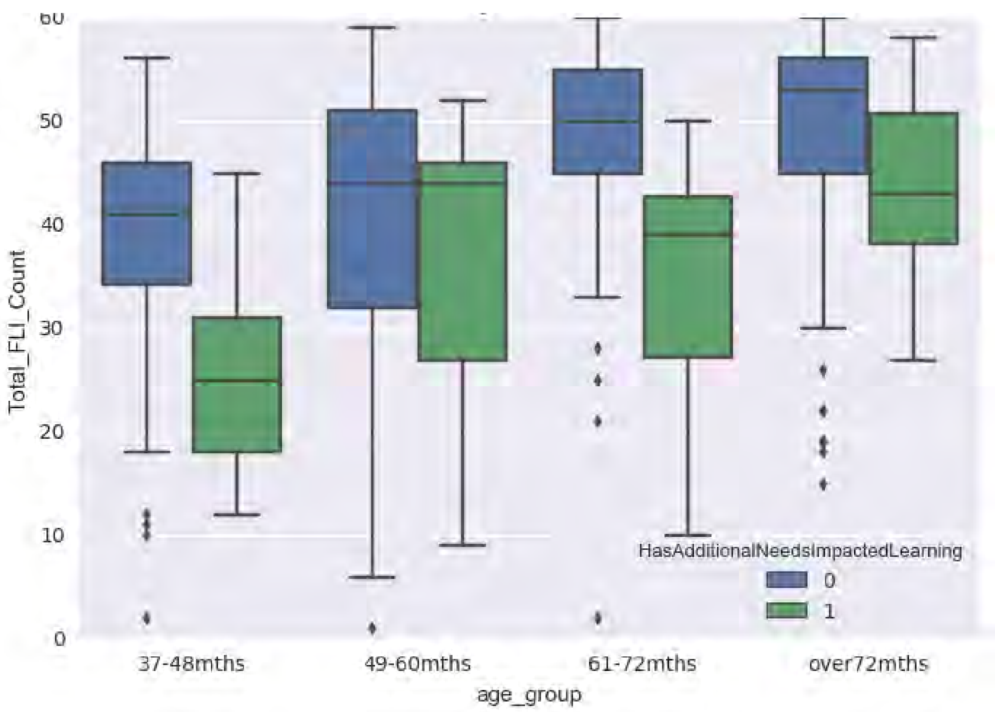


Figure 5. The upper and lower quartiles for each age group where blue/0 = hearing loss alone, and green/1 = presence of an additional development need. The whiskers for each group indicate highest and lowest count of FLI scores. The range of FLI scores were lower for children with an additional need across all age groups, with the most difference observed in the 37 – 48-month group.

Known-groups validity was also examined for children whose families engaged in intervention services soon after diagnosis of the hearing loss compared with those who engaged later. It was expected that children who entered sooner would have higher FLI scores than those who had a longer time between diagnosis and commencement of educational intervention. Participants were grouped according to whether they enrolled in intervention services within 3 months of diagnosis (early group), or 3 months or more (later group). Of children 0 - 12 months of age, 17 children were in the early group and 4 in the later group. At 13 – 24 months of age, there were 18 children in the early group and 22 children in the later group; at 25 – 36 months of age, 28 children in the early group and 21 in the later group; at 49 – 60 months of age, 23 children in the early group and 27 in the later group; at 61 – 72 months of age, 24 children were in the early group and 31 children in the later group; and for children over 72 months of age, 27 children enrolled in their educational intervention program within 3 months of diagnosis, and 54 children after 3 months (Table 23). Results indicate a wider range of scores for children in the later group, in particular for children between 25 and 60 months of age (Figure 6). Mann Whitney U test results indicated significant differences in the mean rank of distribution of scores for children aged 25 – 36 months ($p = 0.012$) and over 72 months ($p = 0.008$) (Table 24).

Table 23: Entry to educational intervention before and after 3 months of diagnosis

Age Group (months)	0 -12	13 - 24	25 - 36	37 - 48	49 - 60	61 - 72	> 72
EI service ≤ 3 months	17	18	28	21	23	24	27
EI service > 3 months	4	22	21	26	27	31	54

Figure 6: FLI scores for children by age group who engaged in their educational intervention program within 3 months of diagnosis compared with those who engaged later

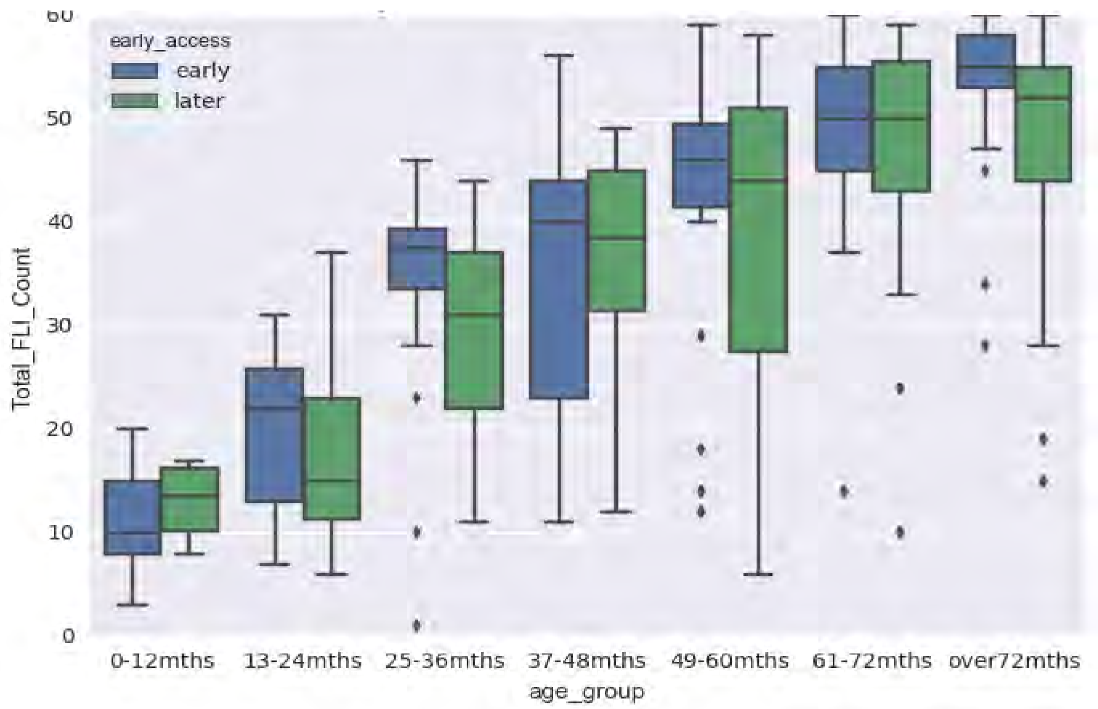


Figure 6. Upper and lower quartiles for each age group, where blue/0 = engaged in educational intervention services within 3 months of diagnosis, and green/1 = engaged in educational intervention services later than 3 months after diagnosis. Whiskers for each group indicate the highest and lowest count of FLI scores. Larger ranges of FLI scores were observed across the later group, apart from the 13 – 24 months and 37 – 48 months.

Table 24: Mann-Whitney U test results by early and later entry into educational intervention

Age Group (months)	p-value for U statistic from Mann-Whitney U (using normal approximation)
0 – 12	0.294
13 – 24	0.091
25 – 36	*0.012
37 – 48	0.427
49 – 60	0.238
61 – 72	0.432
> 72	*0.008

Results from Mood's median test indicated no significant difference between median FLI scores of the two groups at any of the four age groups (Table 25). For children aged 0 - 12 months, seven children from the early group to intervention were above the group median FLI score (compared to two from the later group), and 10 children equal to or below (again compared to two children). Of the 18 children aged 13 – 24 months, 11 children in the early group had a median FLI score above the group median (compared to eight children in the later group), whereas seven children in the early group had a median FLI score equal to or below the group median (compared to 17 in the later group to intervention). For children 25 – 36 months of age, 16 children in the early to intervention group had a median FLI score above the group median (compared to seven children in the later group), and 12 children in the early group had a median FLI score equal to or below the group median (in comparison to 14 children in the later group). Of children between 37 – 48 months of age, 10 children in the early to intervention group had median FLI scores above the group median (compared to 10 in the later group), and 11 children in the early group had median FLI scores equal to or below the group median (16 children in the later to intervention group). For children 49 – 60 months of age, 12 children in the early group had a median FLI score above the group median (and 12 children in the later group), whilst 11 children had a median FLI score equal to or below the group median of FLI scores (and 11 in the later group). Of children 61 – 72 months of age, 11 children in the early group had a median FLI score above the group median (14 children in the later group) and 13 children in the early group had a median FLI score equal to or below the group median FLI score (in comparison to 17 children in the later group). Lastly for children older than 72 months of age, 16 children who were early to educational intervention had a median FLI score above the group median (21 in the later group), and 11 children had a median FLI score equal to or below the group median FLI score (compared to 33 children in the later to intervention group). (Table 26).

Table 25: p-values for Mood's Median test for FLI scores for children engaging in intervention services before and after 3 months of diagnosis

Age Group (months)	p-value for Mood's Median test
0 – 12	0.80
13 – 24	0.21
25 – 36	0.17
37 – 48	0.73
49 – 60	0.60
61 – 72	0.82
> 72	0.13

Table 26: Distribution of median scores in comparison to the combined group median of FLI scores for children who engaged in intervention services before and after 3 months of diagnosis

	EI services ≤ 3 months	EI services >3 months
0 - 12-month age group		
Above combined group median	7	2
Equal or below combined group median	10	2
13 - 24-month age group		
Above combined group median	11	8
Equal or below combined group median	7	14
25 - 36-month age group		
Above combined group median	16	7
Equal or below combined group median	12	14
37 - 48-month age group		
Above combined group median	10	10
Equal or below combined group median	11	16
49 - 60-month age group		
Above combined group median	12	12
Equal or below combined group median	11	11
61 - 72-month age group		
Above combined group median	11	14
Equal or below combined group median	13	17
> 72-month age group		
Above combined group median	16	21
Equal or below combined group median	11	33

Predictive Validity

To determine the extent to which a child's FLI score could predict language outcomes, cumulative counts of FLI scores were used from 30 through to 57 months of age in 3-month intervals. As would be expected, the dataset contained a growing number of scores at each interval, with 33 at 30 months, 35 at 33 months, 38 at 36 months, 41 at 39 months, 48 at 42 months, 56 at 45 months, 64 at 48 months, 70 at 51 months, 76 at 54 months and 81 at 57 months. The variation in sample sizes across age brackets reflects the clinical nature of the study and growing numbers of children in the intervention program. FLI scores at each interval were analysed in a linear regression model with language scores at five years of age. Intercept values, coefficient values, p-values (of the coefficient), R^2 values and correlation coefficients are provided in Table 27.

Table 27: Linear regression results of language scores at 5 years and FLI scores at intervals between 30 and 57 months of age

FLI Total (months)	Sample size	Intercept	Coefficient (slope)	P-Value (of coefficient)	Coefficient of determination: R^2	Correlation coefficient
30	33	59.0	0.97	0.016	0.17	0.41
33	35	71.7	0.61	0.029	0.08	0.28
36	38	65.7	0.72	0.025	0.13	0.36
39	41	64.5	0.69	*0.008	0.13	0.36
42	48	41.1	1.22	*0.000	0.35	0.59
45	56	30.5	1.38	*0.000	0.32	0.57
48	64	36.1	1.24	*0.000	0.33	0.57
51	70	28.8	1.37	*0.000	0.32	0.56
54	76	35.6	1.19	*0.000	0.25	0.50
57	81	13.8	1.61	*0.000	0.34	0.59

The pattern of results indicates that FLI scores become increasingly predictive of a child's language score over time. Correlation coefficient scores demonstrate that FLI and language scores at 5 years have positive linear relationships from 30 months. Weaker relationships are observed at 30 months (0.41) through to moderate to strong relationships from 42 months of age (0.59) (Figure 7). Analysis of p-values indicate the correlation coefficient is statistically significant for 39 months and above. Lower R^2 values indicate the variance explained by the FLI is low in comparison with the total variance in scores.

Figure 7: Linear regression modelling of FLI scores and children's language scores at 5 years of age

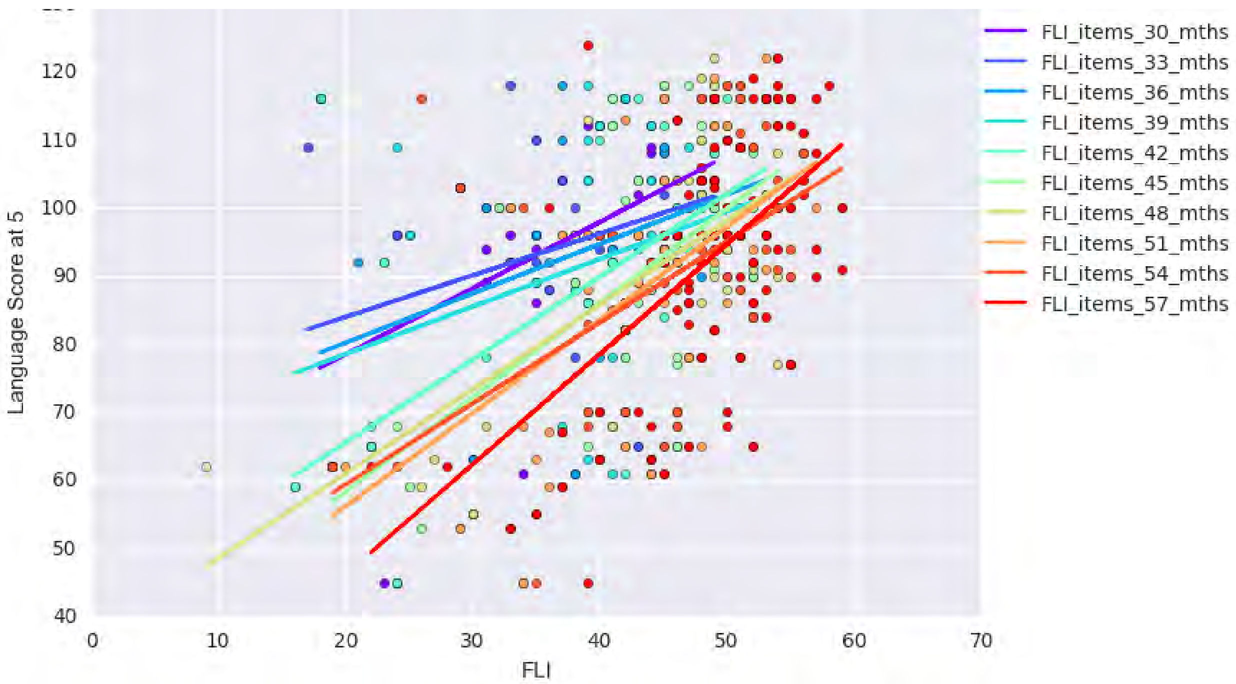


Figure 7. Group results indicate positive linear relationships between FLI scores and language assessment scores at 5 years of age. Weak relationships (in blue from 30 – 36 months of age) get stronger with age to moderate

relationships (in green and yellow from 42 to 48 months of age) to strong relationships (in red at 54 and 57 months)

Similar results were seen in linear regression models for the cumulative count of FLI scores in three-month intervals from 18 – 45 months and the language results of children at four years of age. FLI counts increased by intervals with 28 scores at 18 months, 33 at 21 months, 42 at 24 months, 54 at 27 months, 64 at 30 months, 71 children at 33 months, 78 at 36 months, 83 at 39 months, 94 at 42 months and 101 at 45 months. Coefficient values were significant from 24 months and above (Table 28). Correlation coefficient scores were positive for all ages with weak values at 18 months (0.21) through to moderate values at 39 months and above (0.51 – 0.54) (Figure 8). Consistent with analysis of the 5-year results, low R^2 values indicate the variability in language scores are not explained by FLI scores alone.

Table 28: Linear regression results of language scores at 4 years and FLI scores at intervals between 18 and 45 months of age

FLI total (months)	Sample size	Intercept	Coefficient (slope)	P-Value (of coefficient)	Coefficient of determination: R^2	Correlation coefficient
18	28	86.55	0.33	0.283	0.044	0.21
21	33	79.07	0.59	0.057	0.112	0.34
24	42	68.71	0.88	*0.001	0.236	0.48
27	54	70.07	0.77	*0.000	0.223	0.47
30	64	51.99	1.22	*0.000	0.342	0.58
33	71	59.87	0.916	*0.000	0.216	0.46
36	78	57.34	0.913	*0.000	0.249	0.49
39	83	53.14	0.964	*0.000	0.256	0.51
42	94	52.39	0.964	*0.000	0.270	0.52
45	101	42.28	1.162	*0.000	0.295	0.54

Figure 8: Linear regression modelling of FLI scores and children's language scores at 4 years of age

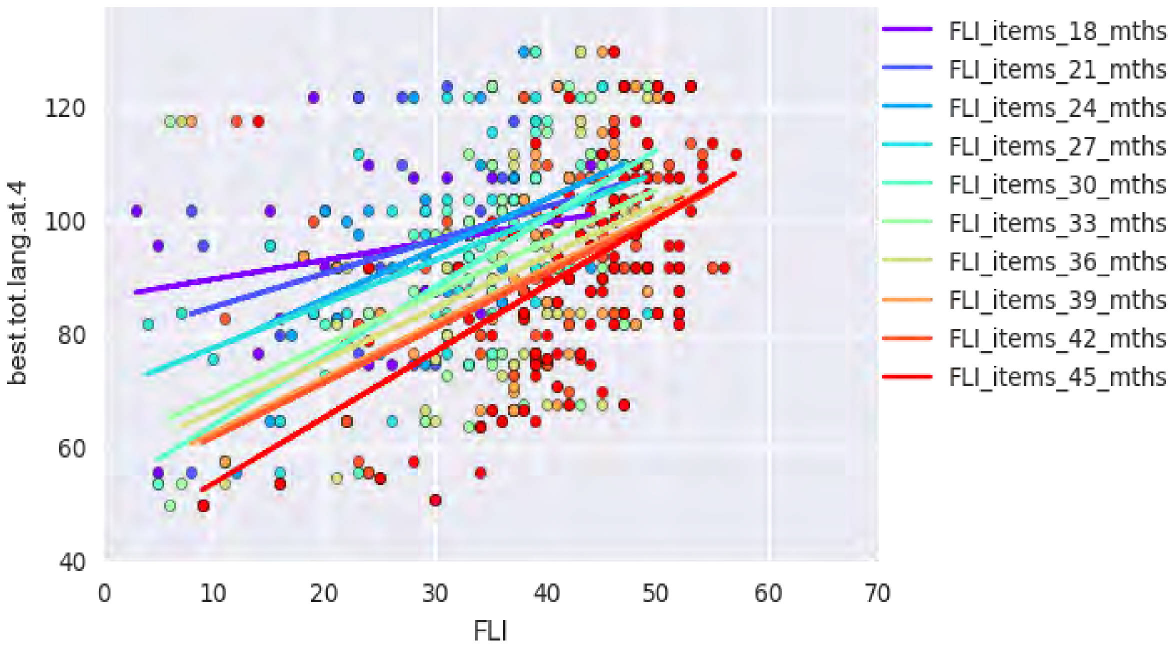


Figure 8. Positive linear relationships are indicated between FLI scores and language assessment results at 4 years of age, although not as significant as observed in analysis of FLI scores and language results at 5 years

Discussion

This study set out to examine the internal validity of the FLI in terms of:

a) concurrent validity against similar assessments,

b) construct validity by differences in known groups, and

c) predictive validity of a child's language skills.

Overall, there were mixed findings across all three areas. In regard to similar assessments, outcomes on the FLI were found to be significantly associated with scores on the LEAQ, but not with scores on the PEACH+. For known groups, expected differences were found in the majority of age groups for children with an additional need and for some groups who were earlier to enrol in educational intervention, although no difference in group medians were observed across any of the age groups. With respect to predicting language outcomes, positive linear relationships were found between FLI scores and language scores at 4 and 5 years of age from 30 and 24 months respectively.

Relationship to Existing Tools

Concurrent validity of the FLI was measured by analysing the results of children's FLI scores to the same children's scores on similar assessments that have previously been validated. In this context the LEAQ and PEACH+ were chosen as two of the most widely used and validated auditory questionnaires. Results of the analysis indicated a significant relationship between children's listening scores on the FLI and the LEAQ, yet no observable relationship between children's scores on the FLI and the PEACH+, which was an unexpected finding. There could be a number of reasons for this.

As a measure of audibility, the PEACH+ ranks 13 auditory behaviours on 5-point scales, by frequency (how often a child exhibits a described behaviour), and ease (how easy or hard it is for the child to demonstrate the described behaviour)[11]. As such, it can be can be administered at different intervals over time to evaluate the effectiveness of a child's use of hearing in real-world environments, to determine if a child's amplification is effective, and to guide audiological intervention (Bagatto & Scollie, 2013; Ching & Hill, 2005). On the other hand, the FLI is a measure of a child's rate of acquisition of listening skills over time, that is, a cumulative count and developmental tracking of their listening progress. The purpose of administering the FLI is to identify new listening skills and auditory behaviours that a child has acquired. The differences in what the two tools measure (frequency and ease of auditory behaviours versus acquisition of listening skills) and how they are used (test-retest versus cumulative count over time) could explain the lack of relationship observed between children's scores.

[11] Although only the frequency of each auditory behaviour was recorded and analysed in this study in line with the published validation data for the PEACH+ (Ching & Hill, 2005)

It is also possible the lack of similarity in scores could be in part due to the impact of parent administration (PEACH+) and clinician administration (FLI). Some correlations have been found between family and clinician ratings in child health measures, however, these are not always significant and low levels of inter-rater reliability are often reported (Miller, Perkins, Dai, & Fein, 2017; Schneider, Ryan, & Mahone, 2020; Terrelonge & Fugard, 2017). These findings can be due to experience, time, opportunity with the child, perception, and level of understanding of items/skills and behaviours being measured. To reduce this variability all three assessments in this study (FLI, LEAQ and PEACH+) were completed by clinicians with parent input and involvement. The LEAQ has also been validated using parent administration yet still had a significant correlation with FLI scores.

The differences in the age range of children in the PEACH+/FLI dataset may also have been a contributing factor to results. Although the PEACH+ is still able to be used with children of all ages, it has been identified to be of most value to younger children (Ching & Hill, 2007). The majority of children in the data set in the current study were over 3 years of age which resulted in most of the PEACH+ scores in the top third of possible scores (32 to 48), whereas the range for FLI scores were spread across the upper half of possible scores (30 to 60). Further analysis of PEACH+ and FLI scores of children aged 0 – 2 years would assist in understanding further similarities and differences between these measures. The significant relationship between scores on the LEAQ and the FLI indicate the similar content and purpose of the tools (acquisition of auditory skills over time) and provides evidence for validation of the FLI as a measure of a child's listening development.

Despite significant results, there are a number of differences between the LEAQ and the FLI that should be noted. First, the baseline measure of age. The LEAQ uses a child's hearing age (time since hearing device fitted), whereas the FLI uses a child's chronological age. There are inherent complexities in accurately determining a child's hearing age. For example, device/s can be fitted but amplification levels not optimally set, not worn all/part of the day, and the time taken for programming to be optimised post implant activation needs to be taken into account. A child may be fitted with hearing aids at a very young age, yet they provide minimum benefit or access to sound over a number of months or years. Subsequently they may proceed to cochlear implant surgery, then following activation they require a number of programming appointments until an appropriate electrical current level for each electrode provides the child with a dynamic range from audible to maximum comfortable hearing sensations (Incerti et al., 2018; Shapiro & Bradham, 2012). Consequently, calculating a hearing age from the time devices are initial fit, or implant activated, becomes problematic as this is not the point at which they have appropriate access to sound. The difference in hearing age (LEAQ) and chronological age (FLI) may have contributed to some of the variability observed, and results may be more significant if the same age mark was used for comparison by both measures.

It should also be noted that although the LEAQ was specifically designed for children under 3 years of age using a cochlear implant, children in this dataset were representative of children with hearing loss enrolled in an early intervention service and were a range of ages (above and below 3 years of age), with a range of hearing levels (mild through to profound), and used a range of device/s (hearing aids, bone conduction devices and cochlear implants. The extended demographics of this dataset may have also contributed to an increased variance in results. The two outlying scores in Figure 3 demonstrate that older children are capable of a greater number of listening skills as reflected by high FLI scores and the larger number of items in the FLI as compared to the LEAQ. A higher degree of correlation between outcomes might have been demonstrated if the analysis was specifically for children under 3 years of age using cochlear implants.

Expected Differences Between Groups

Construct validity of the FLI was examined through a known-groups validity measure, in which the FLI was administered to two groups that are known to have different levels of a construct, to confirm if the hypothesised difference is reflected in the FLI scores of the two groups (Davidson, 2014). The presence of another disability in addition to hearing loss has long been established as a significant factor in a child's outcomes (Birman, Elliott, & Gibson, 2012; Ching, Dillon, et al., 2013a; Cupples et al., 2018). As cognitive processes are intrinsically linked to listening skill development, it is reasonably hypothesised that a child's listening scores on the FLI would similarly be impacted by the presence of an additional developmental need. Results from this study indicate this was the case for all but one age group (49-60 months of age). There were similar numbers of children with an additional developmental need in all four age groups (n = 13, n = 13, n =10, and n = 14), although in comparison, these numbers were much lower than those in the hearing loss alone groups (n = 50, n = 53, n = 65, n = 109 respectively). With fewer children in the additional needs' groups, the variation of the impact of an additional disability is difficult to account for, as are the differences between the additional disabilities that exist in such a group. A larger sample size of children with additional needs would also increase statistical power and overall confidence in these findings.

Further examining the differences between additional needs within groups, within the 49 to 60-month age group there were four children who had developmental needs resulting from cytomegalovirus (of which one child had multiple disabilities), three children were diagnosed with a developmental delay (one of which was mild) and one child had autism spectrum disorder. In comparison, within the 36 – 48-month age group, six children had multiple disabilities and/or a syndrome, five children had a developmental delay, 1 child had cerebral palsy, and the additional diagnosis for one child was not reported. As disabilities are so heterogenous in nature, it is possible that the impact of the additional needs of children in the 49 - 60-month group may not have been as significant as in other groups.

Best practice guidelines for children with hearing loss recommend entry into educational intervention programs at the earliest opportunity, as discussed in detail in Chapter 4 (Joint Committee on Infant Hearing, 2007; Joint Committee on Infant Hearing et al., 2013; Yoshinaga-Itano, 2003a). As such, it was proposed that children who engaged earlier in an educational intervention program would have better listening skills (and subsequently higher FLI scores) than children who engaged later. Results from this study indicated significant differences in distributions between the children who enrolled earlier in only two of the seven age groups (13 – 24-month group and > 72-month group). No significant differences in medians were found for any age group. In retrospect, it is highly likely that categorising groups by early to intervention as 'within 3 months of diagnosis' was too limiting to observe a difference in listening skills. A greater difference would be expected in children for whom there was a larger gap between diagnosis and intervention, for example 12 or 24 months. Analysis of other known groups such as children who have a device fitted earlier compared to those fitted later after diagnosis, or age of implantation could also provide valuable information on which to guide the validation of the FLI for known groups (Ching et al., 2018). Clinically, this comparative information can provide valuable insight for both professionals and parents in providing appropriate educational intervention and clinical services, and for families in guiding engagement and decisions. This is explored further in the feasibility study that is reported in the next chapter.

Relationship to Later Language Outcomes

Given the crucial role that listening plays in the development of spoken language, it follows that a child's listening skills should be a reasonable indicator of later language skills. That is, the poor development of listening skills would not provide the necessary foundations of language through limited exposure, and is likely to result in poor language skills. On the other hand, good listening skills that provide maximum opportunities for linguistic experience and are most likely to result in better language outcomes. The potential that parents and professionals can use the FLI to 'see into the future' to inform earlier intervention decisions to change later outcomes is profoundly valuable.

Results from this study of predictive validity demonstrate a child's listening skills on the FLI at 36 months are predictive of their language score at school entry. This provides critical information for parents and professionals at much earlier opportunities to guide changes in intervention and in supporting early decisions. Results indicate that this information can be used with moderate to strong levels of confidence to change input, engagement and environments to support the development of a child's listening skills and influence language outcomes. A poor acquisition of listening skills as demonstrated by a child's slowly rising or flat score on the FLI would initiate the early intervention team and family working together to understand impacting factors, and decide on actions to address them.

These findings add weight to existing evidence that support the use of tools to predict language results. Ching, Day, et al. (2013) report on the predictive ability of the PEACH at 6 and 12 months after device fitting with a child's 3-year language outcomes. This is also supported by Wong et al. (2018) reporting the PEACH a concurrent predictor of language and psychosocial outcomes at 5 years of age. As the PEACH+ measures frequency and ease of auditory behaviours, it follows that a child who can hear well in real-world environments and demonstrates key auditory behaviours easily and often, is able to maximise their input and language learning capability. In addition to audibility, a child needs to comprehensively expand and grow listening skills to support ongoing language development. Findings from this study indicate the developmental acquisition of listening skills can provide this information. A further enhanced predictive model that considers factors in addition to listening skill development such as age of diagnosis, age of implantation, and presence of additional needs, would add value in understanding the variability and context in which the FLI is used.

Limitations

The use of clinical data poses natural risks and benefits. Primarily in terms of risk, these are related to the level of internal confidence that can be placed in the results of a study due to integrity of the data, data gaps, incomplete datasets and data errors. To maximise the accuracy of the data used and to minimise risks of clinicians' data entry errors, data checks were performed on the final dataset and data gaps were coded as *unknown*. These gaps did impact on understanding the full picture of participant demographics and characteristics in the study. The number of unknown entries also created anomalies with numbers across categories as some data fields were more complete in the database than others (e.g. symmetry of a child's hearing loss was less often completed than degree of hearing loss due to its clinical use 'symmetry unknown' = 55, 'degree unknown' = 37). On the other hand, the benefit of using a clinical dataset is the real-world feasibility, use and application that it provides, contributing to the external validity of the FLI as a measure. This supports the direct application of the FLI to the population range for whom it is intended, rather than the outcomes of a convenience sample recruited solely for the purposes of a validation study.

The issue of reliability is important to address. In the clinical setting in which the FLI was used in this study, each team member was trained in its administration. Questions during use were shared back through the group to build ongoing reliability. As the FLI is a subjective measure, it cannot be demonstrated statistically how consistently all clinicians applied the acquisition criteria and interpreted the items. Determining acquisition criteria for an item was also found to be problematic, as the date an item was marked off was only a close estimate of the date the child acquired the skill since acquisition is not categorical. Chapter 9 of this thesis discusses the ongoing research and developments addressing these particular issues that arose during this study. Given this and the other limitations discussed, it is important to interpret the results from the studies reported within this chapter only within the context of the information that has been used to inform them.

Conclusion

The aim of this study was to establish the internal validity of the FLI through measures of concurrent, construct/known-groups and predictive validity. Results indicated a highly significant level of concurrent validity between children's scores on the FLI and their scores on the LEAQ. No statistically significant relationship was found between FLI and PEACH+ scores. The hypothesised differences between known groups was demonstrated for children with and without a diagnosed additional disability to hearing loss in all but one age group. Limited statistical differences were indicated for children who commenced intervention services within 3 months of diagnosis compared with those who engaged later. Moderate to strong linear relationships and statistically significant correlation coefficients demonstrated a child's listening skills on the FLI at 36 months are predictive of their language score on school entry. These analyses provide empirical support for the FLI as a valid and viable clinical measure to be used in identifying a child's listening skill development across the range of children with hearing loss in an early intervention and cochlear implant program. The predictive relationship that has been demonstrated of a child's listening skills to their later language skills has the potential to be highly impactful in positively influencing the communication outcomes for children with hearing loss and useful by both professionals and parents.

The next chapter will present information on the feasibility and viability of the FLI in clinical use as a measure of a child's listening development in an early intervention and cochlear implant setting for children with hearing loss. The outcomes of a retrospective clinical study using the FLI with 543 children aged 0 - 6 years over a five-year period will be reported, and the FLI scores of children with typical hearing used for comparison. Individual children's trajectories of FLI scores are reviewed to determine if a child's score changes over time as would be expected, and group data are analysed by audiological characteristics (i.e., age of implant, device used, level, type and symmetry of hearing loss) to identify if the expected differences between groups are observed.

Chapter 7

CLINICAL FEASIBILITY AND VIABILITY OF THE FLI®

The previous chapter explored the validity of the FLI as a clinical measure through establishing levels of internal concurrent, construct and predictive validity with a dataset of children with hearing loss in a clinical setting. This chapter will continue to examine the feasibility and viability of the FLI by reporting on its use as a standard measure of listening for an entire population of children with hearing loss attending an integrated early intervention and cochlear implant program. FLI scores for the children with hearing loss will be compared to FLI scores for a sample of children with typical hearing.

Aim

The aim of this clinical retrospective study was to determine the feasibility and viability of the FLI as a clinical measure for all children with hearing loss enrolled in an early intervention and cochlear implant program, through three research objectives.

1. Can the FLI be used successfully with an entire population of children with hearing loss in a clinical/educational setting?
2. Do children's individual FLI trajectories change over time as would be expected?
3. Do the data for known groups show the expected differences (typical hearing versus hearing loss, bilateral versus unilateral hearing loss, presence of an additional disability to hearing, ANSD, age at diagnosis, type of device, level of loss, age of implant)?

Method

Participants

Two groups of children participated in this feasibility study. The first group were children with hearing loss from 0 to 72 months of age, enrolled in the same integrated early intervention and cochlear implant program in Australia (EI group) (n = 543). This particular early intervention program provided family-centered early intervention services across three states of Australia for families choosing a listening and spoken language communication approach. Families attended individual and/or group sessions at varying degrees of frequency dependent upon individual need. Weekly intervention frequency was typical for children under 3 years of age with bilateral moderate hearing loss or greater. For children 4 to 5 years of age, group sessions often took the place of individual therapy sessions if listening and language development was progressing well, with intervention focusing on social skills in noisy, real life environments, and readiness for school.

The second group of participant children all had typical hearing (TH) and had passed a newborn hearing screening test (n = 32). This group was a convenience sample of children who were either attending the preschool program for typical hearing children at two of the early intervention centres (n = 20), or children of the research and clinical team members (n = 12). The TH group served as an initial group to provide benchmark functional listening skills for children with typical hearing[12].

Early Intervention (EI) Group

Demographic and audiological information was collected during routine clinical services. Demographic information included date of birth, gender, presence and type of additional needs, language background, and date of enrolment to early intervention. Audiological information collected included Universal Newborn Hearing Screening (UNHS) result, date of diagnosis, date of device fitting, hearing loss etiology, presence of middle ear pathology, level of hearing loss (left and right at 500Hz, 1kHz, 2kHz, 4kHz), type of hearing loss (left and right), device type (left and right), symmetry of hearing loss, FLI scores, and date of cochlear implant/s surgery. Audiological and demographic characteristics of the EI group are provided in Table 29 – Table 35. The only children excluded from the study were children newly enrolled to the service who did not yet have the FLI administered as part of their routine clinical protocols. Throughout the duration of the study, there were no children reported by the clinical team who were unable to have their listening skills measured using the FLI.

The dataset included children from a variety of language backgrounds, classified as either monolingual children who spoke English only, bilingual children who spoke English as a primary language, bilingual children who spoke English as an additional language or monolingual children who spoke only a language other than English. Where necessary, the FLI was administered to families in non-English languages through an interpreter with the family and case manager. All children enrolled in the program had a permanent sensorineural and/or conductive hearing loss (hearing thresholds greater than 25dBHL inclusive (WHO, 2019)) in one or both ears. Levels of hearing loss ranged from mild through to profound, and included both unilateral and bilateral hearing losses. Children in the program were fitted with a range of device types and configurations including monaural, binaural and bone anchored hearing aids; unilateral and bilateral cochlear implants; and bone anchored implantable devices. One in five children (20%) enrolled in the program had a diagnosed disability in addition to hearing loss.

[12] A larger prospective multi-centre study of the listening skills of approximately 500 children with typical hearing using the FLI has been completed in conjunction with the HEARing CRC, Cochlear Ltd, The Shepherd Centre and the University of Western Sydney (Ethics Approval H11517).

Table 29: EI group participant characteristics

EI group	Characteristic	Number of children
Gender	Male	285
	Female	258
Symmetry of hearing loss (HL)	Bilateral	385
	Unilateral	140
	Unknown	18
Presence of additional needs that impact on learning	Yes	92
	No	451
UNHS	Pass	54
	Refer	427
	Not tested	19
	Unknown	43
Age at diagnosis (months)	< 3	380
	3 – 6	23
	7 – 11	15
	12 – 23	37
	24 – 36	23
	> 36	33
	Unknown	32
Age at first device fitting (months)	< 3	177
	3 – 6	73
	7 – 11	34
	12 – 23	81
	24 – 36	44
	> 36	51
	Unknown	83
Age at entry to EI (months)	< 3	168
	3 – 6	96
	7 – 11	70
	12 – 23	86
	24 – 36	53
	> 36	70
	Unknown	0

Table 30: EI Group children (FLI data points) by type of bilateral hearing loss

		Left				
		Conductive	Sensorineural	Mixed	Unknown	ANSD
Right	Conductive	23 (88)	3 (23)	1 (2)	n/a	n/a
	Sensorineural	1 (3)	286 (1616)	2 (6)	1 (1)	2 (5)
	Mixed	2 (20)	3 (6)	24 (138)	1 (1)	n/a
	Unknown	n/a	n/a	n/a	15 (45)	n/a
	ANSD	n/a	1 (6)	n/a	n/a	13 (127)
	Normal	n/a	4 (19)	n/a	n/a	n/a

Table 31: EI Group children (FLI data points) by type of unilateral hearing loss

EI Group	Type	Number of children
Left	Conductive	14
	Sensorineural	37
	Mixed	5
	Unknown	1
	Auditory Neuropathy Spectrum Disorder	11
	Normal	n/a
Right	Conductive	26
	Sensorineural	29
	Mixed	7
	Unknown	1
	Auditory Neuropathy Spectrum Disorder	9
	Normal	n/a

Table 32: EI group by device used (bilateral hearing loss)

EI Group	Type	Number of children
Left	Cochlear implant	138
	Hearing aid	218
	Bone conduction device	13
	Unknown	14
	Unaided	1
Right	Cochlear implant	146
	Hearing aid	215
	Bone conduction device	9
	Unknown	15
	Unaided	0

Table 33: EI group by device used (unilateral hearing loss)

EI Group	Type	Number of children
Left	Cochlear implant	11
	Hearing aid	15
	Bone conduction device	15
	Unknown	30
Right	Cochlear implant	10
	Hearing aid	18
	Bone conduction device	21
	Unknown	31

Table 34: EI group by level of bilateral hearing loss

EI Group	Type	Number of children
Left	Normal	81
	High frequency (mild - profound)	8
	Mild	52
	Mild - moderate to profound	106
	Mod - moderate/ severe to profound	122
	Severe, severe – profound	58
	Profound	80
	Unknown	36
Right	Normal	70
	High frequency (mild - profound)	8
	Mild	50
	Mild - moderate to profound	115
	Mod - moderate/ severe to profound	128
	Severe, severe – profound	49
	Profound	85
	Unknown	38

Table 35: EI group by level of unilateral hearing loss

EI Group	Type	Number of children
	Normal	70
	High frequency (mild - profound)	1
	Mild	6
	Mild - moderate to profound	6
	Mod - moderate/ severe to profound	25
	Severe, severe – profound	19
	Profound	9
	Unknown	4

Typical Hearing (TH) Group

Parents of children in the TH group (n = 32) reported no concerns for their child's speech and language development or additional needs that impacted on learning. All children attending the preschool program completed the Clinical Evaluation of Language Fundamentals - Fourth Edition, Screening Test Australian & New Zealand Language Adapted Edition (Semel, Wiig, & Secord, 2004) to ensure language was at age appropriate levels. There were five children who failed the screening test and were excluded from the study. As a result, there were 27 children in the TH group.

Procedures: EI Group

The FLI was administered to all children in the EI group as part of routine clinical protocols. Administration of the FLI was completed by their case manager in collaboration with the child's family. The case manager was either a pediatric audiologist, or listening and spoken language therapist/ specialist with either speech pathology or teacher of the deaf qualifications. Each child's listening progress was reviewed every three to four months and the FLI and data entered in the clinical database. In some cases, the FLI was used more regularly, for example when a team member was concerned about progress or development, for specific populations, or in situations of rapid increase, or decline, in listening skill.

Procedures: TH group

The FLI was administered by a clinician experienced with the tool, either at one time or at variable intervals.

Definitions

The following terminology and protocols were used to standardise and define demographic and audiological characteristics.

- The presence of additional needs was recorded only if a formal written diagnosis had been received, and if it was considered by the case manager to impact on learning or language development.
- Age of implant was defined as the date of the child's (first) surgery, rather than date of CI activation (which was typically within 1 week of surgery)[13].
- Hearing loss level was categorised according to a child's hearing in their better ear and defined as mild = 26 - 40 dB, moderate = 41 - 55 dB, moderately severe = 56 – 70 dB, severe = 71 - 80 dB and profound = > 91 dB (Clark, 1981; modified from Goodman 1965).
- Auditory Neuropathy Spectrum Disorder (ANSD) was defined as a type of hearing loss rather than an additional need, and not included in level of hearing loss classifications.
- Middle ear pathology was defined as 3 consecutive months of evidence of type B tympanometry.

Parents of all children gave informed consent for de-identified data to be used in this study. The study was approved by the Macquarie University Human Research Ethics Committee (Reference No: 5201600650). There were no incentives offered to clinicians or families for participation in this research.

[13] Evaluation criteria for cochlear implant candidacy in the program was 70dBHL or greater, or ANSD in one or both ears. If bilaterally indicated and recommended children either received simultaneous or sequential cochlear implantation depending upon medical and audiological considerations and surgical availability.

Data Collection, Extraction and Validation

FLI scores were collected for the EI group between August 2012 and February 2018, and extracted from the clinical database in March 2018. The data were verified for validation and accuracy and incorrect scores removed. FLI scores for the TH group were collected between January 2014 and February 2018. As the study was a retrospective analysis, the information reported is representative of what was in the database at the time of extraction. Blank fields were reported as *unknown* and categorised accordingly.

Data Analysis

A total of 2,869 FLI results were collected for the 543 children in the EI group (mean = 5.3, SD = 4.3) and 51 FLI results for the 27 children in the TH group (mean = 5.2, SD = 1.7). Results were exported from the database for analysis by demographic and audiological information including level of hearing loss, age of implant, presence of additional needs, presence of ANSD, middle ear pathology, drop in hearing threshold, and use of a language other than English. Group data were aggregated and analysed in accordance for differences including typical hearing and hearing loss, presence of a disability in addition to hearing loss, bilateral and unilateral hearing loss, presence of ANSD, age of diagnosis, type of device, level of hearing loss, and age of implant. FLI assessments which were incomplete were removed from the dataset (n = 27).

Results

1. Use of the FLI in a Clinical/Educational Setting

The listening skills of all children with hearing loss enrolled in the intervention program (EI group) during the period of the study were able to be measured using the FLI. All FLI results are displayed in Figure 9 by each child’s age in months. Results indicate an increase in FLI scores with age, with wide variability as would be expected for the heterogeneity of the population of children with hearing loss in the program.

Figure 9: EI group total FLI data points

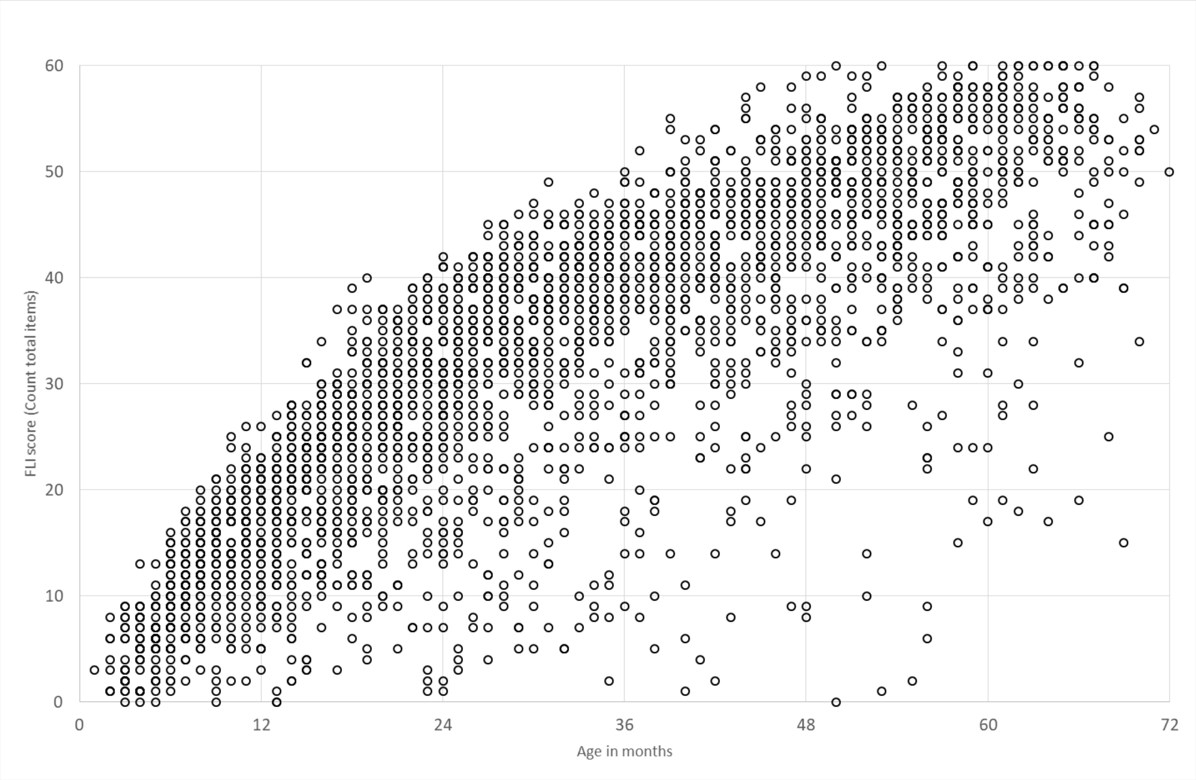


Figure 9. FLI scores collected from all children enrolled in the program over the course of the study. Each point may represent more than 1 child (if two children have identical FLI scores) and each child may have a number of scores

2. Changes to Children's Individual Scores Over Time

Each child's FLI results were collected and tracked over the time period of the study and used to build individual listening trajectories. The trajectory of all children with a bilateral hearing loss and 5 or more recorded FLI scores (n = 257) were graphed according to level of hearing loss (mild, mild - moderate and mild - profound; moderate and moderate - severe; severe and severe - profound; and profound). Children with only high frequency hearing loss were included in the mild and in the mild to profound group for the purposes of the analysis. Children with a developmental need in addition to hearing loss, ANSD in one or both ears and asymmetrical hearing losses were excluded from this analysis for comparative purposes.

Individual trajectories for each group are displayed against all FLI results for the EI group in Figure 10 – Figure 13. Variability in trajectories increases with level of hearing loss from mild, mild – moderate, and mild – profound hearing loss (Figure 10), moderate and moderate – severe (Figure 11), severe and severe – profound (Figure 12, to the most varied FLI trajectories for children with profound hearing loss (Figure 13).

Figure 10: Individual listening trajectories of FLI scores for children with bilateral mild, mild – moderate, and mild - profound hearing loss

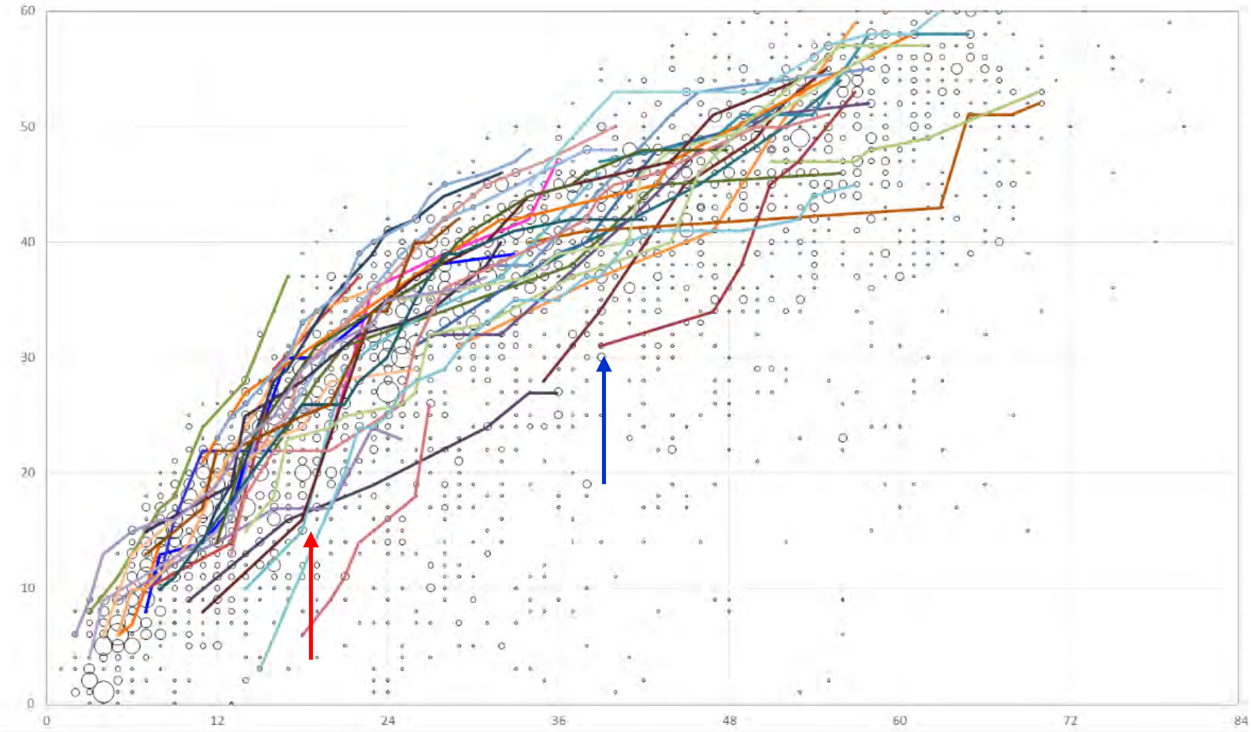


Figure 10. Trajectories indicate the expected growth over time and follow similar development patterns with individual differences due to specific known factors, such as for example, late diagnosis (blue arrow) and increased

Figure 11: Individual listening trajectories of FLI scores for children with bilateral moderate and moderate - severe hearing loss

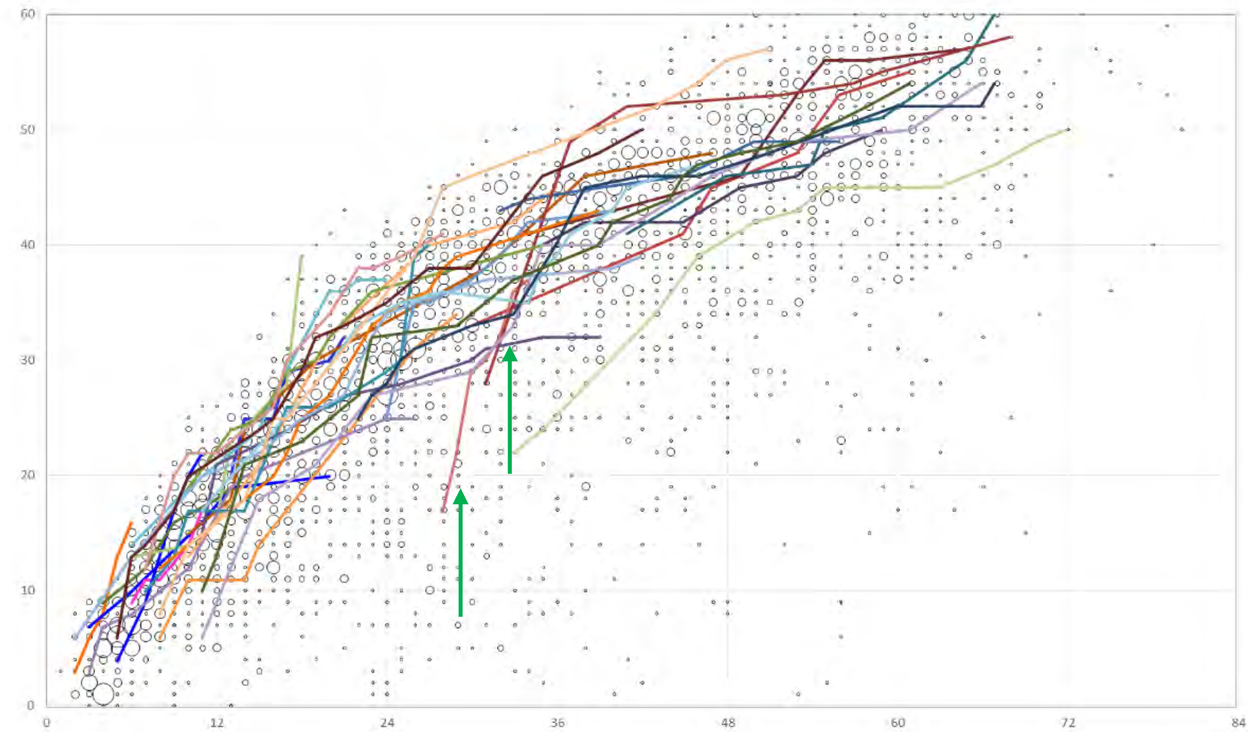


Figure 11. Individual listening trajectories for children with bilateral moderate and moderate – severe hearing loss indicate overall increases over time as would be expected with individual differences relating to specific factors e.g., rapid acquisition of skills following device fitting (green arrows)

Figure 12: Individual listening trajectories of FLI scores for children with bilateral severe and severe - profound hearing loss

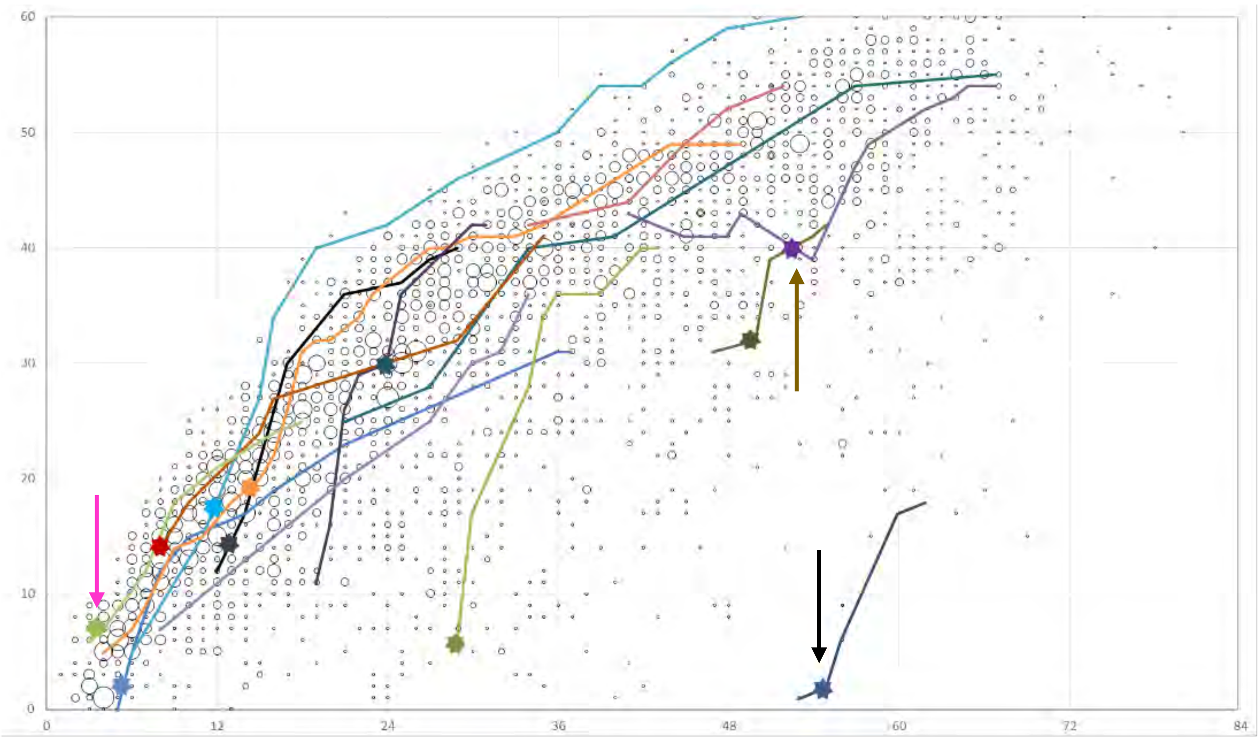


Figure 12. Trajectories indicate mostly expected growth patterns with increased variability. Steep trajectories indicate a rapid acquisition of skills following cochlear implantation (points marked by large dots). Trajectories highlight sensitivity of the FLI to individual context for example drops in hearing levels (brown arrow), late diagnosis and fitting (black arrow), compared with early diagnosis, fitting and implantation (pink arrow)

Figure 13: Individual listening trajectories of FLI scores for children with bilateral profound hearing loss

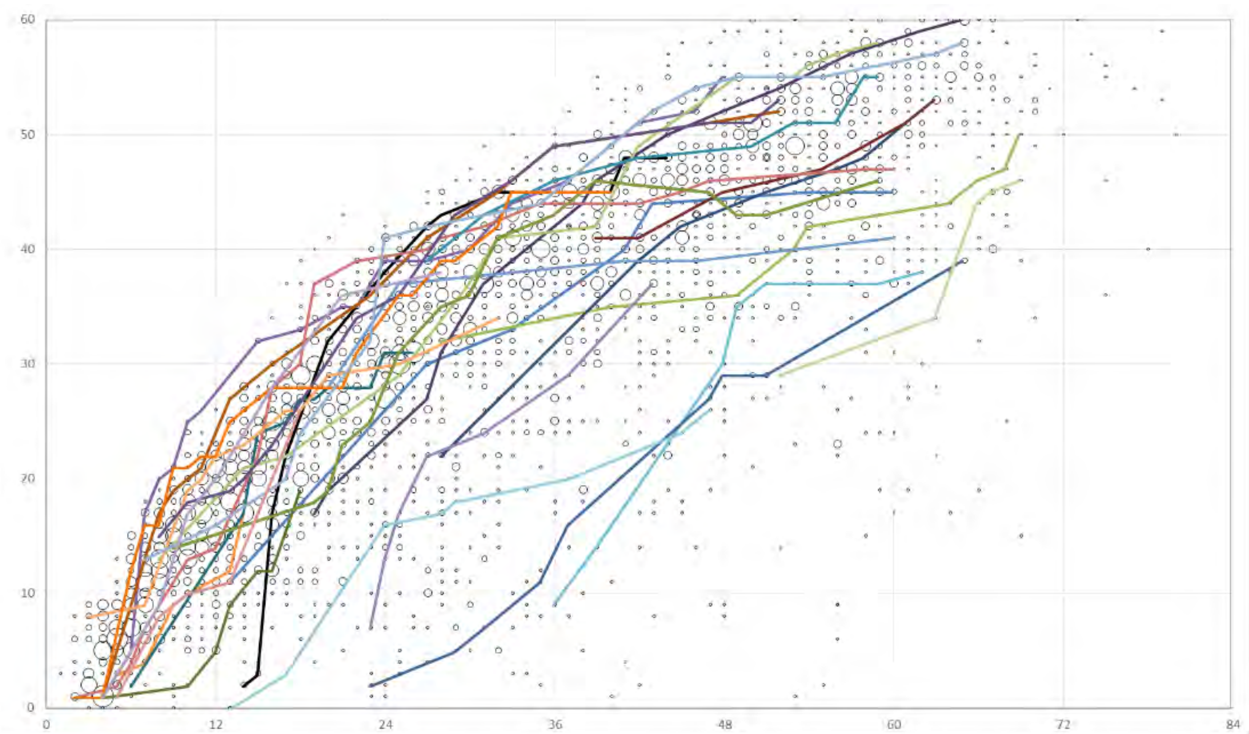


Figure 13. The listening development of children with profound hearing loss over time indicate overall development of listening skills with wide variability as would be expected given differing circumstances and impact of level of hearing loss on listening skill acquisition. All children in this group had cochlear implants but points have not been marked to maintain visibility of individual trajectories.

Age of Implant

Children's individual listening development by FLI score over time was tracked and compared by age of first implant (< 6 months, 6 - 11 months, and 12 - 23 months). FLI scores for children with a disability in addition to hearing loss or ANSD in one or both ears were excluded given their impact on outcomes. These individual FLI scores by trajectory for children with 5 recorded scores or above are presented in Figure 14 – Figure 16. Trajectories for children who received a cochlear implant < 6 months of age show the smallest amount of variation and seem to be performing at mostly the top levels of the EI group (Figure 14). Given the small numbers in this group and the exclusion of impacting factors (late diagnosis, late to intervention, presence of an additional disability, ANSD) this is as expected. There is increased variability in FLI scores with age for children who received an implant at older ages (6 - 11 months in Figure 15, and 12 - 23 months in Figure 16).

Figure 14: Individual listening trajectories of FLI scores for children with bilateral profound hearing loss who received their first cochlear implant under 6 months of age

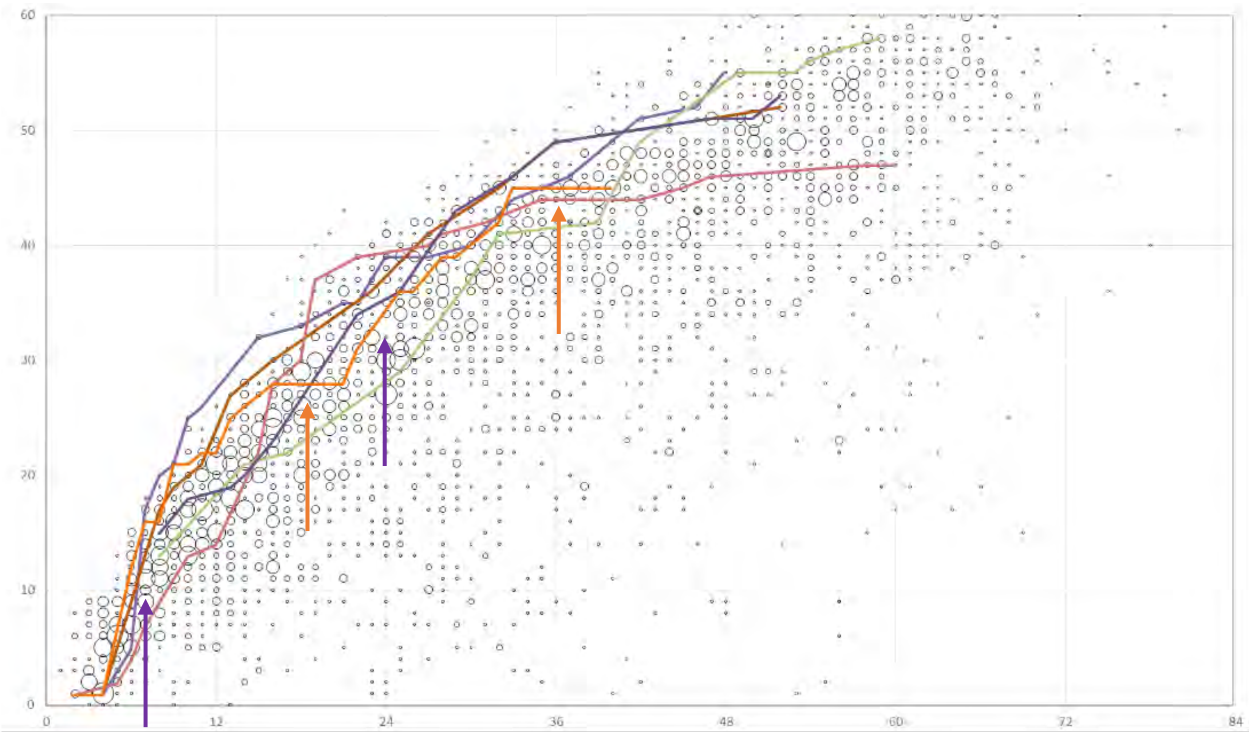


Figure 14. Scores indicate a steep increase in skills post implantation in all cases and ongoing acquisition with age. Different rates of acquisition at stages can be observed, ranging from no new development of skills (orange arrows) to periods where a number of skills are gained (purple arrows)

Figure 15: Individual listening trajectories of FLI scores for children with bilateral profound hearing loss, first cochlear implant between 6 - 11 months of age

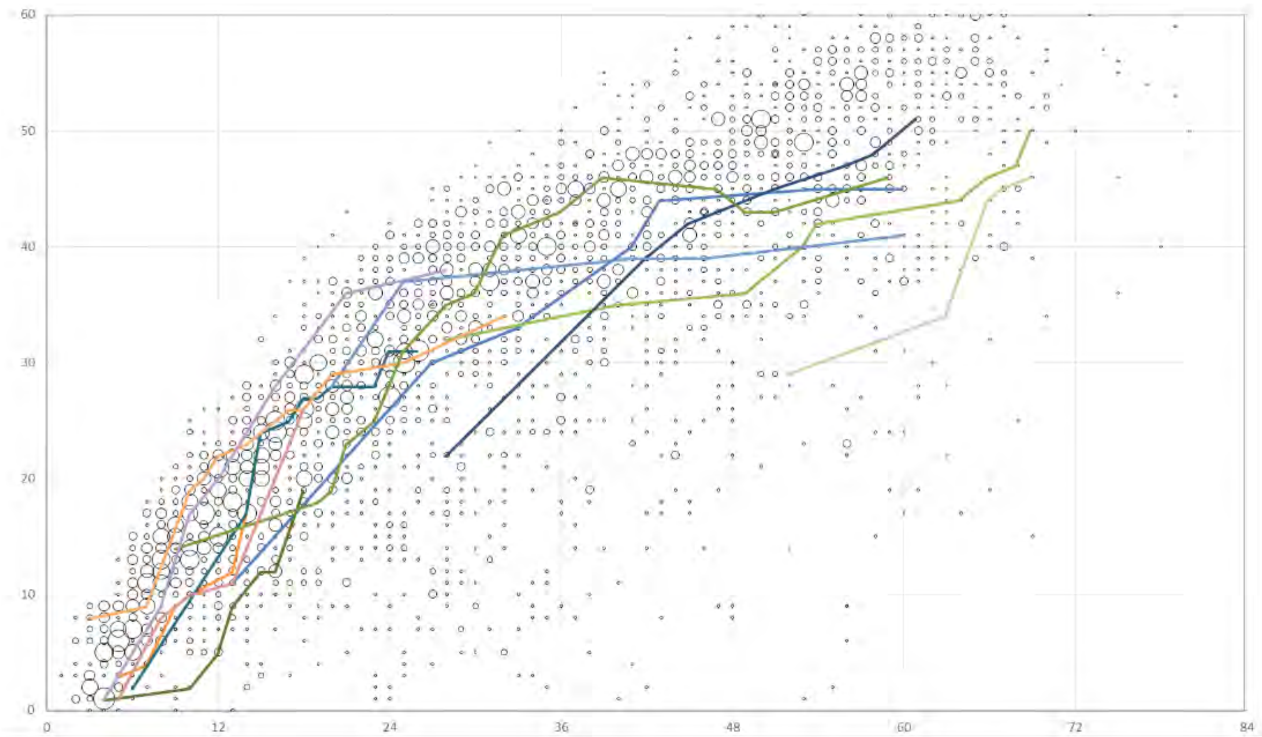


Figure 15. FLI scores indicate a greater variability in development of listening skills over time for children receiving a cochlear implant between 6 and 11 months of age, compared to children implanted under 6 months of age in Figure 14.

Figure 16: Individual listening trajectories of FLI scores for children with bilateral profound hearing loss, first cochlear implant between 12 - 23 months of age

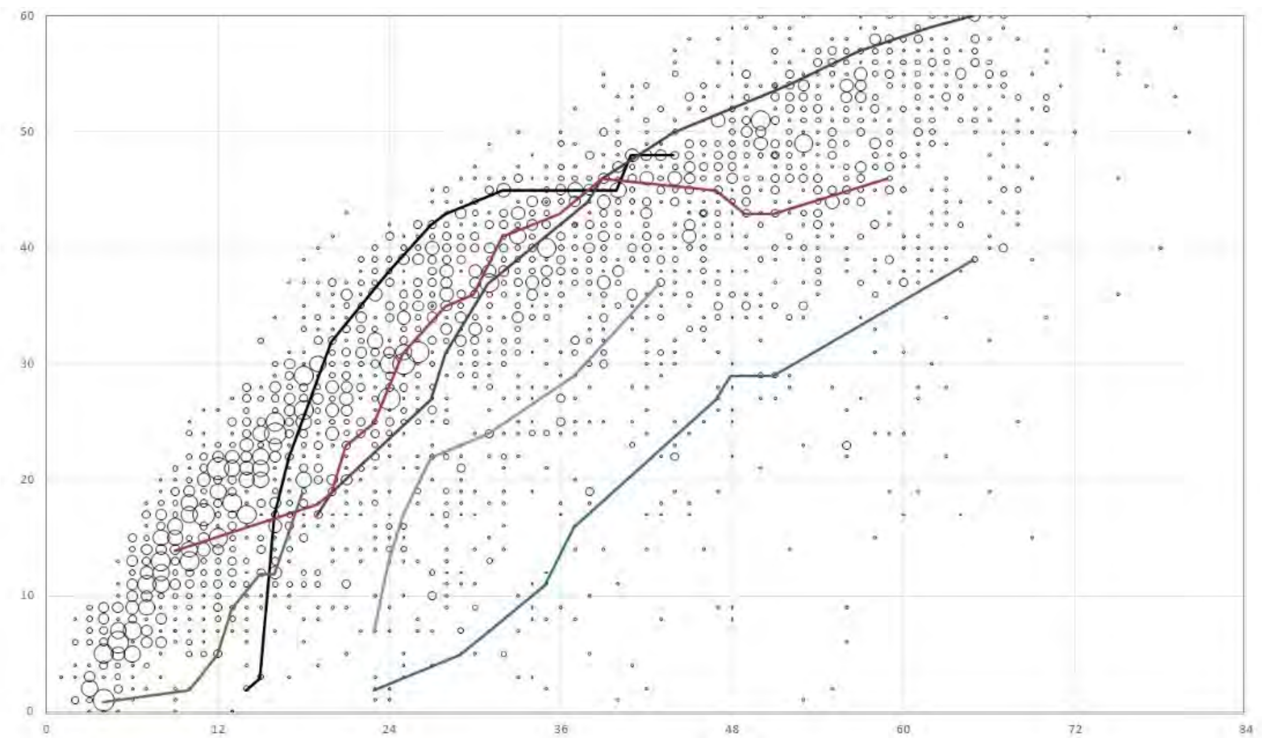


Figure 16. Further variability is indicated by FLI scores for children receiving their first cochlear implant between 12 and 23 months of age. All continue to develop skills over time.

Developmental Need in Addition to Hearing Loss

The development of listening skills of all children with an additional disability in the program were measured routinely using the FLI. The individual trajectories of children with additional needs and a cochlear implant are provided in Figure 17 (n = 14).

Figure 17: Individual trajectories of FLI scores for children with cochlear implants, bilateral severe, severe - profound and profound hearing loss and a diagnosed additional disability

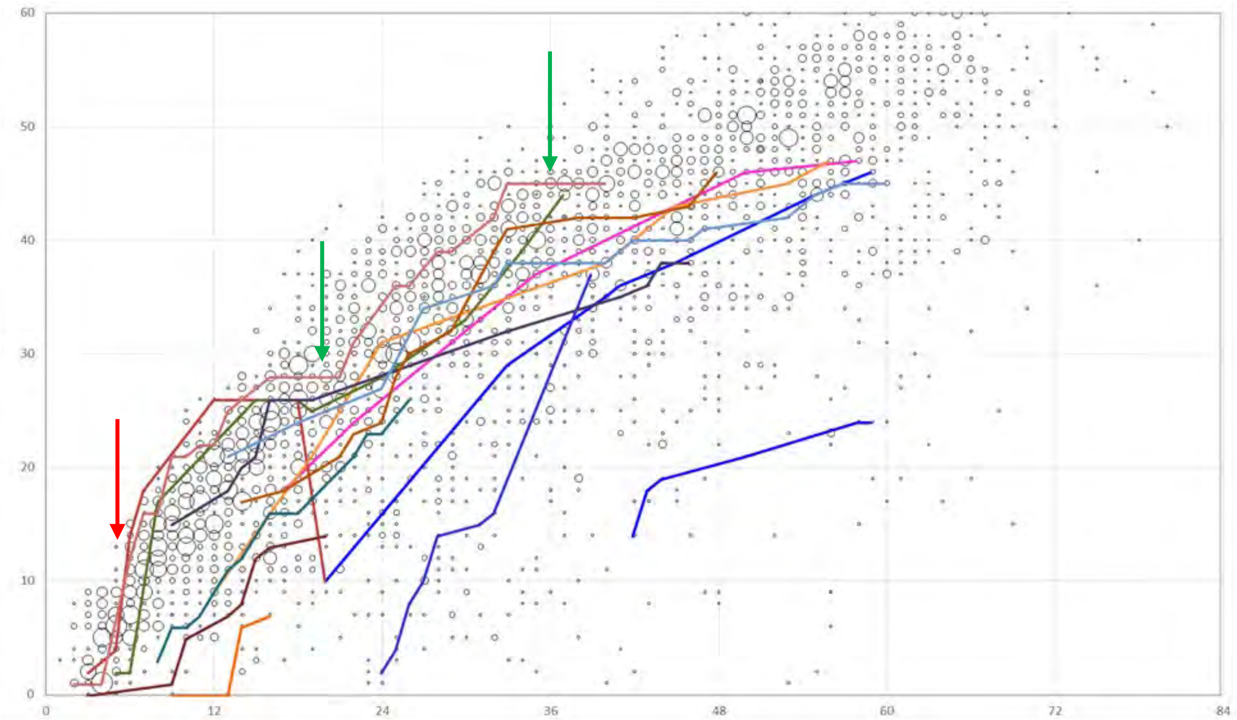


Figure 17. Trajectories indicate a sensitivity to individual progress over time and range of rates of skill development. Some rapid gains in skills can be observed at early ages after implantation (red arrow) and slower periods of acquisition which may be due to specific known factors such as cognitive capacities, device use, or language exposure levels (green arrows)

Auditory Neuropathy Spectrum Disorder

The trajectories of functional listening development in individual children with ANSD were graphed by FLI score over time. Figure 18 presents results for all children with bilateral ANSD and 5 or more recorded FLI scores (n = 10). This is compared to the results for all children with unilateral ANSD (no hearing loss in the other ear) who had 5 or more recorded FLI scores in Figure 19 (n = 10). Results for both bilateral and unilateral ANSD indicated a range of listening skills by age, as would be expected with different levels of neuropathy and the range of clinical presentations in children with ANSD.

Figure 18: Individual listening trajectories of FLI scores for children with bilateral ANSD

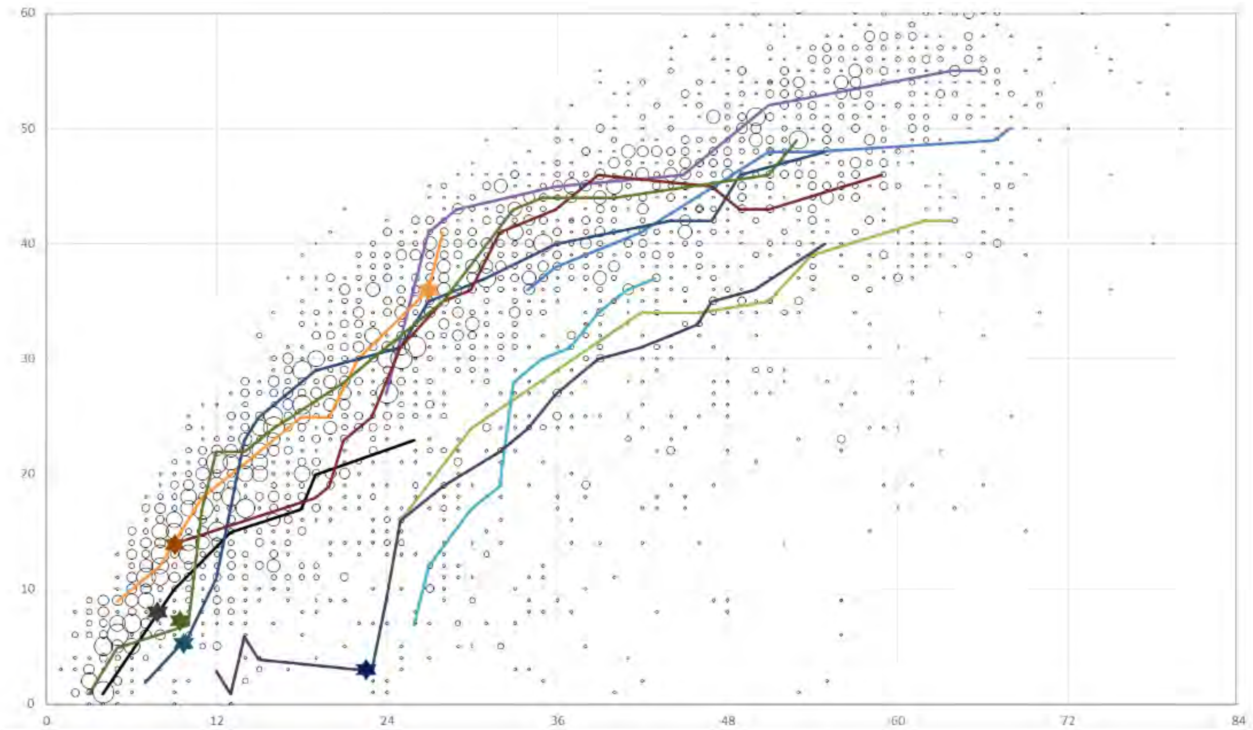


Figure 18. Results indicate a range in the listening skill development as expected for children with ANSD. Increases in listening skills are evidence post cochlear implantation (marked by large dots).

Figure 19: Individual listening trajectories of FLI scores for children with unilateral ANSD

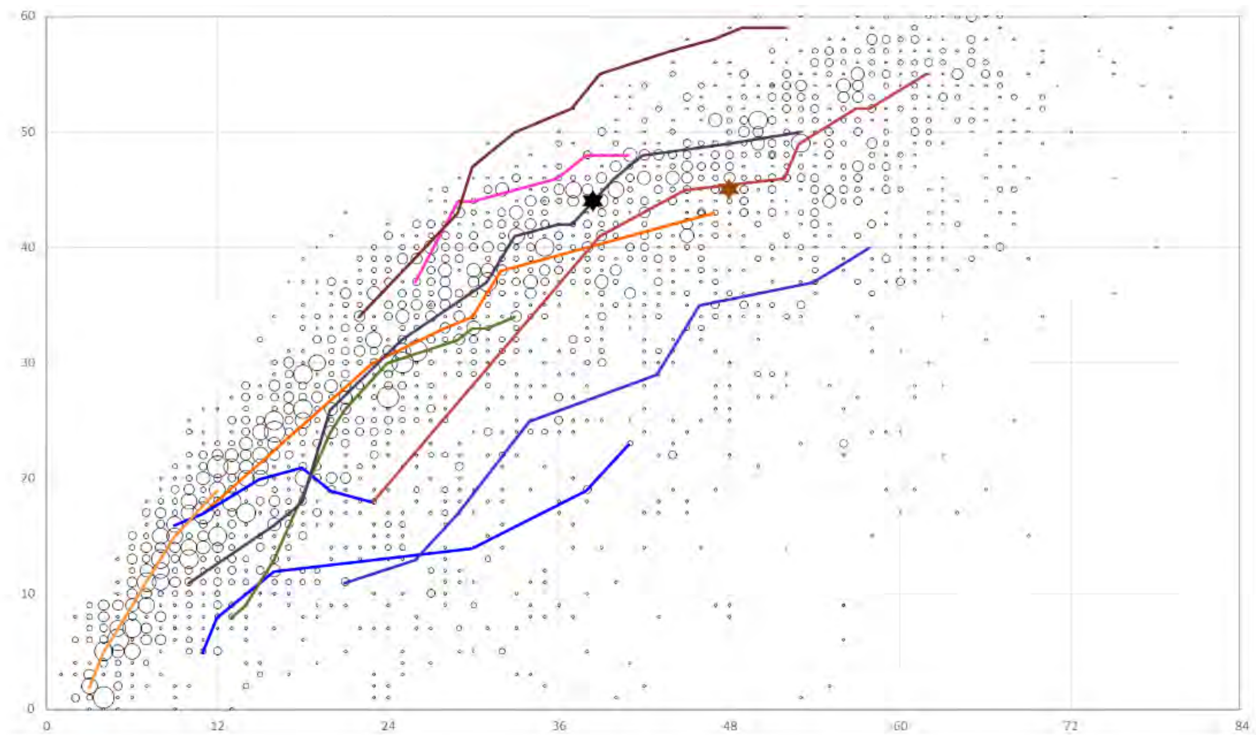


Figure 19. Despite typical hearing levels in one ear, FLI scores indicate varied rates of listening development.

Case Studies by Known Impacts to Outcomes

To determine the sensitivity of the FLI in identifying expected changes over time, case studies were examined from the dataset of children with known impacts to outcomes.

Middle Ear Pathology

Results of FLI scores of two children in the EI group with an identified clinical history of middle ear pathology, and over 5 FLI data points were graphed (Figure 20). Slower progress in listening skill development matched periods of middle ear pathology, reflecting reduced access to sound during these periods and subsequent impact on auditory development. In both cases, clinical records identified that devices were unable to be worn during the periods of middle ear pathology, contributing to the slow development of listening skills at this time.

Figure 20: Individual listening trajectories of FLI scores for children with identified periods of middle ear pathology

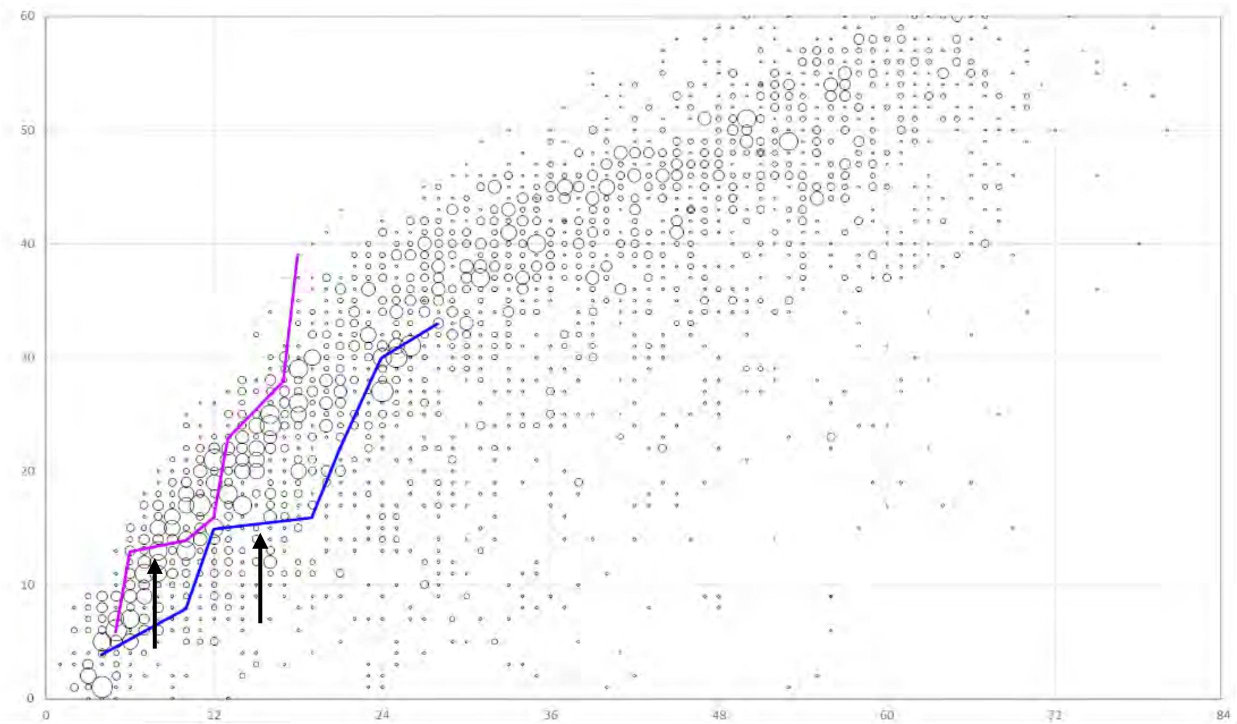


Figure 20. Periods of slower listening skill development (as indicated by arrows) match clinical records of middle ear pathology and inability to wear devices

Drop in Hearing Thresholds

The FLI scores of three children who experienced a drop in hearing thresholds and had 5 or more recorded FLI scores were analysed (Figure 21). As would be expected these children indicate slow and flat trajectories at this point.

Figure 21: Individual listening trajectories of FLI scores for children who experienced a drop in hearing thresholds

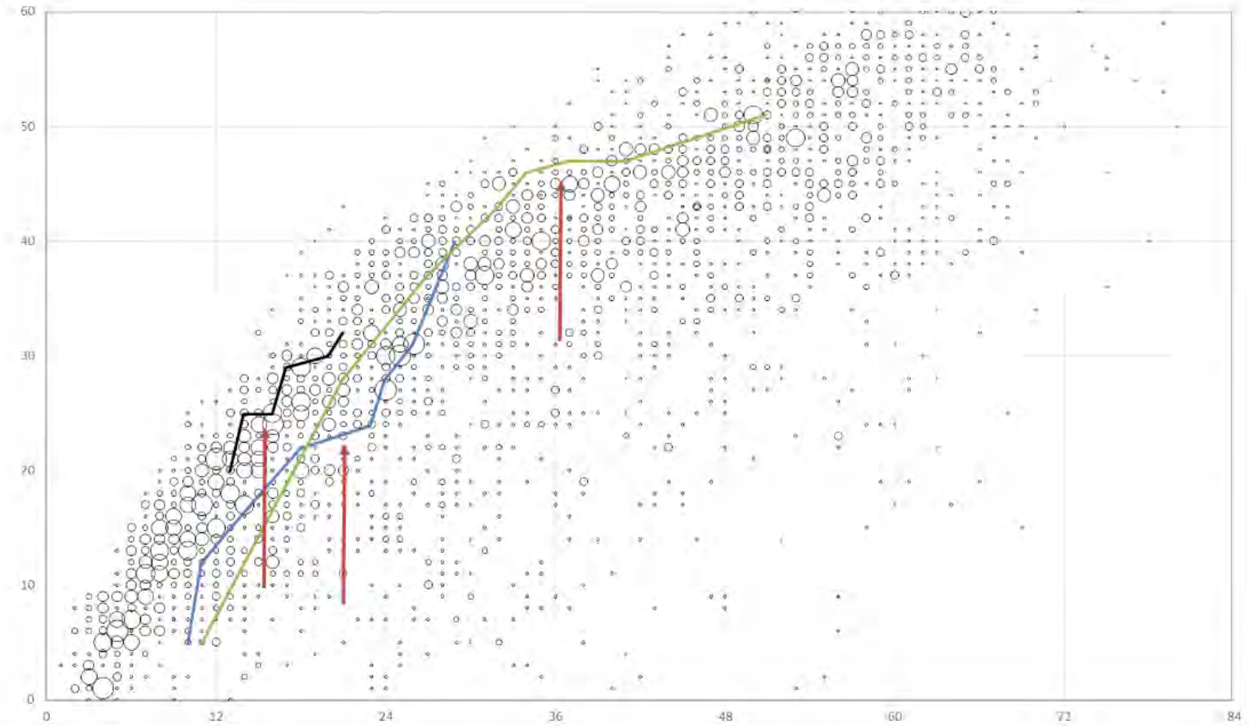


Figure 21. FLI scores indicate slow periods of listening development at the time of identified threshold drops (indicated by arrows).

Languages Other Than English

To determine if the FLI can be used effectively with children learning a language other than English, FLI scores for five children who spoke only another language were analysed (Figure 22). Results indicate a range of listening skills across ages and dependent on individual context. For the three children in the group who had cochlear implants, as would be expected, their listening trajectories demonstrated a sharp increase in skills post implantation.

Figure 22: Individual listening trajectories of FLI scores for monolingual children learning only a language other than English

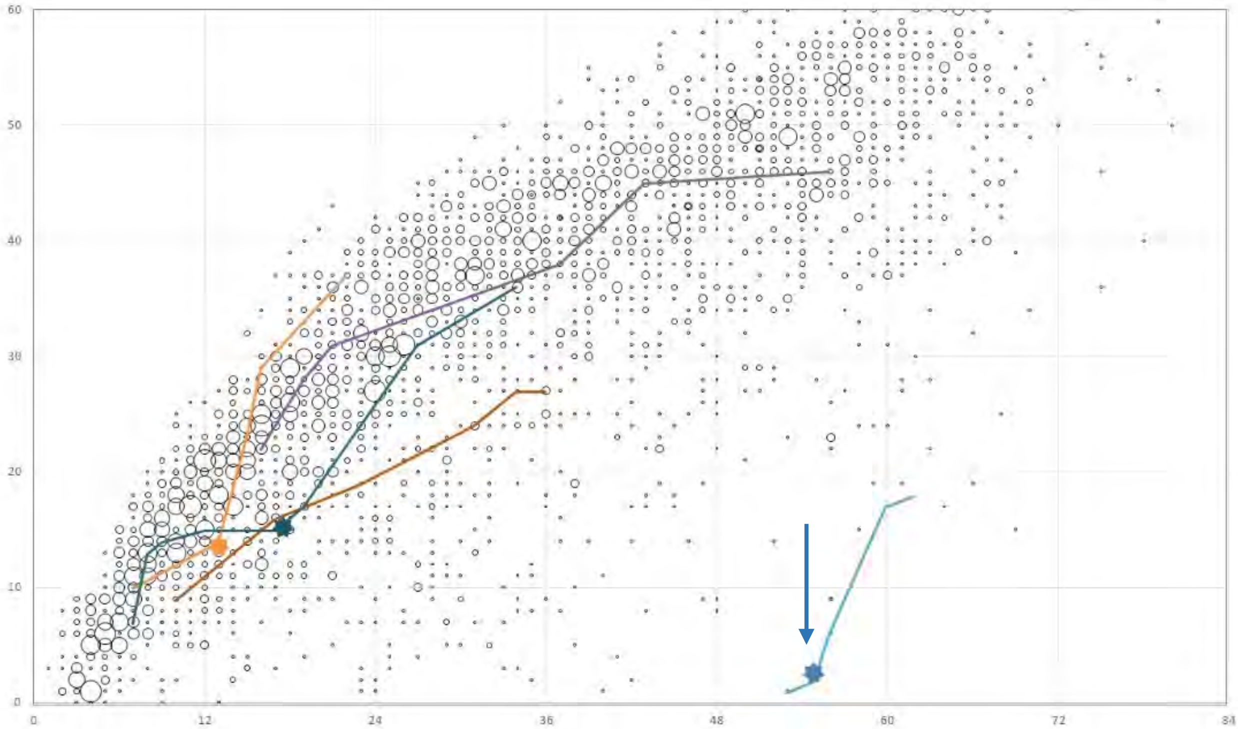


Figure 22. FLI scores for monolingual children learning only a language other than English demonstrate expected listening development and indicate variability in the development of listening skills due to known specific factors, for example late diagnosis and device fitting (as indicated by the blue arrow) and exist independent of language background.

3. Differences in Group Scores

TH group/EI group

Group data of children's FLI scores were aggregated to determine if the expected differences were observed between the FLI scores for children in the EI group to the FLI scores for children in the TH group. There were 46 FLI results collected for 27 children in the TH group, and the age at data collection ranged from 2 to 63 months (average age 32 months). A single FLI result was collected for 20 children, 2 data points for four children and 3, 5 and 10 data points for the other three children in the group. The lowest FLI score for the TH group was 2 items at 1 month of age, and the highest score was 49 items (of the 60 in total) at 63 months of age. The FLI results for the TH group are graphed against age in months in Figure 23. A line of best fit indicated linear relationships over time ($R^2 2$ = 0.807).

Figure 23: TH group total FLI results

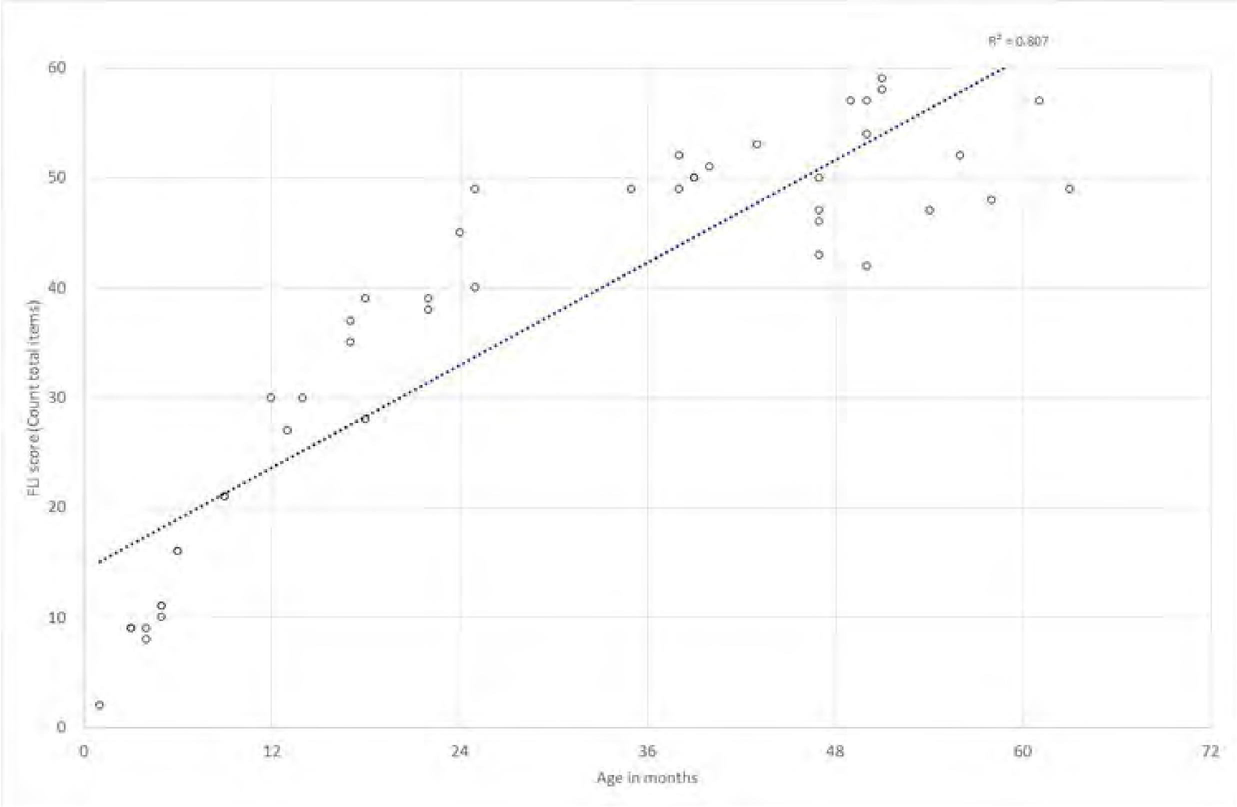


Figure 23. FLI scores for children in the typical hearing group indicate an increase in listening skills with age. Variability in scores was seen in children above 4 years of age

A comparison of FLI scores for children in the EI and TH groups indicate expected differences (larger variation and less developed listening skills across age ranges excluding children with an additional disability for the purposes of comparison) as seen in Figure 24. Results demonstrate that a number of children with hearing loss achieved similar FLI scores to children in the TH group. Lines of best fit indicate significant linear relationships for both the TH group (R^2 = 0.80) and the EI group (R^2 = 0.70), despite large numbers and variability in the EI group.

Figure 24: FLI results scores groups (TH vs. EI)

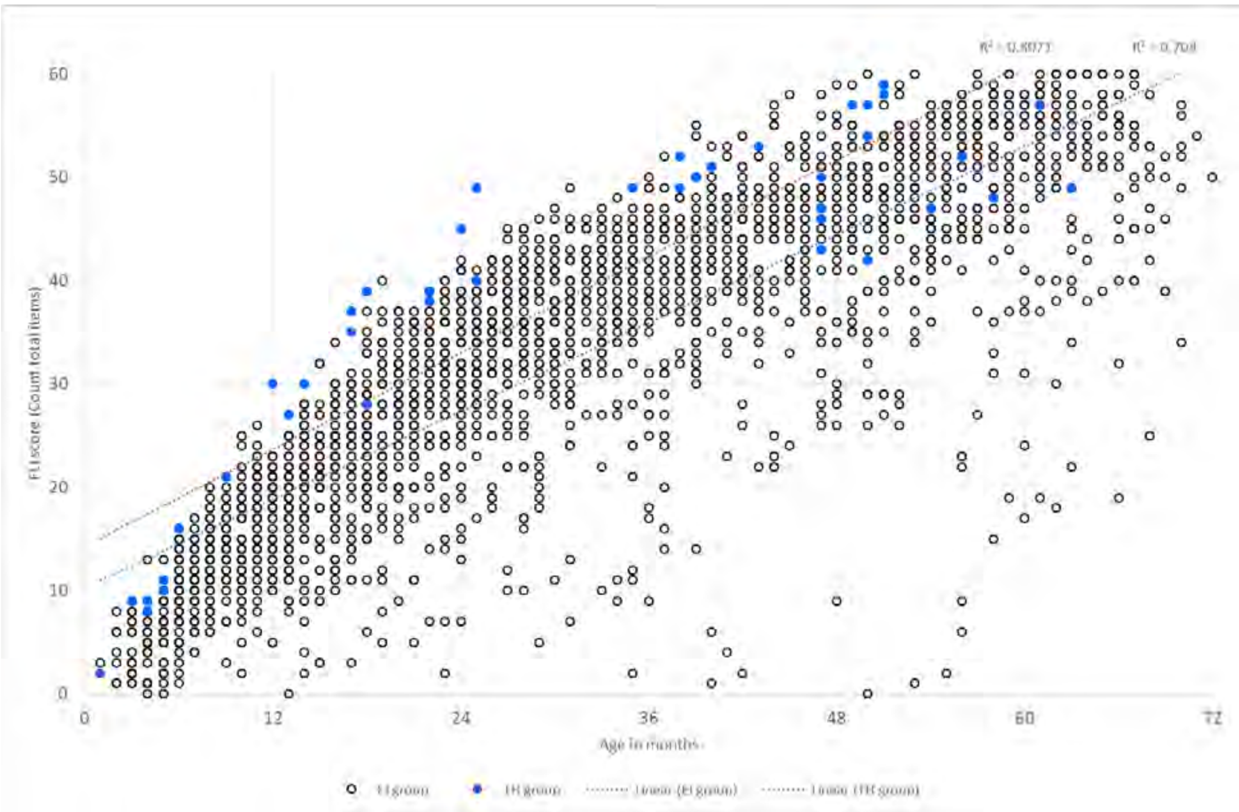


Figure 24. Comparative scores for the two groups indicate expected differences (n = 451 children, 2340 data points). Strong linear relationships were found for both groups

Bilateral and Unilateral Hearing Loss

The FLI results for children with bilateral hearing loss (n = 385, 2130 FLI scores) were compared to FLI results for children with unilateral hearing loss (n = 140, 696 FLI scores) (Figure 25). No information was recorded in the database for symmetry of hearing loss for 18 children (43 FLI scores) and were not included. Results indicate similar FLI scores across ages for both groups despite the expectation that children with unilateral hearing loss may have better FLI scores as they have one ‘good ear’ and results would be more similar to typical hearing children. R^2 values indicate similarly strong linear relationships, with a mildly stronger relationship for children with unilateral hearing loss (R^2 = 0.79) than for children with bilateral hearing loss (R^2 = 0.69).

Figure 25: FLI scores between groups (bilateral vs. unilateral HL)

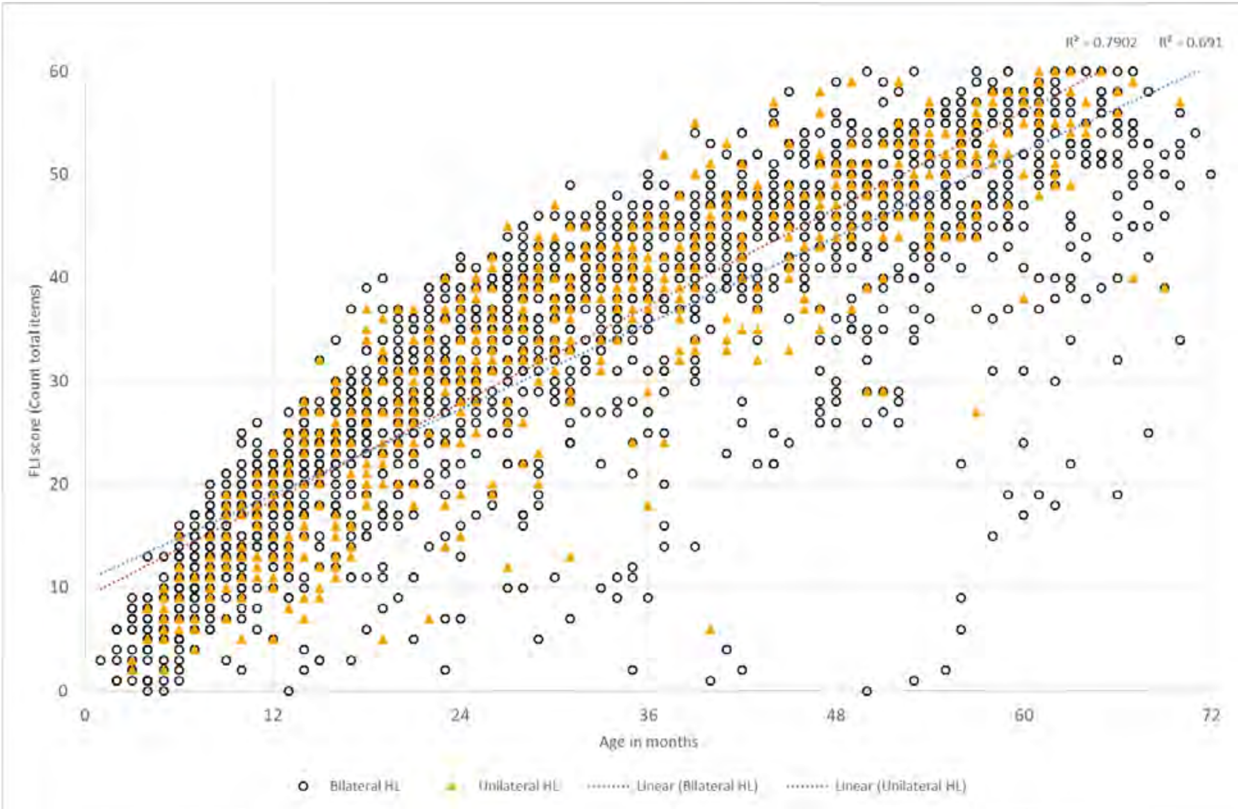


Figure 25. Similar FLI scores for children with bilateral and unilateral hearing losses

The range of listening skills for children with unilateral hearing loss reflects the mixed outcomes for children with unilateral hearing loss reported elsewhere in the literature. Reviews indicate speech and language delays in some but not all studies (Krishnan & Van Hyfte, 2016; Lieu, 2004), difficulties at school with 22% to 35% of children with UHL repeating at least one grade, 12% to 41% receiving additional educational assistance (Lieu, 2013) and poor levels of auditory performance (Bess, Tharpe, & Gibler, 1986; Oyler & McKay, 2008).

Additional Needs

The FLI scores for children in the EI group with additional disabilities (n = 92, 529 data points) were compared to children with hearing loss alone, regardless of level of hearing loss or device (n = 315, 1706 FLI scores) (Figure 26). Results for the group with additional disabilities indicated the expected difference in listening skills, below the TH group, and below that of the hearing loss alone group. FLI scores for children with a disability in addition to hearing loss indicated greater variation (R^2 = 0.59) than for the hearing loss alone group (R^2 = 0.70). These differences reflect the evidence of the impact of an additional disability on outcomes of children with hearing loss (Birman et al., 2012; Cupples et al., 2018; Yoshinaga-Itano, 2003b).

Figure 26: FLI scores between groups (presence vs. absence of an additional developmental need)

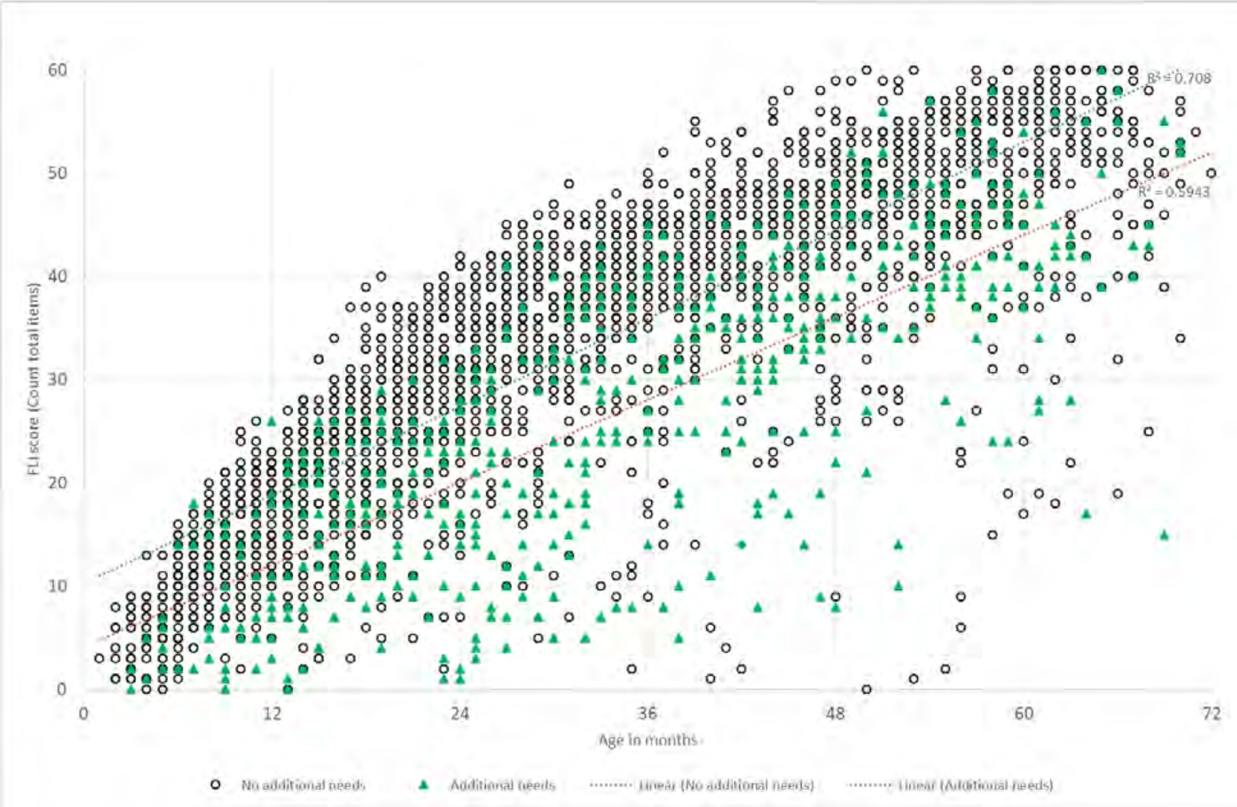


Figure 26. FLI scores indicated expected differences in listening skills on the FLI for children with additional disabilities compared to children with hearing loss alone.

Auditory Neuropathy Spectrum Disorder

The FLI scores for children with bilateral ANSD (n = 13, 127 FLI scores) were compared to children with unilateral ANSD (n = 20, 112 FLI scores). Children in each of these groups used a range of devices due to the individual nature of each child's neuropathy. For children with bilateral ANSD this included 2 hearing aids (n = 1), 1 cochlear implant and 1 hearing aid (n = 1), and bilateral cochlear implants (n = 10). The 20 children with unilateral ANSD had no hearing loss in the other ear. These children wore cochlear implants (n = 3), bone conductor hearing aids (n = 3), a conventional hearing aid (n = 1), unaided (n = 1), and not recorded (n = 12). The 3 children with a diagnosis of ANSD and a sensorineural hearing loss were not included in this analysis due to their mixed etiology.

Results indicate similar listening skills by ages for children with both bilateral and unilateral ANSD (Figure 27). A further analysis was conducted excluding children with an additional disability which indicated less variation, as would be expected (Figures 28 and 29). Comparisons by age of implant indicated lower functional listening scores for children who received their first cochlear implant between 12 and 23 months than children who received their first implant between 6 and 11 months of age (Figure 30). The FLI results for children with ANSD in this study also reflect the evidence of wide variability in outcomes (Breneman, Gifford, & Dejong, 2012; Ching, Day, et al., 2013; Harrison, Gordon, Papsin, Negandhi, & James, 2015; Teagle et al., 2010). Results indicated that the most closely matched FLI scores of the TH group were children with bilateral ANSD who received the earliest implants. Also consistent with the literature, results demonstrated a number of children with ANSD were developing listening skills aided with conventional hearing aids (Ching, Day, et al., 2013).

Figure 27: FLI scores between groups (bilateral and unilateral ANSD)

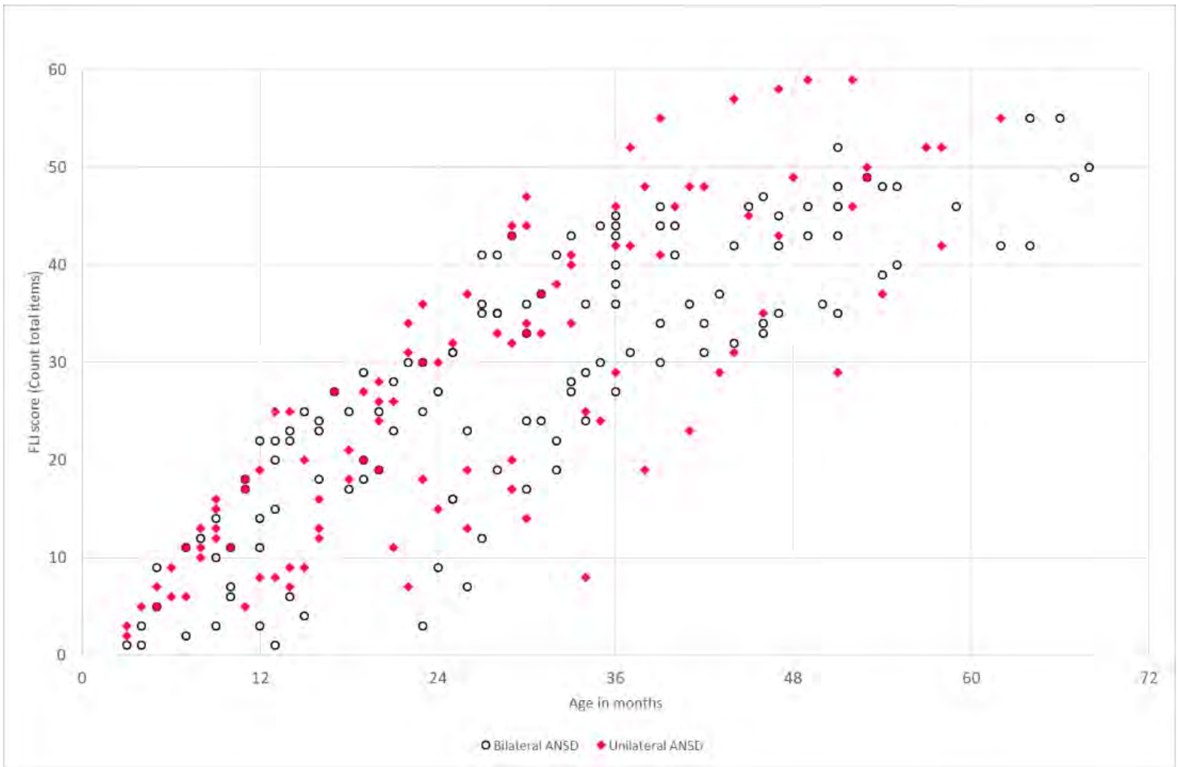


Figure 27. A range of FLI results across ages were observed for children with bilateral and unilateral ANSD

Figure 28: FLI scores between groups (bilateral and unilateral ANSD, no additional developmental needs)

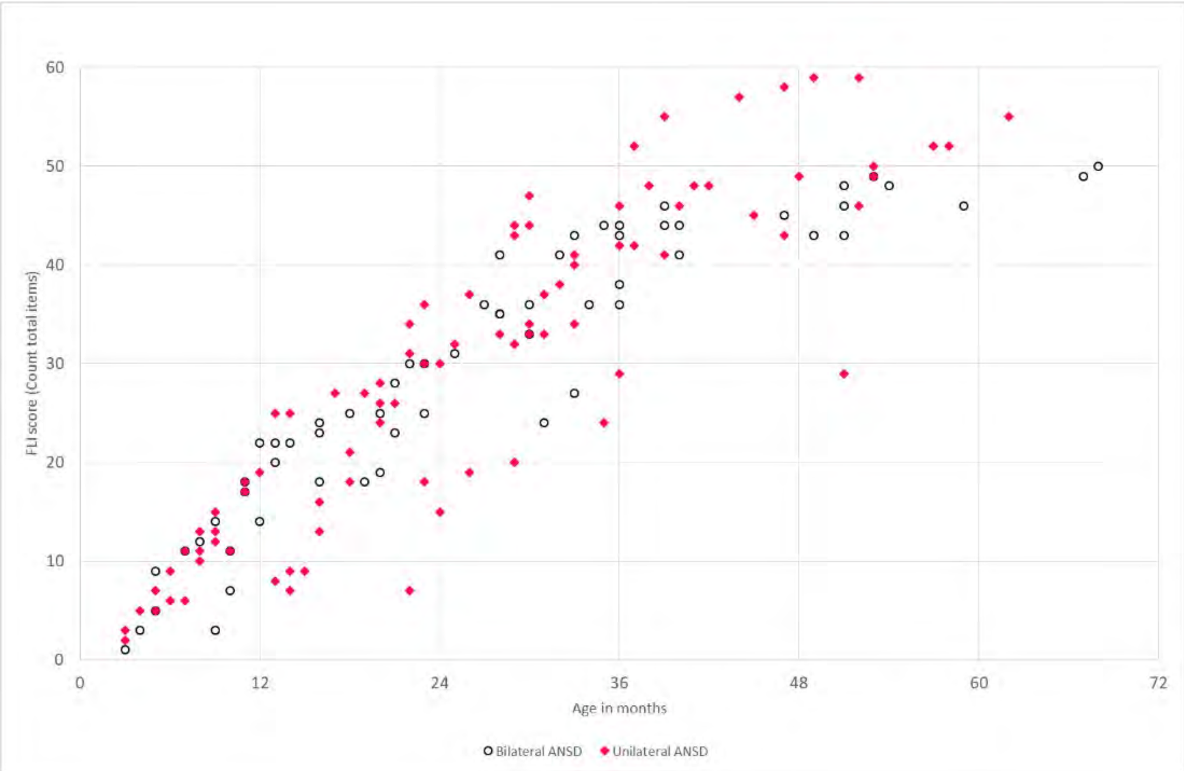


Figure 28. Less variability for children with ANSD and no other additional developmental needs

Figure 29: FLI scores children with unilateral ANSD, no additional developmental needs

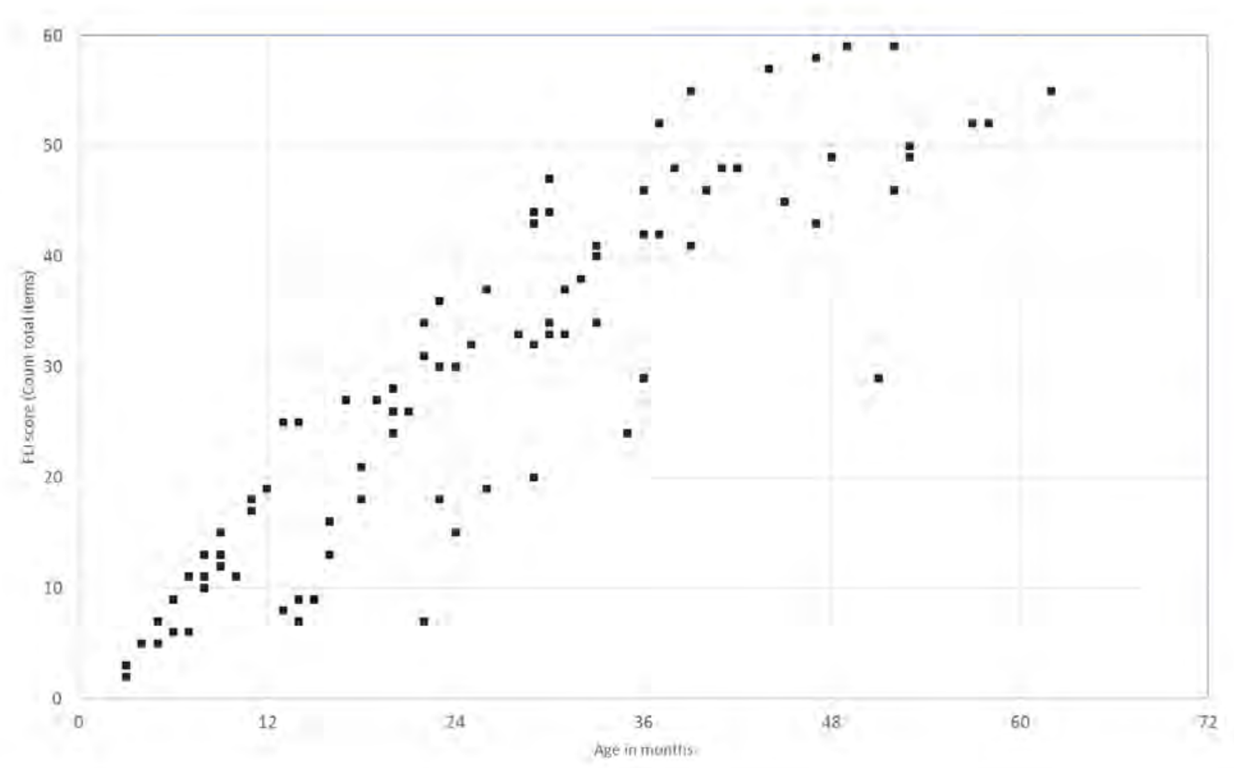


Figure 29. FLI results for children in the EI group with unilateral ANSD and no hearing loss in the other ear (n = 15) indicates a range in functional listening skills across ages, with a spread similar to the bilateral ANSD group

Figure 30: FLI scores between groups (bilateral ANSD by age of implant)

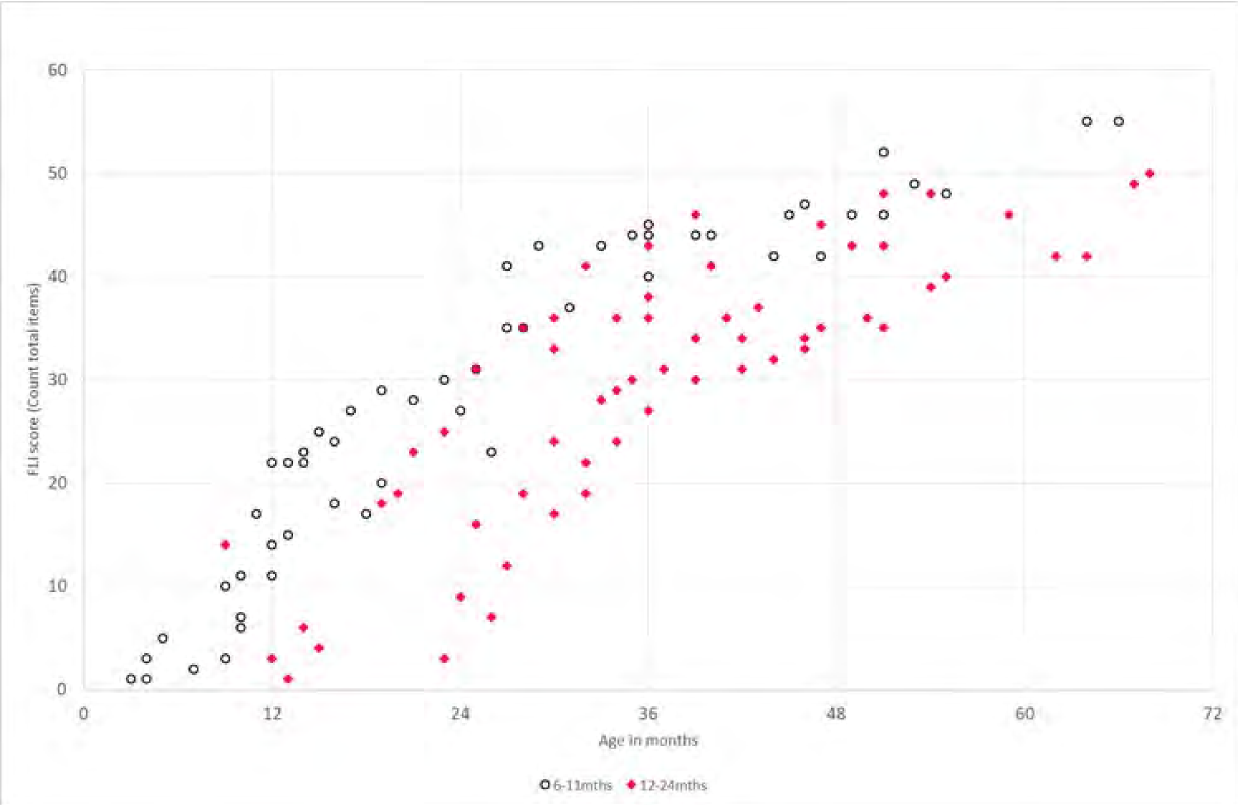


Figure 30. FLI results indicate expected differences in listening skills by age of implant with lower functional listening scores for children receiving their first cochlear implant between 12 and 23 months of age (n = 6) compared with those who receiving an implant between 6 and 11 months of age (n = 5)

Age at Diagnosis

The FLI scores for the children with hearing loss who were referred for diagnostic testing of hearing following newborn screening (n = 427, 2442 FLI scores) were compared to the FLI scores of children who passed newborn screening and were later diagnosed with a hearing loss (n = 54, 168 FLI scores). Information was not recorded in the database for 43 children (183 scores), and 19 children did not have their hearing screened at birth (76 FLI scores). For comparative purposes Figure 31 displays the results of children with a bilateral moderate hearing loss or greater, referred through newborn hearing screening and had their first device fitted < 6 months of age, compared with children who passed newborn hearing screening and had their first devices fitted > 12mths of age. Greater variability in FLI scores can be seen in all age ranges for children who passed newborn hearing screening. Given the amount of time children who are later diagnosed may have had without aiding and necessary access to sound, lower listening scores and higher levels of variability in scores would be expected.

Figure 31: FLI scores between groups (by refer vs. pass newborn hearing screening)

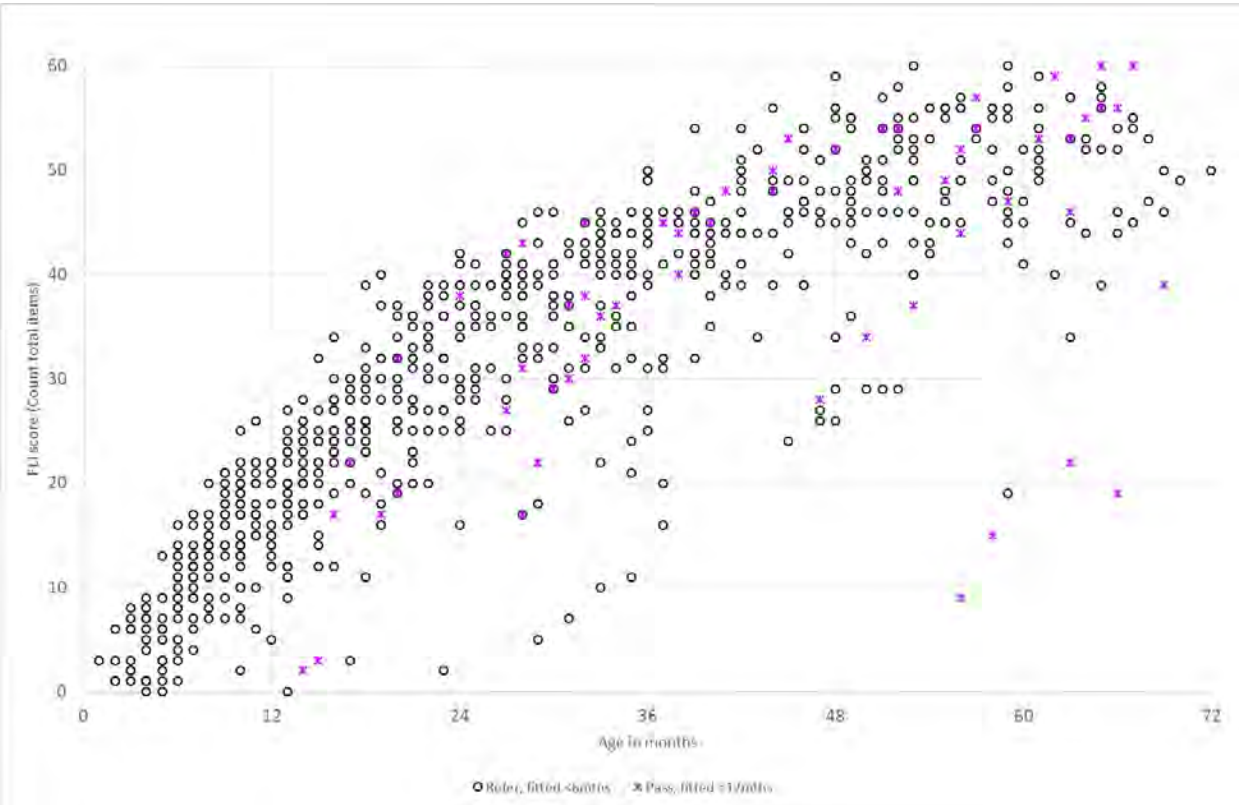


Figure 31. FLI scores for the group referred through newborn screening increase with age as expected with some variability indicated at older ages

The FLI scores of children diagnosed with a hearing loss following newborn screening in this study is consistent with the large body of evidence that early diagnosis enables the early development of auditory skills to support language acquisition (Blaiser, 2012; White, 2014; Yoshinaga-Itano, Coulter, & Thomson, 2000). In this study, variation in listening skill development as measured by the FLI was observed particularly for children at older ages who passed screening. Given the potential time gaps between the onset of the hearing loss following screening and diagnosis/fitting of devices, this matches the expected pattern.

Type of Device

FLI scores were compared by type of hearing device[14]. Devices were categorised according to bilateral cochlear implants (n = 96, 628 FLI scores), cochlear implant and hearing aid (n = 21, 130 FLI scores), bilateral hearing aids (n = 177, 864 FLI scores), and bilateral bone conductors (n = 6, 43 FLI scores). FLI scores for 9 children (25 FLI scores) were excluded as devices were unknown. Results indicated no clear patterns between listening scores and devices (Figure 32). Since access to sound is a key predictor of a child's outcomes as discussed in Chapter 4, these data suggest that the device type a child uses is unlikely to be associated with listening outcomes. Instead, it is their access sound through their device that is critical.

Figure 32: FLI scores by device (bilateral HL)

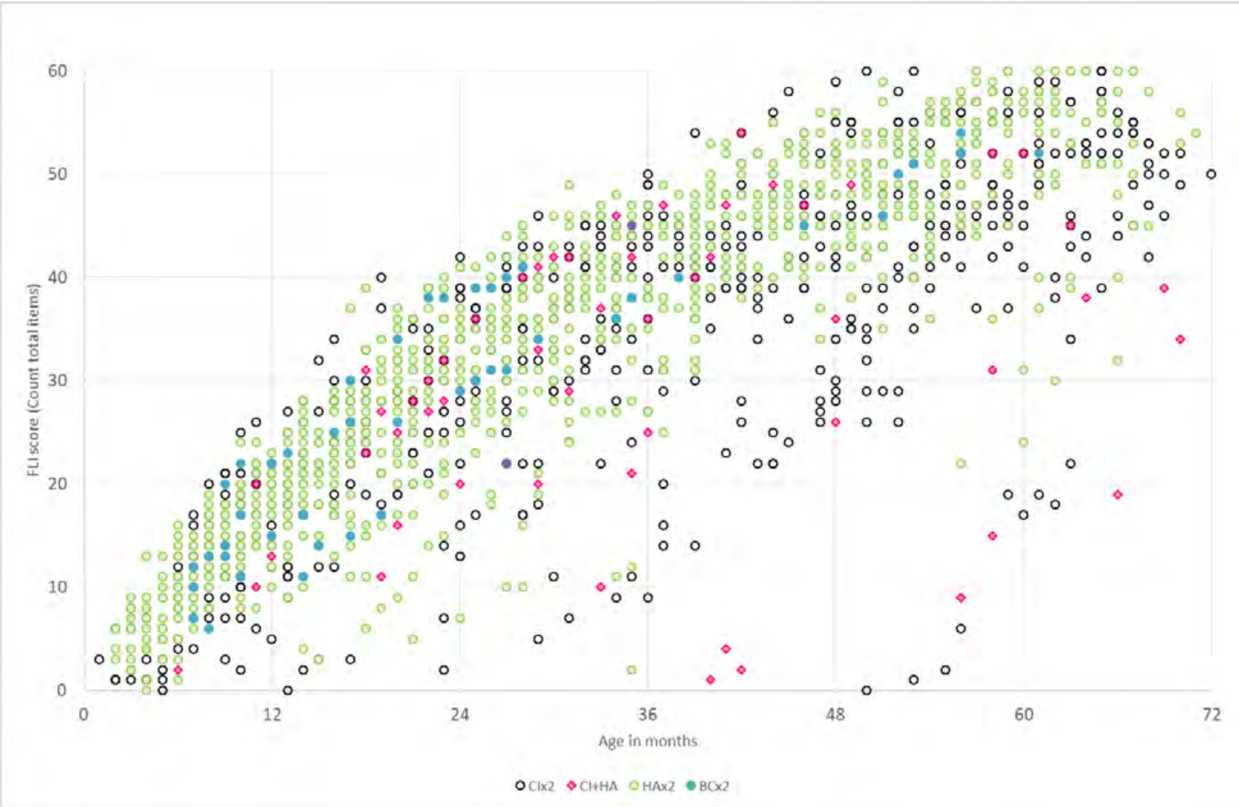


Figure 32. Results indicate a range of listening skills across devices with no observable patterns

Similar results are indicated for listening scores on the FLI for children with unilateral hearing loss by device with no observable pattern (Figure 33). Device categorisations included hearing aid (n = 21, 110 FLI scores), cochlear implant (n = 15, 73 FLI scores), and bone conduction device (n = 37, 148 FLI scores).

---

[14] Device was categorised at the point of data extraction, so children using a cochlear implant are likely to have FLI scores from earlier data points coded as CI whilst they were using hearing aids.

Figure 33: FLI scores by device (unilateral HL)

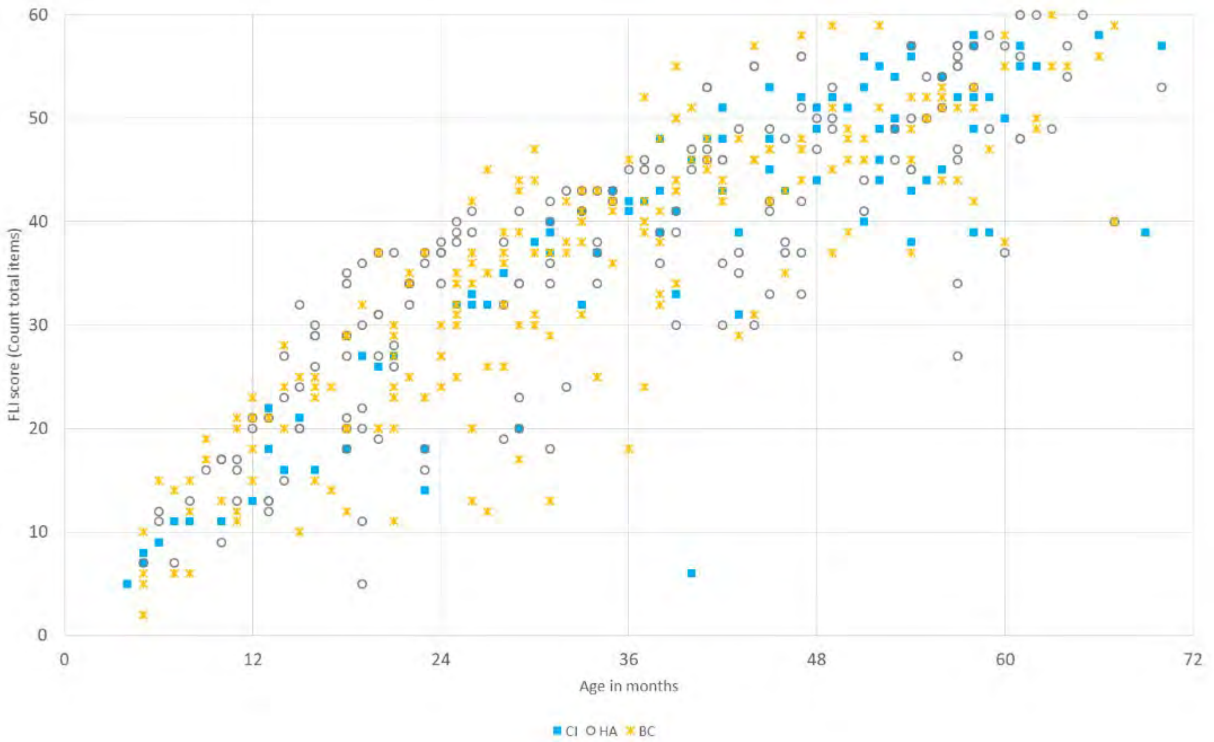


Figure 33. Listening scores by device for children with unilateral hearing loss also show no observable patterns

Level of Hearing Loss

FLI scores were compared by level of hearing loss across age groups. Hearing loss was again grouped in 5 categories: mild - moderate and mild -profound (bilateral n = 114, 551 FLI scores), moderate and moderate – severe (bilateral n = 59, 381 FLI scores), severe and severe - profound (bilateral n = 20, 74 FLI scores), and profound (bilateral n = 44, 323 FLI scores). Children with high frequency hearing loss only were grouped in the mild and mild to profound group for the purposes of the analysis, and children with asymmetrical hearing losses were excluded due to the difficulty categorising their hearing loss into a comparable group. FLI results for children with no level of hearing loss recorded in the database were excluded for 36 children (left ear) and 38 children (right ear). All results are reported in Figure 34, and by level (Figure 35 – Figure 38).

Figure 34: FLI scores between groups (HL level)

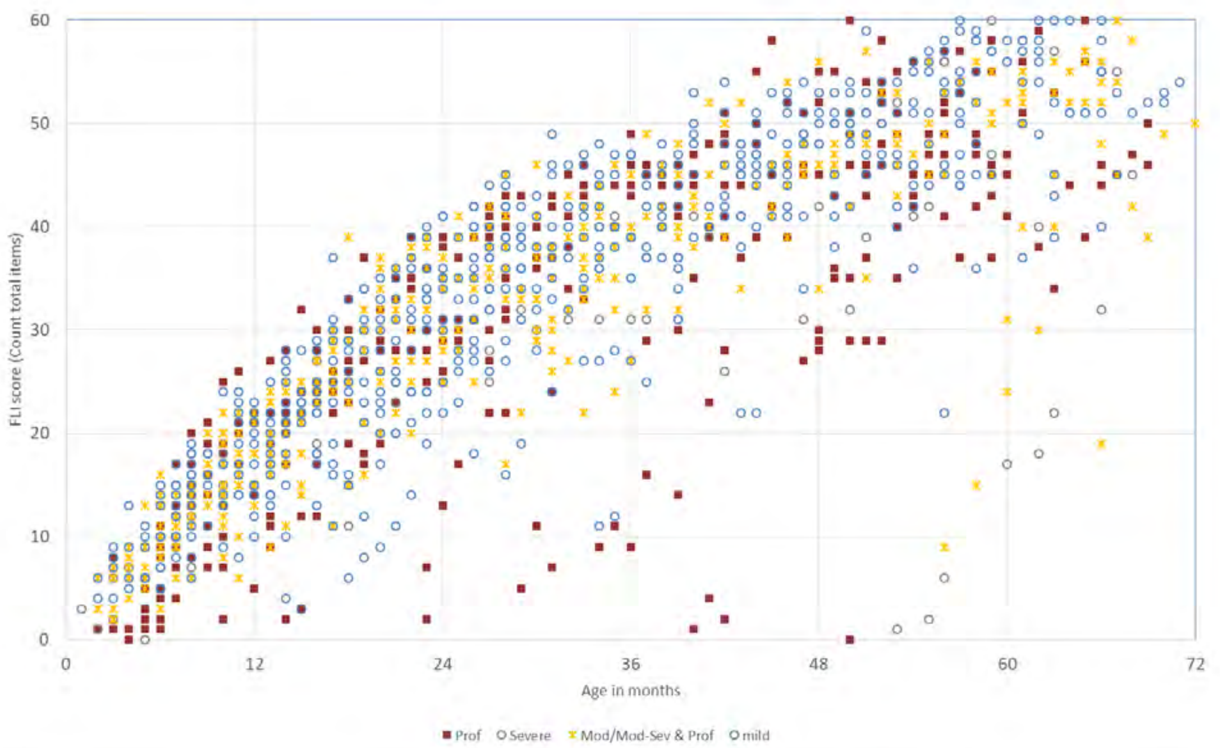


Figure 34. Results show a range of listening skills across hearing loss levels. Variability in scores increase with age across all levels

Figure 35: FLI scores between groups (mild and mild – profound bilateral HL, no additional needs)

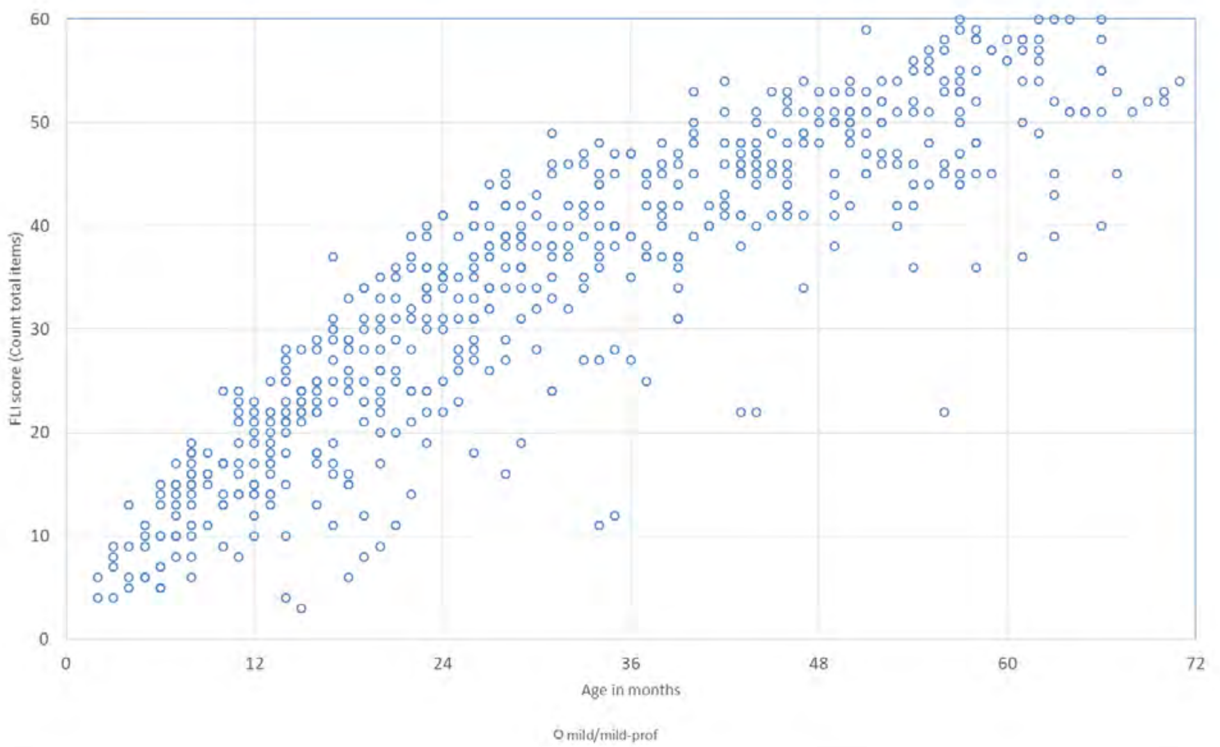


Figure 35. Results indicate a range of listening skills on the FLI across ages for children with mild and mild – profound hearing losses. Children acquired 50% of items on the FLI (a score of 30) between 18 and 36 months of age and a number of complete scores by 60 months.

Figure 36: FLI scores between groups (moderate and moderate – severe bilateral HL, no additional needs)

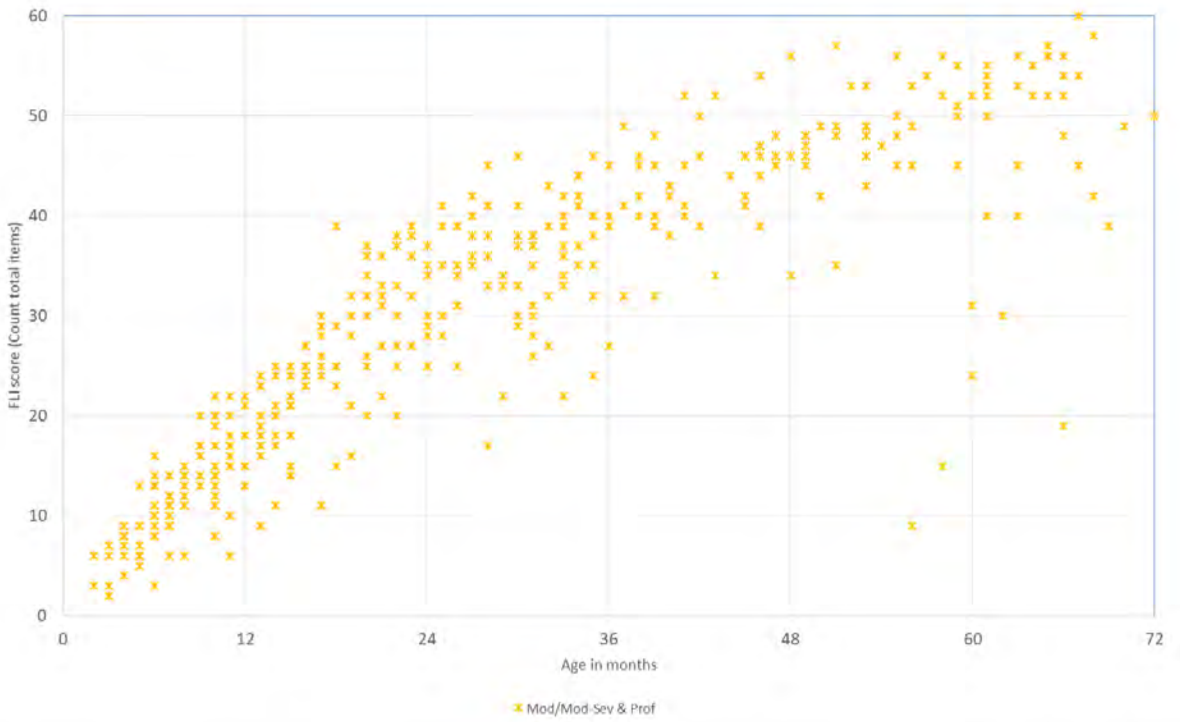


Figure 36. Results demonstrate less variation in FLI scores at younger ages, and fewer scores at very high/complete scores at the oldest age

Figure 37: FLI scores between groups (severe and severe – profound bilateral HL, no additional needs)

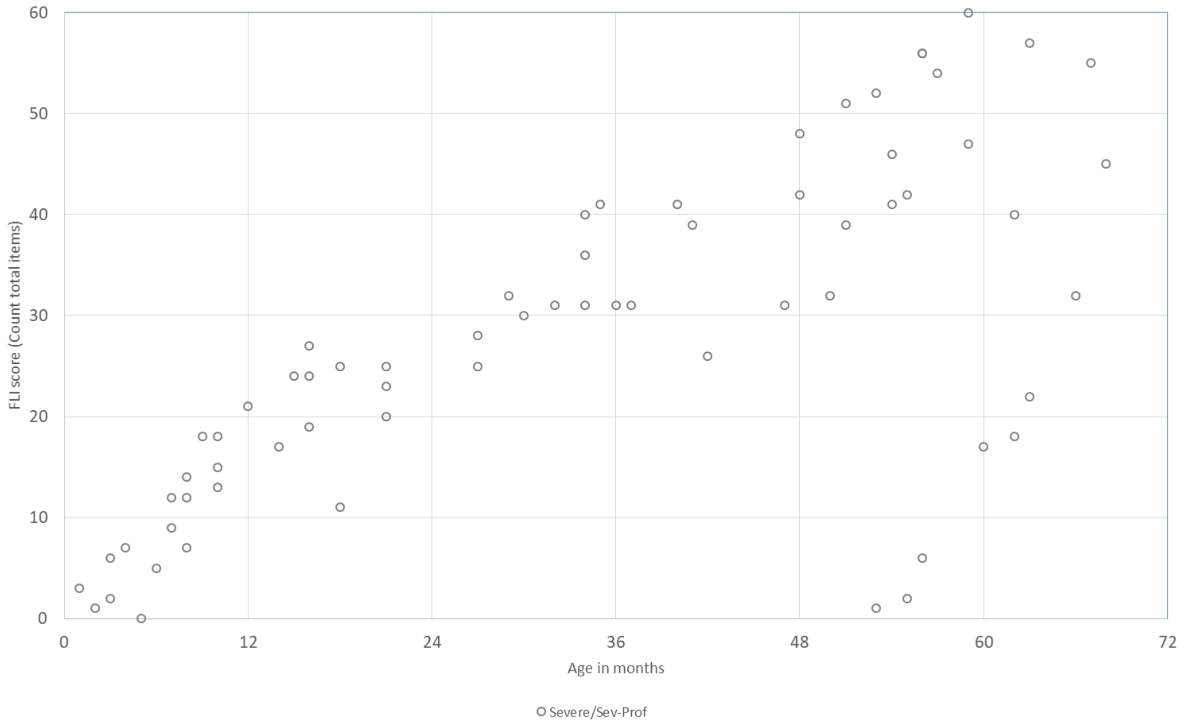


Figure 37. Functional listening scores for children with bilateral severe and severe-profound hearing loss. There were the least scores in this group, yet still indicated variability in scores at older ages. The few very low FLI scores above 50 months of age indicate scores for a child very late to be diagnosed and developing listening skills

Figure 38: FLI scores between groups (profound bilateral HL, no additional needs)

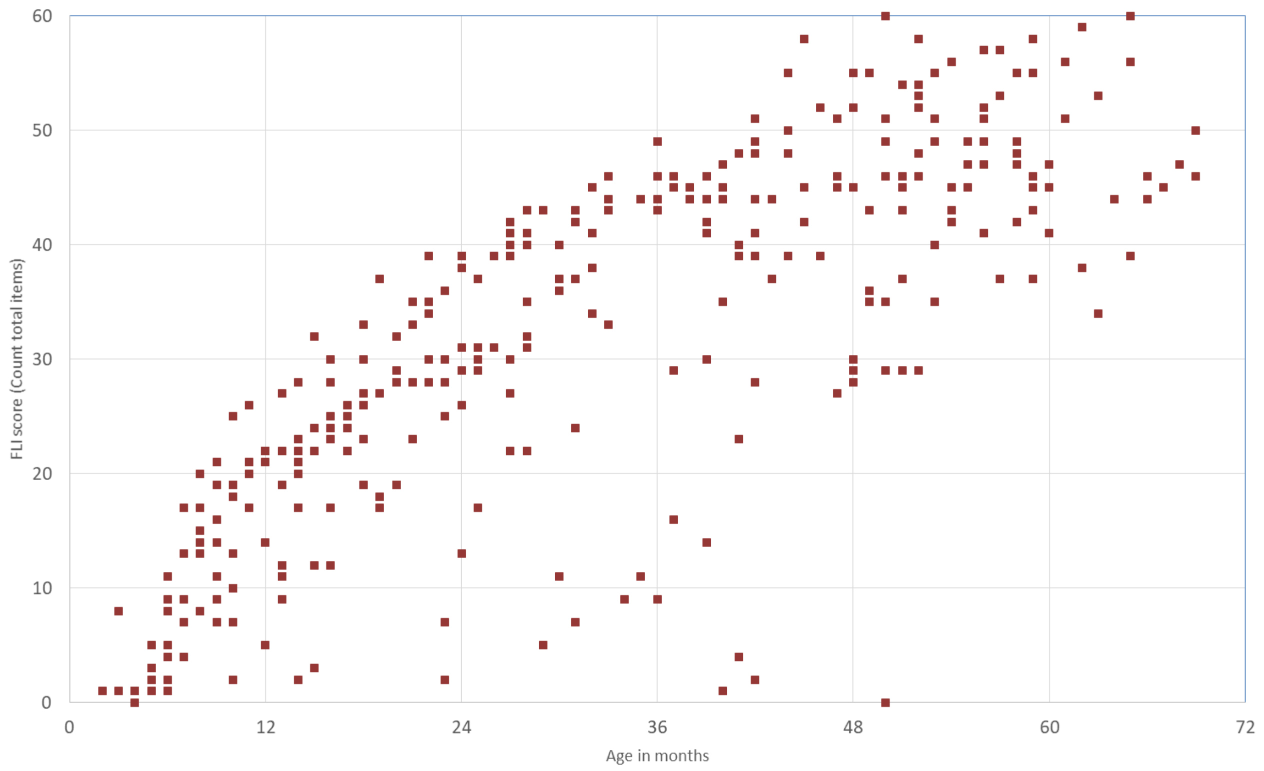


Figure 38. Results indicate wide variability of listening skills across ages. This group is inclusive of children diagnosed at all ages

It has been consistently reported that outcomes for children with hearing loss are impacted by level of hearing loss (Ching et al., 2018; Sininger et al., 2010; Tomblin et al., 2015). These results in the current study do not strongly support such findings. Although the widest variability can be seen for children with profound hearing loss, levels of variability were observed across all levels. Consistent with the literature that early cochlear implants can result in age-appropriate outcomes, some FLI scores in both the severe and profound groups were commensurate with those in the TH group (Fulcher, Purcell, Baker, & Munro, 2012b; Leigh, Dettman, Dowell, & Briggs, 2013; Percy-Smith et al., 2013). Lower FLI scores may well have been associated with other known factors to outcomes (Ching et al., 2018; Geers, Brenner, & Davidson, 2003). Further analysis of these groups accounting for known factors would be useful in understanding the full cause of the variability. FLI scores of children with different hearing levels in this study suggest that level of hearing loss may not be as strong an impacting factor as, for example, age of access to appropriate levels of sound.

Age at Implant

FLI scores were further analysed by age of implantation, a recognised factor impacting outcomes (Cupples et al., 2018; Geers, Nicholas, & Moog, 2007; Niparko et al., 2010). Listening scores for children with bilateral profound hearing loss using cochlear implants were grouped according to age of first implant: over 24 months (n = 48, 238 FLI scores), 12 - 24 months (n = 25, 166 FLI scores), 6 - 11 months (n = 29, 200 FLI scores) and under 6 months (n = 16, 150 FLI scores). Age of implant was recorded as unknown for 1 child (6 FLI scores) and was excluded from this analysis. Results are presented in Figure 39 – Figure 42. FLI scores indicate that children receiving the youngest cochlear implants (under 6 months of age, R^2 = 0.85 and 6 – 11 months of age, R^2 = 0.80) demonstrate the FLI scores most similar to the TH group (R^2 = 0.80) and consistent with the reported literature. The similarity of scores to the TH group appears to reduce with older implant ages, and as variability in listening scores increase. Linear relationships match variability levels: over 24 months (R^2 = 0.30), 12 - 24 months (R^2 = 0.56), 6 - 11 months (R^2 = 0.80), and < 6 months (R^2 = 0.85).

Figure 39: FLI scores between groups (implant < 6 months of age)

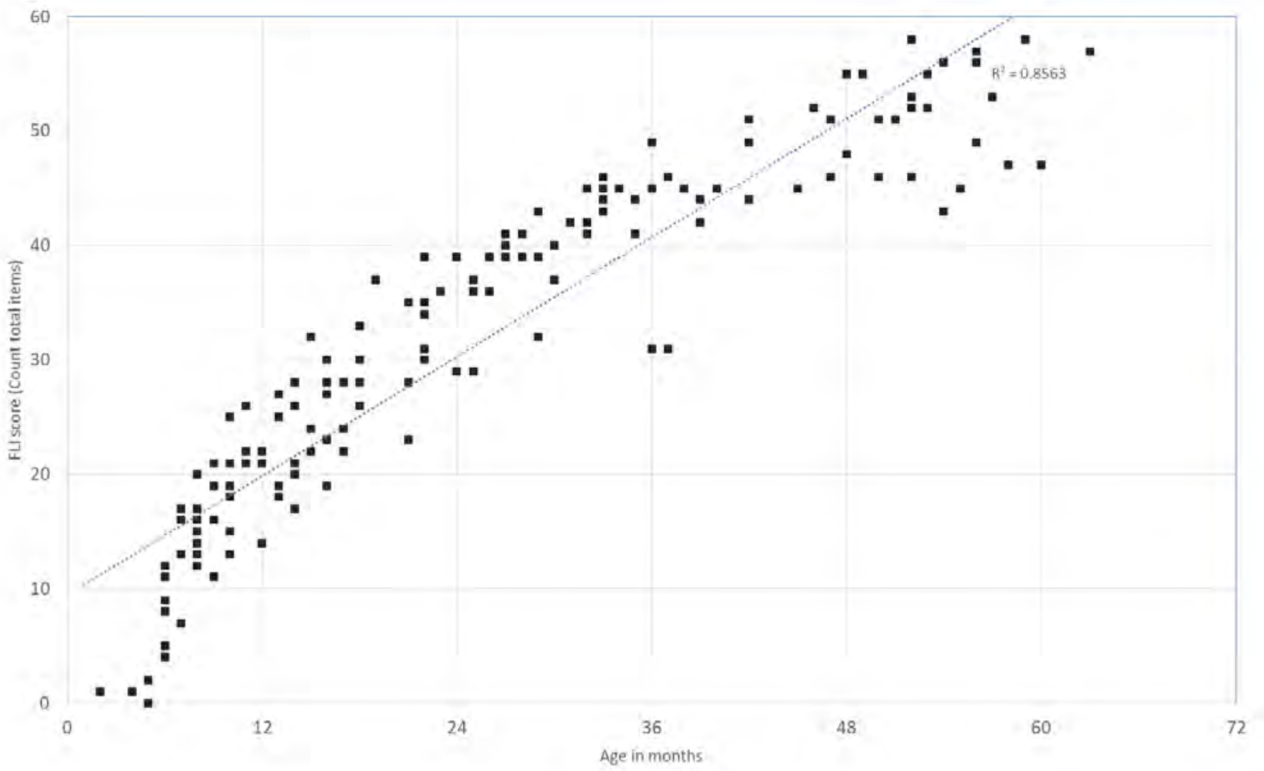


Figure 39. Children with a bilateral profound hearing loss receiving their first cochlear implant < 6 months of age demonstrate the most similar FLI scores to the TH group and the least amount of variability

Figure 40: FLI scores between groups (implant 6 - 11 months of age)

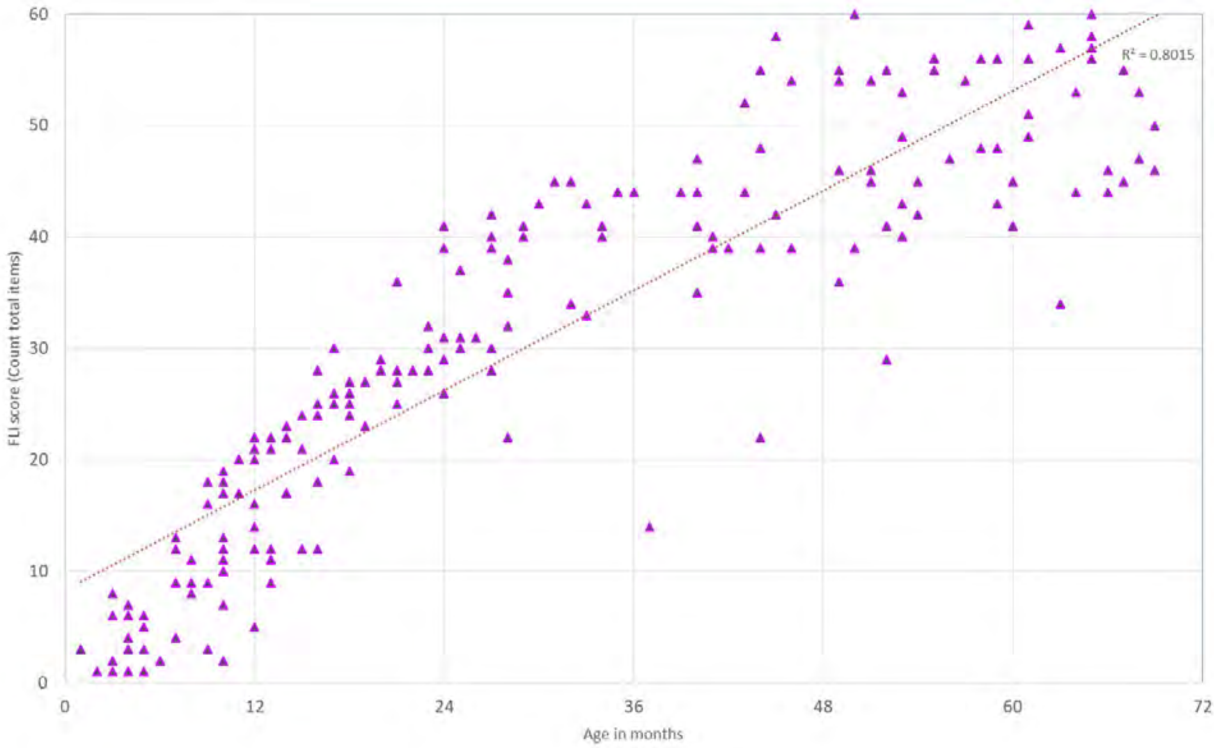


Figure 40. Less variation in FLI scores over ages are observed for children receiving their first cochlear implant between 6 and 11 months of age

Figure 41: FLI scores between groups (implant 12 - 23 months of age)

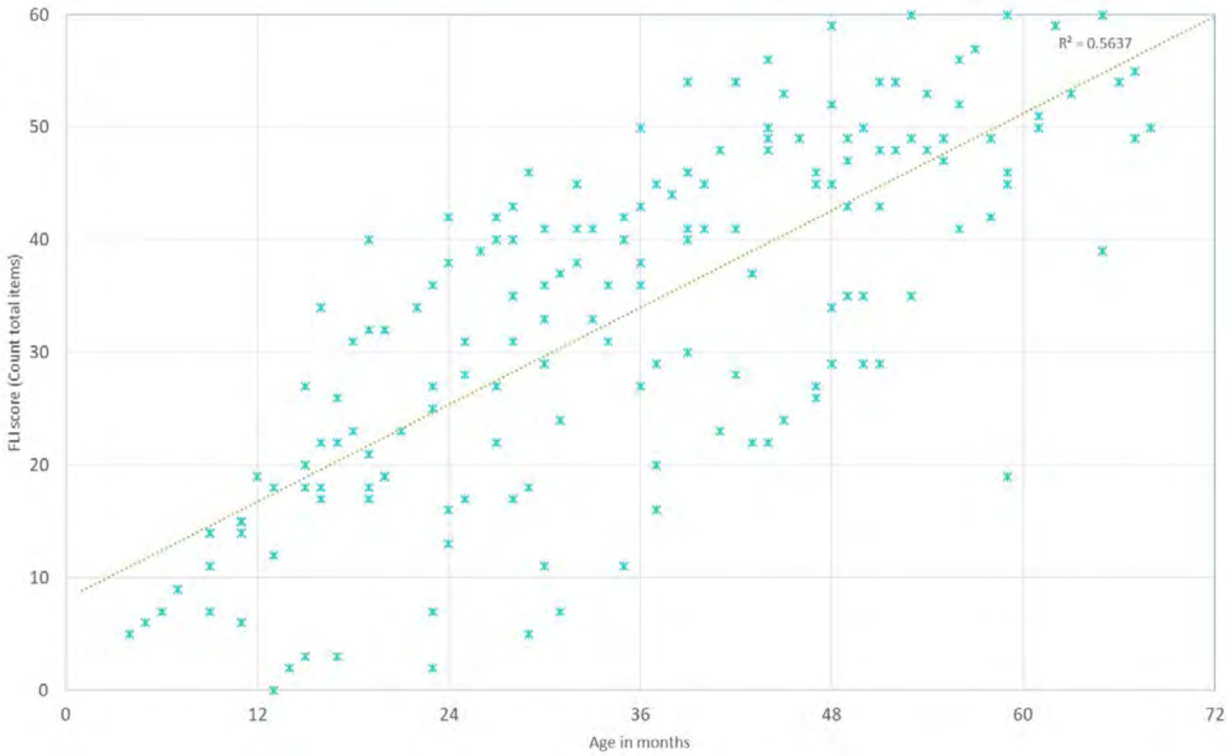


Figure 41. Wide variability in FLI scores across age ranges is indicated for children receiving their first cochlear implant between 12 and 23 months of age

Figure 42: FLI scores between groups (implant > 24 months of age)

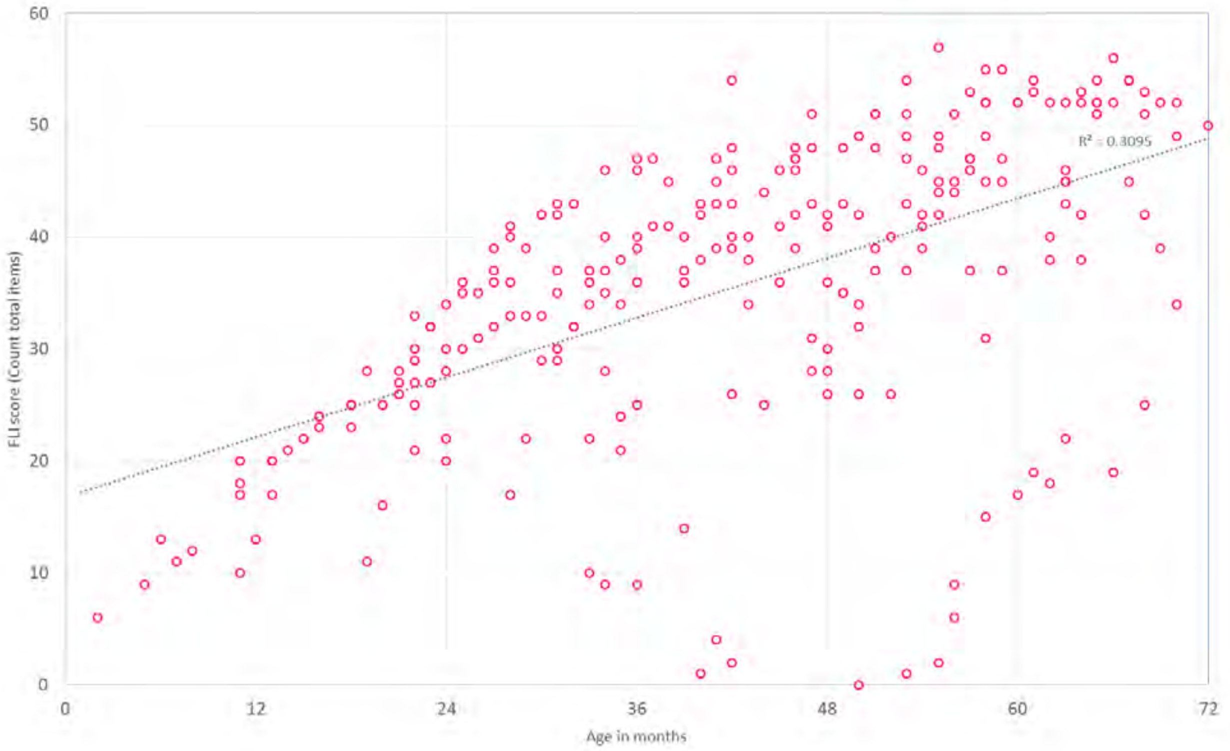


Figure 42. The greatest variation in FLI scores were observed for children receiving implants 24 months and older (R^2 = 0.30), FLI scores under implant age indicate listening skill development with hearing aids

Discussion

The aim of this study was to determine the feasibility and viability of the FLI as a clinical measure for all children with hearing loss enrolled in an early intervention and cochlear implant program. To establish this, the research objectives explored:

1. whether the FLI could be used successfully with the entire population of children with hearing loss in a clinical/educational setting;
2. if children's individual FLI trajectories change with time as would be expected; and
3. if the data for known groups demonstrated the expected differences.

Results on all three objectives indicate good preliminary support for the ongoing use of the FLI as a clinical measure in an early childhood service for children with hearing loss. Data demonstrated that the FLI can be used successfully with the entire population of children with hearing loss enrolled in clinical/educational setting. That is, it can be used with a full range of children including those with all levels and types of hearing loss, who use a range of devices, from diverse language backgrounds, and with developmental needs in addition to hearing loss. Individual children's FLI scores changed over time and appeared to be impacted as would be expected by various known factors and demonstrated sensitivity to factors such as middle ear pathology and a drop in hearing thresholds through case study examination. FLI scores for different groups identified the expected differences i.e., between children with typical hearing and hearing loss, disabilities in addition to hearing loss, and by age of implant. Although no clear differences in FLI scores across ages were indicated for children with bilateral and unilateral hearing loss, by type of hearing loss or device used, these findings are consistent with the evidence and prior discussions in this thesis supporting the importance of age of access to all levels of sound through appropriate amplification device/s.

Use of the FLI in a Clinical/Education Setting

During the 5-year period in which the study was conducted, there were no children with hearing loss who entered the early intervention and implant program for which the FLI was unable to be used, regardless of audiological or demographic characteristics. This broad demographic demonstrates the potential universality of the FLI for all children from birth through to 6 years of age. Highly significant correlations were found between age and FLI score for both the TH and EI group, indicating the expected growth in listening skills over time.

Changes to Children's Individual Scores Over Time

FLI scores were shown to be reflective of a both a child's longitudinal development of listening skills as well as skills at any given point in time. When FLI scores over time were graphically analysed, the resulting developmental 'listening paths' provided a *listening trajectory* for each child. Such trajectories provide a visual representation of a child's progress over time that are easily accessible and could be used by parents and professionals to support, guide, and where necessary inform intervention changes. A child's trajectory, when set alongside those of others with selected characteristics can, for example, provide an early indication of slower than expected progress for an individual context. This enables parents and professionals to consider possible contributing factors, including a child's use and integration of sound, levels of input, language exposure, and potential changes in access. Early identification of an impacting factor to outcomes can result in earlier changes to intervention in order to support positive changes.

Children's individual FLI scores and group data recorded during routine clinical practice supported the findings in Chapter 6 that the FLI is responsive to the expected differences between groups, such as children with a disability in addition to hearing loss, and age at implant. Consistent with Finestack and Fey (2017)'s research translation and implementation model discussed in Chapter 3, the use of the FLI across the population of a clinical setting demonstrates its generalisability and application for everyday use, supporting its external validity as a measure of auditory progress.

Differences in Group Scores

The typical hearing (TH) group provided a benchmark for comparison of FLI scores with the EI group. FLI scores that most closely matched the TH group were children with the earliest access to sound, regardless of level of hearing loss or type of device. As expected, the group of children with a disability in addition to hearing loss and the group with ANSD in one or both ears had the widest range of variability in FLI scores of any of the EI participant groups.

Interestingly, with respect to level of hearing loss, the FLI scores of the EI group with lower levels of hearing loss (unilateral, mild and moderate) still indicated a considerable range in scores when compared to those with greater levels of hearing loss and the most variation. Although these findings are not well documented elsewhere, they do reflect clinical experience that children with less significant levels of hearing loss (mild and moderate) do not necessarily experience the consistent, early, optimal access to sound as children with, for example, profound hearing loss who have audiological and educational intervention from a very early age. Future comparisons of FLI data with larger controlled cohorts across hearing levels could further explore this finding.

Clinical Implications and Limitations

Comparative analyses in this study concentrated primarily on audiological and demographic characteristics. Analysis of other group data beyond the scope of this work could provide additional information. Other factors such as hearing loss etiologies, cognitive and psychosocial profiles would be ideal areas for further investigation. Opportunities to better understand the impact of linguistic input and language learning environments on children's developing listening skills, through the use of data logging and language environment analysis technologies could be of substantial benefit in considering how to optimise a child's language learning context. The listening development of children in different multilingual settings could also be explored.

Greater analysis of the listening skills of children with unilateral hearing loss and their corresponding language skills would also provide interesting insights. For example, a child who demonstrates scores significantly below the predicted trajectory or age norms for their particular characteristics (despite average language skills) may generate a review of their access to sound. Current practice generally defines that language scores for a child with hearing loss within the typical range indicate adequate access, and adequate progress. Their potential though, may be much more. A sensitive measure of listening skills over time, such as the FLI, could contribute to supporting all children in being optimally amplified and reaching their language and communication potential—which may be much more than average. This could also provide critical information for children with unilateral hearing loss about access to sound for families making amplification choices, given the lack of current evidence and the challenges in relying on standardised language assessments to provide such guidance as discussed in Chapter 5 (Boyd, 2015; Kuppler, Lewis, & Evans, 2013).

There are both strengths and weaknesses of undertaking this study across the population of children in an early intervention setting. It enabled access to valuable whole-of-clinic data rather than recruited, self-selected participants that may bias the data in unknown ways. Additionally, the generalisability of results is high and all analysed data were reported, minimising the risk of experimenter bias. On the other hand, the increased data gaps and clinical service delivery model are likely to have introduced an inherent bias. Although FLI scores were verified and extraneous entries deleted from the database, data gaps still existed. The clinical service model meant that action was taken by the team to address cases of poor listening development, dynamically changing trajectories. Considering future studies, a sensitivity analysis would assist in comprehensively understanding the extent of the relationships between analysed factors and FLI scores over time. A reliability analysis would support understanding of how likely it is that clinicians are using the tool in the same way, and multicentre studies would indicate the generalisability of the FLI over different clinical settings.

Conclusion

Results of this study indicate that the FLI is a feasible and viable clinical measure that can be used to identify and track a child's developing listening skills between birth and 6 years of age. The FLI was found to be translatable for use across the whole population of children with hearing loss in a clinical/educational setting, supporting its broad application. Children's individual scores changed over time as expected and were sensitive to factors that are known to impact listening development, whilst group data indicated expected differences and variations. Information provided by children's listening scores on the FLI can guide and support discussions and intervention decisions and bridge the gap between information provided by audiological assessments of hearing levels and language measures.

The next chapter will conclude this thesis, which has examined how to improve the communication outcomes for children with hearing loss in their early years by tracking progress and guiding intervention. The purpose, aims, objectives and findings of the work will be reviewed, and results discussed in light of the current evidence. Overall limitations are examined, suggestions and recommendations made for future studies, and contributions to knowledge considered. A final chapter, Chapter 9 has been added as a postscript to provide context to the development, commercialisation and broader application of the FLI since the completion of the studies reported as part of this body of work.

Chapter 8

CONCLUSIONS AND CONSIDERATIONS

The previous chapter reported the results of 5 years of use of the Functional Listening Index (FLI) in a clinical retrospective study to identify its feasibility and viability as a measure of children's functional listening at individual points and over time. Results established that the FLI is usable across the population of children in a clinical/education setting regardless of individual demographic or audiological characteristics. Individual children's FLI scores demonstrated the expected changes over time and showed sensitivity to factors known to impact listening development. Expected differences were seen in comparisons of group data and a dataset of typical hearing children provided an initial benchmark of expected listening development for comparison. Given the results reported in Chapters 6 and 7 with respect to the validity of the FLI as a clinical measure, its application across a clinical setting and the meaningful clinical information it provides for parents and professionals to support a child's listening development, ongoing development is warranted. Following the discussion of conclusions and considerations in this chapter, Chapter 9 has been provided as a postscript to detail the ongoing improvements, advances and applications of the FLI since the completion of the studies in the scope of this work.

Review of Purpose, Aim and Objectives

"Understanding how a child with hearing loss detects, uses and processes linguistic input in their everyday settings, that is, their functional listening skills, is critical to understanding how well they are able to develop oral language".

The importance of maximising children's wellbeing is undisputed (Mashford-Scott et al., 2012). Children with speech and language difficulties and disorders are at particular risk in relation to psychological, social and emotional wellbeing (Lindsay & Dockrell, 2000; Lyons & Roulstone, 2018), in addition to the impact on literacy and educational outcomes (Roulstone, Law, Rush, Clegg, & Peters, 2011; Schuele, 2004). Children with hearing loss are at particular risk given the impact of reduced auditory input on language exposure (Tomblin et al., 2014). To maximise the wellbeing of children with hearing loss and to ensure they have the communication skills to thrive through their early learning and school years, appropriate and individualised support is critical (Lo, Das, & Horton, 2017). This thesis has considered the means by which the linguistic development of children with hearing loss can be supported through the close monitoring and tracking of a child's developing listening skills and the creation of a listening trajectory to provide information to parents and professionals to guide early and informed intervention decisions. In supporting early decisions in such a way, listening and language development can build a child's learning opportunities and communicative capacities. This has the potential to impact life-long social interactions and possibilities for inclusion, participation, employment and quality of life.

The intent of this thesis was to contribute knowledge to inform and further guide clinical practice thereby improving the communication outcomes of children with hearing loss. Three research objectives were identified. First, to systematically evaluate the evidence for effective intervention, therapy and training programs that support the development of communications skills of children with hearing loss. Second, to identify an effective way of furthering the communication development of children with hearing loss through development of a direct measure of functional listening and auditory development that informs and supports intervention decisions by parents and professionals. Third, to explore the feasibility and viability of the use of a direct measure of functional listening and auditory development for young children with hearing loss.

To achieve the first objective, research commenced by seeking to establish the current evidence base. In the initial stages of this work, it became apparent that it would first be necessary to define the term *intervention* due to the numerous ways it is used in academic and research literature, and in clinical practices across professional disciplines. The definitional study (Smith & Davis, 2018) used a general and specific 260,000-word corpus that consisted of peer reviewed research papers from an early version of the systematic review reported in Chapter 3. Results indicated three common meanings: 1) audiological intervention (the fitting of devices); 2) therapeutic intervention (the implementation of a specific therapy (e.g., therapy program); and 3) educational intervention (enrolment in a larger educational or curriculum program). Consistent with the purpose of this thesis, and given the extent of the existing evidence of the impact of audiological and educational interventions, the criteria for the systematic review in Chapter 3 focused specifically on therapeutic interventions.

Once this definition was established, the systematic review examined the evidence for therapeutic interventions and training programs that support the development of communications skills for children with hearing loss. The methodology and reporting of the systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009), with inclusion and exclusion criteria consistent with the Cochrane Protocol for Systematic Reviews (Higgins & Green, 2008). Criteria were formed using the Participants, Intervention, Control, Outcomes and Study Design (PICOS) tool (Methley et al., 2014) and therapeutic interventions categorised according to eight linguistic areas: lexicon and vocabulary (1), syntax and semantics (2), morphology (3), phonetics and phonology (4), pragmatics and social communication (5), reading and comprehension (6), writing and spelling (7), and narrative and discourse (8). All communication approaches for children with hearing loss were included: sign language, spoken language, total communication, and cued speech. Results were analysed by relevant frameworks to evaluate the validity of studies and strength of evidence.

The review identified 38 experimental and quasi-experimental papers that met study criteria, and a large number of these were literacy, vocabulary, and articulation-based training programs. Results identified a lack of evidence to guide professionals in using therapeutic interventions with children with hearing loss, and highlighted the opportunity for clinicians and researchers to work collaboratively to design and develop methodologically rigorous studies conducted in real-world settings. It was suggested the inclusion of single subject designs with high levels of internal validity could provide valuable information to growing a meaningful evidence base given the challenges of typically recognised robust study designs such as randomised control trials. The range of outcome measures were reviewed and a framework that considers a combination of measuring skills on a broad, participation level as well as an activity based specific linguistic task level was suggested. Additionally, the benefit of measures where children can serve as their own controls to guide individually targeted intervention was also proposed.

The second research objective, identifying an effective way of furthering the communication development of children with hearing loss, was addressed in Chapters 4 and 5. In order to provide benefit to the greatest number of children with hearing loss, the central principles in the development of strong communication systems for children with hearing loss and the factors that influence communication approach decisions were explored. Given the scale of children reported in the literature to be using a spoken language approach (or component thereof), factors key to developing effective oral communication systems were considered. These included the importance of early access to sound, the influence of a sensitive period on auditory development, the impact of real-world language learning environments, and the integration and ability to attach meaning to sounds. All four of these factors are dependent on auditory skills and ability. A measure of functional listening development that could track a child's skills and provide an acquisition trajectory that could inform and support early decisions by parents and professionals, thereby influencing communication outcomes was proposed.

The extent to which current listening assessments support the ability to measure and track a child's functional listening development in real-world listening conditions was reviewed in Chapter 5. This discussion identified a wide range of auditory measures that are in use across educational and clinical settings to assess the listening and hearing skills of children with hearing loss. Content, application, considerations for use and interpretation were reviewed for each tool, and limitations identified. As a result, the design and development of the Functional Listening Index (FLI) was discussed as a universal measure to accurately determine children's listening skill levels and, in collaboration with families, provide meaningful information to support intervention decisions.

The third and final research objective, was to establish the validity, feasibility and viability of the FLI. Statistical and clinical validation studies in Chapters 6 and 7 established levels of internal and external validity, sensitivity, and applicability. Significant levels of concurrent validity were found with existing tools with similar content and purpose, and expected differences seen between groups. Scores on the FLI at 3 years of age were a moderately strong predictor of a child's language scores at 5 years of age, indicating the benefit listening scores could provide as an early ‘crystal ball’ of communication outcomes. Results of a 5-year retrospective study of the FLI in use in a clinical and education intervention setting demonstrated its universal application across a population of children with hearing loss. FLI scores indicated expected changes in individual scores, and expected levels of variation. These preliminary results provide support to its ongoing clinical use and development.

Research Limitations

The results reported in these studies should be considered in light of a number of limitations, as discussed in each chapter. There are also limitations to acknowledge and consider in terms of the overall body of work when interpreting the knowledge contribution to the field that it provides. These limitations lie primarily in the linking of research objectives, the nature of the data collection, and the scope of discussions and analyses.

I began this research project as a clinical professional, as an investigation to inform and further clinical practice to improve the communication outcomes of children with hearing loss. The lack of evidence to guide therapeutic interventions was known but not documented (apart from evidence supporting outcomes from different communication approaches). I observed the different ways hearing health care professionals and researchers used the term ‘intervention’, often causing confusion. The need to track the progress and development of a child’s listening skills was clinically apparent and the gap in current measures clear. The value of the information provided by a child’s listening trajectory became discernable and the support this clinical evidence gave to professionals and parents to guide intervention was compelling. A series of research objectives were required to link these areas together in a body of work to enable the robust exploration, examination and analysis that was required. This resulted in three specific objectives that ranged from a wide review of therapeutic interventions to improve communication outcomes, through to determining a specific way to measure of functional listening and auditory development, and subsequent clinical and validation studies. This enabled the focus of the work to start very broadly, considering all children with hearing loss and the overarching goal of improving outcomes, and become more specific as the discussions and results indicated how this could best be achieved. An initial version of the systematic review reported in Chapter 3 considered only spoken language outcomes, but as this was narrow in focus, the methodology was amended to include therapeutic interventions regardless of communication approach. This resulted in an important discussion in Chapter 4 on the factors impacting communication development and influencing decisions on a communication approach, which is pivotal background to the context of this thesis. It is important to acknowledge though that this ‘broad through to specific’ approach required considerable leaps in discussions, as the project became more specific in nature in each objective. An easier link for example, may have been to commence with a review of the evidence for listening and auditory measures, or review the current implementation of functional listening measures to understand gaps and potential impact and value.

As previously stated, there are both strengths and weaknesses in undertaking this study in a real-life setting, across the population of children in early intervention rather than a tightly-controlled, specifically recruited dataset. The nature of this type of data collection provided powerful evidence of the application and use of the FLI as a listening development measure, and valuable clinical data for use in understanding acquisition patterns. In addition to data gaps, one of the limitations to acknowledge is the impact of the educational program on a child's FLI scores, and that there was no inclusion of a group of children with hearing loss not receiving early intervention services. Logistical and ethical challenges aside, such a group could provide information on the use of the FLI in tracking children's listening development in different contexts, and the effectiveness of clinical/educational settings. As the evidence for therapeutic interventions grow for children with hearing loss as indicated in Chapter 3, so does the potential use for a standardised listening acquisition measure such as the FLI.

Although all attempts have been made to ensure the discussions and analyses throughout the chapters cover the necessary aspects to the fullest depth and maximum scope, no doubt there is the possibility these could be further extended. To reduce this risk, advice and mentorship was sought from experienced colleagues in the field in their respective area of expertise. This included clinical, research and statistical analyses. This helped to ensure necessary aspects were accurately covered in discussions, and interpretations of results were accurate and appropriate. This body of work was undertaken part-time over an 8-year period whilst being employed in a full-time clinical role, bringing with it both benefits and limitations. The extended time period enabled the longitudinal data collection and use of the FLI in both the validation and feasibility studies, and to ensure each research objective could be thoroughly addressed. It also enabled clinical insights into the needs, gaps and potential further opportunities for professionals and parents in improving outcomes by tracking listening progress and guiding development. In limitations, the part-time nature of the work did not enable an entire focus on the studies over a period of time, and clinical needs in development and use of the FLI were often prioritised due to commercial and organisational needs above outstanding research priorities (discussed further in Chapter 9).

Conclusion

The series of work in this research program has identified the FLI as a measure of functional listening that can provide information to guide decisions and intervention for children with hearing loss and thereby support improved communication outcomes. Clinical use indicated that the FLI is a feasible and viable clinical measure to identify and track a child's developing listening skills throughout their early years, and was found to be appropriate for use across the whole population of children with hearing loss in a clinical/educational setting supporting its broad application. Children's individual scores changed over time as expected and were sensitive to factors known to impact listening development, whilst group data indicated expected differences and variations. Information provided by children's listening scores on the FLI can guide and support discussions and decisions, and bridge gaps between the information provided by audiological assessments of hearing levels, language outcome measures, and the current auditory and listening checklists. A postscript is provided as a further chapter to detail the ongoing research and development that has continued with the FLI due to extensive commercial and wider clinical interest in the broader application of the FLI as a result of international conference presentations on the studies presented in Chapters 6 and 7.

Chapter 9

POSTSCRIPT – THE DEVELOPMENT, COMMERCIALISATION AND BROADER APPLICATION OF THE FUNCTIONAL LISTENING INDEX

This postscript serves to provide context to the research and development of the FLI since completion of the statistical and clinical studies reported in Chapters 6 and 7, as this thesis work was conducted in parallel to and within the context of the HEARing CRC program. As a government-funded research consortium that focuses on industry-led projects to improve outcomes for adults and children with hearing loss, the FLI, and later FLI-P were good fits to the aims of the HEARing CRC's Project xR3.3.4, as well as its focus on commercial and/or clinical application of research outcomes. This support enabled the work reported within this postscript chapter to be completed.

Since the compilation and presentation of the studies reported in this thesis at professional conferences, there has been extensive interest in potential clinical application of the FLI in clinical settings and industry interest in collaborations and partnerships, many of which through the HEARing CRC research program. This has since included the development of the FLI Version 2.0 (known as the Functional Listening Index – Paediatric); commercialisation of the tool with licences, terms for use, branding, trademarks, intellectual property and collaboration agreements, and considerations for broader applications of use outside of its current context. As these are outside the scope of this thesis but provide insight and understanding regarding the interest in and evidence of the need for a functional listening measure such as the FLI, the translational implications of this research, and contributions that this research provides, they are documented here.

Development of the FLI-P v2.0

As a result of the uptake of the FLI and the reported benefits from the families and team using it at The Shepherd Centre[15] since its initial clinical use in 2012, further work has gone into its development to support the reliability of use and value of the information it provides. Following the collation and review of feedback and questions from use, improvements focused on four key areas:

1. the development of administration guidelines, including basal and ceiling limits to improve reliability;
2. clarification and simplification of items, including the addition of examples and suggestions so it can be completed by parents and non-experienced professionals;
3. the addition of items where there were identified gaps, and deletion of items where there was duplication; and
4. a review of the rating scale used to measure the acquisition of each listening item.

[15] An integrated early intervention and cochlear implant program for children with hearing loss with Headquarters in Sydney, Australia

These improvements were consolidated into a second version of the FLI, now termed the FLI-P v2.0 (Functional Listening Index – Paediatric) (Appendix E)[16]. Initial analyses of the FLI and FLI-P v2.0 have indicated strong levels of correlation and equivalence reliability (n = 53, R^2 = 0.93) (Fig 43) (Rosenthal & Rosnow, 1991). A preliminary inter-rater reliability analysis of the FLI-P v2.0 when completed by a parent compared to when completed by a familiar professional also indicates a strong correlation (n = 128, R^2 = 0.90) (Fig 44).

Figure 43: FLI and FLI-P v2.0 regression analysis

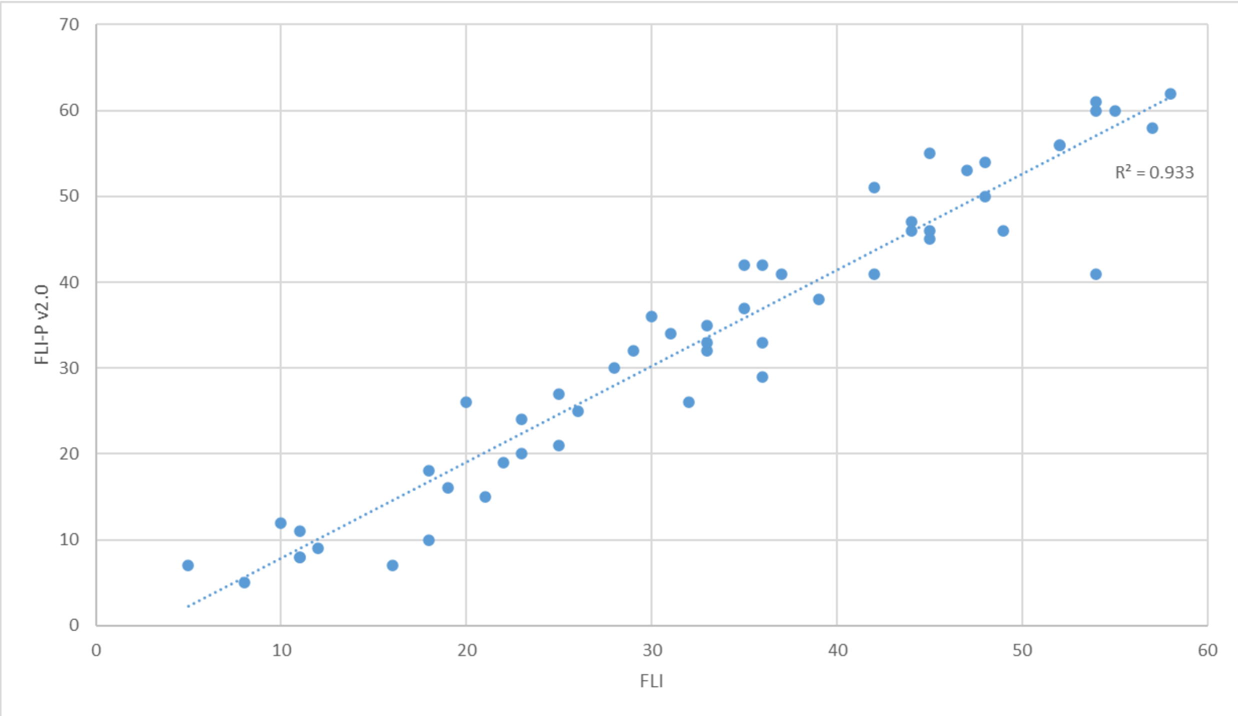


Figure 43. FLI and FLI-P v2.0 scores for 38 children at the same time point indicate a strong correlation

[16] Further information on the nomenclature for the FLI is provided later in the chapter on page 218

Figure 44: FLI-P v2.0 parent and FLI-P v2.0 professional regression analysis

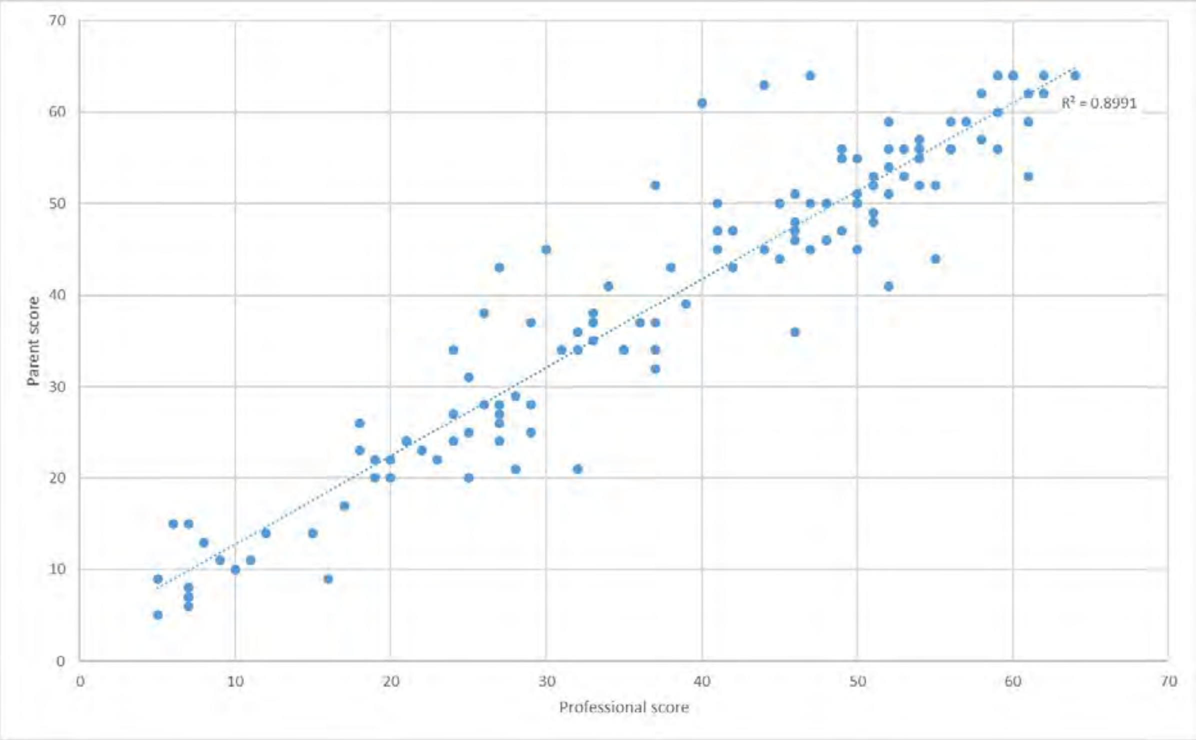


Figure 44. FLI scores for each child by parent and professional demonstrated strong levels of co and FLI-P v2.0 scores for 38 children at the same time point indicate a strong correlation

Administration Guidelines

Common questions asked by users included: “How often should I be using the FLI?”, “Can I use it with a child who doesn’t speak English?”, “Should I be repeating items?” and “How many is a small range?” Answers to these and other Frequently Asked Questions were documented for reference in a structured User Guide and FAQ to increase consistency amongst clinical professionals using the tool (Appendices F and G).

Item Clarification and Simplification

User feedback indicated a number of specific items on the FLI were being interpreted differently. These items contained either clinical language that was heavy with linguistic terminology (for example ‘demonstrates morpho-syntactic understanding’), or words without a clear reference point (for example ‘demonstrates a range of …’). These items were identified and revised to improve consistency and reduce subjective interpretation. To further support these clarifications, examples and techniques to elicit the listening behaviour described in each item were developed (see Appendix H). Removing cultural and demographic biases in items was necessary to support appropriateness for use by children and families from all backgrounds. To support family-centered early childhood intervention guidelines (Ciciriello et al., 2016; Holzinger et al., 2011), adaptions were made so the FLI could be used by parents, early educators, special education teachers, speech pathologists and health and disability professionals without backgrounds or experience in hearing loss. Each item was re-written using the simplest description fitting a standard format (‘My child…’). To maximise readability all items, examples, elicitation techniques and accompanying user guides were reviewed using the Flesch Reading Ease scale (Flesch, 1948). Improvement examples are provided in Table 36.

Table 36: FLI-P v2.0 item simplification and clarification examples

Aim	FLI example item	FLI-P v2.0 example item
To eliminate jargon and linguistic terminology	*To demonstrate anticipatory knowledge of familiar songs/rhymes through listening alone (e.g., braces for tickle)*	*My child… knows what is going to happen next in familiar songs*
To remove any cultural or geographic specific references	*To demonstrate advanced auditory closure e.g. A triangle, circle & square are all…*	*My child… is able to tell me how 3 or 4 things are related when I name them*
To provide quantifiable amounts to maximise reliability of use	*To recognise names of immediate family members*	*My child… knows the names of 3 familiar people or pets*
To maximise readability	*To vocalise when spoken to*	*My child… makes sounds back to me when I talk to them*
	To repeat accurately sentences that have high predictability	*My child… accurately repeats sentences of 5 to 6 words after me if they know all the words*
To add examples and elicitation techniques	*To identify a range of learning to listen sounds*	*My child… matches 3 to 4 animals or objects with the sounds they make* ***What this can look like:*** *They may look at, point to, pick up or find a toy or picture of the object or animal when you say the sound it makes. For example, when you say, “Where’s the dog, woof woof?” they look around for their dog; or when you say “Where’s the train, choo choo?” they look for their train.* ***How to check:*** *Have a few familiar animals and objects that make a sound near the child. Make one of the sounds, and watch to see what they do. Do they stop what they are doing and look for it? Do they reach for it and give it to you?*

Item Addition and Deletion

Clinical observations and analyses indicated additional FLI items were required. These were added for children above 3 years of age due to flattening trajectories > 36 months (5 items added), gaps in the development of some listening skills (3 items added) and real-world listening skills at an early age to reflect the nature of language learning environments for children (1 item added). Item acquisition analysis also indicated the ordering of items needed review, and a number of very similar items needed to be removed (8 items). These adjustments resulted in a total of 64 items in the FLI-P v2.0, compared to 60 in the original FLI (Table 37).

Table 37: FLI-P v2.0 additions and deletions

Status	FLI Item	Item #	FLI-P v2.0 Item	Item #
Added	Not present	n/a	Recognises a favourite song or music from the TV, tablet or phone	11
Added	Not present	n/a	Repeats 3 familiar sounds after me	19
Added	Not present	n/a	Repeats 'ah', 'oo', 'ee' and 'mm' from the "Ling 6" sounds clearly after me	25
Added	Not present	n/a	Is able to tell the difference between 'ss' and 'sh' from the "Ling 6" sounds	26
Added	Not present	n/a	Understands 10 words or phrases	28
Added	Not present	n/a	Follows 2 instructions when given in the same sentence	36
Added	Not present	n/a	Recognises a familiar person on the phone	42
Added	Not present	n/a	Follows 3 instructions in the same sentence	51
Added	Not present	n/a	Understands that the way something is said changes the meaning of the sentence.	60
Deleted	To imitate adult speech sounds appropriate for age	25	Not present	n/a
Deleted	To occasionally respond when called by name e.g., by stopping activity or turning	14	Not present	n/a
Deleted	To wear hearing devices during all waking hours (if no devices fitted, put date of birth in "record date")	1	Not present	n/a
Deleted	To search for the source of a sound	3	Not present	n/a
Deleted	To show signs of development an 'auditory feedback loop' (e.g., increases/decreases vocalisations when devices on/off; changes vocalisations based on what is heard)	13	Not present	n/a
Deleted	To respond appropriately to everyday requests without contextual clues	32	Not present	n/a
Deleted	To attend to a story or rhyme for 3-4 pages/screens with added suprasegmental information	39	Not present	n/a
Deleted	To recall a narrative/story with a known topic, recalling details in sequence	51	Not present	n/a

Measuring Skill Acquisition

Early childhood developmental and milestone checklists such as the FLI typically assess the presence or absence of a skill, behavior or knowledge, and the item is 'checked off' as met/achieved, or not. Items on these scales are formulated as yes/no questions (for example "Does the child….?", "Can the child…?") (Couchenour & Chrisman, 2016). Scales are also used to assess the degree of accomplishment. That is, how often, or how much a skill or behavior has emerged (for example 'never' 'sometimes' 'always') (Reynolds, Livingston, Willson, & Willson, 2010). Early use of the FLI demonstrated that the inherent challenge in 'checking off' the development of a child's skills is in measuring when they have developed the skill or behaviour, compared to when they have not. Core to this difficulty is that skill acquisition is not an ‘all or nothing’ concept. Rather, like language or literacy competency, there are levels of proficiency (Brown, 2014; North, 1995). As children begin their *listening competency,* they may use a skill only once, or every so often. As their skills develop further, they may use it more often, but not all the time. These stages of development make it difficult to categorise achievement in a yes/no format. Does it mean a child has developed a listening behaviour if they have used it once? What if a child demonstrates it once, but then not again for a while? Have they acquired the skill if they demonstrate the skill most of the time but not all? Competency checklists circumvent this issue by using scales of proficiency such as ‘beginning’, ‘developing’, ‘competent’ or ‘mostly at this age’ and ‘roughly around this time’ (Morin, 2019; Neilson & Konza, 2013).

Feedback from use of the FLI also indicated recording the date when an item was ‘checked off’ also created difficulty. As this was the date of administration, it did not reflect the true date the child acquired the listening skill. A review of checklists and scales used in communication measures and competency development in the health, education and disability fields indicated that the use of a 2 item rating scale (‘mostly’, ‘rarely’) would be appropriate in addressing these challenges, as used in the Social Attention and Communication Surveillance System (SACS-R) (Barbaro & Dissanayake, 2013). These terms were defined in the user guides as follows:

Mostly: “You are quite confident the child has the skill in question. They do it easily and frequently with different people and in different contexts”.

Rarely: “The child is unable to do the task required or you are not sure if the child has consolidated this skill. They show the skill in question sometimes but not frequently or easily. The child may do the skill in question only in some circumstances or with specific people or in specific places”.

Commercialisation and Broader Applications of Use

Interest following the conference presentations detailed in the preface of this work instigated requests for use and partnership, and collaboration opportunities from researchers, clinicians and industry colleagues. This resulted in requests for use by hearing health care professionals internationally (US, South America, NZ, UK, Australia, Asia, South Africa and Europe); academic research partnerships to administer a normative data collection study of the FLI scores of typical hearing children (n = 654) to provide benchmark comparisons[17]; financial license agreements for use by Cochlear Ltd; cobranding, marketing and intellectual property agreements between the HEARing CRC, The Shepherd Centre and Cochlear Ltd; and an approved trademark registration application.

[17] Run in partnership with the HEARing CRC, Cochlear Ltd, The Shepherd Centre and The MARCS Institute BabyLab, at the University of Western Sydney. Approved by WSU HREC (S5: H11517, ‘Listening Skills Development of Australian Children without Hearing Loss’ (see Appendix I)

Considerations for the broader application of use of the FLI have resulted in the development of accredited training modules to support administration and standardisation of use of the FLI in professional contexts (both in person and online workshops and courses); development of a digital version for an easy, quick and effective means to provide an immediate visualisation of a child's listening development trajectory and support parent and professionals partnerships (Blue-Banning et al., 2004; Moore, 2008; Tomasello, Manning, & Dulmus, 2010); translation to languages other than English; a grouping analysis for similar listening skills (for example 'items in background noise') to provide further clinical information on patterns of development; and a weighting analysis to more accurately reflect the population on which it is used.

Further to the success of the FLI in clinical use, research work has commenced to scope, design and develop the Functional Listening Index – Adults (FLI-A). This is envisaged to be similar in concept to the FLI-P, but at the opposite end of the spectrum of listening development, wherein it will track the loss of listening skills over time to identify the impact of hearing loss for adults and support early device choices and intervention. The concept of the Functional Listening Index – Youth (FLI-Y) has also been proposed to explore the development of advanced listening competency in children during their school years to support learning and literacy development. Future research and developments of the FLI have also been planned to include a sensitivity analysis, validation for use of the FLI across cultures, and translation validation studies. The current state of all FLI-P developments is depicted in Figure 45.

Figure 45: FLI-P developments

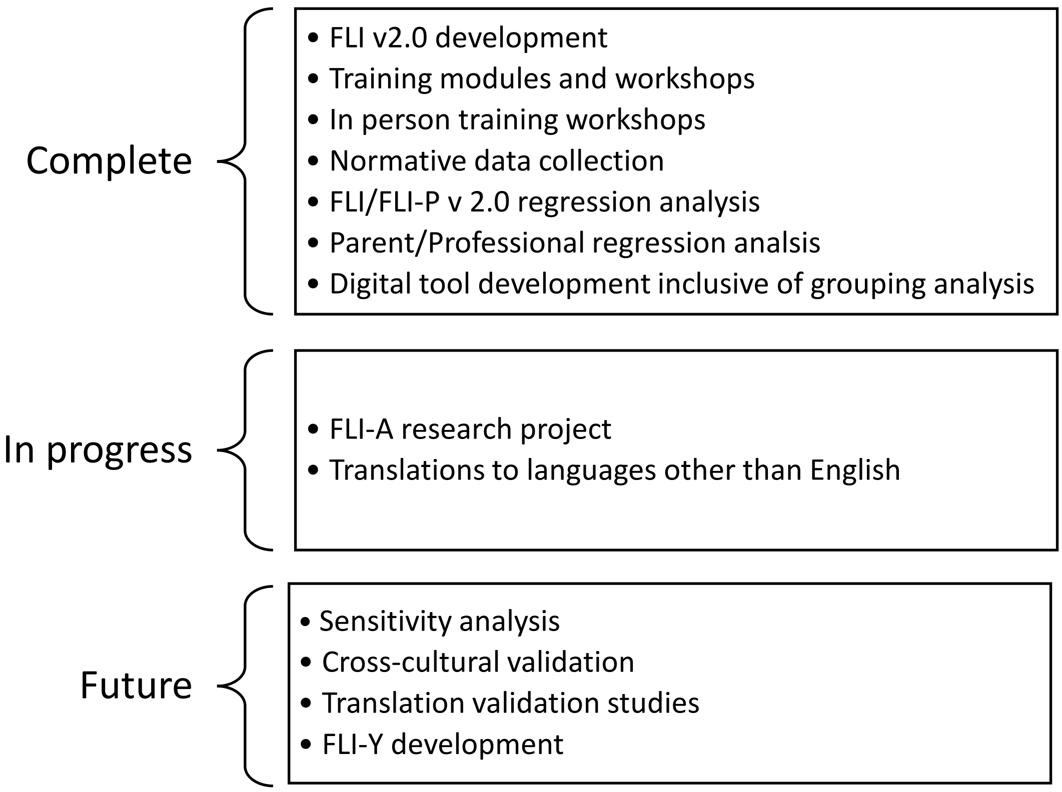


Figure 45. Complete, in progress and future FLI development work

These developments of the FLI have far surpassed initial expectations of use and highlight the organic nature in which the application of the concept of a listening trajectory has grown. The interest and uptake by hearing health care professionals indicates the value to clinical practice and benefit to children with hearing loss and their families, in supporting and empowering their journey. The potential next step, is for families to use the FLI directly to routinely track their child's progress. In doing so, the FLI can educate parents on the next steps of their child's listening development, encourage them in how best to teach and model these crucial listening skills and create rich, listening and language learning opportunities particular to their child's stage—an incredibly powerful concept to consider.

REFERENCES

Allen, T. E., Letteri, A., Choi, S. H., & Dang, D. (2014). Early visual language exposure and emergent literacy in preschool deaf children: Findings from a national longitudinal study. *American Annals of the Deaf, 159*(4), 346.

Alo, C. J., & Howe, H. L. (1997). *Trends in the prevalence of birth defects in illinois and chicago, 1989 to 1995* (Vol. 97): Illinois Department of Public Health, Division of Epidemiologic Studies.

Alton, S., Herman, R., & Pring, T. (2011). Developing communication skills in deaf primary school pupils: Introducing and evaluating the smile approach. *Child Language Teaching and Therapy, 27*(3), 255-267.

Anca, M., & Hategan, C. (2007). Personalizing the hearing training of the children with cochlear implant by selecting and adapting the linguistic material. *Studia Universitatis Babes-Bolyai. Serie: Psychologia-paedagogia, lii*(2), 97-108.

Anderson, K. (2002). Elf: Early listening function. *Tampa, FL: Educational Audiology Association*.

Anderson, K., & Smaldino, J. (2000). Children's home inventory for listening difficulties (child). *Educational Audiology Review, 17*(3).

Anderson, K. L. (2004). Auditory skills checklist. Retrieved from https://successforkidswithhearingloss.com/resources-for-profes-sionals/early-intervention-for-children-with-hearing-loss

Andrews, J., & Smith, Z. (2000). A study of four african-american families reading to their young deaf children (1996-1997). Final report.

Antia, S. D., Jones, P. B., Reed, S., & Kreimeyer, K. H. (2009). Academic status and progress of deaf and hard-of-hearing students in general education classrooms. *Journal of Deaf Studies and Deaf Education, 14*(3), 293-311. doi:10.1093/deafed/enp009

Aragon, M., & Yoshinaga-Itano, C. (2012). Using language environment analysis to improve outcomes for children who are deaf or hard of hearing. *Seminars in speech and language, 33*(4), 340-353. doi:10.1055/s-0032-1326918

Archbold, S., Lutman, M., & Marshall, D. (1995). Categories of auditory performance. *The Annals of otology, rhinology & laryngology. Supplement, 166*, 312-314.

Asad, A. N., Hand, L., Fairgray, L., & Purdy, S. C. (2013). The use of dynamic assessment to evaluate narrative language learning in children with hearing loss: Three case studies. *Child Language Teaching and Therapy, 29*(3), 319-342.

Australian Bureau of Statistics. (2018). 2033.0.55.001 - census of population and housing: Socio-economic indexes for areas (seifa). Retrieved from https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2033.0.55.001~2016~Main%20Features~IRSAD~20

Bachmann, K. R., & Arvedson, J. C. (1998). Early identification and intervention for children who are hearing impaired. *Pediatrics in Review, 19*, 155-165.

Bacsfalvi, P. (2007). *Visual feedback technology with a focus on ultrasound: The effects of speech habilitation for adolescents with sensorineural hearing loss.* (Doctoral Dissertation, University of British Columbia).

Bagatto, M., & Moodie, S. (2016). Relevance of the international classification of functioning, health and disability: Children & youth version in early hearing detection and intervention programs. *37*(03), 257-271. doi:10.1055/s-0036-1584406

Bagatto, M. P., Moodie, S. T., Seewald, R. C., Bartlett, D. J., & Scollie, S. D. (2011). A critical review of audiological outcome measures for infants and children. *Trends in Amplification, 15*(1), 23-33. doi:10.1177/1084713811412056

Bagatto, M. P., & Scollie, S. D. (2013). Validation of the parents' evaluation of aural/oral performance of children (peach) rating scale. *Journal of the American Academy of Audiology, 24*(2), 121-125.

Baker, E., & McLeod, S. (2011). Evidence-based practice for children with speech sound disorders: Part 1 narrative review. *Language, Speech, and Hearing Services in Schools, 42*(2), 102-139. doi:10.1044/0161-1461(2010/09-0075)

Barbaro, J., & Dissanayake, C. (2013). Early markers of autism spectrum disorders in infants and toddlers prospectively identified in the social attention and communication study. *Autism, 17*(1), 64-86.

Barnes, S., & Bloch, S. (2018). Why is measuring communication difficult? A critical review of current speech pathology concepts and measures. *Clinical Linguistics & Phonetics*, 1-18.

Beeson, P. M., & Robey, R. R. (2006). Evaluating single-subject treatment research: Lessons learned from the aphasia literature. *Neuropsychology review, 16*(4), 161-169.

Bell, P., Staines, P., & Michell, J. (2001). Evaluating, doing and writing research in psychology. doi:10.4135/9781849209106

Bench, J., Kowal, Å., & Bamford, J. (1979). The bkb (bamford-kowal-bench) sentence lists for partially-hearing children. *British Journal of Audiology, 13*(3), 108-112.

Benedict, H. (1979). Early lexical development: Comprehension and production. *Journal of Child Language, 6*(2), 183-200.

Bergelson, E., & Swingley, D. (2015). Early word comprehension in infants: Replication and extension. *Language Learning and Development, 11*(4), 369-380.

Bergeron, J. P., Lederberg, A. R., Easterbrooks, S. R., Miller, E. M., & Connor, C. M. (2009). Building the alphabetic principle in young children who are deaf or hard of hearing. *The Volta Review, 109*(2-3), 87-119.

Bernhardt, B., Loyst, D., Pichora-Fuller, K., & Williams, R. (2000). Speech production outcomes before and after palatometry for a child with a cochlear implant. *The Journal of the Academy of Rehabilitative Audiology, 33*, 11-37.

Bess, F. H., Dodd-Murphy, J., & Parker, R. A. (1998). Children with minimal sensorineural hearing loss: Prevalence, educational performance, and functional status. *Ear and Hearing, 19*(5), 339-354.

Bess, F. H., & Humes, L. E. (2003). *Audiology: The fundamentals*: Lippincott Williams & Wilkins.

Bess, F. H., Tharpe, A. M., & Gibler, A. M. (1986). Auditory performance of children with unilateral sensorineural hearing loss. *Ear and Hearing, 7*(1), 20-26.

Biringen, Z., Derscheid, D., Vliegen, N., Closson, L., & Easterbrooks, M. (2014). Emotional availability (ea): Theoretical background, empirical research using the ea scales, and clinical applications. *Developmental Review, 34*(2), 114-167.

Birman, C. S., Elliott, E. J., & Gibson, W. P. (2012). Pediatric cochlear implants: Additional disabilities prevalence, risk factors, and effect on language outcomes. *Otology & Neurotology, 33*(8), 1347-1352.

Blaiser, K. (2012). Supporting communicative development of infants and toddlers with hearing loss. *Seminars in speech and language, 33*(4), 273-279. doi:10.1055/s-0032-1326911

Bloom, L., & Lahey, M. (1978). *Language development and language disorders*. New York: Wiley.

Blue-Banning, M., Summers, J. A., Frankland, H. C., Nelson, L. L., & Beegle, G. (2004). Dimensions of family and professional partnerships: Constructive guidelines for collaboration. *Exceptional Children, 70*(2), 167-184. doi:10.1177/001440290407000203

Bobsin, L. (2011). *Essential aspects of language development: Suprasegmental abilities of children with cochlear implants.* (Doctoral Dissertation). Available from Proquest Dissertations Publishing. (UMI No. 3485329)

Bobzien, J., Richels, C., Schwartz, K., Raver, S. A., & Morin, L. (2015). Using repeated reading and explicit instruction to teach vocabulary to preschoolers with hearing loss. *Infants Young Child., 28*(3), 262-280. doi:10.1097/IYC.0000000000000039

Bonilla Yanez, M. (2016). *The effect of a fluent signing narrator on quality of maternal behavior during e-book shared reading interactions with their children with hearing loss.* (Doctoral Dissertation, University of Texas at El Paso).

Boons, T., Brokx, J., Frijns, J., Philips, B., Vermeulen, A., Wouters, J., & van Wieringen, A. (2013). Newborn hearing screening and cochlear implantation: Impact on spoken language development. *B-ENT, Suppl 21*, 91-98.

Boons, T., Brokx, J. P., Dhooge, I., Frijns, J. H., Peeraer, L., Vermeulen, A., . . . van Wieringen, A. (2012). Predictors of spoken language development following pediatric cochlear implantation. *Ear and Hearing, 33*(5), 617-639. doi:10.1097/AUD.0b013e3182503e47

Borum, V. (2012). Perceptions of communication choice and usage among african american hearing parents: Afrocentric cultural implications for african american deaf and hard of hearing children. *American Annals of the Deaf, 157*(1), 7-15.

Bow, C., Blamey, P., Paatsch, L., & Sarant, J. (2004). The effects of phonological and morphological training on speech perception scores and grammatical judgments in deaf and hard-of-hearing children. *Journal of Deaf Studies and Deaf Education, 9*(3), 305-314.

Bowers, L., & Schwarz, I. (2013). Assessing response to basic concept instruction: Preliminary evidence with children who are deaf. *Communication Disorders Quarterly, 34*(4), 221-231.

Boyd, P. J. (2015). Potential benefits from cochlear implantation of children with unilateral hearing loss. *Cochlear Implants International, 16*(3), 121-136.

Brady, N. C., & Bashinski, S. M. (2008). Increasing communication in children with concurrent vision and hearing loss. *Research and Practice for Persons with Severe Disabilities (RPSD), 33*, 59-52), p.59-70.

Braswell, J. (2004). *The effect of vestibular exercise on dynamic visual acuity and reading acuity in children with sensorineural hearing impairment and vestibular hypofunction.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing. (UMI No. 3141874)

Broekelmann, C. (2012). Ihear[r] internet therapy program: A program by st. Joseph institute for the deaf. *The Volta Review, 112*(3), 417-422.

Brown, C. S. (2014). Language and literacy development in the early years: Foundational skills that support emergent readers. *Language and Literacy Spectrum, 24*, 35-49.

Brown, G. W., & Mood, A. M. (1951). *On median tests for linear hypotheses.* Paper presented at the Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability, The Regents of the University of California.

Brown, R. (1973). *A first language: The early stages*: Harvard University Press.

Brownell, R. (2000). *Expressive one-word picture vocabulary test*. California: Academic Therapy Publications Novato.

Bruder, M. B. (2000). Family-centered early intervention: Clarifying our values for the new millennium. *Topics in Early Childhood Special Education, 20*(2), 105-115.

Burke, V. (2012). *Word reading strategy development of deaf and hard-of-hearing preschoolers.* (Doctoral Dissertation, Georgia State University).

Byrne, B., & Fielding-Barnsley, R. (1991). Evaluation of a program to teach phonemic awareness to young children. *Journal of Educational Psychology, 83*(4), 451.

Calderon, R. (2000). Parental involvement in deaf children's education programs as a predictor of child's language, early reading, and social-emotional development. *Journal of Deaf Studies and Deaf Education, 5*(2), 140-155.

Caleffe-Schenck, N., & Stredler-Brown, A. (1992). Auditory skills checklist. *Available from the Colorado Home Intervention Program, 33*.

Carding, P., & Hillman, R. (2001). More randomised controlled studies in speech and language therapy. *BMJ (Clinical research ed.), 323*(7314), 645-646. doi:10.1136/bmj.323.7314.645

Carey, T. A., & Stiles, W. B. (2016). Some problems with randomized controlled trials and some viable alternatives. *Clinical psychology & psychotherapy, 23*(1), 87-95.

Carney, A. E., & Moeller, M. P. (1998). Treatment efficacy: Hearing loss in children. *Journal of Speech, Language, and Hearing Research, 41*(1), S61-S84.

Carnio, M. (2012). Phonemic awareness in students before and after language workshops. *Jornal da Sociedade Brasileira de Fonoaudiologia, 24*(1).

Carter, L., Golding, M., Dillon, H., & Seymour, J. (2010). The detection of infant cortical auditory evoked potentials (caeps) using statistical and visual detection techniques. *Journal of the American Academy of Audiology, 21*(5), 347-356.

Carvill, S. (2001). Sensory impairments, intellectual disability and psychiatry. *Journal of Intellectual Disability Research, 45*(Pt 6), 467-483.

Chan, S. C., Chan, S. K., Kwok, I. C., & Yu, H. C. (2000). The speech and language rehabilitation program for pediatric cochlear implantees in hong kong. *Advances in oto-rhino-laryngology, 57*, 247-249.

Chang, H.-W., Dillon, H., Carter, L., van Dun, B., & Young, S.-T. (2012). The relationship between cortical auditory evoked potential (caep) detection and estimated audibility in infants with sensorineural hearing loss. *International Journal of Audiology, 51*(9), 663-670. doi:10.3109/14992027.2012.690076

Charlesworth, A., Charlesworth, R., Raban, B., & Rickards, F. (2006). Teaching children with hearing loss in reading recovery. *Literacy Teaching and Learning, 11*(1), 21-50.

Chilvers, A. (2013). *Analyzing the effects of a mathematics problem-solving program, exemplars, on mathematics problem-solving scores with deaf and hard-of-hearing students.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing. (UMI No. 3573444)

Ching, T., & Hill, M. (2005). The parents' evaluation of aural/oral performance of children (peach) rating scale. *2013*(August).

Ching, T., King, A., & Dillon, H. (2013). Evidence-based practice for cochlear implant referrals for infants. Retrieved from http://www.outcomes.nal.gov.au/papers

Ching, T. Y., Dillon, H., Leigh, G., & Cupples, L. (2018). Learning from the longitudinal outcomes of children with hearing impairment (lochi) study: Summary of 5-year findings and implications. *International Journal of Audiology, 57*(sup2), S105-S111.

Ching, T. Y., Dillon, H., Marnane, V., Hou, S., Day, J., Seeto, M., . . . Yeh, A. (2013a). Outcomes of early- and late-identified children at 3 years of age: Findings from a prospective population-based study. *Ear and Hearing, 34*(5), 535-552. doi:10.1097/AUD.0b013e3182857718

Ching, T. Y., & Hill, M. (2007). The parents' evaluation of aural/oral performance of children (peach) scale: Normative data. *Journal of the American Academy of Audiology, 18*(3), 220-235.

Ching, T. Y. C., Day, J., Seeto, M., Dillon, H., Marnane, V., & Street, L. (2013). Predicting 3-year outcomes of early-identified children with hearing impairment. *B-ENT, Suppl 21*, 99-106.

Ching, T. Y. C., Dillon, H., Marnane, V., Hou, S., Day, J., Seeto, M., . . . Yeh, A. (2013b). Outcomes of early- and late-identified children at 3 years of age: Findings from a prospective population-based study. *Ear and Hearing, 34*(5), 535-552. doi:http://dx.doi.org/10.1097/AUD.0b013e3182857718

Choosing a communication approach. (2019). Retrieved from https://www.babyhearing.org/parenting/communication-approach

Ciciriello, E., Bolzonello, P., Marchi, R., Falzone, C., Muzzi, E., & Orzan, E. (2016). Empowering the family during the first months after identification of permanent hearing impairment in children. *Acta Otorhinolaryngologica Italica, 36*(1), 64-70. doi:10.14639/0392-100X-1071

Clark, J. G. (1981). Uses and abuses of hearing loss classification. *ASHA, 23*(7), 493-500.

Clay, M. M. (1979). *The early detection of reading difficulties: A diagnostic survey and reading recovery procedures*. Auckland, New Zealand: Heinemann Publishers.

Clay, M. M. (1993). *An observation survey of early literacy achievement*. Portsmouth: Heinemann.

Clay, M. M. (2001). *Running records: For classroom teachers*. Portsmouth: Heinemann.

Clendon, S., Flynn, M., & Coombes, T. (2003). Facilitating speech and language development in children with cochlear implants using computer technology. *Cochlear Implants International, 4*(3), 119-136.

Cochlear Ltd. (2010). Integrated scales of development

Cochlear Ltd. (n.d.-a). Sound foundation for babies. Retrieved from https://www.cochlear.com/au/home/support/rehabilitation-resources/early-intervention/sound-foundation-for-babies

Cochlear Ltd. (n.d.-b). Sound foundation for toddlers. Retrieved from https://www.cochlear.com/au/home/support/rehabilitation-resources/early-intervention/sound-foundation-for-toddlers

Cole, E. B., & Flexer, C. (2015). *Children with hearing loss: Developing listening and talking, birth to six*: Plural Publishing.

Coryell, H. (2001). *Verbal sequential processing skills and reading ability in deaf individuals using cued speech and signed communication.* (Doctoral Dissertation). Gallaudet University

Couchenour, D., & Chrisman, J. K. (2016). *The sage encyclopedia of contemporary early childhood education*: SAGE Publications.

Crandell, C. C., & Smaldino, J. J. (2000). Classroom acoustics for children with normal hearing and with hearing impairment. *Language, Speech, and Hearing Services in Schools, 31*(4), 362-370.

Crowe, K., Fordham, L., McLeod, S., & Ching, T. Y. C. (2014). 'Part of our world': Influences on caregiver decisions about communication choices for children with hearing loss. *Deafness and Education International, 16*(2), 61-85.

Crowe, K., & McLeod, S. (2014). A systematic review of cross-linguistic and multilingual speech and language outcomes for children with hearing loss. *International Journal of Bilingual Education and Bilingualism, 17*(3), 287-309.

Cunningham, M., Cox, E. O., Practice, C. o., & Medicine, A. (2003). Hearing assessment in infants and children: Recommendations beyond neonatal screening. *Pediatrics, 111*(2), 436-440.

Cupples, L., Ching, T. Y., Button, L., Leigh, G., Marnane, V., Whitfield, J., . . . Martin, L. (2018). Language and speech outcomes of children with hearing loss and additional disabilities: Identifying the variables that influence performance at five years of age. *International Journal of Audiology, 57*(sup2), S93-S104.

Cutler, G. M. B. (2001). *The effectiveness of verbotonal therapy for children with cochlear implants.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing.

Daczewitz, M. (2015). *Delivering the parent-implemented communication strategies (pics) intervention using distance training and coaching with a father and his child who is hard of hearing.* (Doctoral Dissertation, Illinois State University).

Dashash, N. (2004). *A preliminary study of the effects of a mother or care provider training model using play intervention on the language and social development of hearing impaired children in saudi arabia.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing (UMI No. 3162037)

Davidson, M. (2014). Known-groups validity. *Encyclopedia of quality of life and well-being research*, 3481-3482.

Davis, A., Smith, P., Ferguson, M., Stephens, D., & Gianopoulos, I. (2007). Acceptability, benefit and costs of early screening for hearing disability: A study of potential screening tests and models. *Health Technology Assessment Southampton, 11*(42).

Davis, A. C. (1989). The prevalence of hearing impairment and reported hearing disability among adults in great britain. *International journal of epidemiology, 18*(4), 911-917.

Dawson, P., Nott, P., Clark, G. M., & Cowan, R. S. (1998). A modification of play audiometry to assess speech discrimination ability in severe-profoundly deaf 2-to 4-year-old children. *Ear and Hearing, 19*(5), 371-384.

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*(4448), 1174-1176.

Decisions...Decisions. (2015). Retrieved from https://www.aussiedeafkids.org.au/decisions.html

Decker, K., Vallotton, C. D., & Johnson, H. (2012). Parents' communication decision for children with hearing loss: Sources of information and influence. *American Annals of the Deaf, 157*(4), 326-339.

Dickinson, D. K., & Tabors, P. O. (2001). *Beginning literacy with language: Young children learning at home and school*: Paul H Brookes Publishing.

Dillon, H. (2005). So, baby, how does it sound? Cortical assessment of infants with hearing aids. *The Hearing Journal, 58*(10), 10-12.

Dodd, B., Holm, A., Oerlemans, M., & McCormick, M. (1996). Queensland university inventory of literacy. *St. Lucia, OLD: Department of Speech Pathology and Audiology*.

Dodd, J., Saggers, S., & Wildy, H. (2009). Constructing the 'ideal' family for family-centred practice: Challenges for delivery. *Disability & Society, 24*(2), 173-186. doi:10.1080/09687590802652447

Dodd, K. J., Taylor, N. F., & Damiano, D. L. (2002). A systematic review of the effectiveness of strength-training programs for people with cerebral palsy. *Archives of Physical Medicine and Rehabilitation, 83*(8), 1157-1164.

Dornan, D., Hickson, L., Murdoch, B., Houston, T., & Constantinescu, G. (2010). Is auditory-verbal therapy effective for children with hearing loss? *The Volta Review, 110*(3), 361-387. Retrieved from http://simsrad.net.ocs.mq.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=57389365&site=ehost-live

Douglas, M. (2016). Improving spoken language outcomes for children with hearing loss: Data-driven instruction. *Otology & Neurotology, 37*(2), e13. doi:10.1097/MAO.0000000000000902

Dunn, L. M., & Dunn, D. M. (2007). *Peabody picture vocabulary test*. Minneapolis: Pearson Assessments.

Dunst, C. J., & Paget, K. D. (1991). Parent-professional partnerships and family empowerment. In *Collaboration with parents of exceptional children.* (pp. 25-44). Vermont: Clinical Psychology Publishing Co.

Dwyer, C. H., Robb, M. P., O'Beirne, G. A., & Gilbert, H. R. (2009). The influence of speaking rate on nasality in the speech of hearing-impaired individuals. *Journal of Speech, Language, and Hearing Research, 52*(5), 1321-1333. doi:10.1044/1092-4388(2009/08-0035)

Easterbrook, P. J., Gopalan, R., Berlin, J., & Matthews, D. R. (1991). Publication bias in clinical research. *The Lancet, 337*(8746), 867-872.

Easterbrooks, S. R., & Beal-Alvarez, J. S. (2012). States' reading outcomes of students who are d/deaf and hard of hearing. *American Annals of the Deaf, 157*(1), 27-40.

Easterbrooks, S. R., Lederberg, A. R., Miller, E. M., Bergeron, J. P., & Connor, C. M. (2008). Emergent literacy skills during early childhood in children with hearing loss: Strengths and weaknesses. *The Volta Review, 108*(2), 91-114.

Eimas, P. D. (1975). Auditory and phonetic coding of the cues for speech: Discrimination of the [rl] distinction by young infants. *Perception & Psychophysics, 18*(5), 341-347.

Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. (1971). Speech perception in infants. *Science, 171*(3968), 303-306.

Eisenberg, L. S., Kirk, K. I., Martinez, A. S., Ying, E. A., & Miyamoto, R. T. (2004). Communication abilities of children with aided residual hearing: Comparison with cochlear implant users. *Archives of otolaryngology--head & neck surgery, 130*(5), 563.

Elliott, L. L., & Katz, D. R. (1980). *Northwestern university children's perception of speech:(nu-chips)*: Auditec of St. Louis.

Encinas, D., & Plante, E. (2016). Feasibility of a recasting and auditory bombardment treatment with young cochlear implant users. *Language, Speech, and Hearing Services in Schools, 47*(2), 157-170. doi:10.1044/2016_LSHSS-15-0060

Enna, S., & Williams, M. (2009). Defining the role of pharmacology in the emerging world of translational research. In *Advances in pharmacology* (Vol. 57, pp. 1-30): Elsevier.

Enns, C. J., & Herman, R. C. (2011). Adapting the assessing british sign language development: Receptive skills test into american sign language. *Journal of Deaf Studies and Deaf Education, 16*(3), 362-374.

Erber, N. P. (1982). *Auditory training*: Alexander Graham Bell Association for the Deaf.

Ertmer, D. J., Leonard, J. S., & Pachuilo, M. L. (2002). Communication intervention for children with cochlear implants: Two case studies. *Language, Speech & Hearing Services in Schools, 33*(3), 205-217.

Espe-Sherwindt, M. (2008). Family-centred practice: Collaboration, competency and evidence. *Support for learning, 23*(3), 136-143.

Esser-Leyding, B., & Anderson, I. (2012). Ears® (evaluation of auditory responses to speech): An internationally validated assessment tool for children provided with cochlear implants. *Journal for Oto-Rhino-Laryngology, Head and Neck Surgery, 74*(1), 42-51.

Estabrooks, W. (1998). *Cochlear implants for kids*. Washington, DC: Alexander Graham Bell Association for the Deaf, Inc.

Esterhuyse, K. G. F. (1997). Die opstel en standaardisering van lees-en speltoetse vir prim^ereskoolleerlinge.

Evelyn, C. (2000). Year 2000 position statement: Principles and guidelines for early hearing detection and intervention programs. *American Journal of Audiology, 9*(1), 9-29.

Finestack, L. H., & Fey, M. E. (2017). Translational and implementation research in child language disorders. In *Handbook of child language disorders: 2nd edition*: Taylor and Francis.

Fink, N. E., Wang, N.-Y., Visaya, J., Niparko, J. K., Quittner, A., Eisenberg, L. S., & Tobey, E. A. (2007). Childhood development after cochlear implantation (cdaci) study:

Design and baseline characteristics. *Cochlear Implants International, 8*(2), 92-116. doi:10.1002/cii.333

Fitzpatrick, E. M., Crawford, L., Ni, A., & Durieux-Smith, A. (2011). A descriptive analysis of language and speech skills in 4-to 5-yr-old children with hearing loss. *Ear and Hearing, 32*(5), 605-616. doi:10.1097/AUD.0b013e31821348ae

Fitzpatrick, E. M., Hamel, C., Stevens, A., Pratt, M., Moher, D., Doucet, S. P., . . . Na, E. (2015). Sign language and spoken language for children with hearing loss: A systematic review. *Pediatrics*, peds. 2015-1974.

Flesch, R. (1948). A new readability yardstick. *Journal of applied psychology, 32*(3), 221.

Flexer, C. (2004). The impact of classroom acoustics: Listening, learning, and literacy. *Seminars in Hearing, 25*(02), 131-140.

Fortnum, H. M., Davis, A., Summerfield, A. Q., Marshall, D. H., Davis, A. C., Bamford, J. M., . . . Hind, S. (2001). Prevalence of permanent childhood hearing impairment in the united kingdom and implications for universal neonatal hearing screening: Questionnaire based ascertainment studycommentary: Universal newborn hearing screening: Implications for coordinating and developing services for deaf and hearing impaired children. *British Medical Journal, 323*(7312), 536.

Foster, R., Giddan, J. J., & Stark, J. (1973). *Assessment of children's language comprehension*: Consulting Psychologists Press, Incorporated.

Fromkin, V., Rodman, R., & Hyams, N. (2015). *An introduction to language* (Eight edition. ed.). Boston, Massachusetts: Cengage Learning.

Fukushima, K., Kasai, N., Omori, K., Sugaya, A., Fujiyoshi, A., Taguchi, T., . . . Fujino, H. (2012). Assessment package for language development in japanese hearing-impaired children (aladjin) as a test battery for the development of practical communication. *Annals of Otology, Rhinology & Laryngology, 121*(4), 3-15.

Fulcher, A., Purcell, A. A., Baker, E., & Munro, N. (2012a). Listen up: Children with early identified hearing loss achieve age-appropriate speech/language outcomes by 3 years-of-age. *International Journal of Pediatric Otorhinolaryngology, 76*(12), 1785-1794. doi:10.1016/j.ijporl.2012.09.001

Fulcher, A., Purcell, A. A., Baker, E., & Munro, N. (2012b). Listen up: Children with early identified hearing loss achieve age-appropriate speech/language outcomes by 3 years-of-age. *International Journal of Pediatric Otorhinolaryngology, 76*(12), 1785-1794. doi:10.1016/j.ijporl.2012.09.001

Gallaudet Research Institute. (2011). *Regional and national summary report of data from the 2009–10 annual survey of deaf and hard of hearing children and youth*. Retrieved from Washington, DC:

Gardner-Berry, K., Hou, S., & Ching, T. (2017). *Managing infants and children with auditory neuropathy spectrum disorder (ansd)*: Thieme Publishers.

Gardner, M. F. (1985). *Taps: Test of auditory-perceptual skills-upper level: Manual*: Psychological and Educational Publications.

Geers, A., Brenner, C., & Davidson, L. (2003). Factors associated with development of speech perception skills in children implanted by age five. *Ear & Hearing, 24(1)*(Supplement), 24S-35S.

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

Geers, A. E. (2004). Speech, language, and reading skills after early cochlear implantation. *Archives of Otolaryngology—Head & Neck Surgery, 130*(5), 634-638. doi:10.1001/archotol.130.5.634

Geers, A. E., Nicholas, J., Tye-Murray, N., Uchanski, R., Brenner, C., Davidson, L. S., . . . Tobey, E. A. (2000). Effects of communication mode on skills of long-term cochlear implant users. *The Annals of otology, rhinology & laryngology, Supplement. 185*, 89-92.

Geers, A. E., Nicholas, J. G., & Moog, J. S. (2007). Estimating the influence of cochlear implantation on language development in children. *Audiological Medicine, 5*(4), 262-273.

Geers, A. E., & Sedey, A. L. (2011). Language and verbal reasoning skills in adolescents with 10 or more years of cochlear implant experience. *Ear & Hearing, 32(1) Supplement, Long-Term Outcomes of Cochlear Implantation in Early*(Childhood), 39S-48S.

Gillam, R. B., & Pearson, N. A. (2004). *Tnl: Test of narrative language*: Pro-ed.

Gilmore, A., Croft, C., & Reid, N. A. (1981). *Burt word reading test*: New Zealand Council for Educational Research Wellington, New Zealand.

Gluud, L. L. (2006). Bias in clinical intervention research. *American journal of epidemiology, 163*(6), 493-501.

Goldman, R., & Fristoe, M. (2001). *Goldman-fristoe test of articulation*. Shoreview: American Guidance Service.

Golos, D. B., & Moses, A. M. (2011). How teacher mediation during video viewing facilitates literacy behaviors. *Sign Language Studies, 12*(1), 98-118.

Golos, D. B., & Moses, A. M. (2013). Developing preschool deaf children's language and literacy learning from an educational media series. *American Annals of the Deaf, 158*(4), 411.

Goodman, A. (1965). Reference zero levels for pure-tone audiometer. *ASHA, 7*(262), 1.

Govaerts, P. J., De Beukelaer, C., Daemers, K., De Ceulaer, G., Yperman, M., Somers, T., . . . Offeciers, F. E. (2002). Outcome of cochlear implantation at different ages from 0 to 6 years. *Otology & Neurotology, 23*(6), 885-890.

Granda, L. (2014). *Increasing english reading comprehension of a deaf english language learner (ell) youth: A case study.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing. (UMI No. 3623016)

Gravel, J., & O'Gara, J. (2003). Communication options for children withhearing loss. In *Mental Retardation and Developmental Disabilities Research* (Vol. 9, pp. 243-251).

Green, L. W. (2008). Making research relevant: If it is an evidence-based practice, where's the practice-based evidence? *Family practice, 25*(suppl_1), i20-i24.

Grol, R., & Grimshaw, J. (2003). From best evidence to best practice: Effective implementation of change in patients' care. *The Lancet, 362*(9391), 1225-1230.

Grol, R., & Wensing, M. (2004). What drives change? Barriers to and incentives for achieving evidence-based practice. *Medical Journal of Australia, 180*(6 Suppl), S57.

Guiberson, M. (2013). Survey of spanish parents of children who are deaf or hard of hearing: Decision-making factors associated with communication modality and bilingualism. *American Journal of Audiology, 22*(1), 105-119. doi:10.1044/1059-0889(2012/12-0042)

Guralnik, E., & Room, A. (1993). *A screening test for preschool hebrew-speaking children.* Paper presented at the Environmental Education: Teachers College Yearbook—Seminar HaKibbutzim.

Hagan, J. F., Shaw, J. S., & Duncan, P. M. (2007). *Bright futures: Guidelines for health supervision of infants, children, and adolescents*: American Academy of Pediatrics.

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

Hart, B., & Risley, T. R. (2003). The early catastrophe: The 30 million word gap by age 3. *American educator, 27*(1), 4-9.

Hellquist, B. (1995). Lilla fonemtestet malmö: Pedagogisk design.

Herman, R., Ford, K., Thomas, J., Oyebade, N., Bennett, D., & Dodd, B. (2015). Evaluation of core vocabulary therapy for deaf children: Four treatment case studies. *Child Language Teaching and Therapy, 31*(2), 221-235. doi:10.1177/0265659014561875

Higgins, J. P., & Green, S. (2008). *Cochrane handbook for systematic reviews of interventions* (Vol. 5): Wiley Online Library.

Higgins, M., McCleary, E., & Schulte, L. (2000). Use of visual feedback to treat negative intraoral air pressures of preschoolers with cochlear implants. *American Journal of Speech-Language Pathology, 9*(1), 21-35.

Hillenbrand, J. M., Clark, M. J., & Nearey, T. M. (2001). Effects of consonant environment on vowel formant patterns. *The Journal of the Acoustical Society of America, 109*(2), 748-763.

Holmer, E. (2016). *Signs for developing reading: Sign language and reading development in deaf and hard-of-hearing children: Teckenspråk och läsutveckling hos döva och hörselskadade barn*.

Holzinger, D., Fellinger, J., & Beitel, C. (2011). Early onset of family centred intervention predicts language outcomes in children with hearing loss. *International Journal of Pediatric Otorhinolaryngology, 75*(2), 256-260. doi:10.1016/j.ijporl.2010.11.011

Hong, J. (2013). *The effects of a tier 3 pre-kindergarten language intervention on children with hearing loss who communicate orally.* (Doctoral Dissertation, University of Kansas).

Howard, D., Best, W., & Nickels, L. (2015). Optimising the design of intervention studies: Critiques and ways forward. *Aphasiology, 29*(5), 526-562.

Huls, E. (2015). *Effects of a music intervention in children with a hearing impairment: A case study and proposed preliminary study.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing. (UMI No. 3643965)

Incerti, P. V., Ching, T. Y., Hou, S., Van Buynder, P., Flynn, C., & Cowan, R. (2018). Programming characteristics of cochlear implants in children: Effects of aetiology and age at implantation. *International Journal of Audiology, 57*(sup2), S27-S40.

Ingber, S., & Eden, S. (2011). Enhancing sequential time perception and storytelling ability of deaf and hard of hearing children. *American Annals of the Deaf, 156*(4), 391-401.

Invernizzi, M., Sullivan, A., Meier, J., & Swank, L. (2004). Phonological awareness literacy screening for preschool. *Charlottesville, VA: University of Virginia*.

Jackson, R. L. W. (2011). *The montessori method's use of seguin's three-period lesson and its impact on the book choices and word learning of students who are deaf or hard of hearing.* (Doctoral Dissertation, Columbia University).

James, D. M., Wadnerkar-Kamble, M. B., & Lam-Cassettari, C. (2013). Video feedback intervention: A case series in the context of childhood hearing impairment. *International Journal of Language & Communication Disorders, 48*(6), 666-678.

Janssen, M. J., Riksen-Walraven, J. M., & Van Dijk, J. P. M. (2003). Contact: Effects of an intervention program to foster harmonious interactions between deaf-blind children and their educators. *Journal of Visual Impairment & Blindness, 97*(4), 215-229.

Johnson, C., & Von Almen, P. (1997). The functional listening evaluation. *Educational audiology handbook*, 336-339.

Johnson, K. (2011). *Acoustic and auditory phonetics*: John Wiley & Sons.

Joint Committee on Infant Hearing. (2000). Year 2000 position statement: Principles and guidelines for early hearing detection and intervention programs. *American Journal of Audiology, 9*(1), 9-29. doi:10.1044/1059-0889(2000/005)

Joint Committee on Infant Hearing. (2007). Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. *Pediatrics, 120*(4), 898-921.

Joint Committee on Infant Hearing. (2013). Supplement to the jcih 2007 position statement: Principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics, 131*(4), e1324-1349.

Joint Committee on Infant Hearing, Muse, C., Harrison, J., Yoshinaga-Itano, C., Grimes, A., Brookhouser, P. E., . . . Martin, B. (2013). Supplement to the jcih 2007 position statement: Principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics, 131*(4), e1324-1349.

Justice, E., Swanson, L., & Buehler, V. (2008). Use of narrative-based language intervention with children who have cochlear implants. *Topics in Language Disorders, 28*(2), 149-161.

Katz, J., Chasin, M., English, K. M., Hood, L. J., & Tillery, K. L. (1978). *Handbook of clinical audiology* (Vol. 428): Williams & Wilkins Baltimore.

Kaufman, A. S., & Kaufman, N. L. (2013). Kaufman assessment battery for children. *Encyclopedia of Special Education: A Reference for the Education of Children, Adolescents, and Adults with Disabilities and Other Exceptional Individuals*.

Kazdin, A. E. (2011). *Single-case research designs: Methods for clinical and applied settings*: Oxford University Press.

Kennedy, C. R., McCann, D. C., Campbell, M. J., Law, C. M., Mullee, M., Petrou, S., . . . Stevenson, J. (2006). Language ability after early detection of permanent childhood hearing impairment. *New England Journal of Medicine, 354*(20), 2131-2141. doi:10.1056/NEJMoa054915

Kewley-Port, D., Burkle, T. Z., & Lee, J. H. (2007). Contribution of consonant versus vowel information to sentence intelligibility for young normal-hearing and elderly hearing-impaired listeners. *The Journal of the Acoustical Society of America, 122*(4), 2365-2375.

Killion, M. C., & Fikret-Pasa, S. (1993). The 3 types of sensorineural hearing loss: Loudness and intelligibility considerations. *Hearing Journal, 46*, 31-31.

Klieve, S., & Jeanes, R. (2001). Perception of prosodic features by children with cochlear implants: Is it sufficient for understanding meaning differences in language? *Deafness and Education International, 3*(1), 15-37.

Kmet, L. M., Cook, L. S., & Lee, R. C. (2004). Standard quality assessment criteria for evaluating primary research papers from a variety of fields.

Koch-Weser, S., Dejong, W., & Rudd, R. E. (2009). Medical word use in clinical encounters. *Health Expectations, 12*(4), 371-382.

Konishi, H., Kanero, J., Freeman, M. R., Golinkoff, R. M., & Hirsh-Pasek, K. (2014). Six principles of language development: Implications for second language learners. *Developmental neuropsychology, 39*(5), 404-420.

Koren, R., Kofman, O., & Berger, A. (2005). Analysis of word clustering in verbal fluency of school-aged children. *Archives of Clinical Neuropsychology, 20*(8), 1087-1104.

Krishnan, L. A., & Van Hyfte, S. (2016). Management of unilateral hearing loss. *International Journal of Pediatric Otorhinolaryngology, 88*, 63-73. doi:10.1016/j.ijporl.2016.06.048

Krogman, W. M. (1972). *Child growth* (Vol. 519): University of Michigan Press Ann Arbor.

Kronenberger, W., Pisoni, D., Henning, S., Colson, B., & Hazzard, L. (2011). Working memory training for children with cochlear implants: A pilot study. *Journal of Speech, Language, and Hearing Research, 54*(4), 1182-1196.

Kuhl, P. K. (2004). Early language acquisition: Cracking the speech code. *Nature reviews neuroscience, 5*(11), 831.

Kuppler, K., Lewis, M., & Evans, A. K. (2013). A review of unilateral hearing loss and academic performance: Is it time to reassess traditional dogmata? *International Journal of Pediatric Otorhinolaryngology, 77*(5), 617-622. doi:10.1016/j.ijporl.2013.01.014

Ladefoged, P. (1996). *Elements of acoustic phonetics*: University of Chicago Press.

Lam-Cassettari, C., Wadnerkar-Kamble, M. B., & James, D. M. (2015). Enhancing parent-child communication and parental self-esteem with a video-feedback intervention: Outcomes with prelingual deaf and hard-of-hearing children. *Journal of Deaf Studies and Deaf Education, 20*(3), 266-274. doi:10.1093/deafed/env008

Lasky, R. E., Syrdal-Lasky, A., & Klein, R. E. (1975). Vot discrimination by four to six and a half month old infants from spanish environments. *Journal of Experimental Child Psychology, 20*(2), 215-225.

Law, M., Hanna, S., King, G., Hurley, P., King, S., Kertoy, M., & Rosenbaum, P. (2003). Factors affecting family-centred service delivery for children with disabilities. *Child: Care, Health and Development, 29*(5), 357-366.

Lawlor, D. A., & Hopker, S. W. (2001). The effectiveness of exercise as an intervention in the management of depression: Systematic review and meta-regression analysis of randomised controlled trials. *British Medical Journal, 322*(7289), 763.

Lederberg, A. R., Schick, B., & Spencer, P. E. (2013). Language and literacy development of deaf and hard-of-hearing children: Successes and challenges. *Developmental Psychology, 49*(1), 15-30.

Lee, Y., Jeong, S.-W., & Kim, L.-S. (2013). Aac intervention using a voca for deaf children with multiple disabilities who received cochlear implantation. *International Journal of Pediatric Otorhinolaryngology, 77*(12), 2008-2013. doi:10.1016/j.ijporl.2013.09.023

Leigh, J., Dettman, S., Dowell, R., & Briggs, R. (2013). Communication development in children who receive a cochlear implant by 12 months of age. *Otology & Neurotology, 34*(3), 443-450.

Leigh, J., Dettman, S., Dowell, R., & Sarant, J. (2011). Evidence-based approach for making cochlear implant recommendations for infants with residual hearing. *Ear & Hearing (01960202), 32*(3), 313-322. doi:10.1097/AUD.0b013e3182008b1c

Lenihan, S. (2017). *Preparing to teach, committing to learn: An introduction to educating children who are deaf/hard of hearing*: National Center for Hearing Assessment and Management, Utah State University.

Lerner, E. B., Jehle, D. V., Janicke, D. M., & Moscati, R. M. (2000). Medical communication: Do our patients understand? *The American journal of emergency medicine, 18*(7), 764-766.

Levitt, H., Youdelman, K., & Head, J. (1990). *Fundamental speech skills test: Fsst*: Resource Point.

Lew, J., Purcell, A. A., Doble, M., & Lim, L. H. (2014). Hear here: Children with hearing loss learn words by listening. *International Journal of Pediatric Otorhinolaryngology, 78*(10), 1716-1725. doi:10.1016/j.ijporl.2014.07.029

Li, Y., Bain, L., & Steinberg, A. G. (2003). Parental decision making and the choice of communication modality for the child who is deaf. *Archives of Pediatrics & Adolescent Medicine, 157*(2), 162.

Lieu, J. E. C. (2004). Speech-language and educational consequences of unilateral hearing loss in children. *Archives of Otolaryngology–Head & Neck Surgery, 130*(5), 524-530.

Lieu, J. E. C. (2013). Unilateral hearing loss in children: Speech-language and school performance. *B-ENT, Suppl 21*, 107-115.

Lin, H.-C., Yang, C.-C., Chiang, Y.-W., Hung, P.-W., Yang, E. Y., Wang, L., & Lin, G. (2011). Effect of identification and intervention age on language development for mandarin-speaking deaf children with high family involvement. *International Journal of Pediatric Otorhinolaryngology, 75*(3), 409-414. doi:10.1016/j.ijporl.2010.12.017

Lindsay, G., & Dockrell, J. (2000). The behaviour and self-esteem of children with specific speech and language difficulties. *British Journal of Educational Psychology, 70*(4), 583-601.

Ling, D. (1976). *Speech and the hearing-impaired child: Theory and practice*: Alexander Graham Bell Association for the Deaf Washington, DC.

Ling, D. (1989). *Foundations of spoken language for hearing-impaired children*: Alexander Graham Bell Association for the Deaf Washington, DC.

Lo, S., Das, P., & Horton, R. (2017). A good start in life will ensure a sustainable future for all. *The Lancet, 389*(10064), 8-9.

Lonigan, C. J., Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (2007). *Topel: Test of preschool early literacy*: Pro-Ed Austin, TX.

Lowenbraun, S., Appelman, K. I., & Callahan, J. L. (1980). *Teaching the hearing impaired through total communication*: Merrill.

Luckner, J. L. (2006). Evidence-based practices with students who are deaf. *Communication Disorders Quarterly, 28*(1), 49-52.

Luckner, J. L., Sebald, A. M., Cooney, J., Young III, J., & Muir, S. G. (2005). An examination of the evidence-based literacy research in deaf education. *American Annals of the Deaf, 150*(5), 443-456.

Lund, E., & Douglas, W. (2016). Teaching vocabulary to preschool children with hearing loss. *Exceptional Children, 83*(1), 26-41. doi:10.1177/0014402916651848

Lyons, R., & Roulstone, S. (2018). Well-being and resilience in children with speech and language disorders. *Journal of Speech, Language, and Hearing Research, 61*(2), 324-344.

Madell, J. R. (1998). *Behavioral evaluation of hearing in infants and young children*: Thieme New York.

Madell, J. R., & Flexer, C. A. (2008). *Pediatric audiology: Diagnosis, technology, and management*: Thieme.

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The annals of mathematical statistics*, 50-60.

Marcus, G. F., Vijayan, S., Rao, S. B., & Vishton, P. M. (1999). Rule learning by seven-month-old infants. *Science, 283*(5398), 77-80.

Marshall, J., Goldbart, J., Pickstone, C., & Roulstone, S. (2011). Application of systematic reviews in speech-and-language therapy. *International Journal of Language and Communication Disorders, 46*(3), 261-272. doi:10.3109/13682822.2010.497530

Martin, R., Villasenor, M., Dillon, H., Carter, L., & Purdy, S. (2008). Hearlab: Bringing hearing to infants. *Frye Electronics Inc, Tigard, Ore, USA*.

Mashford-Scott, A., Church, A., & Tayler, C. (2012). Seeking children's perspectives on their wellbeing in early childhood settings. *International Journal of Early Childhood, 44*(3), 231-247.

Mason, J. A., & Herrmann, K. R. (1998). Universal infant hearing screening by automated auditory brainstem response measurement. *Pediatrics, 101*(2), 221-228.

Masoomeh, S., Ali Agha, S., Raheb, G., Behrooz Mahmoodi, B., Marziyeh, M., Sepideh, S., . . . Fatemeh, Z. (2012). Treatment efficiency in children with severe to profound hearing impairment: A comparative study of general language stimulation and developmental-descriptive approach based on morphological changes. *Koomesh, 13*(4), 452-459.

Massaro, D. W., & Light, J. (2004). Improving the vocabulary of children with hearing loss. *The Volta Review, 104*(3), 141-174.

Maxwell, M. M. (1990). Simultaneous communication: The state of the art & proposals for change. *Sign Language Studies, 69*(1), 333-390.

McGhee, R., Ehrler, D., & DiSimoni, F. (2007). Token test for children. *Austin, TX: Pro-Ed*.

McLean, J. E., & McLean, L. K. (1999). *How children learn language*: Singular.

Mehl, A. L., & Thomson, V. (1998). Newborn hearing screening: The great omission. *Pediatrics, 101*(1), e4-e4. doi:10.1542/peds.101.1.e4

Mehl, A. L., & Thomson, V. (2002). The colorado newborn hearing screening project, 1992–1999: On the threshold of effective population-based universal newborn hearing screening. *Pediatrics, 109*(1), e7. doi:10.1542/peds.109.1.e7

Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29*(2), 143-178.

Mehta, K., Watkin, P., Baldwin, M., Marriage, J., Mahon, M., & Vickers, D. (2017). Role of cortical auditory evoked potentials in reducing the age at hearing aid fitting in children with hearing loss identified by newborn hearing screening. *Trends in hearing, 21*, 2331216517744094.

Meinzen-Derr, J., Wiley, S., Creighton, J., & Choo, D. (2007). Auditory skills checklist: Clinical tool for monitoring functional auditory skill development in young children with cochlear implants. *Annals of Otology, Rhinology & Laryngology, 116*(11), 812-818.

Merton, R. K. (1993). *On the shoulders of giants: The post-italianate edition*: University of Chicago Press.

Methley, A. M., Campbell, S., Chew-Graham, C., McNally, R., & Cheraghi-Sohi, S. (2014). Pico, picos and spider: A comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *BMC health services research, 14*(1), 579.

Mich, O., Pianta, E., & Mana, N. (2013). Interactive stories and exercises with dynamic feedback for improving reading comprehension skills in deaf children. *Computers & Education, 65*(0), 34-44. doi:10.1016/j.compedu.2013.01.016

Miller, E. M., Lederberg, A. R., & Easterbrooks, S. R. (2013). Phonological awareness: Explicit instruction for young deaf and hard-of-hearing children. *Journal of Deaf Studies and Deaf Education, 18*(2), 206-227. doi:10.1093/deafed/ens067

Miller, J., & Chapman, R. (1985). Systematic analysis of language transcripts. *Madison, WI: Language Analysis Laboratory*.

Miller, L., Gillam, R. B., & Peña, E. (2001). Dynamic assessment and intervention: Improving children's narrative abilities.

Miller, L. E., Perkins, K. A., Dai, Y. G., & Fein, D. A. (2017). Comparison of parent report and direct assessment of child skills in toddlers. *Research in Autism Spectrum Disorders, 41*, 57-65.

Miller, P. (2009). Learning with a missing sense: What can we learn from the interaction of a deaf child with a turtle? *American Annals of the Deaf, 154*(1), 71-82.

Miyamoto, R. T., Kirk, K. I., Robbins, A. M., Todd, S., & Riley, A. (1996). Speech perception and speech production skills of children with multichannel cochlear implants. *Acta oto-laryngologica, 116*(2), 240-243.

Moeller, M. P. (2000). Early intervention and language development in children who are deaf and hard of hearing. *Pediatrics, 106*(3), U83-U91.

Moeller, M. P., Carr, G., Seaver, L., Stredler-Brown, A., & Holzinger, D. (2013). Best practices in family-centered early intervention for children who are deaf or hard of hearing: An international consensus statement. *Journal of Deaf Studies & Deaf Education, 18*(4), 429-445.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The prisma statement. *Annals of internal medicine, 151*(4), 264-269.

Mohr, P. E., Feldman, J. J., Dunbar, J. L., McConkey-Robbins, A., Niparko, J. K., Rittenhouse, R. K., & Skinner, M. W. (2000). The societal costs of severe to profound hearing loss in the united states. *Int J Technol Assess Health Care, 16*(4), 1120-1135.

Montgomery, J. (2013). *A case study of the "preventing academic failure" orton-gillingham approach with five students who are deaf or hard of hearing: Using the mediating tool of cued speech.* (Doctoral Dissertation, Columbia University).

Moog, J., Biedenstein, J., & Davidson, L. (1995). Speech perception instructional curriculum and evaluation. *St. Louis, MO: Central Institute for the Deaf*.

Moog, J. S., Popelka, G. R., Geers, A. E., & Russo, M. H. (1990). *Early speech perception test for profoundly hearing-impaired children*: Central Institute for the Deaf.

Moon, C., Cooper, R. P., & Fifer, W. P. (1993). Two-day-olds prefer their native language. *Infant Behavior and Development, 16*(4), 495-500.

Moore, T. (2008). *Early childhood intervention: Core knowledge and skills*: Citeseer.

Morin, A. (2019). Developmental milestons from birth to age 1. Retrieved from https://www.understood.org/en/learning-attention-issues/signs-symptoms/developmental-milestones/developmental-milestones-from-birth-to-age-1

Morton, C. C., & Nance, W. E. (2006). Newborn hearing screening — a silent revolution. *New England Journal of Medicine, 354*(20), 2151-2164. doi:doi:10.1056/NEJMra050700

Mueller, V. (2008). *The effects of a fluent signing narrator in the iowa e-book on deaf children's acquisition of vocabulary, book related concepts, and enhancement of parent-child lap -reading interactions.* (Doctoral Dissertation, The University of Iowa).

Nakajima, R., Horai, T., Sugita, T., Tatsumi, H., & Hamanaka, T. (1997). Syntactic and communication abilities of aphasics as assessed by cadl, sta and cadl family questionnaire. *The Japan Journal of Logopedics and Phoniatrics, 38*(2), 161-168.

Nakeva von Mentzer, C., Lyxell, B., Sahlén, B., Wass, M., Lindgren, M., Ors, M., . . . Uhlén, I. (2013). Computer-assisted training of phoneme–grapheme correspondence for children who are deaf and hard of hearing: Effects on phonological processing skills. *International Journal of Pediatric Otorhinolaryngology, 77*(12), 2049-2057. doi:10.1016/j.ijporl.2013.10.007

National Acoustics Laboratory. (2016). Client oriented scale of improvement - child version. Retrieved from https://www.nal.gov.au/wp-content/uploads/sites/2/2016/11/COSI-C-Questionnaire.pdf

National Heart Lung and Blood Institute and Research Triangle Institute International. (2018). Nih study quality assessment tools. Retrieved from https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

Neilson, R., & Konza, D. (2013). *Sutherland phonological awareness test-revised*: Kanopy.

Niparko, J. K., Tobey, E. A., Thal, D. J., Eisenberg, L. S., Wang, N.-Y., Quittner, A. L., . . . Team, C. I. (2010). Spoken language development in children following cochlear implantation. *The Journal of the American Medical Association, 303*(15), 1498-1506.

Niskar, A. S., Kieszak, S. M., Holmes, A., Esteban, E., Rubin, C., & Brody, D. J. (1998). Prevalence of hearing loss among children 6 to 19 years of age: The third national health and nutrition examination survey. *The Journal of the American Medical Association, 279*(14), 1071-1075.

Nock, M. K., Michel, B. D., & Photos, V. (2007). *Single-case research designs* (2008 ed.): Sage.

North, B. (1995). The development of a common framework scale of descriptors of language proficiency based on a theory of measurement. *System, 23*(4), 445-465.

Northern, J. L., & Downs, M. P. (2014). Hearing in children (6th ed.). *702*.

Nott, P., Cowan, R., Brown, P. M., & Wigglesworth, G. (2009a). Early language development in children with profound hearing loss fitted with a device at a young age: Part i--the time period taken to acquire first words and first word combinations. *Ear and Hearing, 30*(5), 526-540.

Nott, P., Cowan, R., Brown, P. M., & Wigglesworth, G. (2009b). Early language development in children with profound hearing loss fitted with a device at a young age: Part ii--content of the first lexicon. *Ear and Hearing, 30*(5), 541-551. doi:10.1097/AUD.0b013e3181aa00ea

O'Connor, S., & Pettigrew, C. M. (2009). The barriers perceived to prevent the successful implementation of evidence-based practice by speech and language therapists. *International Journal of Language & Communication Disorders, 44*(6), 1018-1035.

O'Grady, W. (2005). *How children learn language*: Cambridge University Press.

Oster, A.-M. (2006). *Computer -based speech therapy using visual feedback with focus on children with profound hearing impairments.* (Doctoral Dissertation, KTH School of Computer Science and Communication).

Oyler, R., & McKay, S. (2008). Unilateral hearing loss in children: Challenges and opportunities. *ASHA Leader, 13*(1), 12-15.

Paatsch, L. (1997). *The effectiveness of the auditory skills program in developing auditory skills in severe to profoundly hearing impaired children.* (Masters Thesis, The University of Melbourne).

Paatsch, L., Blamey, P., & Sarant, J. (2001). Effects of articulation training on the production of trained and untrained phonemes in conversations and formal tests. *Journal of Deaf Studies and Deaf Education, 6*(1), 32-42.

Paatsch, L., Blamey, P. J., Sarant, J. Z., & Bow, C. P. (2006). The effects of speech production and vocabulary training on different components of spoken language performance. *Journal of Deaf Studies and Deaf Education, 11*(1), 39-55.

Paatsch, L., Blamey, P. J., Sarant, J. Z., Martin, L. F. A., & Bow, C. P. (2004). Separating contributions of hearing, lexical knowledge, and speech production to speech-perception scores in children with hearing impairments. *Journal of Speech, Language, and Hearing Research, 47*(4), 738-750.

Pakulski, L. A., & Kaderavek, J. N. (2001). Narrative production by children who are deaf or hard of hearing: The effect of role-play. *The Volta Review, 103*(3).

Pakulski, L. A., & Kaderavek, J. N. (2012). Reading intervention to improve narrative production, narrative comprehension, and motivation and interest of children with hearing loss. *The Volta Review, 112*(2), 87-112.

Palmer, C. V., & Mormer, E. (1999). Goals and expectations of the hearing aid fitting. *Trends in Amplification, 4*(2), 61-71.

Pantelemidou, V., Herman, R., & Thomas, J. (2003). Efficacy of speech intervention using electropalatography with a cochlear implant user. *Clinical Linguistics & Phonetics, 17*(4-5), 383-392.

Pappas, N. W., & McLeod, S. (2008). *Working with families in speech-language pathology*: Plural Publishing.

Parsons, L., Cordier, R., Munro, N., Joosten, A., & Speyer, R. (2017). A systematic review of pragmatic language interventions for children with autism spectrum disorder. *PloS one, 12*(4), e0172242.

Pataki, K. W., Metz, A. E., & Pakulski, L. (2014). The effect of thematically related play on engagement in storybook reading in children with hearing loss. *Journal of Early Childhood Literacy, 14*(2), 240-264.

Paul, R. (2007). *Language disorders from infancy through adolescence: Assessment & intervention*: Elsevier Health Sciences.

Percy-Smith, L., Busch, G., Sandahl, M., Nissen, L., Josvassen, J. L., Lange, T., . . . Cayé-Thomasen, P. (2013). Language understanding and vocabulary of early cochlear implanted children. *International Journal of Pediatric Otorhinolaryngology, 77*(2), 184-188. doi:10.1016/j.ijporl.2012.10.014

Pilnick, A., & James, D. (2013). "I'm thrilled that you see that": Guiding parents to see success in interactions with children with deafness and autistic spectrum disorder. *Social Science & Medicine, 99*, 89-101.

Pinker, S. (1999). Out of the minds of babes. *Science, 283*(5398), 40-41.

Pinker, S. (2003). *The language instinct: How the mind creates language*: Penguin UK.

Poobrasert, O. (2008). *An evaluation of life: Bone numbing! — a multimedia support system for students with deafness.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing.

Purdy, S. C., Farrington, D. R., Moran, C. A., Chard, L. L., & Hodgson, S.-A. (2002). A parental questionnaire to evaluate children's auditory behavior in everyday life (abel). *American Journal of Audiology*.

Rance, G. (2005). Auditory neuropathy/dys-synchrony and its perceptual consequences. *Trends in Amplification, 9*(1), 1-43.

Raven, J. (1990). Court, jh, & raven, j.(1990). Coloured progressive matrices. *Manual for Raven's Progressive Matrices and Vocabulary Scales*.

Reynolds, C. R., Livingston, R. B., Willson, V. L., & Willson, V. (2010). *Measurement and assessment in education*: Pearson Education International Upper Saddle River.

Rhoades, E. A. (2011). Auditory development scale 0-6 years. Retrieved from https://www.researchgate.net/profile/Ellen_Rhoades/publication/315493731_Auditory_Developmental_Scale_0-6_years_English/data/58d27dbb92851cf4f8f5e750/WEBSITE-Auditory-Dvlpmtal-Scale.doc

Rivera-Gaxiola, M., Silva-Pereyra, J., & Kuhl, P. K. (2005). Brain potentials to native and non-native speech contrasts in 7-and 11-month-old american infants. *Developmental Science, 8*(2), 162-172.

Robbins, A. M. (2003). Communication intervention for infants and toddlers with cochlear implants. *Topics in Language Disorders, 23*(1), 16-33.

Robbins, A. M., & Estabrooks, W. (1998). Meaningful auditory integration scale (mais). *Cochlear implants for kids*, 373-378.

Robertson, C., & Salter, W. (1997). *The phonological awareness test*: LinguiSystems, Incorporated.

Roeser, R. J., Valente, M., & Hosford-Dunn, H. (2000). *Audiology: Diagnosis* (Vol. 5): Thieme New York.

Romanik, S. (1993). Auditory skills program.

Rosenberg, M. (2015). *Society and the adolescent self-image*: Princeton university press.

Rosenthal, R., & Rosnow, R. L. (1991). Essentials of behavioral research: Methods and data analysis. *Boston, MA*.

Rossetti, L. M. (2006). *The rossetti infant-toddler language scale*: LinguiSystems East Moline, IL.

Roulstone, S., Law, J., Rush, R., Clegg, J., & Peters, T. (2011). Investigating the role of language in children's early educational outcomes.

Sacks, C., Shay, S., Repplinger, L., Leffel, K., Sapolich, S., Suskind, E., . . . Suskind, D. (2014). Pilot testing of a parent-directed intervention (project aspire) for underserved children who are deaf or hard of hearing. *Child Language Teaching and Therapy, 30*(1), 91-102.

Satake, T., Higachie, H., & Chinen, H. (1996). Manual for test of query-answering relationship. *Tokyo, Japan: Escor Co*.

Schafer, E. C. (2010). Speech perception in noise measures for children: A critical review and case studies.

Schirmer, B. R., Schaffer, L., Therrien, W. J., & Schirmer, T. N. (2012). Reread-adapt and answer-comprehend intervention with deaf and hard of hearing readers: Effect on fluency and reading achievement. *American Annals of the Deaf, 156*(5), 469-475.

Schneider, H., Ryan, M., & Mahone, E. M. (2020). Parent versus teacher ratings on the brief-preschool version in children with and without adhd. *Child Neuropsychology, 26*(1), 113-128. doi:10.1080/09297049.2019.1617262

Schopmeyer, B., Mellon, N., Dobaj, H., Grant, G., & Niparko, J. (2000). Use of fast forward to enhance language development in children with cochlear implants. *Annals of Otology, Rhinology & Laryngology, 109*(12), 95-98.

Schuele, C. M. (2004). The impact of developmental speech and language impairments on the acquisition of literacy skills. *Mental Retardation and Developmental Disabilities Research Reviews, 10*(3), 176-183.

Scollie, S. D., Ching, T. Y., Seewald, R. C., Dillon, H., Britton, L., Steinberg, J., & King, K. (2010). Children's speech perception and loudness ratings when fitted with hearing aids using the dsl v. 4.1 and the nal-nl1 prescriptions. *International Journal of Audiology, 49*(sup1), S26-s34.

Seely, E. W., & Grinspoon, S. (2009). Patient-oriented research: Clinical pathophysiology and clinical therapeutics. In *Clinical and translational science* (pp. 3-12): Elsevier.

Semel, E. M., Wiig, E. H., & Secord, W. (1995). *Celf 3: Clinical evaluation of language fundamentals*: Psychological Corporation, Harcourt Brace.

Semel, E. M., Wiig, E. H., & Secord, W. (2004). *Celf 4: Clinical evaluation of language fundamentals 4* Pearson, PsyhCorp.

Serry, T., Blamey, P., Spain, P., & James, C. (1997). Casala: Computer aided speech and language analysis. *Australian Communication Quarterly*, 27-28.

Shapiro, W. H., & Bradham, T. S. (2012). Cochlear implant programming. *Otolaryngologic Clinics of North America, 45*(1), 111-127. doi:10.1016/j.otc.2011.08.020

Shargorodsky, J., Curhan, S. G., Curhan, G. C., & Eavey, R. (2010). Change in prevalence of hearing loss in us adolescents. *The Journal of the American Medical Association, 304*(7), 772-778.

Sharma, A., Dorman, M. F., & Kral, A. (2005). The influence of a sensitive period on central auditory development in children with unilateral and bilateral cochlear implants. *Hearing Research, 203*(1–2), 134-143. doi:10.1016/j.heares.2004.12.010

Sharma, A., Gilley, P. M., Martin, K., Roland, P., Bauer, P., & Dorman, M. (2007). Simultaneous versus sequential bilateral implantation in young children: Effects on central auditory system development and plasticity. *Audiological Medicine, 5*(4), 218-223.

Silvestre, N., & Valero, J. (2005). Oral language acquisition by deaf pupils in primary education: Impact of musical education. *European Journal of Special Needs Education, 20*(2), 195-213.

Simser, J. (2011). Auditory verbal techniques and hierachies. Retrieved from http://auditory-verbalcommunicationcenter.blogspot.com/2011/06/auditory-verbal-techniques-and.html

Simser, J. I. (1993). Auditory-verbal intervention: Infants and toddlers. *The Volta Review*.

Sininger, Y. S., Grimes, A., & Christensen, E. (2010). Auditory development in early amplified children: Factors influencing auditory-based communication outcomes in children with hearing loss. *Ear and Hearing, 31*(2), 166-185. doi:10.1097/AUD.0b013e3181c8e7b6

Sininger, Y. S., Martinez, A., Eisenberg, L., Christensen, E., Grimes, A., & Hu, J. (2009). Newborn hearing screening speeds diagnosis and access to intervention by 20-25 months. *Journal of the American Academy of Audiology, 20*(1), 49-57.

Smith, A., & Davis, A. (2018). Disambiguating the use of common terms across related medical fields: The problem of intervention. *Lexicography*, 1-18.

Smith, A., & Wang, Y. (2010). The impact of visual phonics on the phonological awareness and speech production of a student who is deaf: A case study. *American Annals of the Deaf, 155*(2), 124-130.

Smith, R. J., Bale Jr, J. F., & White, K. R. (2005). Sensorineural hearing loss in children. *The Lancet, 365*(9462), 879-890.

Smith, Z. (1999). *A study of four african-american families reading to their young deaf children.* (Doctoral Dissertation). Available from Proquest Dissertations Publishing. (UMI No. 993781)

Smoski, W., Brunt, M. A., & Tannahill, J. C. (1998). Children’s auditory performance scale (chaps). *Tampa, FL: Educational Audiology Association*.

Soukup, M. (2005). *Incorporating a multi-sensory, see /cover /write /compare intervention procedure to improve the spelling performance of students who are deaf and exhibit characteristics consistent with learning disabilities.* (Doctoral Dissertation). Available from ProQuest Dissertations Publishing. (UMI No. 3188190)

Sparrow, S. S., Balla, D. A., Cicchetti, D. V., Harrison, P. L., & Doll, E. A. (1984). Vineland adaptive behavior scales.

Spoth, R. L., Kavanagh, K. A., & Dishion, T. J. (2002). Family-centered preventive intervention science: Toward benefits to larger populations of children, youth, and families. *Prevention Science, 3*(3), 145-152.

Starr, A., McPherson, D., Patterson, J., Don, M., Luxford, W., Shannon, R., . . . Waring, M. (1991). Absence of both auditory evoked potentials and auditory percepts dependent on timing cues. *Brain, 114*(3), 1157-1180.

Starr, A., Picton, T. W., Sininger, Y., Hood, L. J., & Berlin, C. I. (1996). Auditory neuropathy. *Brain, 119*(3), 741-753.

Stevens, G., Flaxman, S., Brunskill, E., Mascarenhas, M., Mathers, C. D., & Finucane, M. (2011). Global and regional hearing impairment prevalence: An analysis of 42 studies in 29 countries. *The European Journal of Public Health, 23*(1), 146-152.

Stierman, L. (1994). *Birth defects in california: 1983-1990*: California Birth Defects Monitoring Program.

Stredler-Brown, A., & Johnson, D. (2001). Functional auditory performance indicators: An integrated approach to auditory development. *Denver, CO: Colorado Department of Education*.

Strong, C. J., Mayer, M., & Mayer, M. (1998). *The strong narrative assessment procedure (snap)*: Thinking Publications.

Stubbs, M. (2001). *Words and phrases: Corpus studies of lexical semantics*: Blackwell Publishers Oxford.

Sugaya, A., Fukushima, K., Kasai, N., Ojima, T., Takahashi, G., Nakagawa, T., . . . Nishizaki, K. (2014). Effectiveness of domain-based intervention for language development in japanese hearing-impaired children: A multicenter study. *The Annals of otology, rhinology, and laryngology, 123*(7), 500.

Sung, N. S., Crowley Jr, W. F., Genel, M., Salber, P., Sandy, L., Sherwood, L. M., . . . Getz, K. (2003). Central challenges facing the national clinical research enterprise. *The Journal of the American Medical Association, 289*(10), 1278-1287.

Svirsky, M., Chute, P., Green, J., Bollard, P., & Miyamoto, R. (2002). Language development in children who are prelingually deaf who have used the speak or cis stimulation strategies since initial stimulation. *The Volta Review, 102*(4), 199-213.

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

Syrnyk, C., & Meints, K. (2017). Bye-bye mummy–word comprehension in 9-month-old infants. *British Journal of Developmental Psychology, 35*(2), 202-217.

Tait, M., & Lutman, M. (1997). The predictive value of measures of preverbal communicative behaviors in young deaf children with cochlear implants. *Ear and Hearing, 18*(6), 472-478.

Tajalli, P., & Satari, S. (2013). Effectiveness of metacognitive strategies on reading skills of students with hearing disorders. *Procedia - Social and Behavioral Sciences, 84*(0), 139-143. doi:10.1016/j.sbspro.2013.06.524

Tate, R., Perdices, M., McDonald, S., Togher, L., Moseley, A., Winders, K., . . . Smith, K. (2004). Development of a database of rehabilitation therapies for the psychological consequences of acquired brain impairment. *Neuropsychological Rehabilitation, 14*(5), 517-534.

Terrelonge, D. N., & Fugard, A. J. (2017). Associations between family and clinician ratings of child mental health: A study of uk camhs assessments and outcomes. *Clinical Child Psychology and Psychiatry, 22*(4), 664-674. doi:10.1177/1359104517713240

Tomasello, N. M., Manning, A. R., & Dulmus, C. N. (2010). Family-centered early intervention for infants and toddlers with disabilities. *Journal of Family Social Work, 13*(2), 163-172.

Tomblin, J. B., Barker, B. A., Spencer, L. J., Zhang, X., & Gantz, B. J. (2005). The effect of age at cochlear implant initial stimulation on expressive language growth in infants and toddlers. *Journal of Speech, Language, and Hearing Research, 48*(4), 853-867. doi:10.1044/1092-4388(2005/059)

Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. *Ear and Hearing, 36 Suppl 1*(0 1), 76S-91S. doi:10.1097/AUD.0000000000000219

Tomblin, J. B., Oleson, J. J., Ambrose, S. E., Walker, E., & Moeller, M. P. (2014). The influence of hearing aids on the speech and language development of children with hearing loss. *The Journal of the American Medical Association Otolaryngology - Head and Neck Surgery, 140*(5), 403-409. doi:10.1001/jamaoto.2014.267

Torppa, R., & Huotilainen, M. (2010). The meaning of music in the rehabilitation of children with hearing impairment. *Puhe ja Kieli/Tal och Sprak, 30*(3), 137-155.

Tsafnat, G., Glasziou, P., Choong, M. K., Dunn, A., Galgani, F., & Coiera, E. (2014). Systematic review automation technologies. *Systematic reviews, 3*(1), 74.

Tsiakpini, L., Weichbold, V., Kuehn-Inacker, H., Coninx, F., D'haese, P., & Almadin, S. (2004). Littlears auditory questionnaire. *Innsbruck, Austria: MED-EL*.

Tuohy, J., Brown, J., & Mercer-Moseley, C. (2005). St. Gabriel' s curriculum for the development of audition, language, speech, cognition, early communication, social interaction, fine motor skills, gross motor skills: A guide for professionals working with children who are hearing-impaired (birth to six years).

Turnbull, H. R., Huerta, N., Stowe, M., Weldon, L., & Schrandt, S. (2009). *The individuals with disabilities education act as amended in 2004*: Pearson Boston, MA.

Ueno, K., Nagoshi, S., & Konuki, S. (2008). Picture vocabulary test–revised. *Hiroshima, Japan: Saccess/Bell Co Ltd*.

Uno, A., Shinya, N., Haruhara, N., & Kaneko, M. (2005). Raven's coloured progressive matrices in japanese children. *The Japan Journal of Logopedics and Phoniatrics, 46*(3), 185-189.

Using sign language and voice for total communication. (2018). Retrieved from https://www.verywellhealth.com/using-sign-language-and-voice-for-total-communication-1046220

Van Dun, B. (2017). Hearlab® technical paper.

van Staden, A. (2013). An evaluation of an intervention using sign language and multi-sensory coding to support word learning and reading comprehension of deaf signing children. *Child Language Teaching and Therapy, 29*(3), 305-318.

Vandali, A. E., & van Hoesel, R. J. (2011). Development of a temporal fundamental frequency coding strategy for cochlear implants. *The Journal of the Acoustical Society of America, 129*(6), 4023-4036.

Vardi, I. (1991). Phonological profile for the hearing impaired: Manual.

Vohr, B. R., Oh, W., Stewart, E. J., Bentkover, J. D., Gabbard, S., Lemons, J., . . . Pye, R. (2001). Comparison of costs and referral rates of 3 universal newborn hearing screening protocols. *The Journal of Pediatrics, 139*(2), 238-244.

Walker, B. (2009). Auditory learning guide. *Chapel Hill, NC: First Years*.

Walker, E., Holte, L., McCreery, R. W., Spratford, M., Page, T., & Moeller, M. P. (2015). The influence of hearing aid use on outcomes of children with mild hearing loss. *Journal of Speech, Language, and Hearing Research, 58*(5), 1611-1625. doi:10.1044/2015_JSLHR-H-15-0043

Wang, Y., Spychala, H., Harris, R. S., & Oetting, T. L. (2013). The effectiveness of a phonics-based early intervention for deaf and hard of hearing preschool children and its possible impact on reading skills in elementary school: A case study. *American Annals of the Deaf, 158*(2), 107-120.

Wass, M., Ibertsson, T., Lyxell, B., Sahlen, B., Hällgren, M., Larsby, B., & Maki-Torkko, E. (2008). Cognitive and linguistic skills in swedish children with cochlear implants–measures of accuracy and latency as indicators of development. *Scandinavian Journal of Psychology, 49*(6), 559-576.

Watson, L. M., Archbold, S. M., & Nikolopoulos, T. P. (2006). Children's communication mode five years after cochlear implantation: Changes over time according to age at implant. *Cochlear Implants International, 7*(2), 77-91. doi:10.1002/cii.301

Webb, M.-Y. L., Schwanenflugel, P. J., & Kim, S.-H. (2004). A construct validation study of phonological awareness for children entering prekindergarten. *Journal of Psychoeducational Assessment, 22*(4), 304-319.

Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science, 24*(11), 2143-2152.

Wendel, E., Cawthon, S. W., Ge, J. J., & Beretvas, S. N. (2015). Alignment of single-case design (scd) research with individuals who are deaf or hard of hearing with the what works clearinghouse standards for scd research. *Journal of Deaf Studies and Deaf Education, 20*(2), 103-114.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*(1), 49-63.

Werker, J. F., & Tees, R. C. (2005). Speech perception as a window for understanding plasticity and commitment in language systems of the brain. *Developmental Psychobiology: The Journal of the International Society for Developmental Psychobiology, 46*(3), 233-251.

Wheeler, A., Archbold, S. M., Hardie, T., & Watson, L. M. (2009). Children with cochlear implants: The communication journey. *Cochlear Implants International, 10*(1), 41-62. doi:10.1002/cii.370

White, K. R. (2014). The evolution of ehdi: From concept to standard of care. *A Resource Guide for Early Hearing Detection and Intervention. National Center for Hearing Assessment and Management*.

White, K. R., Forsman, I., Eichwald, J., & Munoz, K. (2010). The evolution of early hearing detection and intervention programs in the united states. *Seminars in Perinatology, 34*(2), 170-179. doi:10.1053/j.semperi.2009.12.009

Wiig, E. H., Secord, W., & Semel, E. M. (2004). *Celf preschool 2: Clinical evaluation of language fundamentals preschool*: Pearson/PsychCorp.

Wilkes, E. M. (2001). *Cottage acquisition scales for listening, language & speech: User's manual*: Sunshine Cottage School for Deaf Children.

Williams, C. N. (2004). Cow—designed with children in mind. *The Hearing Journal, 57*(3), 68.

Wilson, B. S., & Dorman, M. F. (2008). Cochlear implants: Current designs and future possibilities. *Journal of Rehabilitation Research and Development, 45*(5), 695-730.

Wilson, J. M. G., Jungner, G., & Organization, W. H. (1968). Principles and practice of screening for disease.

Wong, C. L., Ching, T. Y., Leigh, G., Cupples, L., Button, L., Marnane, V., . . . Martin, L. (2018). Psychosocial development of 5-year-old children with hearing loss: Risks and protective factors. *International Journal of Audiology, 57*(sup2), S81-S92.

Woodcock, R. W., McGrew, K. S., Mather, N., & Schrank, F. (2001). Woodcock-johnson r iii nu tests of achievement. *Itasca, IL: Riverside*.

World Health Organization. (2001). *Icf : International classification of functioning, disability and health*. Geneva: World Health Organization.

World Health Organization. (2006). Child growth standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development.

World Health Organization. (2017). *Global costs of unaddressed hearing loss and cost-effectiveness of interventions: A who report, 2017*: World Health Organization.

World Health Organization. (2019). Hearing loss and deafness. Retrieved from https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss

Yamada, A., Suzuki, M., Kato, M., Suzuki, M., Tanaka, S., Shindo, T., . . . Furukawa, T. A. (2007). Emotional distress and its correlates among parents of children with pervasive developmental disorders. *Psychiatry and clinical neurosciences, 61*(6), 651-657.

Yorkston, K. M., Hakel, M., Beukelman, D. R., & Fager, S. (2007). Evidence for effectiveness of treatment of loudness, rate, or prosody in dysarthria: A systematic review. *Journal of Medical Speech-Language Pathology, 15*(2), xi-xi.

Yoshinaga-Itano, C. (2003a). Early intervention after universal neonatal hearing screening: Impact on outcomes. *Mental Retardation and Developmental Disabilities Research Reviews, 9*(4), 252-266.

Yoshinaga-Itano, C. (2003b). From screening to early identification and intervention: Discovering predictors to successful outcomes for children with significant hearing loss. *Journal of Deaf Studies and Deaf Education, 8*(1), 11-30.

Yoshinaga-Itano, C. (2004). Levels of evidence: Universal newborn hearing screening (unhs) and early hearing detection and intervention systems (ehdi). *Journal of Communication Disorders, 37*(5), 451-465.

Yoshinaga-Itano, C., Coulter, D., & Thomson, V. (2000). The colorado newborn hearing screening project: Effects on speech and language development for children with hearing loss. *Journal of Perinatology, 20*(8 part 2), S132-137.

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

Yoshinaga-Itano, C., Sedey, A. L., Wiggin, M., & Chung, W. (2017). Early hearing detection and vocabulary of children with hearing loss. *Pediatrics, 140*(2). doi:10.1542/peds.2016-2964

Zimmerman-Phillips, S., Osberger, M., & Robbins, A. (1997). Infant-toddler: Meaningful auditory integration scale (it-mais). In. California: Advanced Bionics Corporation.

Zimmerman-Phillips, S., Osberger, M., & Robbins, A. (2001). Infant-toddler meaningful auditory integration scale. In. California: Advanced Bionics Corporation.

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2002). Preschool language scale. In. San Antonio: The Psychological Corporation.

Appendix A: Ethics approval letter

Office of the Deputy Vice-Chancellor
(Research)

Research Office
Research Hub, Building C5C East
Macquarie University
NSW 2109 Australia
T: +61 (2) 9850 4459
http://www.research.mq.edu.au/
ABN 90 952 801 237

MACQUARIE University
SYDNEY·AUSTRALIA

3 November 2016

Dear Dr Harrison

Reference No: 5201600650

Title: *The validity of the Functional Listening Index – Pediatric (FLI-P) for children with hearing impairment*

Thank you for submitting the above application for ethical and scientific review. Your application was considered by the Macquarie University Human Research Ethics Committee (HREC (Medical Sciences)).

I am pleased to advise that ethical and scientific approval has been granted for this project to be conducted at:

- Macquarie University

This research meets the requirements set out in the *National Statement on Ethical Conduct in Human Research* (2007 – Updated May 2015) (the *National Statement*).

Standard Conditions of Approval:

1. Continuing compliance with the requirements of the *National Statement,* which is available at the following website:

http://www.nhmrc.gov.au/book/national-statement-ethical-conduct-human-research

2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol.

3. All adverse events, including events which might affect the continued ethical and scientific acceptability of the project, must be reported to the HREC within 72 hours.

4. Proposed changes to the protocol and associated documents must be submitted to the Committee for approval before implementation.

It is the responsibility of the Chief investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Ethics Secretariat on 9850 4194 or by email ethics.secretariat@mq.edu.au

The HREC (Medical Sciences) Terms of Reference and Standard Operating Procedures are available from the Research Office website at:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics

The HREC (Medical Sciences) wishes you every success in your research.

Yours sincerely

Professor Tony Eyers
Chair, Macquarie University Human Research Ethics Committee (Medical Sciences)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.

Details of this approval are as follows:

Approval Date: 27 October 2016

The following documentation has been reviewed and approved by the HREC (Medical Sciences):

Documents reviewed	Version no.	Date
Macquarie University Ethics Application Form		Received 10/8/2016
Appendix D – Privacy and Access to Personal Information		Received 10/8/2016

Documents Noted	Version no.	Date
Email agreement for participation from Jim Hungerford, CEO, The Shepherd Centre		26/7/2016
The Shepherd Centre *Consent to Participate in Research* form	1.2	22/2/2012

*If the document has no version date listed one will be created for you. Please ensure the footer of these documents are updated to include this version date to ensure ongoing version control.

Appendix B: Excluded studies at full text analysis

	Author	Title	Reason for exclusion
1	Pataki et al. (2014)	The effect of thematically related play on engagement in storybook reading in children with hearing loss	Dependent variable not direct language measure
2	Pilnick and James (2013)	"I'm thrilled that you see that": guiding parents to see success in interactions with children with deafness and autistic spectrum disorder	Dependent variable not direct language measure
3	Torppa and Huotilainen (2010)	The meaning of music in the rehabilitation of children with hearing impairment	Dependent variable not direct language measure
4	Broekelmann (2012)	ihear[R] internet therapy program: a program by St. Joseph Institute for the Deaf	Descriptive
5	Andrews and Smith (2000)	A study of four African-American families reading to their young Deaf children	Limited intervention detail
6	Aragon and Yoshinaga-Itano (2012)	Using Language ENvironment Analysis to improve outcomes for children who are DHH	Limited intervention detail
7	Masoomeh et al. (2012)	Treatment efficiency in children with severe to profound hearing impairment: a comparative study of general language stimulation and developmental-descriptive approach based on morphological changes	Limited intervention detail
8	Sacks et al. (2014)	Pilot testing of a parent-directed intervention (project ASPIRE) for underserved children who are DHH	Limited intervention detail
9	Smith (1999)	A study of four African-American families reading to their young Deaf children	Limited intervention detail
10	Tajalli and Satari (2013)	Effectiveness of Metacognitive Strategies on Reading Skills of Students with Hearing Disorders	Limited intervention detail
11	Mich, Pianta, and Mana (2013)	Interactive stories and exercises with dynamic feedback for improving reading comprehension skills in Deaf children	Limited intervention detail
12	Bacsfalvi (2007)	Visual feedback technology with a focus on ultrasound: the effects of speech habilitation for adolescents with sensorineural hearing loss	Not in peer review publication
13	Bonilla Yanez (2016)	The effect of a fluent signing narrator on quality of maternal behavior during E-Book shared reading interactions with their children with hearing loss	Not in peer review publication
14	Braswell (2004)	The effect of vestibular exercise on dynamic visual acuity and reading acuity in children with sensorineural hearing impairment and vestibular hypofunction	Not in peer review publication
15	Burke (2012)	Word reading strategy development of DHH Preschoolers	Not in peer review publication
16	Daczewitz (2015)	Delivering the parent-implemented communication strategies (PICS) intervention using distance training and coaching with a father and his child who is hard of hearing	Not in peer review publication
17	Dashash (2004)	A preliminary study of the effects of a mother or care provider training model using play intervention on the language and social development of hearing impaired children in Saudi Arabia	Not in peer review publication
18	Granda (2014)	Increasing English reading comprehension of a Deaf English Language Learner (ELL) youth: a case study	Not in peer review publication
19	Holmer (2016)	Signs for developing reading: sign language and reading development in DHH children	Not in peer review publication
20	Hong (2013)	The effects of a tier 3 pre-kindergarten language intervention on children with hearing loss who communicate orally	Not in peer review publication

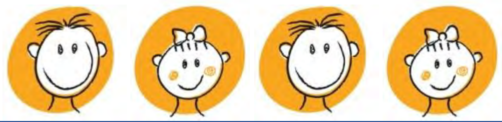
	Author	Title	Reason for exclusion
21	Huls (2015)	Effects of a music intervention in children with a hearing impairment: a case study and proposed preliminary study	Not in peer review publication
22	Jackson (2011)	The Montessori method's use of Seguin's three-period lesson and its impact on the book choices and word learning of students who are DHH	Not in peer review publication
23	Montgomery (2013)	A case study of the "Preventing Academic Failure" Orton-Gillingham approach with five students who are DHH: using the mediating tool of Cued Speech	Not in peer review publication
24	Mueller (2008)	The effects of a fluent signing narrator in the Iowa E-Book on deaf children's acquisition of vocabulary, book related concepts, and enhancement of parent-child lap-reading interactions	Not in peer review publication
25	Oster (2006)	Computer-based speech therapy using visual feedback with focus on children with profound hearing impairments	Not in peer review publication
26	Poobrasert (2008)	An evaluation of Life: Bone Numbing! — a multimedia support system for students with deafness	Not in peer review publication
27	Soukup (2005)	Incorporating a multi-sensory, See /Cover /Write /Compare intervention procedure to improve the spelling performance of students who are deaf and exhibit characteristics consistent with learning disabilities	Not in peer review publication
28	Anca and Hategan (2007)	Personalizing the hearing training of the children with cochlear implant by selecting and adapting the linguistic material	Not in peer review publication
29	Chilvers (2013)	Analyzing the effects of a mathematics problem-solving program, Exemplars, on mathematics problem-solving scores with deaf and hard-of-hearing students	Not in peer review publication
30	Cutler (2001)	The effectiveness of verbotonal therapy for children with cochlear implants	Not in peer review publication
31	Ertmer, Leonard, and Pachuilo (2002)	Communication intervention for children with cochlear implants: two case studies	Observational
32	Miller (2009)	Learning with a missing Sense: what can we learn from the interaction of a Deaf child with a turtle?	Retrospective
33	Douglas (2016)	Improving spoken language outcomes for children with hearing loss: data-driven instruction	Retrospective
34	Janssen, Riksen-Walraven, and Van Dijk (2003)	Contact: effects of an intervention program to foster harmonious interactions between Deaf-blind children and their educators.	Theoretical model
35	Carnio (2012)	Phonemic awareness in students before and after language workshops	Typical hearing children

Appendix C: Eligible studies by linguistic area

Linguistic Area	Reference	Intervention
Language	Schopmeyer et al. (2000)	Fast ForWord™
Language	Silvestre and Valero (2005)	Musical education
Language	Sugaya et al. (2014)	Domain-based training
Reading and comprehension	Bergeron et al. (2009)	Semantic association strategy embedded in the Children's Early Intervention program
Reading and comprehension	Bergeron et al. (2009) (S2)	Semantic association strategy embedded in an early literacy curriculum (Foundations for Literacy)
Reading and comprehension	Charlesworth et al. (2006)	Reading recovery
Reading and comprehension	Miller et al. (2013)	Phonological awareness instruction
Reading and comprehension	Nakeva von Mentzer et al. (2013)	Phoneme–grapheme correspondence training
Reading and comprehension	Pakulski and Kaderavek (2012)	Cross-age reading program with manipulatives
Reading and comprehension	Schirmer et al. (2012)	Reread-adapt and answer-comprehend intervention
Reading and comprehension	Smith and Wang (2010)	Visual phonics in conjunction with a modified version of the Fountas and Pinnell Kindergarten phonics Curriculum
Reading and comprehension	van Staden (2013)	Balanced reading
Reading and comprehension	Wang et al. (2013)	Visual phonics with phonics-based group reading instruction with smart board technology; phonics-based individual reading instruction
Morphology	Encinas and Plante (2016)	Enhanced conversational recast and auditory bombardment
Morphology	Bow et al. (2004)	Phonological and morphological training
Narrative and discourse	Asad et al. (2013)	Use of dynamic assessment to evaluate narrative language learning in children with hearing loss
Narrative and discourse	Ingber and Eden (2011)	Sequential time perception and storytelling
Narrative and discourse	Justice et al. (2008)	Narrative-based language intervention
Narrative and discourse	Klieve and Jeanes (2001)	Meaning differences conveyed by prosody
Pragmatics and social Communication	Alton et al. (2011)	SmiLE approach
Pragmatics and social Communication	James et al. (2013)	Video interaction guidance
Pragmatics and social Communication	Lam-Cassettari et al. (2015)	Video interaction guidance
Phonetics and phonology	Bernhardt et al. (2000)	Palatometry treatment program
Phonetics and phonology	Bow et al. (2004)	Phonological and morphological training
Phonetics and phonology	Chan et al. (2000)	Intensive tone perception training
Phonetics and phonology	Clendon et al. (2003)	Earobics and SpeechViewer III software
Phonetics and phonology	Dwyer et al. (2009)	Training to increase speaking rate

Linguistic Area	Reference	Intervention
Phonetics and phonology	Higgins et al. (2000)	Visual feedback to treat negative intraoral air pressure
Phonetics and phonology	Paatsch et al. (2001)	Effects of phonetic and phonological training methods
Phonetics and phonology	Paatsch et al. (2006)	Speech production and vocabulary training
Phonetics and phonology	Pantelemidou et al. (2003)	Electropalatography
Lexicon and vocabulary	Bobzien et al. (2015)	Repeated storybook reading paired with explicit teacher instruction to teach novel vocabulary
Lexicon and vocabulary	Bowers and Schwarz (2013)	Basic concept instruction
Lexicon and vocabulary	Brady and Bashinski (2008)	Adapted version of prelinguistic milieu teaching
Lexicon and vocabulary	Golos and Moses (2013)	Video from an educational video series in ASL
Lexicon and vocabulary	Herman et al. (2015)	Core vocabulary therapy
Lexicon and vocabulary	Lew et al. (2014)	Speech Perception Education and Assessment Kit programme
Lexicon and vocabulary	Lund and Douglas (2016)	Vocabulary instruction
Lexicon and vocabulary	Massaro and Light (2004)	Language player software training program with animated computer tutor

Appendix D: Functional Listening Index



The Shepherd Centre
Giving deaf children a voice

Functional Listening Index

Child's First Name: Surname:

Birth Date: Gender:

Staff Member:

Phase 1: SOUND AWARENESS	
	Record Date Consistently Observed (if date is unknown, record date of birth)
To wear hearing devices during all waking hours	
To show an involuntary response to sound	
To search for the source of a sound	
To attend to voice with interest	
To begin to localise sound, although may be inconsistent	
To attend to talking/singing for a couple of minutes	
To consistently detect all The Seven Sounds at close range	
To show a detection response to a range of Learning to Listen Sounds through listening alone	
To respond to whispered voiceless phoneme (e.g. 'p… p…' and 'h…h…') through listening alone	

Phase 2: ASSOCIATING SOUND WITH MEANING	
To respond to music with body movement or voice e.g. vocalising, kicking, stilling, dancing	
To demonstrate auditory association of environmental sound (e.g. turns to a door on doorknock)	
To vocalise when spoken to	
To increase/decrease the amount of vocalising when hearing devices are turned on	
To occasionally respond when called by name e.g. by stopping activity or turning	
To localise source of voice accurately	
To demonstrate auditory association of familiar voices (e.g. looks to mum when mum speaks, dad when dad speaks)	
To discriminate between angry/firm and friendly tones	
To consistently detect all The Seven Sounds at distances of 1m or greater	
To demonstrate anticipatory knowledge of familiar songs/rhymes through listening alone (e.g. braces for tickle)	
To identify a small range of familiar songs/rhymes through listening alone	

Phase 3: COMPRHENDING SIMPLE SPOKEN LANGUAGE	
To consistently respond when called by name in quiet	
To respond appropriately to everyday words or phrases in quiet without gesture	
To imitate all The Seven Sounds accurately at close range	
To imitate all The Seven Sounds accurately at distances of 3m or greater	
To imitate adult speech sounds appropriate for age	
To identify a range of Learning to Listen Sounds	
To select one item by name through listening alone	
To recognise names of immediate family members	
To demonstrate early auditory closure e.g. completes final word/ phrase in familiar song	
To consistently respond when called by name in background noise (e.g. outside with traffic noise, in a noisy daycare)	
To imitate words heard	

Phase 4: COMPREHENDING LANGUAGE IN DIFFERENT LISTENING CONDITIONS	
To respond appropriately to everyday requests without contextual clues	
To imitate a wide variety of speech sounds accurately	
To sing fragments of familiar tunes and songs	
To respond appropriately to longer utterances that combine two elements in novel ways (e.g. put your shoe on your head)	
To identify familiar songs/rhymes from a digital signal through listening alone (e.g. on an iPad)	
To imitate utterances of 2 or more words	
To select 2 units through listening alone	
To attend to a story or rhyme for 3-4 pages/screens with added suprasegmental information	

Phase 5: LISTENING THROUGH DISCOURSE AND NARRATIVES	
To use words/expressions not directly taught (demonstrates over-hearing)	
To identify a page/screen that corresponds to a segment of a familiar story/rhyme	
To identify an object from several related descriptors (closed set) e.g. it has fins, swims in water and goes swish swish	
To select three units through listening alone	
To retell a simple familiar story/rhyme through listening alone	
To participate in a simple conversation about a known topic	
To answer simple questions about a known topic	
To repeat accurately sentences that have high predictability	
To demonstrate listening skills by understanding morphological, phonemic, syntactic and semantic markers e.g. plurals, past tense, comparatives (est) etc.	
To identify a familiar concrete object from several related descriptors (open set)	
To demonstrate advanced auditory closure eg. A triangle, circle & square are all…	
To recall a narrative/story with a known topic, recalling details in sequence	
To select 4 and 5 units through listening alone	

Phase 6: ADVANCED OPEN SET LISTENING	
To identify an unfamiliar abstract object from descriptors (open set)	
To repeat a sentence of 6-10 words with an unknown topic, which may include unfamiliar vocabulary, live voice	
To recall a narrative/story with an undisclosed topic, recalling 3-4 details in sequence	
To carry out an instruction containing multiple elements (more than five)	
To have 2-3 appropriate conversational turns on the phone with a familiar person	
To repeat a sentence of 6-10 words with an unknown topic, which may include unfamiliar vocabulary, digital voice	
To demonstrate comprehension skills while listening in background noise to a live voice (e.g. comprehends live voice with noise from household appliances, competing speakers etc)	
To demonstrate comprehension skills while listening in background noise to a digital signal (e.g. comprehends digital voice with noise from household appliances, competing speakers etc)	

Suggestions for Family

REFERENCES AND ACKNOWLEDGEMENTS

Auditory Skills Checklist, (2004) Adapted by Karen Anderson, from Auditory Skills Checklist by Nancy S. Caleffe-Schneck, M.Ed., CCC-A (1992).

Auditory Skills Program, New South Wales Department of School Education (https://www.det.nsw.edu.au/)

Archbold, S., Lutman, M. E., & Marshall, D. H. (1995). *Categories of Auditory Performance*. Annals of otology, rhinology & laryngology. Supplement, 166, 312.

Cochlear Limited, *Integrated Scales of Development. (2009)*

Cole, E. B., & Flexer, C. A. (2007). *Children with hearing loss: developing listening and talking birth to six*: Plural Pub.

Estabrooks, W. (1998). Cochlear implants for kids: Alexander Graham Bell Association for the Deaf.

Joint Committee on Infant Hearing of the American Academy of, P., Muse, C., Harrison, J., Yoshinaga-Itano, C., Grimes, A., Brookhouser, P. E., . . . Martin, B. (2013). Supplement to the JCIH 2007 position statement: principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics, 131*(4), e1324-1349.

E., Martin, B. (2013). Supplement to the JCIH 2007 Position Statement: *Principles and Guidelines for Early Intervention After Confirmation That a Child Is Deaf or Hard of Hearing*. Pediatrics, 131(4)

Pollack, D., Goldberg, D. M., & Caleffe-Schenck, N. (1997). *Educational audiology for the limited-hearing infant and preschooler: An auditory-verbal program*. Charles C Thomas Pub Limited.

Simser, J.I. (1993). Auditory-verbal intervention: Infants and toddlers. *Volta Review*, 95(3): 217-229.

Tuohy, J., Brown, J. and Mercer-Mosely, C., 2001, St. Gabriel's Curriculum for the Development of Audition, Language, Speech, Cognition, Trustees of the Christian Brothers, St. Gabriel's School for Hearing Impaired Children, Sydney, NSW, Australia.

Walker, B. (2009). *Auditory Learning Guide*. (http://www.firstyears.org/c4/alg/alg.pdf)

TERMS OF USE

The index is currently in the process of validation (April 2015). For any questions on use please contact research@shepherdcentre.org.au

Appendix E: Functional Listening Index – Paediatric version 2.0

(FLI-P®)

FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

Administration Form

Child's Name: ______________________ Date of Birth: ______________

HOW TO USE THIS FORM

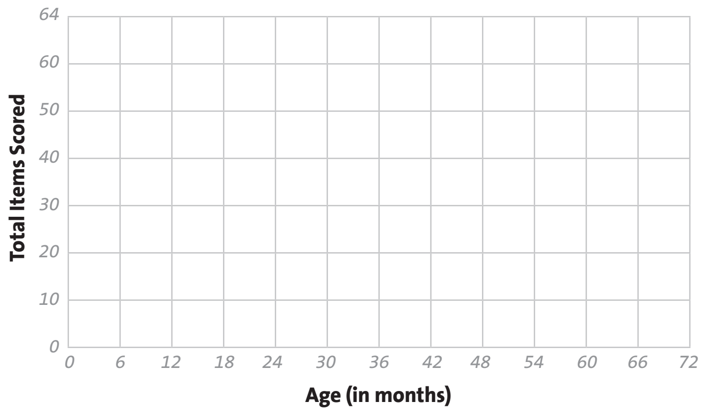
The Functional Listening Index-Paediatric has six phases. Start at the beginning of the first phase, and tick 'Rarely' or 'Mostly' for each item. Add the 'Mostly' scores for each phase and record in the 'Total' section for each phase. An overall Total score is the sum of all of the phase scores.

Record the overall Total items scored in the box below, along with the date, the child's age in months, and whether it has been completed by a parent or health professional. Each time you use the form, plot the child's overall total score against their age in months on the graph to track their listening trajectory.

Refer to the User Guide, Item descriptions and Conditions of Use for further information.

Date	Total items scored	Child's age in months	Parent/health professional

Functional Listening Index™- Paediatric Listening Trajectory



	Rarely	Mostly	Total
PHASE 1: SOUND AWARENESS			
1.1 Jumps or startles to loud sounds			
1.2 Looks or smiles at me when I talk to them in a 'sing-song' voice			
1.3 Hears at least 3 or 4 different animal or transport noises when I make them			
1.4 Pays attention to talking, singing or music for 20-30 seconds, even when there is nothing to see			/7
1.5 Hears all of the "Ling 6" sounds when presented with emphasis			
1.6 Can work out where a sound is coming from			
1.7 Hears me when I whisper			
PHASE 2: ASSOCIATING SOUND WITH MEANING			
2.1 Makes sounds back to me when I talk to them			
2.2 Can tell the difference between talking and singing			
2.3 Knows the voices of 2 family members			
2.4 Recognises a favourite song or music from the TV, tablet or phone			
2.5 Pays attention and stays engaged through 2 to 3 nursery rhymes in a row or with a favourite book for a couple of minutes			
2.6 Knows some of the sounds around us			/11
2.7 Looks at who is talking in a group			
2.8 Knows what is going to happen next in familiar songs			
2.9 Hears all the "Ling 6" sounds when I say them in a normal voice without looking at me when I am close by			
2.10 Knows if someone is happy or angry from the sound of their voice			
2.11 Recognises at least 3 songs or nursery rhymes when I sing them without the actions			

Administration Form FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

	Rarely	Mostly	Total
PHASE 3: COMPREHENDING SIMPLE SPOKEN LANGUAGE			
3.1 Repeats 3 familiar sounds after me			
3.2 Understands a word or phrase without any actions or gestures			
3.3 Matches 3 to 4 animals or objects with the sounds they make			
3.4 Knows their own name and will look at me when I say it.			
3.5 Can give me one thing when I ask for it without pointing			
3.6 Repeats some of the words that I say			
3.7 Repeats 'ah', 'oo', 'ee' and 'mm' from the "Ling 6" sounds clearly after me			/12
3.8 Is able to tell the difference between 'ss' and 'sh' from the "Ling 6" sounds			
3.9 Says some words in familiar songs			
3.10 Understands 10 words or phrases			
3.11 Knows the names of 3 familiar people or pets			
3.12 Hears me when I call their name in a noisy place			
PHASE 4: COMPREHENDING LANGUAGE IN DIFFERENT LISTENING CONDITIONS			
4.1 Follows short directions that are unpredictable or silly			
4.2 Knows the actions for several different verses of a song			
4.3 Repeats a 2 to 3 word sentence			
4.4 Sings a line of a familiar song			
4.5 Can go and get two things that I ask for			
4.6 Follows 2 instructions when given in the same sentence			/11
4.7 Repeats all of the "Ling 6" sounds accurately			
4.8 Repeats words and phrases that they have heard on TV, tablet or phone			
4.9 Repeats most of the sounds I say			
4.10 When I am more than 3 meters away, they can accurately repeat all of "Ling 6" sounds			
4.11 Follows instructions or answers questions they have heard on TV, tablet or phone			
PHASE 5: LISTENING THROUGH DISCOURSE AND NARRATIVES			
5.1 Recognises a familiar person on the phone			
5.2 Says things that surprise me because I don't know where they heard it			
5.3 Guesses which item I am talking about when I describe something that they can see			
5.4 Can find a page in a familiar book if I describe what is on it			
5.5 Is able to sing or say most of a familiar nursery rhyme or song			
5.6 Can answer simple questions about a favourite toy or activity			
5.7 Hears differences in similar sounding words and understands that this changes their meaning			
5.8 Will fetch 3 things at once if I ask for them			/14
5.9 Has a short conversation with me if I start it by telling them what we are talking about			
5.10 Follows 3 instructions in the same sentence			
5.11 Guesses what I'm describing from clues when I describe an object or an animal they know			
5.12 Accurately repeats sentences of 5 to 6 words after me if they know all the words			
5.13 Is able to tell me how 3 or 4 things are related when I name them			
5.14 Brings back 4 things that I ask for in one sentence			
PHASE 6: ADVANCED OPEN SET LISTENING			
6.1 Can have a simple conversation with a familiar person on the phone			
6.2 Guesses a less familiar item from clues that I give			
6.3 Remembers 4 things that happened in a story in the right order after reading a book together			
6.4 Easily repeats a sentence of 8 to 10 words after me, even when one or two of the words are new to them			
6.5 Understands that the way something is said changes the meaning of the sentence			/9
6.6 Is able to follow a long, complicated instruction that has more than 5 components			
6.7 Easily repeats a sentence of 8 to 10 words they have heard on TV, tablet or phone, even when one or two of the words are new to them			
6.8 Follows instructions, has a conversation or can listen to a story and answers questions about it when we are in a noisy place			
6.9 When we're somewhere noisy, they can have a conversation on the phone, or they can listen to a story on a digital device and answer questions or tell you about it			

Appendix F: Functional Listening Index – Paediatric (FLI-P®) User Guide and FAQ

FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

User Guide and FAQ

Background & Development

The Functional Listening Index for Paediatric (FLI™-P) has been designed to assist the tracking and monitoring of a child's listening skills in everyday situations. It has been developed for parents, caregivers and health professionals to use with children from birth through to 6 years of age. It is based on clinical research conducted by the HEARing CRC and The Shepherd Centre since 2013. It has been developed as a clinical tool to guide both parents and professionals in the acquisition of a child's hearing and listening abilities, to support intervention, assist with goals and targets and inform amplification decisions. As listening is the foundation of spoken language and communication skills, tracking a child's early functional auditory skill development can assist in providing an indication of later language outcomes.

It has been developed from the formative auditory scales and tools in the field of paediatric hearing loss (see Acknowledgements).

It provides:

- a single scale that covers early to advanced listening skills
- a measure of listening for children from birth, with any degree, type and level of hearing loss
- a measure of listening that is relevant for children with additional needs and those learning languages other than English
- a comparative measure of listening skill development for children with hearing loss and with typical hearing
- a comprehensive list of early, mid and later developing audition skills
- a measure that can indicate how a child using their functional listening in every day environments
- a measure beyond the detection and perception of sound, that includes the cognitive components of identification and comprehension

The FLI™-P has been used clinically with children with all levels and types of hearing loss including unilateral and bilateral hearing, those diagnosed through universal newborn hearing of screening and those diagnosed later, children learning English as both a primary and additional language, and languages other than English, and children with additional needs. It is intended for use with any child developing listening skills.

For further information regarding validity studies and research base behind the FLI™-P, please contact enquiries@shepherdcentre.org.au

FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

User Guide and FAQ

Administration

Who can administer the FLI™-P?

It has been designed to be administered by a parent or health/education professional who knows the child well.

How do I complete the Functional Listening Index?

- Complete each set of questions to indicate the child's skill for each of the items, beginning at Item 1.1. Record the score, date of testing, child's age in months and who completed the index. Map the child's score on the FLI™-P listening trajectory chart to track their progress.
- If you are unsure on any item, refer to the 'Items Description' handout, which will provide more information on each listening skill

What do I need to remember when administering the FLI™-P?

- The FLI™-P is a measure of listening skills so it is important not to provide extra visual information unless otherwise indicated. Children naturally use all the cues they can to understand and communicate, and often this will involve visual cues, particularly in every day interactions. Because the FLI™-P specifically measures listening skills, it's important to ensure these aren't used. This includes pointing, gesturing, looking, lip reading and facial cues.
- Unless otherwise specified, items assume skills in a quiet environment, at a close distance, using a typical voice.

How often should the FLI™-P be administered?

The FLI™-P can be used both to establish current skills and to monitor development of skills over time. As such it should ideally be done every 8-12 weeks. If you are concerned about a certain aspect of listening or communicative development, this might be more often. It might also be at longer intervals e.g. every 6 months.

Regular use provides more information on each child's individual listening trajectory and progress.

Where do I start?

For your first use of the FLI™-P: Start at the first item (1.1). Keep progressing through the items until you have marked 'rarely' for 6 items in a row.
For all return uses of the FLI™-P: Count back 4 items from the first previous 'rarely' response. Check that the child is still 'mostly' doing the first 4 items, check any other items the child was rarely doing previously, and then continue until you have 6 'rarely' responses in a row.

Do I have to see the child perform each item in order to mark it off?

No. The index has been designed to be reflective of the child's current listening skills. As these can often change, think about what you have recently seen them do over the last few weeks.

What if I have only seen the child do it once?

You will be asked to indicate if the child 'mostly' or 'rarely' displays a certain skill. 'Rarely' indicates although you have seen it once or twice, it isn't something they do regularly. 'Mostly' indicates it's something they would most often do or frequently do, and you have seen them do it with different people, in different settings.

Do I mark 'rarely' even if the child never does it?

Yes.

What do I mark if I am not sure or think they do it 'sometimes'?

If you are unsure, mark the item as 'rarely'.

What do I do if I'm not sure?

The item description handout provides more information on types of things that you would see or look for, and suggestions of ways you can check.

User Guide and FAQ

What are the basal and ceiling requirements?

Listening skills are often learnt by children in different orders, depending on experience and exposure to words and sounds. As you go through the form, even if they *'rarely'* do one of the items, they might *'mostly'* be doing items further down the list. Continue down the form even if you are recording that the child 'rarely' does some of the items. Once you record 6 items in sequence that are all *'rarely'* done (or aren't done) you don't need to continue any further.

Can I use the FLI™-P for a child with unilateral hearing loss? Auditory Neuropathy Spectrum Disorder (ANSD)? Large Vestibular Aqueduct Syndrome (LVAS)? Middle Ear Pathology? No hearing loss? Suspected hearing loss? Hearing or Processing concerns?'

Yes. The tool has been designed to use with children with all degrees, levels and types of hearing, however there may be certain considerations for each child's context. For example:

- Children with a unilateral loss who are not aided may have more difficulty with some items (localising sounds, listening in noise).
- Children with ANSD may demonstrate different skills at different times/on different days depending on the nature of the neuropathy.
- Children with LVAS may have lost skills if there has been a drop in hearing, and
- Children with middle ear pathology may have more difficulty or slower acquisition of skills during periods of effusion or infection. If you want to monitor their progress during periods of infection, then continue to administer the FLI™-P, otherwise, wait until the infection has resolved so you can measure the child's listening skills as they are in their usual listening condition with optimal access to sound.
- Children with no hearing loss or hearing/processing concerns may have different skills for many reasons. If you have concerns at any time regarding a child's listening skills, please don't hesitate in contacting your local GP or health professional.

If the child is using cochlear implant/s should I wait for their device to be MAPped prior to administration?

If you are concerned about their access to sound through their cochlear implant/s, MAPping is always recommended to optimise the signal and access, and then complete the FLI™-P.

If one or both of the child's hearing device/s are broken, should I still do the FLI™-P?

The tool should measure their skills when they have good access to sound, ideally bilaterally. As such, either answer the items with respect to what they were doing when their devices were functioning, wait until they are being used again or note during administration the status of the child's current device use.

Is it ok if the child keeps looking at my face?

No. Unless otherwise stated, the items are designed to monitor what the child can do through listening only, without the support of lip reading or other visual cues. Try sitting beside them rather than facing them, encourage them to look at something else or wait until they are looking away.

Why do we use animal and transport noises, rather than the real word?

These sounds (commonly known as performatives) are longer, contain more pitch and intonational information and have more repetitions built in than the real word. Consider the words 'cat' and 'meow'. Meow is longer, has more vowel information making it easier to hear and say, and is much more likely to be acoustically interesting. They are also used because they are fun, and more child-friendly!

Can I repeat the question or item if the child doesn't answer or respond the first time?

Although you can repeat it, it is unlikely you would mark the item as 'mostly' able to do the item, unless you see it many more times and on a consistent basis. The child should be able to do the item without it needing to be repeated or simplified.

If the child's primary language is not English, or doesn't use English at all, can I still use the FLI™-P?

As the FLI™-P measures listening skills, the language in which information is presented, is not important. What is important is whether the child is able to do the task through listening. Score the child for what they are able to do in their primary language, and use linguistic and language modifications as required.

If the child speaks two or more languages, which language should I use?

You can try any or all languages spoken by the child. When the child has a certain skill in one language, it can be marked off. Note that the child may have some listening skills in one language and others in a different language. As the FLI™-P measures listening, and is not a 'language measure' this is appropriate.

Why does the FLI™-P use a TV, tablet or phone?

Listening to digital signals can be much more challenging than listening to a live voice. These items are used to monitor the development of these more difficult and advanced listening tasks. As these skills are such a daily part of listening & communication, and can be fundamental to participation and social inclusion, practice and monitoring of the development of these type of listening skills is important.

Does the child have to acquire all of the skills in one phase before continuing to the next phase?

No. In all cases, skills in the phases overlap and the development of skills is individual. There may be certain skills that are particularly difficult for some children which take longer to develop or may never achieve. They can continue to develop others further down the index.

How do I know if the child is doing what they should be for their age?

Normative data on the listening skills of children with typical hearing is currently in collection through a research project collaboration with The HEARing CRC, The Shepherd Centre, The Babylab at the MARCS Insitutute at the University of Western Sydney and Cochlear Ltd. This data will provide a range of ages where we would expect development of each item on the FLI™ for typically hearing children from birth through to 6 years of age. Until this normative data on the FLI™-P is available, information, information of when to expect listening skills can be found in the Integrated Scales of Development by Cochlear Ltd. (www.cochlear.com)

What do I do if I have concerns about a child's listening progress or development?

We would highly recommend you work with the child's health and education professionals to ensure they have the appropriate access to sound to develop listening skills for communication.

If you have any concerns about a child's listening progress or current auditory skills using the FLI™-P, please contact enquiries@shepherdcentre.org.au or alternatively a hearing professional near you.

Should I be using the child's 'hearing age', 'implant age', or 'chronological age?'

The FLI™-P has been designed to always use a child's chronological age. Although 'hearing age' refers to the time point at which aids were fitted, it can't be guaranteed this is the point that these aids provide useful information for the development of hearing and listening skills. This is similarly with 'implant age'. The date a child's implant is activated doesn't necessarily mean at this point that they have useful and good access to sound for the development of hearing and listening skills, as this happens over time with the optimisation of a child's MAP. Given the recognised standard measures for language development for children with hearing loss compare progress to normative data on typically hearing children, through chronological age, the FLI™-P has been designed similarly.

What do I do if the child can't do an item? Should I be teaching it to them?

The FLI™-P does provide a guide for the listening skills that the child will be developing next. Although we don't advise 'teaching to a test' (i.e. teach a certain item so they can mark off this item on the index), incorporating the next skills the child is rarely doing, are appropriate auditory goals to build into every day activities.

What is the evidence for the use and development of the FLI™-P?

Individual and group data analysis has been used since 2013. Numerous ongoing research projects are underway involving different uses of the FLI™-P. If you would like to participate in future research collaborations and developments using the FLI™-P, please contact enquiries@shepherdcentre.org.au

A FLI™-P training module is currently in development and will be available in the near future through HEARnet Learning (hearnetlearning.org.au). If you would like to be contacted when this becomes available please notify enquiries@shepherdcentre.org.au

Glossary

Auditory memory: The ability to remember information that is heard.

Conversation: A conversation is a communication interaction between two or more people. All communicators should be responsible for maintaining the conversation so one person asking questions and the other just answering them is not a conversation. All participants should make comments as well as ask and answer questions.

Detection vs Identification: Detection means "they heard sound!" It does not mean that the child knows what the sound was or has placed any meaning with it. It is purely acknowledgement that a sound signal reached the brain. If a sound is identified, it must first be detected and then some meaning must be attached to it so it becomes "they know what that sound is"

Discrimination: The ability to hear the difference between two or different sounds. The child may not be able to hear them very clearly but because there are only a small number of options, they can tell which one is which.

Intonation: The rise and fall of a voice when speaking.

Highlighting: Similar to using a 'sing-song' voice. When speaking, add emphasis through volume (louder or whispered sounds), pitch (using pitch changes i.e. going from low to high to low pitch), duration (making a sound longer) or repetition to a word or sound when you say something to the child.

LING 6 sounds: The Ling 6 sounds (Ling 1976) are sounds that cover low, mid and high frequency speech sounds typically fall in between and around these, so if a baby/child can detect all 6 Ling sounds in a quiet place from 1 metre away, you can be confident they can detect all speech sounds under the same conditions (quiet, 1m away).

The sounds are: *mm, oo, ah, ee, sh* and *ss.*

The Ling sounds should be used regularly to check access to speech sounds, that the child's device is working correctly, and to help to identify hearing changes. The Ling sounds should be done both binaurally (both ears together) and for individual ears where possible i.e. left device only or right device only. If a baby/child is not responding to **all 6** sounds, we would recommend consulting an audiologist or hearing professional.

Listening alone: Without any visual, tactile or other cues.

Mostly: You are quite confident the child has the skill in question. They do it easily and frequently with different people and in different contexts.

Noisy place: A place where there is a lot of background noise that makes it harder for the child to hear what you are saying. Examples include a playground with children playing, a café or restaurant with conversations in the background, a preschool or classroom, a room with the TV or radio on in the background.

Quiet environment: A room or area without background noise. The TV is off, no noise from fridges/air conditioners/ fans/people talking. The room or area has carpet/soft furnishings so there is no reverberation.

Rarely: The child is unable to do the task required or you are not sure if the child has consolidated this skill. They show the skill in question sometimes but not frequently or easily. The child may do the skill in question only in some circumstances or with specific people or in specific places.

'Sing-song' voice: Also sometimes called parentese/ baby talk/infant directed speech. Has a high pitch, short sentences, lots of repetition and is used because it is more interesting to babies/young children, and is more likely to gain their listening attention.

Typical voice: One you would use when chatting with someone next to you. When measured with a sound level meter, between 60-65 dB SPL.

Visual cues: These are additional helpful hints to support listening that the child picks up through what they can see. They include gestures (pointing), eye gaze (looking at the thing you are talking about), pictures and lip-reading.

Visual cues are very helpful in natural communication situations where the listening environment is noise, unless specifically stated, they should not be used when doing the items in the FLI™-P as this tool was designed to monitor listening skills without visual support.

Visual cues in conversation: It would be unnatural to have a conversation without occasionally looking at the face of our communication partner to check on their comprehension. However, for the purposes of the FLI™-P, minimise the opportunities for visual cues by sitting next to the child rather than opposite. This way, they can glance at you but if the child needs to constantly look at your face it may mean they are relying on lip-reading, thus they are likely to be rated as 'rarely' for this item.

User Guide and FAQ

References and Acknowledgements

Auditory Skills Checklist, (2004) Adapted by Karen Anderson, from Auditory Skills Checklist by Nancy S. Caleffe- Schneck, M.Ed., CCC-A (1992).

Auditory Skills Program, New South Wales Department of School Education (https://www.det.nsw.edu.au/)

Archbold, S., Lutman, M. E., & Marshall, D. H. (1995). *Categories of Auditory Performance.* Annals of otology, rhinology & laryngology. Supplement, 166, 312.

Cochlear Limited, *Integrated Scales of Development.* (2009)

Cole, E. B., & Flexer, C. A. (2007). *Children with hearing loss: developing listening and talking birth to six:* Plural Pub. Estabrooks, W. (1998). Cochlear implants for kids: Alexander Graham Bell Association for the Deaf.

Joint Committee on Infant Hearing of the American Academy of, P., Muse, C., Harrison, J., Yoshinaga-Itano, C., Grimes, A., Brookhouser, P. E., . . . Martin, B. (2013). Supplement to the JCIH 2007 position statement: principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics,* 131(4), e1324- 1349.

E., Martin, B. (2013). Supplement to the JCIH 2007 Position Statement: *Principles and Guidelines for Early Intervention After Confirmation That a Child Is Deaf or Hard of Hearing.* Pediatrics, 131(4)

Pollack, D., Goldberg, D. M., & Caleffe-Schenck, N. (1997). *Educational audiology for the limited-hearing infant and preschooler: An auditory-verbal program.* Charles C Thomas Pub Limited.

Simser, J.I. (1993). Auditory-verbal intervention: Infants and toddlers. *Volta Review,* 95(3): 217-229.

Tuohy, J., Brown, J. and Mercer-Mosely, C., 2001, St. Gabriel's Curriculum for the Development of Audition, Language, Speech, Cognition, Trustees of the Christian Brothers, St. Gabriel's School for Hearing Impaired Children, Sydney, NSW, Australia.

Walker, B. (2009). *Auditory Learning Guide.* (http://www.firstyears.org/c4/alg/alg.pdf)

FURTHER INFORMATION

For any questions on use please contact enquiries@shepherdcentre.org.au

Appendix G: Functional Listening Index – Paediatric (FLI-P®)

Conditions of Use

FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

Conditions of Use

The Functional Listening Index for Paediatric (FLI™-P) has been designed to assist the tracking and monitoring of a child's listening skills in everyday situations. It has been developed for parents, caregivers and health professionals to use with children from birth through to 6 years of age. It is based on clinical research conducted by the HEARing CRC and The Shepherd Centre since 2013.

Instructions for use:

1. Complete each set of questions to indicate the child's skill for each of the items, beginning at Item 1.1. Record the score, date of testing, child's age in months and who completed the index. Map the child's score on the FLI™-P listening trajectory chart to track their progress.
2. The Index contains a list of questions about a child's listening. Think about whether they *'mostly'* or *'rarely'* do these things.
   a. *Mostly* means the child does it regularly, in different places, with different people.
   b. *Rarely* means they have only done it sometimes, occasionally or not at all.

   Children learn listening skills in different ways that vary and depend on experience and exposure to words and sounds. As you go through the Index, even if a child *'rarely'* does one of the items, they might *'mostly'* be doing other items further down the list. Continue down the Index even if you are recording that the child *'rarely'* does some items.
3. Once you record 6 items in a row that are *'rarely'* (or not) done, stop. Come back to the form in 2 to 3 months or sooner if you are concerned to check where the child is up to.
4. When you return, start 4 items before the first *'rarely'* answer. E.g., if your first *'rarely'* answer is for item 18, next time, you'll start at item 14.
5. If you are unsure on any item, refer to the 'Items Description' handout, which will provide more information on each listening skill.
6. As the FLI™-P is a measure of listening, it is important to remember not to use visual cues (such as lip reading, gestures, or looking at something) unless stated in the instructions.
7. Remember its also okay for a child to score 'rarely's'. They will typically always reach a point where this is the case, so don't be afraid to mark 'rarely'. Those items will then give you good ideas of things you can be working on.

- The User Guide provides further information to assist in using and completing the FLI™-P

The FLI™-P User Guide has further information and Frequently Asked Questions to help you use the Index. Please contact The Shepherd Centre enquiries@shepherdcentre.org.au if you have questions or enquiries about use, research base, validation, or participation in current studies.

Use of the Functional Listening Index-Paediatric must be in line with the Conditions of Use (see over).

FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

Conditions of Use for the Functional Listening Index - FLI™

The Shepherd Centre[1] and the HEARing CRC[2] (referred to after this as 'we' or 'us') have developed the Functional Listening Index assessment tools (which includes the Functional Listening Index-Paediatric; abbreviated as FLI™ and FLI™-P; referred to after this as 'the tools') to assist health professionals and families (referred to after this as 'you'), who want to assess the listening skills of children. The intellectual property (copyright) contained in these tools is jointly owned by these parties.

Cochlear[3] (the cochlear implant manufacturer) is supporting the development of these tools.

We provide you with a restricted license to use these tools subject to all of the following conditions:

1. You accept that any use is at your own risk, without any warranty being provided by us or any liability accepted by us, as further described below.
2. You may not reproduce these tools if you are a Cochlear competitor, as defined below.
3. You accept that the intellectual property in these tools is owned by us and that your use of these tools does not provide you with any ownership or rights to these tools or to any derivatives of them.
4. You will use the tools as written and not vary the text or the construction of the tools.
5. You may not use these tools commercially unless you have our explicit permission in writing.
6. If you make public data that is generated through the use of the tools you will appropriately acknowledge the FLI™-P on all materials, publications or presentations including that data.

No variation to these conditions is allowed without written permission. Any questions you have on the conditions for use of these tools should be sent to enquiries@shepherdcentre.org.au

These tools have been developed based on professional experience with children with hearing loss and the development of their listening skills. Concurrent and convergent validation studies has been demonstrated against other measures and that it identifies the expected differences between groups of children with hearing loss. It has been shown to have predictive validity of children's later language scores and found to be valuable in clinical management for children with hearing loss.

This is not a medical, nor diagnostic tool. It is not overseen by a health care regulator, nor assessed or approved by one. It does not provide health care advice.

We do not provide any warranty as to the suitability of these tools for any individual child nor the value of their use. Although it can provide information it cannot be used as a diagnostic for hearing loss or language development delays or disorders.

This tool will be modified as further research and experience develops in its use but we do not commit to continue to providing this tool or updates in its current form. Any use of these tools or incorporation into the clinical management of children is solely at your discretion. If you decide to use this tool you accept that this is done at your own risk and that we are not responsible for any consequences of that use, to the full extent allowed by law.

A Cochlear competitor is defined as:

a. Any person, firm, corporation, partnership, joint venture, association or government agency that is engaged in (or has ownership or control of) any enterprise or business activity which competes directly with any business of Cochlear or of any Cochlear subsidiary; and
b. Any manufacturer or distributor of remedial hearing devices, which include but are not limited to auditory brainstem implants, cochlear implants, bone conduction devices or middle ear devices.

[1] The Shepherd Centre (ABN 61000699927), of 146 Burren St, Newtown NSW 20142, Australia

[2] The HEARing CRC Limited (ABN 94123522725) of 550 Swanston St, Carlton Victoria 3053, Australia

[3] Cochlear Limited (ABN 96002618073) of 1 University Avenue, Macquarie University NSW 2109, Australia

Appendix H: Functional Listening Index – Paediatric (FLI-P®) Item Descriptions

FUNCTIONAL LISTENING INDEX – PAEDIATRIC (FLI™-P)

Item Descriptions

Functional Listening Index
PAEDIATRIC

PHASE 1: SOUND AWARENESS

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
1.1 Jumps or startles to loud sounds	The child jumps, startles or blinks their eyes when there is a sudden loud noise (e.g., door slamming, loud clap, something falls onto a hard floor) nearby.	Make sure you can see the child, but they can't see you. Make a loud noise and watch for a response. Do they jump? Startle? Blink? *Remember to check that the child's responses aren't from seeing a movement or feeling something else.*
1.2 Looks or smiles at me when I talk to them in a 'sing-song' voice	The child looks at you, smiles, widens their eyes or becomes still when you use this voice. Young babies may stop or start sucking to show they are listening.	When you are holding the child or are closeby, gently talk in a 'sing-song' voice. See if they smile, look at you or change their facial expressions. *Talking with extra rhythm and melody makes it easier for children to listen because it provides extra 'acoustic' cues.*
1.3 Hears at least 3 or 4 different animal or transport noises when I make them	They might widen their eyes, blink, become still or turn to look at you when you make an animal or transport noise. Examples are 'brmmm' - car; 'meow' - cat; 'ee-or' - fire engine; 'quack quack' – duck. This shows the child can hear these sounds and are engaged by them, even when they can't see them.	When you are playing next to them and they aren't looking at you, make an animal or transport noise and see if they pause, look up, look at you or become still. After you make the sound, you could also show them the toy or picture that matches the sound and say 'Yes, you heard it, that's the dog.' *If they didn't seem to hear it, try pointing to your ear and say "Listen". This will encourage them to stop and listen for the sound before you repeat it.*

PHASE 1: SOUND AWARENESS

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
1.4 Pays attention to talking, singing or music for 20-30 seconds, even when there is nothing to see	They will either settle or become excited when you sing or talk to them, even when they can't see you. They may become quiet when they hear music or singing even when they don't see anything. If you are in another room, they remain happy or quiet when you talk or sing, or they hear music.	When they're not looking at you, start gently singing or talking. See how they respond. They may become still, may move more by kicking their legs/bouncing up and down/waving their arms and legs, or even start smiling and looking around. *You could also play some music. Building the ability to listen to sounds for longer periods of time is important in developing attention skills through listening.*
1.5 Hears ALL of the "Ling 6" sounds when presented with emphasis	The child hears and responds to the sounds 'mm', 'oo', 'ah', 'ee', 'sh' and 'ss' when you say them and while they aren't looking at you. They will show this by becoming still, changing where they look, blinking, widening or opening their eyes, raising their eyebrows or turning their heads. They may do this as soon as you start making the sound, or when you stop. Responses to all these sounds show they can hear very low speech frequencies ('oo', 'mm'), mid frequencies ('ar', 'sh') and high frequencies ('ee', 'ss').	When the child is next to you, not looking at you, and quiet, make one of the 6 sounds. See if they show any response, like widening their eyes, blinking, becoming still, turning, stopping, or looking up. *If necessary, add extra volume or patterns to help them hear the sounds. For example: 'ee-ee- ee' or 'oo-OO-oo'. Also, be aware that they may not respond if they are playing with an engaging toy, or watching something they are very interested in.*
1.6 Can work out where a sound is coming from	When you call the child from a different room, they look towards you. Or they might turn their head to look if someone behind them is talking. This shows they can 'localise', or correctly work out where sounds are coming from.	See if the child turns to look for you when you start talking. Hearing the sound is the first step, but working out accurately where it is coming from is important in identifying the sounds around them. *So you can see the child's response, ask someone to call from another room and watch if the child looks to where the voice is coming from.*
1.7 Hears me when I whisper	They may look around or look at you if you whisper something whilst they aren't looking.	When you are sitting next to them and they aren't looking at you, whisper some quiet sounds such as 'pa pa pa', 'ha ha ha' or whisper their name. Do they stop what they are doing? Look around? Look to see what it was? *Listening to sound at different volumes is an essential skill in children being aware of all the different types of sounds, particularly the quieter sounds of speech.*

PHASE 2: ASSOCIATING SOUND WITH MEANING

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
2.1 Makes sounds back to me when I talk to them	They seem to have a 'conversation' with you. They will babble back and forth (you say something, they babble some sounds, you say something else, they babble some more sounds), as if you are having a conversation. They will stop babbling when you talk, and then when you stop, they will begin babbling again.	When you are sitting with them, talk to them either using a 'sing-song' voice or with some babble sounds. After a few words or sounds, pause and look at them, waiting for them to respond. When they say something to you, respond with more sounds, then wait again for them to take their turn. This is the beginning of conversation, where we take it in turns to listen and talk.
2.2 Can tell the difference between talking and singing	When you sing, they may bounce or bob up and down, move their arms or legs, sway from side to side or try to sing along. This is different to their response when you are simply talking or reading them a story.	Start singing to them, and look for signs that they can tell this is different to when you talk to them. You may see them pause/stop or change what they are doing either when you begin, or finish singing. Participating in these back and forth talking and singing games are an essential part of early conversation skills using language and listening.
2.3 Knows the voices of 2 family members	They recognise your voice even when they can't see you, and the voice of another family member or familiar person. If they are unsettled, they will calm down to the sound of your voice but not to the voice of someone they don't know. They will also recognise the voice of another person and will show this by looking at them when they talk, becoming excited when they hear them, or smiling or becoming calm when they hear their voice.	When there's a familiar family member or person around, ask them to call the child's name or start talking to them. Watch to see if the child looks around for them. Think about how they react when they hear someone they know, compared to someone they don't know. Is there a difference?
2.4 Recognises a favourite song or music from the TV, tablet or phone	You see them get excited when the sound of their favourite TV show comes on or when a favourite song plays on a digital device. This is one of the earliest indications that they are understanding and putting meaning to 'digital' sound signals, which are harder to listen to and understand than voices, talking or signing.	Out of their sight, play a favourite song on your phone or tablet, or put the TV on as one of their favourite TV shows starts. Watch to see if they show signs of recognition. They might get excited, smile, look for it, look up at you, or get upset as they want to find it or watch it!
2.5 Pays attention and stays engaged through 2 to 3 nursery rhymes in a row or with a favourite book for a couple of minutes	When you sing or say 2 to 3 nursery rhymes in a row, they look at you or smile throughout. When you talk about the pictures in a book, they will listen to you and look at the book for a couple of minutes before losing interest. This indicates they are starting to pay attention for longer periods of time, using both their listening and visual skills.	When you are sitting somewhere quietly with them, open a book and talk about the pictures in a fun, interested and engaging way. Do they pay attention for a couple of minutes? Alternatively, sing 2 to 3 nursery rhymes in a row. Learning to stay focused and use their listening in longer activities helps develop their 'auditory attention'. *Do the actions with a nursery rhyme to help keep them engaged*

PHASE 2: ASSOCIATING SOUND WITH MEANING

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
2.6 Knows some of the sounds around us	They can identify some of the everyday sounds around us. They may look at the door when the doorbell rings, look outside when they hear a car or a dog bark, run to or away from the bathroom when they hear the bath running, or look to the sky if they hear a plane.	When the child isn't looking, put something in the microwave and wait for it to beep. Do they look towards the microwave? When your mobile phone rings, do they look for your bag? This is one of the first crucial steps children take in attaching meaning to sounds. *Ask a friend or relative to knock on the door so you can see if the child looks at or moves towards the door at the sound.*
2.7 Looks at who is talking in a group	When a group of people are talking, they will look at the person who is talking. When someone else starts talking, they will turn to look towards them.	Watch when you are talking in a group. Does the child look at who is speaking? Do they look to someone else when they start speaking? Do they look between people who are speaking? This functional listening skill further develops their sound localisation skills, which is important for following conversations.
2.8 Knows what is going to happen next in familiar songs	They may start giggling at a familiar nursery rhyme that involves tickling e.g., *"Round and round the garden... tickle him under there!"* Or they may fall down in anticipation during *"Ring a ring a rosie... we all fall down!"*. Or they may scream in advance at *"Row, row, row your boat... if you see a crocodile, don't forget to scream!"*	Sing a familiar nursey rhyme that involves some sort of movement. Watch closely as you get to the point in the song where something happens. Do they tense up? Pull their hand away? Get ready? Smile? Show you they know what's coming? When children show this, it indicates they are using their listening to develop their 'anticipatory knowledge' of what is coming next. *'Humpty Dumpty' (for falling down) or 'Three Little Monkeys' (for jumping on the bed) are great, action-filled nursery rhymes to try.*
2.9 Hears ALL the "Ling 6" sounds when I say them in a normal voice without looking at me when I am close by	When you say all of the Ling 6 sounds with no extra emphasis, they show they can hear them by turning their head, looking at you, stopping or pausing what they are doing, or raising their eyebrows.	Stand within a metre of the child and when they are quiet and not looking, say one of the 6 sounds in your normal speaking voice. Look to see if they heard you. Repeat for all the sounds. Responses to all of these sounds indicate they are able to hear all the sounds of speech at a 'conversational level'. *Watch out that they aren't looking at your face, can see your reflection, or feeling the sound. If they don't respond at first, you may want to cue them to listen by pointing to your ear, saying, 'Listen', and looking expectantly at them.*

PHASE 2: ASSOCIATING SOUND WITH MEANING

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
2.10 Knows if someone is happy or angry from the sound of their voice	You may see the child become upset or quiet if they hear someone use a firm or angry tone. They may also become calm and smile if they hear a happy voice.	Think about how they reacted if you used a firm tone near them. Did they seem upset and understand you used a different type of voice? Did they change when you started using a happy voice? This listening skill reflects early social development and the ability to begin to understand someone's emotion from their tone of voice. *Young children get a lot of cues from faces, so try to make sure their response is only from listening to voices.*
2.11 Recognises at least 3 songs or nursery rhymes when I sing them without the actions	They start doing the actions to familiar songs or nursery rhymes before you do them. They may move their arms 'round and round' when you sing *'The wheels on the bus'*, put their arms up in the air when you sing *'Twinkle, twinkle'* or clap their hands when you sing *'When you're happy and you know it...'*	When you're sitting with them, sing a familiar nursery rhyme or song. See if they do any of the actions without you starting them. If the song doesn't have actions, see if they go and get a toy you have linked to that song. These responses show they can tell the difference between songs.

PHASE 3: COMPREHENDING SIMPLE SPOKEN LANGUAGE

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
3.1 Repeats 3 familiar sounds after me	They copy the sounds that you say when you talk or babble with them, without needing to watch while you say them. So when you say 'mama', they copy you, and when you change to say 'dada', so do they. This ability to listen to others and match their own words and sounds to what they are hearing is called the 'auditory feedback loop'. It is important for developing clear speech.	Make some babble noises that you know they can make. Wait and see if they repeat them. You might say *'mamamamama'*, then look expectantly at them. If they don't do anything, say it again and then say, *'Your turn'* and wait to see if they copy you. Then try changing the sounds and see if they do the same. *Try involving older siblings or other children to help make the sounds.*
3.2 Understands a word or phrase without any actions or gestures	They can understand one simple word or instruction, without you pointing to or looking at what you are talking about. So when you say, *"Where's Mummy/Daddy/the puppy?"* they will look around to find that person or thing. When you say, *"Let's go"*, they might get up. When you say, *"Get your book"*, they do it. Or when you say, *"Yummy, yummy, dinner time!"*, they look to their highchair. This is the first indication of attaching meaning to words.	Try saying something that you would say every day without using actions or looking towards the item or person that you are talking about. Do they point or look towards it? Do they reach for it? Or go and get it?
3.3 Matches 3 to 4 animals or objects with the sounds they make	They may look at, point to, pick up or go and find a toy or picture of the object or animal when you say the sound it makes. For example, when you say, *"Where's the dog, woof woof?"*, they look around for their dog; or when you say *"Where's the train, choo choo?"* they go looking for their train.	Have a few familiar animals and objects that make a sound near the child. Make one of the sounds, and then watch to see what they do. Do they stop what they are doing and look for it? Do they reach for it and give it to you?
3.4 Knows their own name and will look at me when I say it	The child looks up when you call their name. They may look directly at you, or look around to see who called them. If you call another name, they won't respond in the same way.	When they're not looking at you, call their name. When they turn and look, you could wave hello, say something like *"Yes, you heard me call your name!"* or give them a toy to play with. *Sometimes you may have to repeat their name if they are concentrating on something else. But note that if we call young children's names too often for no reason, then they may stop turning when they hear it.*
3.5 Can give me one thing when I ask for it without pointing	They can give you one thing when you ask for it without any gestures or actions to help show them what you want. For example, when you say, *"Give me the ball"* they go and get it for you.	Have a few familiar items (e.g., toy car, spoon, shoe, ball, teddy) around the child. Ask them to give you one of them, being careful not to point, or indicate with your eyes or head which one you want. You may want to hold out your hand to show them you want something, without giving away which one.

PHASE 3: COMPREHENDING SIMPLE SPOKEN LANGUAGE

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
3.6 Repeats some of the words that I say	When you say, *"Look at the doggy"*, they may try to repeat "*doggy*". When you say, *"Here comes Daddy"*, they may try to say *"Daddy"*.	When they aren't looking at you, talk about what they are playing with. Wait and see if they try to say it after you. For example, they have some keys and you say, *"Oh, you've got some **keys**"*, emphasising the object. Wait to see if they say anything. They may turn and look at you, and if they don't say anything, draw their attention back to the keys and say, *"Yes, it's the **keys**"* again,. You could then say, *"Your turn,* (pause) *it's the **keys**."*
3.7 Repeats 'ah', 'oo', 'ee' and 'mm' from the "Ling 6" sounds clearly after me	They can repeat 'ah','oo', 'ee', and 'mm' from the Ling 6 sounds clearly when you say them in a quiet place from about a metre away, and when they're not looking at you.	In a quiet room, tell them you're going to make some sounds that you want them them to repeat. When they're not looking, say make of the sounds in your usual voice. See if they can copy you. They should be able to say 'ah' 'oo' 'ee' and 'mm' after you. Although previously they have been able to hear the sounds, being able to copy them correctly shows they are hearing them clearly. *Don't be tempted to make the sound longer or vary your pitch so it's easier to hear.*
3.8 Is able to tell the difference between 'ss' and 'sh' from the "Ling 6" sounds	The child makes different sounds when trying to say 'ss' and 'sh' even though they may not be correct. Or they might look at the picture of a baby sleeping when you make a 'shh' sound; and at the picture of a snake when you make a 'ss' sound.	Ask the child to make some sounds after you. Make the 'ss' sound and then the 'sh' sound. Do they sound different when they repeat them? You can also make the 'ss' sound to a picture of a snake or with a toy snake; and the 'sh' sound to a baby sleeping. When they know which sound goes with which picture, do they look at the snake when you make the 'ss' sound? And the baby when you make the 'sh' sound? *Don't be concerned if the child can't make the sounds properly as young children often can't do that until they're older. But being able to tell the difference between them shows they can hear different sounds at different frequencies.*
3.9 Says some words in familiar songs	When you sing a familiar song and pause before the last word, they say the word. For example, you sing *"Humpty Dumpty sat on a wall, Humpty Dumpty had a great..."*, they will say *"fall"*. The word may not always be clear but it sounds like it is supposed to.	Start singing a song that you often sing. Stop just before you get to a familiar word and look expectantly at them. Wait to see if they fill in the word. If you are singing *"Twinkle, twinkle little..."* they might say *"da"* or "*ar*" for star, or '*eeeee*' for *"wee-wee-wee-wee... all the way home'.*

PHASE 3: COMPREHENDING SIMPLE SPOKEN LANGUAGE

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
3.10 Understands 10 words or phrases	They understand 10 words or phrases without the help of gestures or actions. For example, when you are leaving somewhere and say *"Wave bye-bye"*, they start waving (when you aren't). If you say, *"Clap your hands"*, they start to clap.	Uses words or phrases that they know well. These could be something like, *"Give me a kiss"*, *"Put it in the bin"*, *"It's bath time"* or *"Come here"*. Try saying these without doing any actions or gestures and see if they show you they understand by doing the action.
3.11 Knows the names of 3 familiar people or pets	When you say, *"Where's Mummy/Daddy/Nonna?"*, they look around for them or find them in a photo. When you say, *"Give it to Mummy/Daddy/Uncle Bob"*, they will take it to the right person, even when you don't point or show them who to take it to.	Ask them, *"Where's Mummy/Daddy/Nonna?"* or someone they know well. They might look at the person, point to them, go to them or try and find them. If you are looking at a family photo they might point to the person, or say their name when they see them.
3.12 Hears me when I call their name in a noisy place	They will turn their head and look at you when you call them from about 3 metres away in a noisy place like a café, their preschool, or at the shops.	When you are at the shops or playground, call the child's name once from about 3 metres away. Do they turn and look at you?

PHASE 4: COMPREHENDING LANGUAGE IN DIFFERENT LISTENING CONDITIONS

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
4.1 Follows short directions that are unpredictable or silly	You give them silly instructions (e.g., *"Put your hat on your ear", "Put your shoe on your head", "Clap your feet"*) that they haven't heard before and they easily follow them, even when you don't use any gestures or actions to help.	Ask them to do something funny or unusual with an object (e.g., *"Brush your toes", "Shake your legs", "Put your ball on your head", "Put the car in the bath").* Do they laugh or do something else that shows they understand you?
4.2 Knows the actions for several different verses of a song	When singing a song with different verses and actions (e.g.,*"The wheels on the bus"*), they do the actions for each verse without you doing them first. So they may move their hands round for wheels, then *"beep the horn"* in the next verse. They can do this even when you mix up the order of the verses.	Sing *"Wheels on the bus"* with them. Wait for them to do the action. Try singing a few verses in different order and see if they do the matching actions. Being able to follow actions in different verses shows they are able to understand the words of a song, as well as recognise the tune. Try this with any familiar song with different actions , such as *'Row, row, row your boat', 'Open, shut them', or 'I'm a little teapot'.*
4.3 Repeats a 2 to 3 word sentence	They can repeat two or three words after you. For example: *"My turn", "Come here"* or *"Open the door".*	See if they can repeat after you some 2 or 3 word phrases you use often. These might be: *"More please", "Hi mummy", "Go car", "Stop now", "Down the stairs"* or *"Bye ball".* Say it a number of times and see if they try repeat it.
4.4 Sings a line of a familiar song	They often try to sing a whole line of a song which has at least 4-6 words. All the words may not be clear, or may just be babble sounds, but it sounds like the song and has a similar pattern.	Start to sing a familiar song. After the first line, pause and see if they sing the next part. *Ask them to sing you a song and see what they do.*
4.5 Can go and get two things that I ask for	They will go and get two things for you when you say something like, *"Go and get your bag and your shoes"*, or *"Can you get me a tissue and a spoon."*	Ask them get two familiar things, or things that are around them. This is developing their two- item auditory memory. *Try showing them that you want two items by holding up two fingers and counting each item.*
4.6 Follows 2 instructions when given in the same sentence	You ask them to do two things and they remember to do both. For example, *"Get your shoes and give them to Daddy"*, or *" Pick up your toys and then go and wash your hands."*	Put a couple of toys that they like to play with near them and ask them to do two things with the toys. For example, *"Give teddy a drink and then put him to bed"*, or *"Push the car then pick up the ball."*

PHASE 4: COMPREHENDING LANGUAGE IN DIFFERENT LISTENING CONDITIONS

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
4.7 Repeats all of the "Ling 6" sounds accurately	They are able to say all six sounds clearly after you when you are standing about a metre away and they aren't looking at you. **All** sounds should be clear and accurate.	Children learn language through hearing others talk, even when they're a small distance away. When you are about a metre away, and they're not looking at you, ask them to listen and say what they hear. Say each of the six sounds in a normal voice one at a time, without making them easier to hear in any way. Wait for them to repeat each sound before saying the next one.
4.8 Repeats words and phrases that they have heard on TV, tablet or phone	They repeat things they hear on the TV, phone or tablet. This could be phrases from their favourite shows.	Sit with them while they watch something on the TV or a digital device. See if they repeat anything they hear. You can repeat what you hear, and see if they can do the same. *There are a number of children's TV shows and apps that ask children questions, or ask them to repeat things.*
4.9 Repeats most of the sounds I say	When they copy your words, most of the sounds are correct. Note that they may have trouble with the 'r', 'th' and 'v' sounds.	Ask them to repeat the alphabet after you. They should be able to properly say most letters, except perhaps more difficult letters like 'j' 'v' 'x' and 'z'.
4.10 When I am more than 3 meters away, they can accurately repeat all of "Ling 6" sounds	They can make all the sounds clearly after you when you are at least 3 metres away and they aren't looking at you.	Listening from a distance can be difficult, but also necessary in everyday life. When you are about 3 metres away, and they're not looking at you, ask the child to listen and repeat what they hear. Say each of the six sounds in a normal voice one at a time, without making them louder because you are further away. Wait for them to repeat each sound before saying the next one. Being able to repeat all these sounds from 3m indicates they can hear the low, medium and high frequency sounds of speech from a further distance.
4.11 Follows instructions or answers questions they have heard on TV, tablet or phone	When they are watching their favourite TV show, they may call out an answer when they hear a question. When they are using an app that asks questions out loud they can answer. They can follow instructions from an app that gives directions out loud.	Repeating a digital signal is more difficult than repeating someone's voice. Answering questions or following directions from a digital signal is even harder. Try sitting with them while they're using a 'speaking' app or watching a children's show that asks questions e.g. 'what should xx do next?' 'Where did xx go?' *Record some questions or instructions on your digital device to make an electronic game of 'Simon Says'. Then see if they can follow them.*

PHASE 5: LISTENING THROUGH DISCOURSE AND NARRATIVES

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
5.1 Recognises a familiar person on the phone	They can recognise on the phone someone that they know. They know who is calling from the sound of the person's voice.	Ask someone they know (family member, close friend, teacher) to talk to them on the phone. Can they tell you who it is?
5.2 Says things that surprise me because I don't know where they heard it	They can say words or phrases that you haven't said or taught them directly. When they say something that you haven't heard, you might think, *"Where did they get that from!?"*	Children learn new words by their exposure to different words and different people talking. Listen closely to what they say and watch them when they are talking to you or their friends at child care/preschool or in the playground. Are they saying things that surprise you? Do they say things you've never heard before or that they don't normally say?
5.3 Guesses which item I am talking about when I describe something that they can see	They can guess correctly when you describe something close by or in front of them. For example, *"I'm thinking of the one that swims in the water, has fins and goes swish, swish"*, or *"Which one is a fruit, has seeds on the outside, is red, goes crunch and you had one for afternoon tea?"*	Have a few items and objects nearby (at least 3 or 4). Talk about one of them, without naming it, pointing to it, or looking towards it. For example, *"It's an animal, it lives on a farm, it gives us milk and it says "moo"*, or *"It's round, you can kick it, roll it, and bounce it"*. See if they look to the object you are talking about. They may reach for it, go and find it, or give it to you.
5.4 Can find a page in a familiar book if I describe what is on it	They turn to the page of a familiar book when you say something like, *"Let's find where the car is stuck in the mud"*, or *"Where's the green sheep asleep under a bush?"*	When you are reading a book that they know well with them, ask them to turn to the page that matches a specific description. For example, *"Find the page where the bull chases the farmer and he's running away"*, or *"Where's the page where the dragon chases the witch?"*
5.5 Is able to sing or say most of a familiar nursery rhyme or song	They sing or say most of a full nursery rhyme or song they know well, like *"Humpty Dumpty"*, *"Twinkle Twinkle"* or *"Happy Birthday"*. They get the rhythm and the tune right, although some of the words may not be very clear.	Take it in turns to choose a nursery rhyme or song to sing. See how much they can sing. You could also ask them to sing a song to a family member, pet or toy, or pretend to 'perform' a song to you.
5.6 Can answer simple questions about a favourite toy or activity	They answer questions about their favourite toy. For example: *"What is it?"*, *"Who bought it for you?"* *"Where did you get it?"* *"What does it do?"* *"How do you like to play with it?"* They may also answer questions about a favourite activity, such as, *"Where did you go?"* *"What did you do?"* *"Who were you with?"* *"What happened then?"*	Ask them about one of their favourite toys or things that they like to do. You can ask questions like, *"What is this?"*, *"What does it do?"*, *"Where did you get it?"* *"How does it work?"* *"What do you like most about it?"*.

PHASE 5: LISTENING THROUGH DISCOURSE AND NARRATIVES

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
5.7 Hears differences in similar sounding words and understands that this changes their meaning	They understand that changing a letter or two in words can change their meaning. For example, *"cat"* means something different to *"cats"*, and *"cat"* and *"cap"* are two different things.	Think of some very similar sounding words which they know that have a different meaning when one sound changes. For example: *tea/key; hat/bat; sock/socks; mum/mum's; jump/jumped.* Use these similar sounding words when you talk with them see if they can show you they understand the difference. They may do this by what they say or do, or by picking up when you use one in the wrong way.
5.8 Will fetch 3 things at once if I ask for them	They can find and bring back 3 things when you ask. For example: *"Can you get me a bowl, a cup and a spoon?"*; *"Let's put away the boat, the car and the plane"*, or *"Put your drink bottle, your hat and your lunchbox in your bag."*	Remembering a growing number of things builds a child's 'auditory memory' skills. Look around and ask them to get you three things that are nearby. For example, *"Give me the apple, the spoon and the teddy".* *You can also count on your fingers as you ask for them, and say, "I'm going to ask you for three things, are you ready? Give me the book, the horse and the hat".*
5.9 Has a short conversation with me if I start it by telling them what we are talking about	When you start a conversation with them, they can continue for a number of turns. For example, you might ask *"Where should we go today?"*, to which they reply, *"The park"*. When you comment further about the last trip to the park, they reply again, saying something like, *"No, you went on the slide and I went on the swing last time"*. Then they might say, *"But I want to go on the slide today."*	Start a conversation by explaining the topic. You could say, *"Let's talk about our visit to grandma's house; I had such a good time!"*. Pause for them to comment. If they don't say anything, ask a question like, *"What did you enjoy most?"* See if you can keep talking about the same topic for a few turns each, even when you make a comment but don't ask them a direct question. Learning to maintain conversations through listening is an important social skill. It helps children know how to appropriately answer and comment on what has been said, and be able to stay focused on a topic.
5.10 Follows 3 instructions in the same sentence	If you ask them to do 3 things, they can remember them. For example, *"Put your toys away, wash your hands and then sit at the kitchen table"*, or *"Put your cup in the kitchen, then go and put your bag in your room, and bring me a book"*. They don't necessarily need to complete them in order, but do need to be able to do them all without prompting.	Playing the popular children's game Simon Says can be a good way to check this. For example, *"Simon says stand up, clap your hands and touch your nose"*, or *"Simon says wave you hand, turn around and touch your toes".* *Tell or show them that they need to remember 3 things. You could say, "I'm going to say 3 things, let's see if you can remember them", or you could count on your fingers each time you say one of the things.* *These sort of cues can be useful strategies that children can use to help develop their auditory memory and listening span.*

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
5.11 Guesses what I'm describing from clues when I describe an object or an animal they know	They answer when you give clues about an item you are thinking of without using any actions as a hint. For example, *"I'm thinking of an animal, it swims in the water, has fins and sharp teeth"*, or *"I'm thinking of a fruit, it is yellow and you have to peel the skin to eat it."*	Explain you are going to play *'I spy'*, or a similar guessing game. Give clues using lots of descriptions and see if they can guess is the object. For example, *"I spy something that is green, has leaves, tall branches and grows in the ground"*, or *"I'm thinking about an animal that lives on a farm, gives us milk and says moo"*. *If you add the sound that an item makes, it turns into a much easier listening task. Try leaving out the sound and see if they can still guess the item: e.g. "I am thinking of an animal that lives on a farm, loves mud, is pink and has a curly tail" (i.e. don't make the 'oink oink' noise). This encourages children to use listening to put pieces of auditory information together.*
5.12 Accurately repeats sentences of 5 to 6 words after me if they know all the words	They will be able to copy you when you say a sentence like *"Yesterday I had a sandwich"* or *"I really like chocolate ice cream"*. However, they may not say all words correctly.	Think of a few sentences containing 5-6 words the child knows. Sit next to them and ask them to repeat what you say. For example, *"I'm going to say something and I want you to say it after me: "I like going to the beach."* *Point at yourself when you are talking, and then at them when it's their turn. If they repeat some and not all the words, encourage them to try to say all the words.*
5.13 Is able to tell me how 3 or 4 things are related when I name them	They able to complete sentences like *"Circle, square, triangle are all..."* or *"Strawberries, firetrucks and stop signs are all..."*	Think of some things that are related in an obvious way. They might be different types of the same thing (animals, fruit or cars), things that are used in the same way (e.g., driven, drawn or ridden), things that look the same (round, yellow, small), or things that live in the same place (under water, in the kitchen, on the farm). You could tell them that you are going to talk about some things that are all the same. *Give an example to start. For example, "Fish, sharks and seals all live... in the water." "Ok, your turn. Cars, motorbikes and trucks all... " Processing information about a number of items develops necessary auditory processing and comprehension skills.*

PHASE 5: LISTENING THROUGH DISCOURSE AND NARRATIVES

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
5.14 Brings back 4 things that I ask for in one sentence	When you ask for 4 things, they get them all without extra prompting. For example: *"Please get me a bowl, a cup, the salt and a spoon?"*, or *"Can you get the boat, the car, the train and the plane?"*. They don't need to get them in the order you gave them, but do need to remember all of them without any hints.	Packing or unpacking are great ways to check these listening skills. When you are next packing toys away, ask them to pack away 4 things. For example: *"Can you pack away the truck, the book, the teddy and the car?"*, or packing for school *"Can you put your lunchbox, your drink bottle and your hat in your bag"*. You can remind them before you start that you are going to ask for 4 things. If they forget one, repeat all 4 things, not just the one that they forgot.

PHASE 6: ADVANCED OPEN SET LISTENING

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
6.1 Can have a simple conversation with a familiar person on the phone	They can have a conversation on the phone with someone they know. They may ask or answer questions, make comments, or tell the other person things without you helping them.	As them which family member or person they would like to call, and help them decide what they'd like to talk about. For example: *"Who would you like to call to tell about your swimming lesson today?"* Can they answer the person's questions? What do they tell them? Do they have a few turns back and forth? *Using your phone's speaker setting lets you hear both sides of the conversation.*
6.2 Guesses a less familiar item from clues that I give	They identify an object you describe that's not common, and when you use less obvious clues. For example: *"I'm thinking of something in the sky that gives us heat and light"*, or *"I'm thinking of how you feel if you lose your favourite toy, or if you fall over and hurt yourself."*	Thinking of things that are more abstract or less common can be difficult, particularly in a listening task. Try telling them that you are going to give them clues about something that might be tricky to think of (and do it without using any pictures or toys as visual cues). It might be a number, a concept, a feeling, an idea, a characteristic or an event.
6.3 Remembers 4 things that happened in a story in the right order after reading a book together	When you tell them a new story, they retell the story to you or someone else and remember at least four things that happened in the right order.	Explain to them you are going to tell them a story, and that they need to remember 4 things that happened in the right order. You might tell them about your day and ask them to retell you the 4 things you did in the right order.
6.4 Easily repeats a sentence of 8 to 10 words after me, even when one or two of the words are new to them	They are able to accurately say sentences of 8 to 10 words, even when they may not know all the words. Each of their words may not sound exactly like yours, but they have a go at saying all of them, even if they don't know exactly what they mean.	Tell them you are going to read a sentence that they need to repeat it. You could find some sentences from new or unfamiliar books, or make some sentences up. Some examples are: *"I love all the flowers but the peony is my favourite"*, or *"Tomorrow we are going to have sponge cake to celebrate Karamay's birthday"*. As children's listening skills develop, so should the length and amount they are able to recall through listening. They should also be able to incorporate new and unfamiliar words.

PHASE 6: ADVANCED OPEN SET LISTENING

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
6.5 Understands that the WAY something is said changes the meaning of the sentence.	Understands that the **way** something is said can change the meaning of a sentence. This could be the pitch, stress or emphasis on a word or part of the sentence. For example, "*You like it?*" with rising intonation is a question, requiring an answer, however *"You like it"* with no rise in pitch is a statement that doesn't need an answer. "He isn't driving to Sydney **tomorrow**" implies that he is driving another day. "He isn't **driving** to Sydney tomorrow" implies he is going by another method such as flying. "**He** isn't driving to Sydney tomorrow" implies that he isn't going but someone else is.	See if the child can tell you if you are saying a question or not. Say sentences with rising intonations and see if they can correctly tell you which ones are questions. You can also ask them to say something back to you, and see if what they say is appropriate given the emphasis you are using. E.g. Say "***I'm*** not going to eat the apple" with the emphasis on the **I'm** . The appropriate thing to say back would be 'Who is?' Then try changing the emphasis to say *"I'm not going to eat the **apple**"*, to which the appropriate response would be *"So what are you going to eat?"* or *"I'm not going to **eat** the apple"*, to which the appropriate response would be *"What are you going to do with it then?"* The ability to pick up cues in how we say things makes conversations easy. Misinterpreting them makes communication difficult and disjointed.
6.6 Is able to follow a long, complicated instruction that has more than 5 components	You give them long instructions and they follow them easily, without you needing to simplify them or make them shorter. You can say things like, *"Go to your bedroom, find your sports shoes in the drawer and put them by the front door"*, or *"Pick up your shirt, socks and shorts from the bathroom and put them in the washing basket in the laundry"*, or *"Draw a pink circle, then a blue triangle and write your name at the bottom of the paper."*	Think about when you ask them to do things at home or during the day. Do you give long, complicated instructions and can they follow them? Remember that children often don't follow instructions because they don't want to, not because they haven't heard. So make sure it's something they really want to do! This could be in games like "Simon Says", or "Let's Draw" during which you deliberately give 4-5 part instructions. Or it could be when they are asking you for something they want. For example, *"You can have some ice-cream once you have put your shoes away, packed up your bag, your plate is in the sink and you're sitting at the table'.*
6.7 Easily repeats a sentence of 8 to 10 words they have heard on TV, tablet or phone, even when one or two of the words are new to them	When they are using an App on a digital device, they can repeat instructions that they hear, or can repeat 8 to 10 word sentences from shows or movies. They may repeat some words incorrectly, particularly new ones, but will give them all a go.	There are several ways you can do this. You may simply hear them repeating long sentences from the TV or a digital device. You could also pause what they're looking at "What did you hear?", or you could play a game that you are going to take it in turns repeating the longest sentence you hear. *Record some long sentences on your digital device, including words they might not know. See if they can repeat the whole sentence.*

PHASE 6: ADVANCED OPEN SET LISTENING

	WHAT THIS CAN LOOK LIKE	HOW TO CHECK
6.8 Follows instructions, has a conversation or can listen to a story and answers questions about it when we are in a noisy place	When you are somewhere noisy like the shops, the park, a café or school, they easily hold a conversation with you, follow long instructions, or listen to a story and tell you or answer questions about it.	Life is often noisy, and listening in real-life situations can be challenging. Think about when you are in noisy places like shopping malls or cafes. Can they follow what you are saying easily when you are explaining something or telling them a story? Can they tell you what you've said? Can they answer questions about what they heard? Do they switch off? Do you have to encourage them to listen or repeat what you are saying? Do you need to move closer for them to pay attention?
6.9 When we're somewhere noisy, they can have a conversation on the phone, or they can listen to a story on a digital device and answer questions or tell you about it	They have a conversation on the phone when it's noisy around them (e.g., in the playground, outside when it's windy), or they listen to something on a digital device at a cafe or at the shops and can talk about it afterwards. They can answer questions or tell you about it in way that shows they could hear it.	Listening to digital signals is more difficult than voices, and even harder in noisy situations. Think about how well they can listen to and use a digital signal in these loud everyday environments. This could be a conversation on the phone in which they use appropriate comments, questions and answers), or they are able to answer questions about a story they have listened to or a show they have watched. *Make sure they include information that could only have come from what they heard, as they can pick up so much visually.*

ACKNOWLEDGEMENTS

Auditory Skills Checklist, (2004) Adapted by Karen Anderson, from Auditory Skills Checklist by Nancy S. Caleffe- Schneck, M.Ed., CCC-A (1992).

Auditory Skills Program, New South Wales Department of School Education (https://www.det.nsw.edu.au/)

Archbold, S., Lutman, M. E., & Marshall, D. H. (1995). *Categories of Auditory Performance.* Annals of otology, rhinology & laryngology. Supplement, 166, 312.

Cochlear Limited, *Integrated Scales of Development.* (2009)

Cole, E. B., & Flexer, C. A. (2007). *Children with hearing loss: developing listening and talking birth to six:* Plural Pub. Estabrooks, W. (1998). Cochlear implants for kids: Alexander Graham Bell Association for the Deaf.

Estabrooks, W., MacIver-Lux, K., & Rhoades, E. A. (2016). *Auditory-Verbal Therapy: For Young Children with Hearing Loss and Their Families, and the Practitioners Who Guide Them:* Plural Publishing.

Joint Committee on Infant Hearing of the American Academy of, P., Muse, C., Harrison, J., Yoshinaga-Itano, C., Grimes, A., Brookhouser, P. E., . . . Martin, B. (2013). Supplement to the JCIH 2007 position statement: principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics,* 131(4), e1324- 1349.

Ling, D. (1976). *Speech and the hearing-impaired child: Theory and practice:* Alexander Graham Bell Association for the Deaf Washington, DC.

E., Martin, B. (2013). Supplement to the JCIH 2007 Position Statement: *Principles and Guidelines for Early Intervention After Confirmation That a Child Is Deaf or Hard of Hearing.* Pediatrics, 131(4)

Pollack, D., Goldberg, D. M., & Caleffe-Schenck, N. (1997). *Educational audiology for the limited-hearing infant and preschooler: An auditory-verbal program.* Charles C Thomas Pub Limited.

Simser, J.I. (1993). Auditory-verbal intervention: Infants and toddlers. *Volta Review,* 95(3): 217-229.

Tuohy, J., Brown, J. and Mercer-Mosely, C., 2001, St. Gabriel's Curriculum for the Development of Audition, Language, Speech, Cognition, Trustees of the Christian Brothers, St. Gabriel's School for Hearing Impaired Children, Sydney, NSW, Australia.

Walker, B. (2009). *Auditory Learning Guide.* (http://www.firstyears.org/c4/alg/alg.pdf)

TERMS OF USE

QUESTIONS AND ENQUIRIES

Questions, please contact enquiries@shepherdcentre.org.au

The Shepherd Centre
Giving deaf children a voice

Appendix I: CLTD 5703 Clinical Investigation Report

Normative Data for the Functional Listening Index – Paediatric (FLI-P®)

Pages 280-307 ("Appendix I: CLTD 5703 Clinical Investigation Report Normative Data for the Functional Listening Index - Paediatric (FLI-P®)") of this thesis have been removed as it contains confidential material.