

LITERACY DEVELOPMENT IN SCHOOL-AGED CHILDREN WITH
SIMULTANEOUS BILATERAL COCHLEAR IMPLANTS

CATERINA RUGGIRELLO

A DISSERTATION SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

GRADUATE PROGRAM IN EDUCATION
YORK UNIVERISTY
TORONTO, ONTARIO

April 2017

© Caterina Ruggirello, 2017

ABSTRACT

This 2-year study investigated the literacy development of school-aged children who were born deaf and received simultaneous bilateral cochlear implants at the age of 2 years old or younger. All participants lived in Ontario, Canada, and were identified with a hearing loss through UNHS or an Audiologist between birth and 21 months of age. Eight students, 2 females and 6 males, ranged in age between 5.5 and 9.1 years old, placing them in senior kindergarten to Grade 4 at initial time of testing. One participant withdrew after Phase 1, therefore data analysis was conducted on 7 participants.

Levels of achievement in reading, writing, language, and phonological processing were measured through standardized assessment tools appropriate for school-aged children: the *Clinical Evaluation of Language Fundamentals—Fifth Edition* (Wiig, Semel, & Secord, 2013), the *Peabody Picture Vocabulary Test, Fourth Edition* (Dunn & Dunn, 2007), *The Comprehensive Test of Phonological Processing* (Wagner, Torgesen, & Rashotte, 2001) and the *Woodcock-Johnson Test of Achievement—III* (Schrank, Mather, & Woodcock, 2004).

Writing samples were assessed using *A Guide to Effective Instruction in Writing, Kindergarten to Grade 3* (Ontario Ministry of Education, 2005), and *The Ontario Curriculum: Exemplars, Grades 1–8: Writing* (Ontario Ministry of Education and Training, 1999). Overall, the results of the study indicate that this cohort of 7 students demonstrates average achievement in reading, receptive and expressive language,

vocabulary, and phonological awareness that is within age norms. It is only in the area of writing that age-appropriate outcomes are not being achieved. It is also worth noting that, of the children in this group, those who received their implants before 12 months showed the strongest performance in all areas.

DEDICATION

With love to my family who have always been a source of strength and encouragement,
and a voice of reason.

ACKNOWLEDGMENTS

Great appreciation to Professor Connie Mayer for guidance and support throughout this research project and over the past 18 years. Appreciation also extends to Professor Pam Millet for her assistance with data analysis and reviewing of the paper.

Acknowledgement to Janet Casali (SLP), Patricia Civitarese, and Michelle Sylvester for taking the time to be my second pair of eyes on the standardized test scores and writing samples.

My deepest gratitude to the participating children and their families for giving up full days of family time to allow me into their homes for two consecutive years so that I could complete my research. Thank you for giving to the field of deaf education and assisting us professionals in supporting your children as learners.

I am indebted to my brother for sculpting an idea into a possibility. I am grateful to my mother, who kept me on track on the road to completion. To my father, who I know is always with me. I am appreciative of Glenn for his patience in having many meals on a table swamped with papers and a laptop. And I thank the many supportive family and friends.

TABLE OF CONTENTS

Abstract	ii
Dedication	iv
Acknowledgments	v
Table of Contents	vi
List of Tables	ix
List of Figures	x
List of Illustrations	xi
Abbreviations and Definitions of Terms	xii
Introduction	1
Chapter One: The Changing Landscape for Literacy Development	2
Understanding the Literacy Learning Challenge	3
Outcomes in Reading	5
Outcomes in Writing	7
The Changing Context	9
Universal Newborn Hearing Screening (UNHS)	10
Cochlear Implant (CI) Technology	16
Cochlear Implantation in Ontario	18
Unilateral Cochlear Implantation	19
Bilateral Cochlear Implantation	21
Sequential versus Simultaneous Implantation	28
Chapter Two: Literature Review	33
Spoken Language Development	33
Literacy Outcomes	37
Research Up to 2005	40
2006 to the Present	48
Reading	48
Writing	64
Research Moving Forward	69
Chapter Three: Methodology	72
Participants	72
Participant 1: Lucia	75
Participant 2: Sophia	77
Participant 3: Steven	79
Participant 4: William	81
Participant 5: Robert	82
Participant 6: Andrew	83
Participant 7: Gregory	85

Participant 8: Kevin	86
Measures	87
Language	87
Phonological Processing	90
Academic Achievement	92
Writing	94
Speech and Auditory Skills	95
Procedures for Administering Standardized Tests	96
Inter-Scorer Reliability	97
Family Observations: Questionnaire and Interview	97
Interview	98
Procedures for Parent Questionnaire and Interview	98
Ethics	99
Chapter Four: Results	100
Observations of Participants During Testing	100
Lucia	100
Sophia	101
Steven	101
William	101
Robert	102
Andrew	102
Gregory	102
Overall Group Performance	103
Oral Language	105
Performance in Reading	108
Phonological Processing	110
Vocabulary	111
Reading Comprehension and Reading Fluency	111
Writing	113
Andrew	117
Gregory	118
Robert	120
William	122
Steven	124
Sophia	127
Lucia	130
Speech and Auditory Skills	133
Connections Between Oral Language, Reading, and Writing	134
Age of Implantation	136

Chapter Five: Discussion	137
Language, Reading, and Writing Outcomes	138
Implications for Research	142
Implications for Practice	143
Limitations	145
Concluding Thoughts	146
References	148
Appendices	173
Appendix A: Parent Questionnaire	173
Appendix B: Parent/Caregiver Interview Questions	184
Appendix C: Request for Informed Consent (Parent)	186
Appendix D: Request for Informed Consent (for Minor Child)	188

LIST OF TABLES

Table 1: UNHS Across Canada

Table 2: Demographic Information

Table 3: Participant Audiological and Amplification History

Table 4: Overall Group Performance on Standardized Tests of Reading, Writing, Language, and Phonological Processing Skills

Table 5: Individual Overall Phase 2 Scores

Table 6: Participants' Writing Performance

Table 7: Comments on Andrew's Writing Performance

Table 8: Comments on Gregory's Writing Performance

Table 9: Comments on Robert's Writing Performance

Table 10: Comments on William's Writing Performance

Table 11: Comments on Steven's Writing Performance

Table 12: Comments on Sophia's Writing Performance

Table 13: Comments on Lucia's Writing Performance

Table 14: Reading and Writing Performance

LIST OF FIGURES

Figure 1: Oral Language Results

Figure 2: Performance in Reading

Figure 3: Phonological Processing

Figure 4: Spoken Language Comprehension and Reading Comprehension

Figure 5: Age of Implantation

LIST OF ILLUSTRATIONS

Illustration 1: Andrew's Writing Sample in Phase 1

Illustration 2: Andrew's Writing Sample in Phase 2

Illustration 3: Gregory's Writing Sample in Phase 1

Illustration 4: Gregory's Writing Sample in Phase 2

Illustration 5: Robert's Writing Sample in Phase 1

Illustration 6: Robert's Writing Sample in Phase 2

Illustration 7: William's Writing Sample in Phase 1

Illustration 8: William's Writing Sample in Phase 2

Illustration 9: Steven's Writing Sample in Phase 1

Illustration 10: Steven's Writing Sample in Phase 2

Illustration 11: Sophia's Writing Sample in Phase 1

Illustration 12: Sophia's Writing Sample in Phase 2

Illustration 13: Lucia's Writing Sample in Phase 1

Illustration 14: Lucia's Writing Sample in Phase 2

LIST OF ABBREVIATIONS

AABR: automated auditory brainstem response

AOAE: automated otoacoustic emissions

AVT: auditory verbal therapy

BCI: bilateral cochlear implants

CAP: categories of auditory performance

CELF: Clinical Evaluation of Language Function

CI: cochlear implant

CMV: cytomegalovirus

CT scan: computerized tomography

CTOPP: Comprehensive Test of Phonological Processing

DHH: deaf and hard-of-hearing

FDA: Food and Drug Administration

FM: Frequency Modulation system

HA: hearing aid

HSC: Hospital for Sick Children

IHP: Infant Hearing Program

JK: junior kindergarten

LRT: learning resource teacher

M: mean

MRI: magnetic resonance imaging

OME: Ontario Ministry of Education

PPVT: Peabody Picture Vocabulary Test

PSB: Provincial School Branch

SARS: Severe Acute Respiratory Syndrome

SBCI: simultaneous bilateral cochlear implants

SD: standard deviation

SERT: support education resource teacher

SES: socioeconomic status

SIR: Speech Intelligibility Rating

SK: senior kindergarten

SL: sign language

SLP: Speech and Language Pathologist

TODHH: teacher of the deaf and hard-of-hearing

TH: typical hearing

UNHS: Universal Newborn Hearing Screening

WJ: Woodcock-Johnson

WM: working memory

INTRODUCTION

As a consultant teacher of the deaf and hard-of-hearing, my role is to support teachers working with students with a hearing loss in the mainstream across Ontario. Over the past 15 years I have seen an increase in children with a hearing loss with one or two cochlear implants, received sequentially or simultaneously, attending their local school or a Provincial School for the Deaf. In the last decade there has been an increase in research demonstrating the literacy outcomes of children with cochlear implants. Because of the small numbers of children with a hearing loss compared to hearing children, research usually combines unilateral implantation, sequential bilateral implantation, and simultaneous bilateral implantation, demonstrating varying results. Much of the research shows outcomes in language development and reading levels of children with cochlear implants. Only recent studies (e.g., Mayer & Trezek, 2015; Mayer, Watson, Archbold, Yen Ng, & Mulla, 2016; Sarant & Bennet, 2015) discuss the academic outcomes of students with cochlear implants that can assist professionals in supporting children with CIs in the mainstream classroom.

In 2006, children began receiving simultaneous bilateral cochlear implants. Today those children are in junior grades. With current students with SBCIs and more entering the school system, I feel it is a professional obligation to these students to be able to understand their strengths, identify needs, place appropriate accommodations, and understand the teaching strategies to provide best access to learning in a classroom while supporting the student with a hearing loss to achieve academic success and well-being.

CHAPTER ONE

THE CHANGING LANDSCAPE FOR LITERACY DEVELOPMENT

A profound hearing loss can impose a serious risk to literacy development. It has been consistently reported that the reading and writing achievement of deaf¹ students lags behind that of their hearing age peers (Bochner & Albertini, 1988; Conrad, 1979; J. A. Holt, 1993; J. A. Holt, Traxler, & Allen, 1997; King & Quigley, 1985; Mayer, 2010; Mayer & Trezek, 2011; Paul, 1998, 2001; Quigley & Paul, 1984; Trezek, Wang, & Paul, 2010) with a reported median reading level of Grade 4 by high school graduation (Traxler, 2000). Only about 10% read above the Grade 8 level (Bochner & Albertini, 1988), with more than 30% of the population being defined as illiterate (Lou, 1988). Trezek, Wang, and Paul (2011) described the annual growth rate for deaf students to be about 0.3 grade levels per year compared to roughly 1.0 grade level for many hearing students. The situation has not changed in the last 40 years (Qi & Mitchell, 2012). These results have remained constant irrespective of the nature of the assessments used (Paul, 1998), and the language approach or modalities employed (see Marschark & Spencer, 2009; Mayer & Trezek, 2015; P. E. Spencer & Marschark, 2010). For many deaf individuals, poor literacy levels present one of the most significant challenges to

¹ I use the term *deaf* to refer to any individual identified with a hearing loss, from mild to profound, irrespective of the use of amplification (i.e., individuals with cochlear implants are deaf). I am not making a distinction between *deaf* and *Deaf*, as I do not view this difference as germane to my discussion of literacy development.

participating in higher education and gaining future employment in careers that require higher literacy proficiency, such as law, medicine, or engineering.

Understanding the Literacy Learning Challenge

It has been well documented that for typically developing hearing children, literacy development hinges on language development. In the usual course of development, the child comes to the task of learning to read and write with a foundation in the spoken form of the language to be read and written; that is, they already know the language of the text—its phonology, morphology, semantics, and syntax—before they attempt to read and write it. It can be argued that for hearing children this language development begins before birth. Access to auditory information begins in utero as early as 20 weeks gestation, with a developing fetus becoming able to respond to external sound and discriminate their mother’s voice from other women’s voices (Hoff, 2009; Houston et al., 2012). There is also evidence that such prenatal exposure affects the development of speech perception (see Houston, 2011, for a review), as being able to hear the sounds of the ambient language plays an important role in shaping infants’ speech perception throughout the first year of life (Houston et al., 2012).

When a child is born with a developed cochlea, the processing of auditory information then develops substantially in postnatal periods (Gordon, Tanaka, Wong, & Papsin, 2008). By 6 months of age, infants have acquired the phonemes found in their native language, having lost the phonemes not used in their native language (Houston, 2002; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Werker & Tees, 1999). By 3 years of age, most hearing children have acquired basic language skills (Hoff, 2009). In

contrast, many deaf children have not developed age-appropriate speech and language in these early years (Mayer, 2007), with the consequence that the activity of learning to read and write becomes an exercise in learning the language itself (Mayer, 2007; Mayer & Trezek, 2011, 2015; Paul, 1998).

This lack of age-appropriate language development can be accounted for by considering the four conditions that need to be in place for any child to acquire a language. A child must have exposure: (a) in quality and quantity, (b) to an accessible language, (c) while engaged in meaningful activity, (d) with others who are already capable users of the language (for a discussion see Mayer, 2007). As a consequence of their hearing loss, deaf children do not have ready access to the target spoken language. Thus even if there is the potential for interaction in the environment (i.e., the parent provides a rich language environment), the child cannot engage in meaningful interaction with parents and others as the spoken language is not available to them. This is the scenario for the vast majority of deaf children as over 95% are born to hearing parents whose first language is spoken (i.e., auditory-oral) (Kushalnagar et al., 2010; Lieberman, Hatrak, & Mayberry, 2014; Marschark & Spencer, 2005).

As a result many deaf children do not develop age-appropriate language in the critical years from birth to 3, meaning that they are attempting to learn pre-literacy skills with a very limited foundation in the language of the text—and also limited background knowledge as a consequence of impoverished input. The research indicates that deaf learners encounter challenges with almost all aspects of the literacy learning process (for reviews see Mayer & Trezek, 2015).

Outcomes in Reading

Quigley and Paul (1984) found that for deaf children, all or most of the multiple processes involved in reading (i.e., word recognition and processing, understanding figurative language, making inferences) were not developed to the same level as in hearing children by the beginning stages of reading. Archbold et al. (2008) concluded that the process of learning to read for typically developing hearing children depends on extensive knowledge of both the vocabulary and the grammar that they will encounter in their reading (p. 1472). The vocabulary of a typically developing child increases by approximately 3,000 new words every year or roughly eight new words each day (Trezek et al., 2010). Most words in a child's vocabulary are learned indirectly through everyday experience consisting of conversations with adults, listening to adults read to them, and reading extensively on their own. The more oral language experiences children have, the more word meanings they acquire (Trezek et al., 2010). Vocabulary size among deaf and hard-of-hearing children has consistently been found to be smaller on average than that of hearing children, both reflecting their language delay and providing a barrier to reading and writing, negatively influencing the comprehension process (P. E. Spencer and Marschark, 2010; Trezek et al., 2010).

More specifically, deaf children often display delays in vocabulary development not only in content items (i.e., nouns and verbs), but also in function words (i.e., determiners, prepositions, and pronouns). Function words have little lexical meaning but are important components of the English language in providing comprehension. Children begin the acquisition of function words in the early stages of language development

through oral language. However, these function words are much more difficult to learn and generalize for deaf children for several reasons: (a) they are difficult to hear, (b) they do not carry intonational emphasis or stress, and (c) they are frequently contracted (e.g., *haven't, I've*), further obscuring their identification (Trezek et al., 2010).

In addition to vocabulary, delays are also evident in phonology, morphology, semantics, and syntax. Phonological awareness is a building block for language development and crucial in predicting beginning reading ability. These building blocks of language lead to literacy because pairing a phoneme to a grapheme is fundamental to the process of reading (Trezek et al., 2010). Studies have shown that children who are better at skills associated with phonological and phonemic awareness, such as the abilities to recognize when words rhyme and to identify initial sounds of words, are more likely to develop better reading skills than those for whom these skills are absent or inconsistent (Ambrose, 2009; National Reading Panel, 2000; Snow, Burns, & Griffin, 1998). Factors correlated with and predicting phonological awareness are speech perception and production, general language abilities, receptive vocabulary, and print knowledge. Speech perception is the process of transforming a continuously changing acoustic signal into discrete linguistic units. Rvachew (2006, cited in Ambrose, 2009) identified speech perception abilities during preschool as one of the variables that explained significant variance in phonological awareness abilities during kindergarten for children with speech-sound disorders.

The awareness that written spelling systematically represents spoken words is referred as *the knowledge of alphabetic principle*. Difficulty in understanding and using

the alphabetic principle at the beginning of reading acquisition can be considered the first potential stumbling block that is “known to throw children off course on the journey to skilled reading” (Snow et al., 1998, p. 4). Deaf students are at risk of stumbling at this stage as they often do not acquire sufficient knowledge of the alphabetic principle to access print as a result of their limited access to the phonological aspects of English (Trezek et al., 2010).

Studies of both morphology and syntax, specifically the understanding and use of simple and complex sentences, reveal that these areas present problems for deaf students in spoken language, reading, and writing (Bochner & Albertini, 1988; King & Quigley, 1985; Quigley, Power, & Steinkamp, 1977). It has been reported that the average 8-year-old hearing student scored higher on comprehension of syntactic structure than the average 18-year-old deaf student (Quigley et al., 1977). Miller (2005) found that although prelingually deafened children can identify many words in isolation, they lacked the syntactic knowledge necessary for proper processing of words at the sentence level. Figurative language (e.g., idioms, similes, metaphors, idiomatic expressions) is another area of difficulty. When comparing deaf students with their hearing peers, research indicates that the performance of deaf readers on comprehension of figurative language is quantitatively reduced and barely varies across ages (Trezek et al. 2010).

Outcomes in Writing

A review of studies dating from the early 20th century to the present day reveals a consistent finding: deaf writers do not write as well as their hearing age peers, with the writing levels mirroring the outcomes which have been reported for reading (Mayer,

2010). It has been reported that the typical 17- to 18-year-old deaf student writes at a level comparable to that of an 8- to 10-year-old hearing child (Paul, 1998, 2001), “failing to master elements of English morphology, grammar structures, and transformational grammar rules, even by age 21” (Yoshinaga-Itano, Synder, & Mayberry, 1996, p. 11). In contrast to hearing peers who produce stories with adult structures by age 6, the vast majority of deaf students by age 18 still do not use minimal components of a story in spontaneously written narratives.

Studies have indicated that in their writing deaf students tend to repeat words and phrases, overuse and misuse articles, use fewer adverbs, make errors of verb tense and agreement, misuse prepositions, use fewer and inappropriate conjunctions, and make errors with pronouns, verbal auxiliaries, and inflectional and derivational morphemes. Overall their sentences tend to be shorter and lack complexity, and are often limited to subject-verb-object sentence patterns (Albertini & Schley, 2003; Bochner & Albertini, 1988; Quigley & Paul, 1984; Webster, 1986; see Mayer, 2010 for a review and discussion).

Hearing and deaf children differ in their early spelling attempts. Hearing children invent spelling based on sound/symbol relationships. Mayer and Moskos (1998) found that young deaf children used print-based, speech-based, and sign-based strategies in their early spelling. More recently it has been argued that deaf writers do make more frequent and qualitatively different spelling errors than their hearing counterparts as a consequence of their inability to hear acoustically based languages and thus develop the phonological

capacity required for accurate encoding (Alamargot, Lambert, Thebault, & Dansac, 2007).

Mayer (2007) argued that deaf children's emergent literacy development begins similarly to hearing children's, but thereafter is not entirely similar to the development of hearing children. She compared writing samples of 4- and 7-year-old deaf children to same-aged hearing peers. Mayer (2007) found little difference between the writing of the hearing and deaf children at the earliest phases of literacy development, when children learn to distinguish between drawing and writing and acquire fundamental concepts about print. At what she refers to as the third level of development, however, when literacy learners come to understand the alphabetic principle and use letter-sound relationships to encode their face-to-face language, the writing samples of the deaf children became quite different from those of their hearing peers. Mayer (2007) concluded that at this third stage of development, which is central to the move from emergent to early conventional literacy, "the trajectories of hearing and deaf children diverge" (p. 412). She suggested that most young deaf children do not readily develop conventional reading and writing abilities because they have not attained sufficient familiarity with the lexicon and syntax of English nor developed the phonological skills necessary to achieve fluency.

The Changing Context

As discussed above, there is an historic and longstanding gap in language and literacy development in deaf children relative to their same-aged hearing peers. Over time, this gap often continues to grow, and as deaf children move through school they may experience increasing academic difficulties (Harris & Terlektsi, 2011), underscoring

the importance of the early years, and particularly the importance of early identification of a hearing loss. If identified early, deaf children can be provided with access to language during the critical years (i.e., via hearing technologies and/or visual communication) along with access to programs and services in order to assist families in supporting language and literacy development. It has been shown that deaf children who have had early and complete access to language do better academically than those for whom language acquisition has been delayed, with knowledge of spoken English shown to be an important concurrent predictor of reading ability for deaf children, and also an important longitudinal predictor of reading ability between the ages 7 and 10 years (Archbold et al., 2008).

Research has demonstrated that children identified with significant hearing loss during the first 6 months of life, and then aided and provided with appropriate early intervention, demonstrated significantly better expressive and receptive language scores, scoring 20 to 40 percentile points higher on school-related measures than children identified after 6 months of age (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Arguably, therefore, if it were possible to provide access to language at an earlier age, it would increase the possibilities for age-appropriate literacy development.

Universal Newborn Hearing Screening (UNHS)

Hearing loss is one of the most common conditions present at birth and occurs more frequently than any other condition that is currently being screened (Picard, 2011; Simonsen, Kristoffersen, & Hyde, 2009). According to a range of studies and surveys conducted in different countries, approximately 0.5 to 5 in every 1,000 neonates and

infants have congenital or early-childhood-onset sensorineural deafness or severe to profound hearing loss (World Health Organization, 2010). Historically, the median age of identification of hearing loss was 5.0 years (interquartile range: 3.6 to 7.0) (Fitzpatrick, Whittingham, & Durieux-Smith, 2013; Patel & Feldman, 2011). Today, under a program known as Universal Newborn Hearing Screening (UNHS), the median age is 0.8 years (interquartile range: 0.3 to 2.3) (Fitzpatrick et al., 2013). UNHS can identify unilateral (one ear) and bilateral (two ears) loss, and hearing-loss levels from mild to profound. UNHS aims for screening by 1 month of age and confirmation of the diagnosis by 3 months, with intervention by 6 months (Hearing Foundation of Canada, 2011; Patel & Feldman, 2011). This is also referred to as “1-3-6” Early Hearing Detection and Intervention (EHDI) goal (Krishnan & Van Hyfte, 2014). The program also aims to have a child fitted with amplification if desired by the family within 1 month of confirmation of hearing loss (Krishnan & Van Hyfte, 2014).

The implementation, degree of implementation, and coverage of UNHS or EHDI programs varies greatly from country to country, and may differ from one region to another within the same country (World Health Organization, 2010). In unscreened children, as is the current situation in some parts of Canada, the average age at diagnosis continues to be approximately 24 months (Patel & Feldman, 2011). Factors contributing to untimely diagnosis and/or loss of follow-up may include low-frequency hearing loss and/or minimal/mild degrees of HL, middle ear fluid, auditory neuropathy/dyssynchrony, other medical conditions in the newborn, parental noncompliance, distance from the testing facility, and information gaps between hospitals, parents, physicians, and

audiologists, as well as a limited number of audiologic testing facilities (Krishnan & Van Hyfte, 2014). Although national guidelines and benchmarks exist for providing UNHS for the purpose of early diagnosis and treatment of hearing loss in infants, there is no uniform national policy in Canada.

It is estimated that there are up to 1,100 new cases of hearing loss in newborns annually in Canada with some researchers placing the figure closer to 2,000 (Alberta College of Speech-Language Pathologists and Audiologists, 2008). In 2016, the Hearing Foundation of Canada reported more than 2,000 children are born with a hearing loss in Canada every year, making it one of our country's most common birth defects.

Approximately six in every thousand babies born in Canada have some degree of hearing loss, including profound deafness (Hearing Foundation of Canada, 2016). Even though the federal government has given the directive that "UNHS shall be offered," UNHS could not be "mandated" by the Canadian government because such screening is beyond the basic coverage mandated by the health care system, and each province must decide whether to fund newborn hearing screening as an additional service (Simonsen et al., 2009; World Health Organization, 2010). More than half of the country ensures partial or full coverage and the others are working on compliance (Hearing Foundation of Canada, 2011, 2016; World Health Organization, 2010). For detailed information see Table 1.

Table 1. UNHS Across Canada

Province/Territory	Rating	Level of Service
British Columbia	Excellent	<ul style="list-style-type: none"> • 2007 implemented screening for babies in the NICU with stays over 48 hours • October 2007, started a phased implementation of screening well babies • Strong comprehensive EHDI program, protocol standards and database • 97%+ of babies screened • Utilizes remote assessment to provide services in remote areas • Follow-up, tracking of births and outcomes
Ontario	Good	<ul style="list-style-type: none"> • 2002 implemented the Ontario Infant Hearing Program (IHP) for newborns in all birthing hospitals • IHP provides universal newborn hearing screening, surveillance for those at risk for developing hearing impairment in early childhood, audiology assessment, hearing aid selection, and follow-up audiology visits and communication/language development services for children identified with permanent hearing impairment until Grade 1 entry. • Utilizes a remote computer system enabling audiologist to perform diagnostic ABR, from an urban centre, in remote locations • 90%+ of babies screened
Nova Scotia	Good	<ul style="list-style-type: none"> • 2007 “A Sound Start Campaign” program implemented in all 10 birthing centres • 95%+ of babies screened • Follow-up, tracking of births and outcomes • Some limitations in reporting
Prince Edward Island	Good	<ul style="list-style-type: none"> • Since 2005, two hospitals that provide obstetrical service have provided UNHS programs • 95%+ babies screened • Screening only by request outside of main hospital • Program with standard and follow-up • Program does not fully track births or outcomes

New Brunswick	Good	<ul style="list-style-type: none"> • UNHS has operated in each of the New Brunswick health authorities since 2002 • 95%+ of babies screened • Follow-up, tracking of births and outcomes • Some limitations in reporting
Newfoundland and Labrador	Insufficient	<ul style="list-style-type: none"> • The Canadian Hard of Hearing Association in Newfoundland and Labrador raised funds for screening equipment to run a UNHS program without support from the provincial government • approximately 2004 UNHS began • exists in 8 of the 11 birthing hospitals in the province, and 3 other hospitals perform high-risk screenings with the intention of implementing UNHS in the near future • 90%+ of babies screened • Not provincewide • Programs with clear standards but variable across province • Program does not fully track births or outcomes
Yukon	Insufficient	<ul style="list-style-type: none"> • 90%+ of babies screened at main hospital • Not territory-wide • Programs with clear standards but variable across province • Program does not fully track births or outcomes
Alberta	Insufficient	<ul style="list-style-type: none"> • Many Alberta health regions do not have the infrastructure or expertise to operate an infant hearing program • Others have the equipment/staff but do not have a universal screening protocol • Spring 2001 two hospitals in Calgary were part of a pilot project which continues to screen today • Government announced intention of provincewide program in March 2013 with no further action • Tracking of births and outcomes vary • Majority of babies remain unscreened

Quebec	Insufficient	<ul style="list-style-type: none"> • 57% of births occur in centres offering some form of newborn hearing screening • 36% of birthing centres offer newborn hearing screening • 9.1% of births occur in birthing centres offering universal screening • 47.9% of births occur in birthing centres offering selective screening. • Delayed program implementation (government announced intention in 2009) • Program does not fully track births or outcomes
Manitoba	Insufficient	<ul style="list-style-type: none"> • No provincewide program • 10–15% of babies screened • There is UNHS with limited funding based out of only two regional health authorities, which started as pilot projects • Program standards not in place, legislation recently introduced to develop programs • Program does not fully track births or outcomes
Nunavut	Insufficient	<ul style="list-style-type: none"> • No birthing hospitals in Nunavut, expectant mothers are flown to the nearest province or territory • Screening dependent on the birth hospital
Saskatchewan	Insufficient	<ul style="list-style-type: none"> • Some high-risk screening is currently conducted in the Saskatoon health region in coordination with NICU neonatologists, but there is no consistent special care nursery screening or UNHS in Saskatchewan
Northwest Territories	Under Review	<ul style="list-style-type: none"> • UNHS has been provided since 2004 for babies in Yellowknife and Inuvik with a screening goal of 95%

Sources: Alberta College of Speech-Language Pathologists and Audiologists, 2008; Canadian Infant Hearing Task Force, 2015; Hearing Foundation of Canada, 2011, 2016; World Health Organization, 2010.

The Ontario Infant Hearing Program (OIHP) was officially launched in the spring of 2002. However, because of the sequential rollout of the program in hospitals across Ontario and the interruption of hearing screening programs as a result of the SARS crisis,

hearing screening in Ontario can only be described as truly universal from late 2003 to early 2004. Each year in Ontario, Canada's most populous province, approximately 400 infants are detected with hearing loss at birth by the OIHP. Although Ontario has an exceptional IHP to detect infants with hearing loss, access to genetic services for identified infants is a barrier both in Ontario and in Canada as a whole, even though up to 50% of congenital hearing loss is due to genetic factors (Stockley, Stanton, & Brown, 2012).

Cochlear Implant (CI) Technology

Early diagnosis of a hearing loss through UNHS provides an opportunity not only for early fitting of hearing technologies such as hearing aids but also for earlier consideration of cochlear implantation for children with a severe to profound sensorineural hearing loss for whom hearing aids would be unsuccessful in facilitating auditory development (Nicholas & Geers, 2006). The candidacy criteria for cochlear implantation have changed over the years, but generally include age, audiological performance, psychosocial assessments, speech and language assessments, medical/surgical criteria, and interviews that must accompany the CI candidacy process for children and their parents. These eligibility factors provide a better sense of the benefits a child may have with a CI.

Understanding that the CI is an auditory device, but that communication benefits will depend on additional factors, is crucial to the informed consent process for candidates and their families. The obvious goal is never to have a single patient perform more poorly with their cochlear implant than they previously performed with hearing aids

alone (Sampaio, Araújo, & Oliveira, 2011). The inner ear, one of three parts of the ear (outer, middle, and inner ear), is where the cochlea and auditory nerve reside. Damage to the inner ear results in a sensorineural hearing loss. This typically involves damage to tiny hair cells in the cochlea, which pick up the vibrations of sounds and send them to the brain through the auditory nerve.

A CI is a surgically implanted device that bypasses the damaged hair cells in the cochlea, providing access to sound for a person who has a severe or profound hearing loss through electrical stimulation of the auditory nerve fibers. A CI does not deliver the entire speech spectrum in terms of the same fine acoustic-phonetic details as in acoustical hearing, but it does provide access to spoken language which is sufficient for typical speech and language development (Nittrouer, Caldwell, Lowenstein et al., 2012). Unlike a hearing aid that amplifies sound, the CI delivers electrical auditory stimulation. Neither hearing aids nor cochlear implants ever restore typical hearing. Hence, children using CIs do not have typical hearing and typically have difficulties hearing at a distance and hearing in noise.

Currently three companies in the United States produce cochlear implant systems that are used in Canada: Advanced Bionics Corporation, Cochlear Americas, and MED-EL Corporation. In December 2010, the U.S. Food and Drug Administration (FDA) reported that approximately 219,000 people worldwide had received implants, half of the number being infants and children (National Institute on Deafness and Other Communication Disorders, 2011). By December 2012, approximately 324,200 registered devices had been implanted worldwide. In the United States, approximately 96,000

individuals have received cochlear implants. Out of the 96,000, roughly 58,000 devices have been implanted in adults and 38,000 in children; 25,000 were implanted in children aged 5 and under (United States Food and Drug Administration, 2015).

The first pediatric cochlear implant program was established at the House Ear Institute in 1980 (Sampaio et al., 2011). There, the first child, a 9-year-old boy, was implanted with the single-channel House CI/3M device (Sampaio et al., 2011; Sarant, 2012). By 1982, 12 children between the ages of 3.5 and 17 years had been implanted in their program. In 1986, the House/3M device obtained FDA approval for implantation in children (Sampaio et al., 2011). In June 1990, the Nucleus-22 channel implant received FDA approval for implantation in children as young as 2 years of age. In 2002, the FDA lowered the recommended age requirement to 12 months of age. This age is not legally binding and some hospital centres are implanting younger children on the basis of expectations of improved outcomes for early implantation (A. L. James & Papsin, 2004).

Cochlear Implantation in Ontario

Ontario has a provincewide program for provision of cochlear implants. Toronto's Hospital for Sick Children (HSC) is one of three designated centres that service the pediatric population. This cochlear implant program was established in 1989. By May 1996, 37 children had been implanted at the HSC (Harrison et al., 1997). From 1990 to 2005, the HSC has implanted more than 1,200 children, plus approximately 500 bilateral cochlear recipients, for a total of about 120 per year, a drastic change from the 8 to 10 implants done in the early years (Hospital for Sick Children, 2010, 2014). Cochlear implant surgery costs a total of \$40,000 to \$60,000, which includes the cost of the device

itself (which may range from \$20,000 to \$35,000) as well as the costs of preoperative assessment and testing, the surgeon's fee, hospital costs, and follow-up (Papsin & Gordon, 2007).

Papsin and Gordon (2008) state that "we practice in an envelope-funded system" which means all patients have universal healthcare and equal access to their program and implantation (p. 72). The HSC CI program is provided with a funding envelope each year, and is unable to provide implants beyond this number. However through additional research funding the CI team have explored the effects of bilateral cochlear implants on auditory development. Therefore, in addition to implanting children by their first birthday, in 2005 the HSC CI program began implanting children bilaterally (Ramsden, Papaioannou, Gordon, James, & Papsin, 2009). By the beginning of 2007, all children brought forward for consideration of cochlear implant candidacy were assessed for the potential of receiving bilateral simultaneous cochlear implants. After the assessment, parents were informed of the results, in terms of whether or not the child was a candidate for a cochlear implant and whether one or two implants were recommended (Ramsden, Papaioannou et al., 2009; Ramsden, Papsin, Leung, James, & Gordon, 2009).

Unilateral Cochlear Implantation

A child with one cochlear implant has hearing restored in only one ear; the effects of having hearing in only one ear can be understood and explained, to some degree, from the research on children with unilateral (one-sided) sensorineural hearing loss. Unilateral hearing loss (UHL) refers to having typical hearing on one side and poor hearing on the other side. Children with unilateral hearing, despite having typical hearing in one ear,

have been shown to be at risk for significant communicative and psychoeducational problems (Peters, 2003). They also experience far greater difficulty in school and are 10 times more likely to fail a grade or to require educational resource assistance; they are twice as likely to exhibit behavioural difficulties in the classroom as their binaurally hearing peers. These difficulties are due to the absence of binaural processing, the inability to localize sounds, and challenges in understanding speech in all listening conditions, but particularly in noisy environments such as the classroom and playground, and difficulty locating sound sources, such as their peers in a group conversation or their teachers in the classroom (Peters, 2003).

Gordon, Jiwani, and Papsin (2013) found that unilateral cochlear implantation promotes the development of normal-like activity in the auditory pathways over the long term, but functional abnormalities persist and deviation from normal cortical processing remain in children despite long-term unilateral implant use. Bess, Tharpe, and Gibler (1986) demonstrated that the higher the background noise, the greater the difference in speech recognition ability between children with typical hearing in both ears and children with single-sided deafness. Word understanding in noise for normal listeners with both ears has been found to be as much as 40% better than for listeners hearing with only one ear (Sammeth, 2007).

In addition, the person with one implanted ear does not actually possess “normal” hearing in that ear. A cochlear implant provides hearing thresholds around 30dB (mild hearing loss). Children with a unilateral hearing loss have less ability to “overhear” spoken conversations, limiting access to incidental learning and restricting their

acquisition of knowledge of language and social interaction. With poor language knowledge, many of these children are unable to piece together poorly heard or overheard information.

Although there are many children with a unilateral cochlear implant who develop language, speech production, and academic or social skills at an age-appropriate rate, there remain many who show delayed development in these areas. Considering the hearing difficulties, the potential benefits of placing implants in both ears become apparent.

Bilateral Cochlear Implantation

An aspect of people with typical hearing is the fact that they rely on input from two ears, something unilateral cochlear implantation does not address. The aim of bilateral cochlear implantation (BCI) is to take advantage of the fact that we have two ears to hear with. When a person with typical hearing listens with two ears, sound quality is improved, it is easier to locate the source of a sound, and it is easier to understand speech, particularly in background noise. A significant amount of auditory system function, designed to enable us to “hear” in the world of sound, depends on having two ears from which the brain can receive input. In fact, our brains are built to process and analyze sound from two ears to maximize our ability to fully use the auditory information we receive. The information from the two ears combines in the brain in a way that makes it easier for the person to cope with the various listening situations encountered in the real auditory environment.

Hence, in the same way that prescription of bilateral hearing aids for children is required by clinical practice guidelines (except in special circumstances) for a bilateral hearing loss (Bagatto, Scollie, Hyde, & Seewald, 2010), the use of two cochlear implants, is becoming the standard option for children who cannot receive adequate benefits from hearing aids. Since bilateral cochlear implants (BCI) became available, by 2007 there were 4,000 bilateral users (Ear Foundation, 2007). Peters, Wyss, and Manrique (2010) conducted a survey that collected data from all three cochlear implant manufacturers which indicated that by January 2008, there were 8,042 bilateral cochlear implant users worldwide; with 4,182 in the United States. The survey indicated that there were 4,986 pediatric patients using bilateral cochlear implants, with 2,300 (55%) of those in the United States and 2,686 children outside of the United States.

BCI may allow children to obtain or maintain binaural hearing. Binaural hearing is a result of integration between inputs from the two ears and auditory pathways (Papsin & Gordon, 2008; Sampaio et al., 2011; Sparreboom et al., 2010). Providing binaural hearing should be considered the standard of care for children with a sensorineural bilateral severe to profound hearing loss, whenever it can be provided without significant risks. The advantage of binaural hearing is speech understanding when competing sounds are present, which is extremely difficult to accomplish when listening with only one ear. Binaural hearing improves speech understanding in quiet and noise and improved sound localization in noisy environments such as the typical classroom compared with monaural listening in typical hearing individuals (Gordon, Deighton, Abbasalipour, & Papsin, 2014). The primary effects ascribed to binaural listening are: the head shadow effect, the

binaural summation effect, and the binaural squelch effect (Firszt, Reeder, & Skinner, 2008; Gordon et al., 2014; Papsin & Gordon, 2008; Sampaio et al., 2011).

The *head shadow effect* occurs in everyday listening conditions and allows the understanding of speech in noise by enabling the listener to use the ear with the most favourable signal-to-noise ratio (SNR). For example, background noise coming from the left side would interfere with the left ear but the head would block some of the interfering noise from reaching the right ear. *Binaural summation* occurs when sounds that are presented to both ears rather than one are perceived as louder. The combined signals from the two ears are perceived as louder by up to 3dB compared with monaural listening to the same signal. This doubling of perceptual loudness is accompanied by increased sensitivity to differences in intensity and frequency and can lead to improvements in speech intelligibility both under quiet conditions and when exposed to noise (Sampaio et al., 2011). The auditory nervous system is wired to help in noisy situations as long as there is functional input from both ears. The *binaural squelch effect* is the ability of the auditory system and the brain to combine information from both ears and reduce the impact of noise, combining the signals from both ears so that the auditory cortex receives a better signal than could be possible from either ear alone (Kimura & Hyppolito, 2013; Sampaio et al., 2011; Sarant, 2012).

There is a significant body of research comparing speech perception in children with only one cochlear implant with children who have two implants. The research on bilateral cochlear implants must be differentiated in terms of whether the individual received both implants at the same time (simultaneous implantation) or received one

implant and then received the second implant months (or sometimes years) later (sequential implantation). Most of the current research compared children with one cochlear implant to children with sequential bilateral cochlear implants. Measured speech intelligibility in noise generally reveals that performance was better when listening under bilateral conditions compared with either the first- or second-implanted ear alone (Litovsky, Johnstone, Godar, Agrawal et al., 2006; Papsin & Gordon, 2008). Kuhn-Inacker, Shehata-Dieler, Muller, and Helms (2004) evaluated the auditory skills of 39 children with sequential bilateral implantation. First implantation age ranged from 8 months to 16.4 years. Age at first implantation ranged from 8 months to 16.4 years, and at second implantation from 1.7 years to 16.4 years. Ten children were implanted on the second side within 1 year following the first implantation; 12 children between 1 and 2 years, 6 children between 2 and 3 years, 5 children between 3 and 4 years, and 2 children during the 5th year. Four children received both implants simultaneously.

The mean word discrimination scores tested with both CIs (86.4%) showed a tendency to be higher than that reached with the left CI (75.1%) or the right CI (71.8%) alone. Word discrimination activities were things as substituting sounds in words e.g. substitute /c/ in cat with an /s/ to make sat; isolate the sounds in the words and blend the sounds to pronounce the word e.g. say /s/.../a/.../t/ the child blend the sounds and say the word sat. All children except the youngest one were able to achieve speech discrimination in noise for bisyllabic words in an open-set format. The open-set speech discrimination to noise scores ranged from 46% to 100% in the bilateral condition and from 21% to 78% in the unilateral condition. The majority of children scored better with the bilateral condition

compared to the unilateral condition. The results of speech audiometry showed that children reached a higher word discrimination scores in quiet with both CIs compared to one CI. There was a significant improvement in speech discrimination abilities in noise with the bilateral conditions compared to the unilateral condition.

Peters, Lake, Litovsky, and Parkinson (2007) reported results from a multicentre trial examining 30 sequentially implanted children aged 3–13 years old who received their first implant prior to 5 years of age and had a minimum of 6 months listening experience with their first device prior to receiving the second implant. Speech perception tests occurred at 3, 6, and 12 months in both unilateral and bilateral conditions. For speech perception in quiet, these children were able to achieve open-set speech perception with the second ear relatively quickly (6 months). Children younger than 8 years of age implanted with the second device progressed more rapidly in tasks of speech recognition in quiet than older children. Speech recognition for spondees² in noise was better for the bilateral condition when compared with the unilateral condition. Additionally, the bilateral benefit increased from 3 to 9 months after activation of the second implant.

If children appear to learn to discriminate right/left source positions better with two implants than with one implant, this indicates that bilateral input provides an advantage. Litovsky, Johnstone, Godar, Agrawal et al. (2006) studied 13 children aged 3–14 years old with bilateral implants and compared them with 6 children with a unilateral cochlear implantation and a contralateral hearing aid. The ability of each child to

² To evaluate hearing loss related to speech recognition a patient is presented with spondees, or words containing two syllables that are equally emphasized when spoken (e.g., *airplane, hotdog, outside, ice cream, baseball*).

discriminate sounds presented to the right and left was measured on the basis of the angle of separation. They found that 70% of bilaterally implanted children were able to correctly discriminate direction when sound sources were separated by as little as 20 degrees. Of those children, 77% performed better with bilateral stimulation than in either unilateral listening condition. Importantly, bilaterally implanted children performed better on average than children with a unilateral implant and a contralateral hearing aid.

Therefore, benefits to a binaural implant are: better sound localization, increased awareness of environmental sound, reduced signal-to-noise ratio, improved voice quality, access to a second device when one fails, and, most importantly, avoidance of auditory deprivation in the non-implanted ear (Litovsky, Johnstone, Godar, Agrawal et al., 2006). In young children, another compelling reason for considering bilateral implantation is that a young child's auditory system is more plastic than that of an adult. Providing sound input to both ears in a young deaf child assures that sound is processed in both sides of the brain. Thus, the right and left auditory cortices can develop in a more normal sequence and plasticity will be maintained (Advanced Bionics Corporation, 2004). Woolley (in Dreyfuss, 2010), states children with bilateral implants show overall better listening skills, both in the classroom and in social situations. Litovsky, Johnstone, and Godar (2006), in a study to determine benefits of BCI in children, reported children with two cochlear implants had an advantage for speech intelligibility and localization acuity over children with a single implant. Intuitively, then, BCI should have the same improved outcomes over unilateral implants as bilateral hearing aids have. BCI can improve the quality of hearing in many everyday listening situations and can provide significant

advantages over unilateral implantation (Brown & Balkany, 2007; Ching, van Wanrooy, & Dillon, 2007; Johnston, Durieux-Smith, Angus, O'Connor, & Fitzpatrick, 2009; Murphy & O'Donoghue, 2007).

Four literature reviews (Brown & Balkany, 2007; Ching et al., 2007; Gordon, Valero, & Papsin, 2007; Murphy & O'Donoghue, 2007) examined studies on the effectiveness of bilateral cochlear implant use compared to unilateral CI use in adults and children. All four reviews concluded that there are benefits for patients receiving bilateral stimulation compared to the use of a single CI on measures of speech recognition in noise and sound localization.

Sarant, Harris, Bennet, and Bant (2014) compared language abilities of children having unilateral and bilateral CIs to quantify the rate of any improvement in language attributable to bilateral CIs and to document other predictors of language development in children with CIs. The receptive vocabulary and language development of 91 children were assessed when they were aged either 5 or 8 years old by using the Peabody Picture Vocabulary Test, and either the Preschool Language Scales or the Clinical Evaluation of Language Fundamentals. Children using bilateral CIs achieved significantly better vocabulary outcomes and significantly higher scores on the Core and Expressive Language subscales of the Clinical Evaluation of Language Fundamentals than did comparable children with unilateral CIs. Scores on the Preschool Language Scales did not differ significantly between children with unilateral and bilateral CIs. Bilateral CI use was found to predict significantly faster rates of vocabulary and language development than

unilateral CI use. The 8-year-old children with bilateral CIs had significantly better language outcomes than did children with unilateral CIs.

Sequential versus Simultaneous Implantation

BCI can be provided to children either in the same surgery (simultaneously) or in two separate surgeries following a period of unilateral implant use (sequentially). In sequential implantation, the time interval between the first and the second surgery can range from weeks to years. This option is common for individuals who received their first CI years ago and want to experience binaural hearing or benefit from a newer technology in the second ear.

Research has shown that bilateral implantation, occurring within a sensitive period of 3.5 years or earlier, takes advantage of the high degree of plasticity in the developing central auditory nervous system providing the listener with binaural summation and binaural squelch (Kuhn-Inacker et al., 2004; Peters et al., 2007; Sharma et al., 2007). Unsurprisingly, the best outcomes are seen when implantation is both early and bilateral (Gordon & Papsin, 2009; Gordon, Wong, & Papsin, 2010). Gordon et al. (2010) have examined data suggesting that after 3 to 4 years of bilateral CI use, normal-like patterns of bilateral cortical activity are promoted in young children receiving bilateral CI either simultaneously or with short delays between implants. Older children with longer delays between the first and second implant did not show the same degree of normalization of cortical activity.

Sharma et al. (2007) assessed whether children who received early simultaneous bilateral cochlear implants showed more rapid development of the central auditory

pathways than children who received early sequential bilateral implants. The simultaneous implant group consisted of 10 children with a mean age of implant fitting of 1.57 years. The sequential implant group comprised 10 children whose mean age was 1.3 years at first implant activation and 2.26 years at activation of the second implant. These 20 children were assessed for longitudinal changes in the morphology and latency of the P1 cortical response over the first 15 months of bilateral cochlear implant use. Results showed that by 3.5 months post-implantation, mean P1 latencies for both groups of children were within normal limits. Overall, the developmental trajectory of the P1 response did not differ significantly for the two groups over the 15-month period. Sharma et al. (2007) concluded that bilateral implantation, whether sequential or simultaneous, occurring within a sensitive period of 3.5 years, takes advantage of the high degree of plasticity in the developing central auditory nervous system.

By contrast, Gordon and Papsin (2009) reported that children who received the two cochlear implants sequentially after long inter-implant delays (>2 years) had persistent unequal auditory function and compromised bilateral benefits for speech perception, even after 36 months of bilateral improvement on speech outcomes than children implanted simultaneously or with limited delay. Gordon and Papsin (2009) found 19 children receiving one implant at 2.1 years old and the second after 4.9 years old of unilateral implant use could hear changes in interaural level differences but had particularly poor abilities to detect interaural timing cues even after several years of bilateral cochlear implant use. Just as implantation as early as possible after the diagnosis of a severe to profound hearing loss has yielded the best opportunity for oral speech and

language development, research suggests a minimal inter-implant delay between cochlear implants is best, and simultaneous implantation is ideal, to allow development of binaural processing.

Gordon et al. (2007) measured electrically evoked auditory brainstem responses in 40 children with early onset severe-profound sensorineural hearing loss to assess effects of bilateral electrical stimulation in children with long, short, or no delays between their first and second implants. All children received their first implant at less than 3 years old. Thirty children had right ear implants and were implanted in the left ear after a long (greater than 2 years) or short (6–12 months) delay. Ten children received simultaneous implants. Binaural wave differences were detected. Gordon et al. (2007) concluded that timing differences between the implanted ears in children receiving sequential bilateral implants reflected a relative immaturity of pathways innervating the second ear and resulted in abnormal timing in binaural processing at this initial implant stage.

Papsin and Gordon (2007, 2008) indicate that there may be more than one “sensitive period” in auditory development, depending on the type of auditory activity or behaviour measured. They suggest that in bilateral cochlear implantation there are two key time periods to consider: the interval of bilateral deafness between the onset of deafness and initial implantation known to affect improvements in speech and language development, and the interval created by delaying implantation of the second ear, which might affect subtler aspects of binaural processing. The sensitive interstage interval could be fairly short (i.e., 1–2 years). Arguments against simultaneous BCI cite the need to preserve the contralateral ear, keeping it available for “newer” rehabilitative methods. As

evidence suggests, for a child successfully using a CI in one ear, preserving the contralateral ear for an implant of improved design, or even for hair cell generation or neural growth at some future date, would be limited by going beyond the “sensitive period” (Graham et al., 2009).

Wie (2010) examined the receptive and expressive language development in 21 profoundly prelingually deaf children (10 boys and 11 girls) who received simultaneous BCI between 5 and 18 months of age and compared the results with language development in chronologically age-matched hearing children. Using communication assessments (LittleEARS questionnaire, the Mullen Scale of Early Learning, and the Minnesota Child Development Inventory), the children were tested at 3, 6, 9, 12, 18, 24, 36, and 48 months of implant use. This study indicated that 81% of these children developed receptive language skills and 57% developed expressive language skills inside the normative range within 12 to 48 months after implantation. The number of children who scored within the normal range increased with increasing CI experience. When comparing language performance and age of implantation, the children who were implanted before 12 months of age had the highest average scores at all times of testing.

As emphasized throughout this chapter, early hearing detection and intervention, including appropriate fitting and management of hearing technologies including cochlear implants, considerably reduce delays in the development of language and the subsequent development of literacy. Efforts continue to build the research evidence base in both of these areas, but particularly in the sphere of reading and writing development as these

have received relatively less research attention. The focus in the next chapter will be to provide an overview and summary of the research evidence that is available to date.

CHAPTER TWO

LITERATURE REVIEW

Overall, the research literature is clear that cochlear implants (CIs) provide profoundly deaf children with greater access to sound, speech awareness, and an enhanced opportunity for oral language development (Geers, 2006; R. F. Holt & Svirsky, 2008; Stacey, Fortnum, Barton, & Summerfield, 2006; Thoutenhoofd, 2006; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999). Children using CIs have been found, on average, to make faster progress in spoken language than those with the same level of hearing loss who use hearing aids (Tomblin, Barker, Spencer, Zhang, & Gantz, 2005; Tomblin et al., 1999).

Spoken Language Development

Studies demonstrate that children who are implanted early develop speech perception and speech production skills close to those of normally hearing children. Several studies have indicated that children who receive their cochlear implants early produce phonemes more accurately after 3 years of implant use than has been reported of previous cohorts of children with the same levels of hearing loss who used hearing aids (Peng, Spencer, & Tomblin, 2004). Data show that 90% of children born with a profound hearing loss who obtain a CI before they are 18 months old attain intelligible speech. If a cochlear implant is obtained between 2 and 4 years of age, about 80% of the children born with profound hearing loss will develop intelligible speech. In contrast, only about

20% of children born with a profound hearing loss who wear hearing aids achieve this goal (Cole & Flexer, 2007).

Connor, Craig, Raudenbush, Heavner, and Zwolan (2006) reported children who receive their implants before age 2.5 years seemed to experience faster rates of vocabulary and consonant production accuracy growth immediately after implantation. Miyamoto, Hay-McCutcheon, Kirk, Houston, and Bergeson-Dana (2008) showed that children who were implanted at less than 2 years of age were more proficient at understanding and using spoken language than children who were implanted over the age of 2 years. Manrique, Cervera-Paz, Huarte, & Molina (2004) measured the spoken language of 36 children with CIs with the General Oral Expression scale of the Reynell Developmental Language Scales—III. They found that children who received an implant by age 2 years had a normal rate of growth, although they were generally 1 year delayed, whereas children who received an implant between ages 2 and 6 years exhibited a slower growth rate and a lag of between 2 and 3 years below achievement levels for hearing age-mates. Houston and colleagues (2012) investigated word learning in children who received cochlear implants between 6 and 24 months of age and who had 12 to 18 months of implant experience. They found that children who received implants before 12 months of age showed similar performance to age-matched hearing children, whereas children who received implants between 12 and 24 months did not.

Hammes et al. (2002) reported exclusively on the spoken language development of 10 children who were implanted by 18 months, comparing their progress with that of 35 children who received their implant later, up to age 48 months. Analyses revealed that

70% of the children implanted by age 18 months, 30% of those implanted between 19 and 30 months, <10% of those implanted between 31 and 40 months, and <5% of those implanted between 41 and 48 months had a spoken-language age within 1 year of their chronological age. Miyamoto, Houston, Kirk, Perdew, and Svirsky (2003) evaluated the language of the youngest patient to have received a cochlear implant at the Indiana University Medical Center. The child was 6 months old when implanted. By 18 months post-implantation, the recipient achieved nearly age-equivalent receptive language scores and exceeded age equivalency on the expressive language scales.

Geers, Moog, Biedenstein, Brenner, and Hayes (2009) analyzed spoken language skills of 153 children with CIs, four of them with bilateral implants. Only one child had received an implant below 1 year of age (at 11 months), with 73 implanted between 12 and 23 months, 45 between 24 and 35 months, 24 between 36 and 47 months, and 10 implanted after their 4th birthday. At time of testing, the children's mean age was 5.10 years old. The majority of children ($n = 126$) were assessed on the Expressive One-Word Picture Vocabulary Test (EOWPVT; Gardner, 2000) with the remaining 27 children assessed on the Expressive Vocabulary Test (EVT; Williams, 1997). Most of the children ($n = 137$) were tested on the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997), with the remaining 16 children on the Receptive One-Word Picture Vocabulary Test (ROWPVT; Brownell, 2000). Most of the children ($n = 147$) were also administered the Clinical Evaluation of Language Fundamentals. Sixty-seven were tested using the first edition of the preschool level (CELF-P; Wiig, Second, & Semel, 1992) and 72 using the second edition (CELF-P2; Wiig, Second, & Semel, 2004). Eight of the children were

tested with the CELF-III (Semel, Wigg, & Second 1995) or CELF-IV (Semel-Mintz, Wiig, & Second, 2003) with six children assessed on the Preschool Language Scale (PLS; Zimmerman, Steiner, & Pond, 2002).

Age-appropriate scores were observed in 50% of the children on measures of receptive vocabulary, 58% on expressive vocabulary, 46% on verbal intelligence, 47% on receptive language, and 39% on expressive language. Individual data reflected cochlear implantation at a younger age serving to promote higher spoken language scores.

Regression analysis indicated that, after controlling for the effects of nonverbal intelligence and parent education level, children who received their implants at young ages had higher scores on all language tests than children who were older at implantation. Geers et al. (2009) concluded that age-appropriate development of complex language skills (e.g. modifiers, syntax, semantics) required earlier cochlear implantation and longer experience with the implant than the development of vocabulary skills.

Markman et al. (2011) reviewed spoken language development in a longitudinal trial of cochlear implantation of young children with severe to profound sensorineural hearing loss in the Childhood Development after Cochlear Implantation study (CDaCI). Out of the 116 children, 20 displayed measurable language before implantation. Thirty-four children had their implant activated before 18 months of age, and 62 had their implant activated after 18 months of age, all of whom had no measurable language. All 116 were evaluated with the Comprehensive Assessment of Spoken Language (CASL) – antonyms, syntax construction, paragraph comprehension of syntax, and pragmatic judgment – at 4–5 years after implant activation. The subgroup of six children who had

implants activated before 12 months of age exhibited the highest level of average spoken language performances across all four CASL core tests. Children who received their implants before 18 months of age exhibited language performance scores that remained roughly within 1 standard deviation of their typical hearing peers. Those who had their implants activated at 18 months of age or older demonstrated syntax construction and pragmatics standard scores that averaged more than 2 standard deviations below the norm.

Vavatzanidis, Murbe, Friederici, and Hahne (2015) studied how congenitally deaf children process vowel length after cochlear implantation. Using electroencephalography (EEG), they assessed which features children process when presented with their first auditory input. Seventeen congenitally deaf children were implanted at 9 months–3.7 years old. EEG recordings were performed longitudinally at the regular bimonthly rehabilitation stays: in the week of initial activation (M0) and after 2 (M2), 4 (M4), and 6 (M6) months of implant use, plus an additional preoperative measurement serving as baseline (Mpre). The children with CIs were compared to a control group of matched age and gender. The participants were presented with syllables with either short or long vowel duration. Directly after the first activation of the implant, there was no sign of discrimination between long and short syllables, but a robust response was identified after 2 months of hearing experience. After 4 months the discriminative response of implanted children resembled that of their age peers.

Literacy Outcomes

As has been described in the previous section, there have been numerous studies investigating auditory and spoken language development in the population with cochlear implants (see also Archbold, 2010; Archbold & Mayer, 2012; Miyamoto et al., 2008 for reviews). However, there are still relatively few studies that focus on literacy development (for reviews, see Marschark, Rhoten, & Fabich, 2007; Marschark, Sarchet, Rhoten, & Zupan, 2010; Mayer & Trezek, 2015). Overall, less is known about the impact cochlear implantation has on literacy levels, and on school performance in general, than about its impact on speech articulation, audition, and spoken language.

That said, on the basis of the evidence available to date, children with CIs as a group are demonstrating better reading and writing outcomes than have been reported in the past. However, while research evidence on the literacy outcomes of children with cochlear implants has generally been positive, it has shown considerable variability. Before going on to present a more detailed review of literacy outcomes, it would be important to delineate some of the reasons for this variability. The first and most fundamental is to recognize that the population of children with CIs is small, geographically dispersed, and heterogeneous, and, therefore, difficult to study as a group.

In addition, there are several other possible causes for the variability in outcomes that relate to rehabilitation factors, medical/audiological influence, and/or child and family characteristics (Barker, 2012; Simonsen et al., 2009). Rehabilitative factors include such items as the age of the child at diagnosis, nature of the habilitation, and cochlear implant fitting (R. F. Holt, Svirsky, Neuburger & Miyamoto, 2004; Connor & Zwolan, 2004; Geers, Tobey, Moog, & Brenner, 2008). The medical/audiological factors

with potential influence include the cause of deafness (Nikolopoulos, Archbold, & O'Donoghue, 2006), age at onset of deafness (Geers, 2004), the degree (if any) of pre-implant hearing available to the child (Nicholas & Geers, 2006), unilateral or bilateral implants, sequential or simultaneous implantation (Gordon et al., 2013), nature of the device (i.e., type of implant, number of active electrodes, type of processor) (Geers, Brenner, & Davidson, 2003), and the positioning of the electrodes of implant (Papsin, 2005). In the case of bilateral implantation, if surgical insertion and the anatomical positioning of the electrode array are not precise enough, it cannot be guaranteed that the electrode arrays in the two ears are physically matched for insertion depth. This will likely cause imprecise matching of inputs in the two ears (Litovsky et al., 2012).

Further variability may be the result of post-implant factors such as inadequate mapping³, device failure, the amount of time the implant device is used on a daily basis, the number of months of experience with the implant at the time of testing, and quality of and access to post-implant resources and support (Archbold et al., 2008; Marschark et al., 2007; Wass, 2009).

We need to keep in mind that the CI is a piece of equipment that is only as good as its user, and there are still children who perform poorly. In addition to the factors already described, it is important to consider the characteristics of the child—level of nonverbal intelligence (R. F. Holt & Kirk, 2005), motor skills, memory/processing

³ Mapping is the term for programming a cochlear implant to the specifications and needs of its user. The cochlear implant processor is connected to the audiologist's computer. Using a series of "beeps," and measuring the CI user's response, the audiologist sets T- and C- levels for each electrode. T-Levels, or Thresholds, are the softest sounds the CI users can detect. C-Levels are Comfortable loudness levels that are tolerable for the CI user.

abilities, gender (Geers, Nicholas, & Moog, 2007), cognitive ability, and presence of an additional disability (Marschark et al., 2007; Marschark et al., 2010). Family variables must also be taken into account—parents’ education level and occupation, family size, mode of communication (Geers et al., 2008), access to support and technological resources, home literacy environment, and family participation (Geers et al., 2007). Markman et al. (2011) noted that an annual family income of less than \$50,000 was associated with lower average standard scores across subdomains. Children in lower SES households receive less encouragement to talk and ultimately experience deficits in language and academic performance when they enter school.

Against the backdrop of all these variables, it is most expedient to present an overview of the research on literacy outcomes in two sections—research published up to 2005, and research published since 2006. Given the improvements in UNHS programs across the country and the world, advances in CI technology, and earlier ages of implantation over the past decade, the population of children implanted in the 1980s, 1990s, and initial 2000s differs in many ways from the more recent population of cochlear implant recipients. For example, in contrast to early bilateral implantation that would now be considered standard practice, the earlier generation of children with CIs would have been implanted later and typically only in one ear. As has been discussed, these factors can have a significant impact on both language and literacy outcomes.

Research Up to 2005

L. J. Spencer, Tomblin, and Gantz (1997) investigated the reading skills in 40 children with prelingual profound deafness who received a Nucleus cochlear implant

between the ages of 2 and 13 years old. The students were in kindergarten through Grade 12 using sign language and spoken language. The children had an average of 63.3 months of experience with their cochlear implants. Reading achievement was assessed using the Paragraph Comprehension subtest of the Woodcock Reading Mastery Test—Revised. The reading-achievement levels of the children with cochlear implants were compared with the results of previous studies of children with profound hearing losses with no amplification. Scores of 28 subjects in Grades 4 through 12 were separated in order to provide results of the Grade 4 level since many older profoundly deaf children fail to surpass the Grade 4 reading level. L. J. Spencer et al. (1997) found that 54% of this group read above the Grade 4 level and 15% of the children were reading at levels that were within 12 to 18 months of their grade levels, while 12% were within 18 to 30 months of their grade levels. Nearly one fourth of the children in this study were reading at or above their grade levels, and almost one fifth were reading within 8 months of their grade levels. L. J. Spencer et al. (1997) found the cochlear implant did appear to support reading development, especially if received early.

Tomblin, Spencer, and Gantz (2000) explored language development in a group of 17 children who had prelingual profound bilateral hearing losses and received cochlear implants between 2.6 and 10 years of age. Reading acquisition was examined in a group of 30 children, including most of the children who participated in the language study. Those children also had prelingual profound bilateral hearing losses and received cochlear implants between 2.6 and 14 years of age. At the time of the testing, children in the language study ranged from 8.5 to 18.4 years. The Woodcock Reading Mastery

Test—Revised and three language measures from the CELF were administered. At the time of the first evaluation (grade level Grade 5), the mean grade-level-equivalent reading score was mid–Grade 3. At the time of the second evaluation ($M = 12$ years), with the mean grade level mid–Grade 6, the mean reading level was mid–Grade 5, a 2-year improvement. The students who were nearing the end of high school were found to be reaching average to above average reading levels, whereas the children in early grades were well below average. Tomblin et al. (2000) concluded that there is a causal relationship between spoken language and reading, but explicit relations between their language data and reading data were not examined.

Crosson and Geers (2001) examined the narrative abilities of 87 children aged 8–9 years who had used their implants for at least 4 years, relative to 28 hearing children. Scores on the Reading Comprehension subtest of the Peabody Individual Achievement Test also were reported. Stories were prompted using an eight-picture sequence, and children’s productions were scored on the basis of several discourse-related features. The children in Grades 3 and 4 obtained an average reading level of Grade 2.5 with a standard deviation of 0.15. Scores were reported as ranging from grade level 0.1 to 8.3, indicating that most of the children were reading at or below grade level.

Watson (2002) suggested that the auditory benefits offered by cochlear implants provide information that benefits bottom-up reading skills, those relating to grammar, morphology, and vocabulary. Top-down skills, such as making inferences and metacognition, were seen to require more complex cognitive and social interactions with other language users. Watson examined inference and phonological strategies in reading

among ten children aged 7 years and older, all of whom had at least 5 years' experience with their cochlear implants. Data were drawn from the children's scores on the National Curriculum assessments in England. Watson reported that seven out of ten children demonstrated reading skills at the "expected" level for their (unspecified) age groups, although complete information was available only for five children. Only one child reached a score of 50% on inference questions.

Perhaps most prominent in the literature on reading abilities following cochlear implantation is a series of reports by Geers (2002, 2003, 2004, 2005), Geers et al. (2002), and Geers et al. (2008) which sought to document the word reading and comprehension levels attained in 8- and 9-year-old children who were implanted by 5 years of age. Children's skills in expressive grammar were evaluated by computing the mean length of utterances, the frequency of inflectional (e.g., plural *-s*, past tense *-ed*) and derivational (e.g., *-ly*, *-ment*) morphemes, and the productive use of grammatical structures in speech-only language samples. Out of the 181 children, 140 were deaf from birth and first aided with a mean age of 1 year 3 months. The children were assessed on reading ability through the Word Attack subtest from the Woodcock Reading Mastery Tests—Revised and the Peabody Individual Achievement Test—Revised reading recognition and reading comprehension subtests. Phonological processing strategies were measured using a lexical decision task, rhyming task, and working memory subtest of the Wechsler Intelligence Scale for Children—III.

Geers found that the children averaged mid to high Grade 2 reading levels on the Word Attack (non-word reading) subtest of the Woodcock Reading Mastery Tests

(WRMT)—Revised and on the Peabody Individual Achievement Test (PIAT). The total reading standard scores revealed that 52% of the children scored within the average range of children their age (within 1 standard deviation of the norm-referenced-sample mean). Geers's results indicate that children identified with a severe to profound hearing loss early in their development have a better prognosis for normal literacy development than ever before. Use of a cochlear implant is associated with greater use of phonological coding strategies for decoding print, longer working memory spans for short-term storage of phonemes, words, and sentences, and accelerated language development for reading comprehension.

Geers (2002) also reported that time spent speaking and listening were positively correlated with better speech and language skills, and that children who used spoken language in mainstream programs were better readers. She concluded that an emphasis on spoken language is an important educational choice for children who receive their cochlear implants early. Moog (2002) also concluded that a spoken language orientation contributes to reading achievement for children with cochlear implants, following a study involving 17 children between 5 and 11 years of age who had been implanted between 2.4 and 7.7 years ($M = 4.2$ years). The children were administered the Phonetically Balanced Kindergarten word lists to test speech perception, the Picture Speech Intelligibility Evaluation to test speech intelligibility, the Peabody Picture Vocabulary Test (third edition) as a measure of perceptive vocabulary, and the Expressive One-Word Picture Vocabulary Test as a measure of expressive vocabulary. They were also tested using the Clinical Evaluation of Language Fundamentals (CELF-3) to examine perceptive and

expressive language skills and the Gates MacGinitie Reading Test (third edition) and the SAT9 to assess reading. Moog did not report statistical analyses, comparison groups, or direct relations between language and reading. Her findings thus do not indicate what is responsible for their reading success. The only reference to reading achievement was that more than 70% of the students (12 of the 17) scored within the average range for their age.

Geers (2004) reported data from children in her sample of 8- and 9-year-olds who had congenital hearing losses and performance IQ scores of 80 or greater. More than half of the children scored in the average range in word reading and sentence comprehension, but neither age of implantation nor duration of implant use was found to be related to reading comprehension. Geers (2005) reported a follow-up to her earlier studies involving data from 24 of the original 181 children in her study. Although that group had been reading at grade level when they were 8 and 9 years old, Geers found that they were close to 2 years behind grade level by the time they were 15 to 16 years old. Geers et al. (2008) reported on a larger follow-up, involving 85 of the original children. Retesting when the students were 15 to 18 years old involved speech perception, language, and reading assessments. Results indicated that speech and language scores improved for a majority of the students. Progress in reading, in contrast, declined significantly from the earlier testing. Only 44% of the students obtained standard reading scores within the average range for hearing age-mates, compared to 56% in the younger sample. There were correlations of reading with age at implantation and age of hearing loss onset, so that both receiving an implant earlier and having more exposure to language prior to becoming

deaf and receiving an implant later were associated with higher reading scores in high school.

L. J. Spencer, Barker, and Tomblin (2003) investigated the relationship between 16 pediatric cochlear implant users' language and literacy skills, which were evaluated and then compared with a reference group of 16 age-matched hearing children. The 16 children with an average age of 9.8 years old were prelingually deaf and received cochlear implants between the ages of 30 months and 76 months (average age of 3.9 years). The average length of experience with a cochlear implant was 5.9 years. The 16 children attended a public school where simultaneous communication⁴ was used in the classroom. To measure expressive and receptive language skills, the Clinical Evaluation of Language Fundamentals—III was administered. The Passage Comprehension Test from the Woodcock Reading Mastery Tests—Revised Form was used as a measure of reading comprehension. Writing samples were analyzed using the Systematic Analysis of Language Transcripts computer program (SALT). Scores in the area of reading comprehension for the children with implants were significantly below those of the hearing children, but only by 10%. Grade-equivalent scores indicated that the children with cochlear implants were reading at an average grade level of 3.3 years and the hearing children at 3.8 years. Children with cochlear implants performed within 1 *SD* of the mean for hearing age-matched children on measures of language comprehension, reading comprehension, and writing accuracy. L. J. Spencer et al. (2003) concluded from this

⁴ Simultaneous communication is a technique sometimes used by deaf, hard-of-hearing or hearing persons in which both a spoken language and a manual variant of that language (such as English and manually coded English) are used at the same time.

study that the language skills of pediatric cochlear implant users are related to and correlated with the development of English literacy skills.

Connor and Zwolan (2004) studied the reading comprehension of 91 prelingual congenitally profoundly deaf children, 45 boys and 46 girls, using cochlear implants. On average, the children were 11 years old and had used their implant for more than 4 years at the time of their reading evaluation. Of the 91 children, 88 used the Nucleus 22 device and three children used the Nucleus 24 device. The assessment tools used were the Passage Comprehension subtest of the Woodcock Reading Mastery Test—Revised, the Picture Vocabulary Test of the Woodcock-Johnson Test of Cognitive Ability and the Expressive One-Word Picture Vocabulary Test. Connor and Zwolan (2004) concluded that the age at which children received their implants strongly affected their reading comprehension. The children who were younger when they received implants achieved higher reading comprehension scores. The younger-implanted children generally had stronger pre-implant vocabulary skills. This trend predicted stronger post-implant vocabulary, which in turn predicted reading comprehension.

L. J. Spencer, Gantz, and Knutson (2004) obtained similar results in a study involving 27 children consecutively implanted at a single centre. All had prelingual hearing losses and received their implants between 2.4 and 12.7 years of age ($M = 6.4$ years). At the time of testing, they had between 3 and 14 years' experience with their implants ($M = 9.9$ years). The children were tested subsequently either when they were in Grade 10 or at least 16 years of age. Of the 27 participants, 24 reported at least 7 years of consistent implant use (8 or more waking hours per day). Seven participants wore their

implants only in school or at work. Another 10 students discontinued use of their implants either during the first 3 years after implantation or later. Scores on the Woodcock Reading Mastery Test—Revised indicated that the entire group of children with implants had a mean score of 89 ($SD = 17$) and those who were consistent users of their implants had a mean score of 92 ($SD = 17$). The inconsistent implant users had a mean score of 77 ($SD = 7$). Thus, those students who consistently used their cochlear implants generally were reading on par with hearing peers.

Sherman and Cruse (2004) studied the literacy achievement in 11 deaf children who were implanted between 27 and 70 months and had an average duration of implant use of 49 months. The children were assessed using the Woodcock-Johnson Letter Recognition Scale. The children's total results for reading scores were $r = -0.89$, letter and word recognition scores were $r = -0.91$, and reading comprehension scores were $r = -0.93$. The duration of use of the cochlear implant was significantly and positively correlated to reading achievement on both Woodcock-Johnson subscales (letter/word recognition and reading comprehension). Sherman and Cruse concluded that earlier implantation and longer use of the cochlear implant resulted in higher achievement.

2006 to the Present

Reading

Thoutenhoofd (2006) conducted a study involving 152 school-aged deaf students with cochlear implants drawn from the population of 1,752 deaf students in Scotland. Children ranged in age from 5 years to 12 years ($M = 8$ years), were an average age of 3 years old when they received their cochlear implants, and had an average of 4 years'

experience with their implants. Thoutenhoofd examined National (UK) Test scores and found that older students with implants were further behind in their reading skills (for their chronological age) than younger students, a finding similar to that reported by Geers et al. (2008). Students aged 11–13 years lagged behind their hearing peers in reading scores by approximately 3 years, whereas students aged 15–17 lagged by 4 to 5 years. Analyses controlling for age of implantation were not conducted, so it is unclear whether such results reflect a real widening gap in literacy skills for implanted children over the school years or a confound due to the circumstance that older children may have received their implants after a longer period of auditory deprivation.

Dillon and Pisoni (2006) investigated phonological processing skills as they relate to reading development in 76 children with cochlear implants. Seventy-four children used a Nucleus 22 CI, one child used a Nucleus 24 implant, and one child used a Clarion implant. The mean chronological age at the time of testing was 8.9 years old. Sixty-four of the children were congenitally deaf, six became deaf before age 1, and the remaining six became deaf by age 3. The children's mean age of implant use was 5.6 years at the time of testing. A non-word repetition task was used to measure phonological processing skills where the participant had to repeat non-words after hearing a speaker present them. The results from the non-word task were compared to the results from three different reading and reading comprehension measures. Dillon and Pisoni found that the children with cochlear implants performed worse than would be expected for children their age. Results also revealed that 70% of the children achieved total reading scores within 1

standard deviation of the mean score of hearing children the same age. A small proportion of children in the study achieved scores above the Grade 4 level.

Vermeulen, van Bon, Schreuder, Knoors, and Snik (2007) examined reading comprehension and word recognition as separate indicators of reading ability in children in the Netherlands. The study involved a comparison of 50 students with implants (aged 7–22 years) with data collected by Wauters, van Bon, and Tellings (2006, in Vermeulen et al., 2007) from 504 deaf students with hearing aids and a comparison group of hearing students. The mean age of onset of hearing loss was 1.1 years ($SD = 1.6$ years), and the mean age of implantation was 6.2 years ($SD = 2.3$ years). All the children with implants had a minimum implant experience of 3 years, but there was a mean duration of auditory deprivation prior to implantation of 5.1 years ($SD = 2.8$ years). Forty-five of the 50 children had prelingual hearing losses, most of them acquired. Vermeulen and colleagues found that the reading comprehension skills of the children with CIs significantly exceeded those of children with hearing aids, but still lagged significantly behind those of hearing peers. On average, the performance of the children with CIs was still more than 3 SDs below the hearing norm. There were no large differences in visual word recognition between the two groups. It was noted that the participants were implanted relatively late (between 2 and 12 years, with a mean of 6.2 years) and educational placement prior to implantation was unrelated to reading scores.

Fagan, Pisoni, Horn, and Dillon (2007) utilized several measures including neuropsychological, sensorimotor, visuospatial, memory, and literacy tasks in a study of 26 children aged 6 to 14 years who received their implants between the ages of 1 and 6

years. Although most of the children scored within the normal range on the neuropsychological and reading tasks, they lagged behind hearing norms on the visuospatial task and vocabulary comprehension. Most notable was the finding that although forward digit-span scores were better than backward digit-span scores, most of the children were more than 1 *SD* below the mean for hearing children on forward span. This finding is important because digit spans were significantly correlated with all measures of reading.

Archbold et al. (2008) performed a study to explore the impact of early implantation on reading development. This study addressed (a) the relationship between chronological age and reading ability at 5 years and 7 years after implantation and (b) the relationship between reading ability at each point and age at implantation. Participants included 105 children (55 boys and 50 girls) who were implanted between 16 and 83 months. At the time of testing, at 7 years post-implant, participants were between 8.4 years and 13.1 years old. For those children for whom the etiology was known, 27 had suffered from meningitis, 6 had suffered from CMV, and 10 had other diagnoses (including Ushers and Charge Syndrome). All children received the Nucleus cochlear implant. The participants completed the Edinburgh reading test, which includes subtests of vocabulary, sequencing, and sentence comprehension. A net reading age was calculated by using the difference between the child's chronological age and their reading age. Therefore, a net reading age of 0 or more would indicate the child was at or above the normative reading level for a child of the same age with typical hearing.

The children with cochlear implants were split into two groups: children implanted before 42 months and the children implanted after 42 months. The results support recent findings of better literacy outcomes in children who receive a cochlear implant. They also provide evidence that early achievements in reading are maintained at 5 and 7 years post-implant. For children who were implanted before the age of 42 months, average reading progress was in line with chronological age at both assessment points. Archbold et al. found that age of implantation had a highly significant effect on IQ scores and the net reading scores for the children implanted at or before 42 months. Only five children in the sample were implanted at or before 24 months. Their net reading scores at 7 years post-implant ranged from +1.6 years to -0.12 years. Overall, the standard deviation of the net reading score was around 1 year for the young-implanted children at 7 years post-implant. This shows that the children were reading at an age-appropriate level and the pattern of distribution was not dissimilar from that for hearing children of the same age.

Torres, Rodriguez, García-Orza, and Calleja (2008) examined inferring during reading. A group of four 12- to 13-year-olds who received their implants between age 3 and 7 and used cued speech was compared to groups of hearing children matched on chronological age or reading age. Relative to hearing norms, the deaf students' spoken language skills were at or above what would be expected for their chronological ages. Torres et al. reported that the deaf students also performed at least as well as the hearing controls on a reading task.

D. James, Rajput, Brinton, and Goswami (2008) explored the effect of age of implantation on phonological awareness, vocabulary, and reading with a sample group of 19 children. Nine children who were implanted between the ages of 2 and 3.6 years were labelled the “early group.” Ten children who were implanted between the ages of 5 and 7 years were labelled the “late group.” All participants had been using their Nucleus-22 CI for at least 3 years. The participants were tested twice in a year which consisted of four test sessions in total over 2 consecutive days. Three tests of phonological awareness were designed for this study: a syllable test, a rhyme test, and a phoneme test. The British Picture Vocabulary Scale was used to assess knowledge of spoken vocabulary. The British Ability Scale to test word reading was used to assess word reading. D. James et al. found that the performance of the early group on the phonological awareness tests fell within the standard distribution, while the late group did not fall within the normal distribution. In the area of receptive vocabulary, the early group had higher performance outcomes but the late group made more progress over the year than the early group.

Those children who had received their implants early performed at or near the level of reading-matched hearing peers on all measures, whereas the children who had received their implants later lagged behind. Overall, results indicated that even when children receive their implants relatively early, they tend to fall towards the lower end of the distribution of hearing children with regard to phonological awareness, just as they do on other measures of language and reading ability.

Lyxell et al. (2009) studied 37 cochlear implant users from Sweden and their performance in phonological processing and reading levels. Lyxell et al. (2009) found

that the children with cochlear implants had low abilities on phonological processing tasks but that 75% of them were reading comparably to the hearing children. They concluded that although children with typical hearing outperformed children with cochlear implants on cognitive and prosodic tasks, the discrepancy was reduced in tasks that did not involve specific phonological processing skills.

Ambrose (2009) assessed whether very early access to speech sounds provided by the cochlear implant enabled 24 children to develop age-appropriate phonological awareness abilities during their preschool years. The participants were children with CIs aged 36 to 60 months and had been wearing their device for a minimum of 18 months. A group of 26 hearing children were the comparison peers. Areas assessed were: (a) phonological awareness, measured by the Test of Preschool Early Literacy (TOPEL); (b) speech perception, measured using the Play Assessment of Speech Pattern Contrasts (PLAYSPAC) test; (c) speech production ability, represented by Percentage of Consonants Correct (PCC) scores; (d) general language abilities, measured by the Preschool Language Scale—4 (PLS-4); (e) receptive vocabulary, measured by the Peabody Picture Vocabulary Test—4 (PPVT-4); and (f) early knowledge about written language conventions and form, as well as knowledge of the letters of the alphabet and the sounds they make, measured by the Print Knowledge subtest of the TOPEL.

Variable results were collected within the group of children with CIs but, overall, the difference in phonological awareness, speech production, general language, and receptive vocabulary between the children in the CI group and their hearing peers was 1 *SD*. The greatest differences between groups were found for stops (consonants that close

off the vocal tract completely and explode as they release a vowel e.g. /d/ and /b/) and fricatives (consonants that cause the breath stream to become turbulent e.g. /s/ and /f/). Overall, the children in the CI group were outperformed by their hearing peers in the areas of phonological awareness, speech production, general language, and receptive vocabulary, but not print knowledge. From the results in this study, Ambrose (2009) concluded that even though age-appropriate speech perception, speech production, oral language, and early literacy skills by school age are reasonable goals for preschoolers who have been implanted for 18 months or more, the results indicate that many children with cochlear implants will lag behind hearing peers in these areas.

Johnson and Goswami (2010) investigated whether speech perception provided by cochlear implants affected phonological awareness skills and reading development. A group of 43 deaf children with implants between 5 and 15 years of age were divided into two groups. Children implanted before 39 months were the early group and children implanted after 43 months of age were the later group. Twenty-one had been implanted at around 2.5 years of age and 22 had been implanted at around 5 years of age. All children received a battery of phonological processing tasks along with measures of reading, vocabulary, and speechreading. The results of this study showed that age of cochlear implantation had a significant effect on vocabulary and reading outcomes when quotient scores were calculated. Results indicated that children in the early cochlear implant group attained reading scores that were close to their typical hearing peers and significantly greater than the later cochlear implant groups' reading scores. Johnson and Goswami concluded that earlier cochlear implantation is associated with development of the oral

language, auditory memory, and phonological awareness skills necessary for developing efficient word recognition skills.

Harrington, DesJardin, and Shea (2010) investigated early child factors such as age at identification, age at enrollment in early intervention, and oral language skills to better understand how these early factors may influence later school readiness skills such as alphabet knowledge, abstract concepts, number cognition, and mathematical concepts in a young group of preschool-aged children with hearing loss. Eight children with a hearing loss participated in this study. Six of the eight children used a CI, receiving the implant at 24.3 months of age and having worn the implant from 19 to 36 months at the time of testing.

Children's total language age equivalent scores (CELF-P) ranged from 29 months to 49 months ($M = 37.8$ months) at T1 and from 44 months to 61 months ($M = 52.5$ months) at T2. Children's SRT age scores (BBCSR) ranged from 34 to 61 months ($M = 45.1$ months) at T1 and from 42 to 67 months ($M = 54.4$ months) a year later. Overall, language and school readiness skills for this group of children were lower than their chronological age for both time points ($M = 48.5$ months at T1 and 60.5 months at T2) yet relatively higher than their "hearing age" or length of sensory device use ($M = 16.8$ months at T1 and 28.8 months at T2). Cognitive scores for the children were available only for T2. Total cognitive SSs (WPPSI-III) ranged from 82 to 125 ($M = 96.4$), demonstrating that the children's intellectual abilities were in the average to above average range. The first major finding revealed that early child factors such as early identification and enrollment in early intervention are negatively related to children's

overall total school readiness skills. Hence, children identified with hearing loss and enrolled in early intervention at a later age may have the basic school readiness skills but might be at risk for not understanding more abstract language concepts (e.g., direction and position, time and sequence, self-social skills) necessary for kindergarten. The second major finding revealed that children's early oral language skills were positively associated with school readiness scores.

Nittrouer, Caldwell, and Holloman (2012) examined how individual language measures obtained from children with cochlear implants during the years from infancy through preschool predict language and literacy performance as children enter school. Thirty-five children with permanent sensorineural hearing loss participated in language and literacy measures. Twenty-seven of those children had severe to profound hearing loss and wore one or two cochlear implants. Eight children had moderate hearing loss and wore bilateral hearing aids. Another 15 children with typical hearing served as a control group. Nine measures fitting into six broad categories were used in the construction of the latent language/literacy variable: (a) Comprehension was tested using the auditory comprehension subscale of the Preschool Language Scales—4 (PLS). (b) A measure of expressive vocabulary was obtained using the Expressive One-Word Picture Vocabulary Test (EOWPVT). (c) Narrative skills were assessed using a rubric developed by Gillam, Pena, and Miller (1999, in Nittrouer, Caldwell, & Holloman, 2012). (d) Two measures of emergent literacy were obtained. One evaluated how well children could read individual words by using the word reading subtest of the Wide Range Achievement Test (WRAT), and the other assessed how well children comprehend passages they read through the

Qualitative Reading Inventory—4 (QRI). (e) Three measures of phonological awareness were used: syllable counting, initial consonant same-different judgments, and final consonant choice tasks. (f) To measure processing speed, the object-naming subtest of the Comprehensive Test of Phonological Processing (CTOPP) was used.

Overall, hearing children performed better than children with hearing loss, but no significant differences could be detected between children with hearing aids and those with cochlear implants. Children with HAs and CIs had mean derived scores more than 2 *SDs* below the mean of hearing children. The study also found the PLS comprehension measure to be one of the best predictors of kindergarten performance at every age tested between 12 and 48 months of age. Similarly, the mean length of children's utterances was a strong predictor of kindergarten performance once children reached 3 years of age. Nittrouer, Caldwell, and Holloman (2012) concluded that using measures that tap into higher-level psycholinguistic processes and sampling those skills more broadly indicates that children with hearing loss are starting school at a disadvantage in terms of their language foundation.

A study by Dillon, de Jong, and Pisoni (2012) provides more detailed knowledge about the cognitive and linguistic processes used by deaf children with cochlear implants as they develop and acquire reading skills. They investigated phonological awareness, reading skills, and vocabulary knowledge in 27 profoundly deaf children (17 boys and 10 girls) who used cochlear implants. The children ranged in age from 6 to 14 years old. The age range of implantation was from 2 years to 5 years. Twenty children had used their implants for over 5 years. Each child was assessed using the Lindamood Auditory

Conceptualization Test—Third Edition, Peabody Individual Achievement Test—Revised (PIAT-R), Word Attack subtest of the Woodcock Reading Mastery Tests—Revised (WRMT), the Reading Comprehension subtest of the PIAT-R, Phonetically Balanced Kindergarten, and the Peabody Picture Vocabulary Test (PPVT). Dillon et al. (2012) found that the deaf children with cochlear implants follow a similar pattern as hearing children in the following areas: development in phonological awareness, strong correlation between reading scores and vocabulary size, and strongly correlation between reading scores and phonological awareness skills. Approximately 40% to 75% of the children in the study obtained scores that were within the normal range (1 *SD* above or below the mean) of hearing children. Approximately 25% of the children performed above the norm compared with their hearing peers.

Nittrouer, Caldwell-Tarr, Sansom, Twersky, and Lowenstein (2014) conducted a study to examine the set of language abilities that might be predicted by non-word repetition (NWR) for children with CIs. The study wanted to find if NWR was a useful assessment tool with this population of children. Skills in three categories were examined as potentially predictable from NWR scores: vocabulary knowledge, reading abilities, and grammar. Sensitivity to phonological structure was tested by three tasks: the initial consonant choice task, the final consonant choice task, and the phoneme deletion task. Expressive vocabulary was assessed with the Expressive One-Word Picture Vocabulary Test (EOWPVT). The Word Reading Subtest of the Wide Range Achievement Test 4 (WRAT) and the Qualitative Reading Inventory (QRI) were used to assess reading of words in context and reading comprehension. Two measures of grammatical abilities

were obtained from a 20-minute sample of narrative language for each child. The story retelling was transcribed later by members of the laboratory staff according to methods first described by Hewitt, Hammer, Yont, and Tomblin (2005, in Nittrouer et al., 2014).

The participants were second graders consisting of 49 with typical hearing and 55 with cochlear implants, making a total of 104 participants. All children with CIs had their hearing loss identified, hearing aids fit, and intervention initiated by 2 years of age. The mean age of identification was 7 months, mean age of receiving hearing aids was 8 months, and mean age of starting intervention was 9 months. Eighty percent of the children received their first CI before turning 2 years old; 36 children had bilateral CIs. Significant results were that children with CIs performed more poorly than children with typical hearing on NWR, and sensitivity to phonological structure alone explained that performance for children in both groups. For children with CIs, being identified with hearing loss at younger ages and having experience wearing a hearing aid on the unimplanted ear at the time of receiving a first CI were two positive influential outcomes on NWR. The problems encountered by children with CIs in their recall of words could largely be explained by difficulty encoding clear phonological representations, precisely the phenomenon thought to underlie NWR (p. 10).

Lyxell et al. (2008) examined and compared development of working memory capacity, phonological, and lexical skills in 31 children with CIs and typical hearing children. The results from the three cognitive abilities were related to performance on a global test of reading ability. The children were between 6 to 13 years old, the median age being 8.6 years. All of the children with CIs were deafened before 3.0 years of age. There

were no differences in nonverbal intelligence between children with CIs and hearing children. In the cognitive tasks, the children with CIs had a generally lower level of performance than the hearing children in all tests, except for the visuospatial word memory test and the latency measure of the phonological skills measure. The results indicated that 65% of the children with CI performed within 1 *SD* for the tasks that tap general working memory capacity and lexical access. For the tasks that tap the phonological working memory and the phonological tasks used in this study, 20% reach the criterion of 1 *SD*. Most children in this study reached a fairly high level of reading comprehension. The process of reading acquisition is a cognitive process that draws heavily on phonological processing, and it is interesting to observe that they can reach fairly high levels of reading comprehension even though they have relatively poor phonological skills. One explanation for this mismatch is that the CI users are employing different word-decoding strategies than hearing children.

Wass (2009) investigated three specific aspects of cognitive ability proven to be fundamental to a number of more complex cognitive skills such as reading ability, arithmetic skills, and various aspects of communication in children with cochlear implants compared to age-matched children with typical hearing: working memory, phonological skills, and lexical access. Nineteen children with CIs and 56 children with typical hearing in the age range of 5.7–13.4 years old participated in the study. All the children with CIs had severe to profound hearing loss before 3 years old, receiving their implants between 1.9 and 10 years of age. Eleven of the children had bilateral implants. Wass found that the children with CI had poorer performance than the hearing children on

tests of phonological and general working memory, phonological skills, and lexical access. In the lexical access tests, approximately 50% of the children with CIs performed within 1 *SD* of their grade-matched comparison group on the latency measures, and 20–30% performed within 1 *SD* of the mean of the hearing children on the accuracy measures.

In a second study, Wass (2009) examined the relationships between working memory capacity, phonological skills, and reading comprehension. Sixteen children with CIs who had been diagnosed with a severe to profound hearing loss before 36 months of age were included in this study. Nine of the children had bilateral cochlear implants. All of the children were 7.2 to 13.4 years of age. Ten out of the 16 children (63%) performed at or above the 25th percentile and within 1 *SD* of hearing children in terms of percent of sentences/words correct.

In a third in-depth study, Wass (2009) considered phonological representations and phonological skills in children with CIs. A second aim was to study reading strategies in children with CIs and to find possible cognitive correlates of the strategies that they used. Six children with CIs, in Grades 1–3 participated in the study (one child in Grade 1, three children in Grade 2, and two children in Grade 3). All six children had severe to profound hearing loss with prelingual onset and had received their implants between 1.7 and 3.7 years of age. Five out of the six had bilateral implants. Forty-three hearing children constituted the comparison group (12–16 children in each grade).

The children were tested in two separate 50-minute sessions at their school. Some of the children with CIs were tested at a regular follow-up at their respective pediatric

cochlear implant programs. Out of the working memory (WM) measures, the children with CIs had most problems with phonological WM but had relatively fewer difficulties when tasks with shorter and suprasegmentally less complex test items were used. Four out of six children with CIs performed comparably to their respective grade-matched comparison group on the measure of general WM. All six children with CIs performed on par with their comparison group on the measure of visuospatial WM. Lexical access performance also varied between tests: five out of six children had a performance equivalent to their typical hearing controls in the Semantic Decision task, whereas only two and three children, respectively, performed on this level in the Wordspotting and Passive Naming tests. These findings may reflect that children with CIs use phonological and semantic representations of words in long-term memory when solving these types of tasks and, to a greater extent, use top-down processing strategies to compensate for distorted auditory perception.

Decoding skills were age-appropriate for all six children, for decoding of words as well as non-words. Reading comprehension was comparable to that of the typical hearing (TH) comparison group for four out of six children. The two children with poorer reading comprehension scores had a poorer performance than both their comparison groups and the other children with CIs on the measures of general and phonological WM and most of the measures of phonological skills.

When comparing results from her three research studies, Wass (2009) concluded that more than 60% of the children had reading comprehension within normal range. She also found that general working memory was related to reading comprehension. The

pattern of results from the studies indicated that phonological working memory is a problematic area for children with CIs, but they have relatively fewer problems in tasks with shorter and less complex test items. She also concluded that children with CIs have specific problems in tasks of phonological skills which use non-words as test items. For lexical assess, CI children had lower levels of correct identification of auditorily presented words compared to their hearing peers. A relatively higher proportion of children performed within the normal range when semantic information was provided. The findings suggest that children with CIs may have relatively efficient processes of lexical access, for both speech production and speech recognition, when the quality of the phonological representation and the auditory input signal are high enough. Their performance is also improved when they are familiar with the words which are to be accessed and when the semantic context provides cues to which words are more plausible.

Writing

Geers and Hayes (2010) studied spelling, reading, and expository writing in a group of 112 high school students from Canada and the United States who had more than 10 years of experience using a cochlear implant and a group of hearing students the same age from the same high school. Participants were tested on vocabulary, comprehension, spelling, syntax, writing, and phonological processing. The aim of this study was to find the reading levels of high school students who had received cochlear implants as preschoolers as compared to hearing students, as well as to examine the correlation between early literacy skills and levels and literacy levels in high school. The CI teenagers were significantly poorer spellers ($M = 67\%$ correct) than the hearing teenagers

($M = 80\%$ correct). More than half (55%) of the CI users exhibited spelling accuracy scores that were within 1 *SD* of age-matched hearing students, indicating that hearing loss did not preclude the development of typical spelling skills. However, when the students' spelling errors were evaluated for phonological plausibility, only 30% of the CI teenagers scored within 1 *SD* of hearing age-mates.

The findings in this study also illustrated high levels of individual variability in literacy outcomes for children with CIs: 36% of the students were judged to be reading at a level equal to their hearing peers (i.e., beyond a Grade 9 equivalency score), whereas another 17% of the students were still reading below the Grade 4 level. The remaining 46% of the sample demonstrated consistent reading growth, but remained delayed in comparison to their hearing peers (i.e., grade equivalencies between Grades 4 and 8).

Hayes, Treiman, and Geers (2014) analyzed spelling errors in a group of 39 deaf children with cochlear implants who used spoken English. The mean age of the children was 8.97 years. Specifically, Hayes et al. looked at whether a child spelled words on the basis of how they sound. Phonologically plausible errors would demonstrate that the child used phonological spelling strategies. It was found that hearing children were much more likely than children with implants to make plausible errors. Of the errors made by hearing children, 75% were phonologically plausible, as compared to 44% for the implanted children. The implant group spelled more poorly than hearing children of the same age. However, 74% of the deaf children had accuracy rates within 1 *SD* of the mean for the hearing group. Although the deaf children with cochlear implants did not use a phonological strategy to the same extent as the hearing group, they often did use

phonology to guide their spellings and did not appear to rely exclusively on visual rote memorization.

Wolff (2011) examined the specific grammatical errors that children with CIs generate in their spontaneous writing. Participants included 52 children with cochlear implants who used oral communication. The children ranged in age from 5.1 years to 11.8 years. Twenty-six of the participants were male. Duration of implant use ranged from 11 months to 7 years, with a mean of 5 years. Teachers were asked to submit samples that had not been corrected and not to provide help to the children with spelling, syntax, or mechanics. Teachers then asked the children to read their writing aloud and noted any pronunciation differences between what the children said and what they wrote. The two groups of participants submitted 455 writing samples containing 2,630 sentences. Wolff scored the writing samples by reading each sentence to determine whether the sentence was grammatically correct or incorrect, then marked what type of error took place (substitution, omission, or addition) and described the nature of the error (e.g., substituted a noun for a verb).

Wolff (2011) found children with CIs had a lower average minimum number of words per sentence than the hearing group (7.76 words compared to 8.41 words). Wolff performed an error analysis to examine the pattern of errors produced by children with CIs and the hearing group. Both groups of children made grammatical errors in their spontaneous written language. Errors were made on verbs, articles, nouns, prepositions, pronouns, conjunctions, plurality, adverbs, adjectives, negatives, and questions. Verb, article, and preposition errors accounted for over 65% of the grammatical errors for

children with CIs. These three categories accounted for almost 50% of the typical hearing participants' errors. Verb errors were the most common type of error made by both groups. Forty-six percent of total errors for children with CIs were made on verbs as compared to 31% of the hearing children's errors.

Verb errors were categorized as tense errors, omissions, substitutions, additions, and subject-verb agreement errors. For children with CIs, 86% of verb errors were tense errors, substituting the present for the past tense. Another verb error produced by children with CIs was the use of the progressive tense inappropriately, 5% using the present progressive tense incorrectly and 3% making errors with the past progressive. Examples of inappropriate use of the progressive tense were: *The boy is sad because it is rain. On Sunday we went sled.* Wolff (2011) also found the students had difficulty with substituting the past for the present tense (e.g., *Shadow liked to be in the rain*). Subject-verb agreement was another area of difficulty (e.g., *The girl were fishing*), with 10% of the children with CIs making such errors compared to 7% of the hearing children. Almost all of the children with CIs (91%) made substitution errors (e.g., *She had never done this cat before*, the verb *done* being substituted for the verb *seen*).

Article errors were the second most common error for children with CIs. Approximately 12% of their errors were on article usage (*a*, *an*, and *the*), compared to 10% for the hearing group. Overall, children with CIs made proportionally more omission and addition errors, and the hearing group made proportionally more substitution errors. The children with CIs made a higher proportion of preposition errors than the hearing

participants. Almost half (47%) of the children with CIs' preposition errors were omissions (e.g., *The girl was walking the store.*).

Mayer, Papoulidis, and Millett (2012) examined reading and writing levels for a cohort of learners using cochlear implants. The results for children with cochlear implants were compared to chronological age norms for hearing learners. A total of 23 students participated in this study. The mean age of participants was 12.7 years, with a range from 7 to 17 years. Data were collected through existing psychoeducational assessments completed by a psychologist: the Test of Nonverbal Intelligence (TONI), the Wechsler Individual Achievement Test—2 to gather reading ability, and the Test of Written Language—3 (TOWL-3) for measures of written language. Students' reading results indicated that 69.6% were reading at grade level. On the basis of writing scores from the TOWL-3, 69.6% of students were found to be writing at grade level. Findings from this research indicate that students with cochlear implants are demonstrating improved literacy outcomes relative to their hearing peers. In both reading and writing, almost 70% of the students in this study were achieving at or above grade level.

Ambrose, Fey, and Eisenberg (2012) had two objectives in their study: to evaluate the phonological awareness skills and print knowledge of a group of preschool-age children who were implanted by 36 months of age and had been using their CIs for at least 18 months at the time of testing. Eleven of the 24 children were using two CIs at the time of evaluation; of these three children received their two CIs simultaneously and the remaining eight received their two CIs sequentially. Twenty-three hearing children were the control group. The CI group's mean score for phonological awareness fell within 1

SD of the TOPEL's normative sample mean but was more than 1 *SD* below the TH group mean. The CI group's performance did not differ significantly from that of the TH group for print knowledge, as slightly more than half of the children in the CI group scored above the typical hearing group mean on the TOPEL print knowledge subtest. The scores confirmed that children with CIs can demonstrate age-appropriate print knowledge skills. The current study indicated that children's early literacy abilities, especially those involving phonological awareness, were tied to their oral language, speech production, and speech perception abilities and that, for many children, these were delayed in comparison to their peers with typical hearing. Together, these predictor variables accounted for 34% of variance in the CI group's phonological awareness but no significant variance in their print knowledge. Children with CIs have the potential to develop age-appropriate early literacy skills by preschool age but are likely to lag behind their TH peers in phonological awareness.

Research Moving Forward

A developmental lag in literacy skills in children with severe to profound hearing loss is well researched and documented. This review of the current literature indicates that the large literacy gap that previously existed between hearing children and children who are deaf is closing. The momentum of change in deaf education has been propelled by the advances in hearing technology. Deaf children have a means of accessing spoken language and information found all around them through cochlear implants. Many studies have acknowledged that early cochlear implantation gives a child who is deaf the greatest chance to succeed in reading.

Most studies that explore reading in children with cochlear implants involve children who have received their implants at 2 years of age or later. Today, however, many children are receiving implants at 12 months of age or earlier. More recent research has also shown the greater speech and language success in children with bilateral cochlear implants compared to unilateral implant users, making two ears better than one; however, much more research needs to be completed in this area. With the possibility of simultaneous bilateral cochlear implantation at a very early age, research needs to continue to gather evidence to address the emergent literacy skills of preschoolers and academic success in school-aged children. Even more concerning is the lack of data on the writing abilities of deaf children with cochlear implants. Greater research effort needs to be dedicated to studying the writing skills of these children.

In light of this changing landscape and the gaps in the research evidence, particularly with respect to the impact of the combination of early diagnosis through UNHS followed by early simultaneous bilateral cochlear implantation, the current study was undertaken to address three main goals: (a) to investigate the language, reading, and writing skills of a group of deaf school-aged children who received simultaneous bilateral cochlear implants before the age of 2 years, (b) to compare the language, reading, and writing skills of this deaf group with those of their hearing age-peers, and (c) to identify relative areas of strength and needs in the language and literacy abilities of this group of implanted children. More specifically the following research questions are addressed:

1. What are the language, reading, and writing outcomes for a cohort of school-aged children using bilateral cochlear implants received simultaneously before the age of 2?
2. How do these outcomes compare to those of their hearing age-peers?
3. What areas of relative strength and need (e.g., phonological abilities, vocabulary) can be identified in the language and literacy achievement of these students?

In the following two chapters, the methodology of the study is described and presented (i.e., participants, data collection, measures, ethics), and the results of the data analyses are reported. In the final chapter, the study results are discussed in light of the previous research evidence and the predicted outcomes for the population of children with CIs, including implications for practice in the field of deaf education and possible directions for future research.

CHAPTER THREE

METHODOLOGY

Participants

All eight participants were graduates of the Resource Services—Home Visiting Program. The Home Visiting Program offered by the Provincial Schools Branch (PSB) of the Ministry of Education is a service to Ontario families with a child between the ages of birth and 4 years old, diagnosed with a hearing loss. The families are supported by an Ontario College of Teachers licensed teacher with a specialist certification in deaf education. The teacher of the deaf and hard-of-hearing (TODHH) supports and educates parents in their homes on hearing loss, communication, and language development and, most importantly, prepares the child for school entry.

Using a purposive sampling, eight participants were selected for this study. The selection criteria included that all participants (a) were identified with a congenital profound bilateral hearing loss, (b) have simultaneous bilateral CIs, (c) were implanted at age 2 years old or younger, (d) were school-aged at time of testing, (e) did not have a concomitant disorder, (f) had English as the family's primary spoken language, and (g) attended a local school with same-aged peers. The participants were attending their neighbourhood school and following the Ontario curriculum. The participants were ages 5:5–9:1 years old, placing them in junior kindergarten (JK) to Grade 4, at time of testing for Phase 1; ages 6:10–10:3 years old, placing them in Grade 1 to Grade 4, at time of testing for Phase 2 (Table 2).

Table 2. Participant Demographic Information

Participant	Gender	Chronological age (yrs:mos)	Grade	Communication mode	Age implant activated
Lucia	F	9:8	4	Oral	1:1
Sophia	F	9:1	3	Oral	1:10
Steven	M	8:10	3	Oral	2:3
William	M	6:7	1	Oral	0:8
Robert	M	6:5	SK	Oral	0:9
Andrew	M	6:2	SK	Oral	1:3
Gregory	M	5:9	SK	Oral	1:2
Kevin	M	5:5	JK	Oral	1:0
Range		5:5 to 9:8			0:8 to 2:3
Mean		7:4			1:4

Source: Parental Questionnaire (see Appendix A)

Families whose children met the criteria were contacted via email and/or followed up via telephone. The caregivers were provided with a brief description of the research, the research questions, and the commitment required. This longitudinal study consisted of two phases or testing periods. Phase 1 took place in June and July 2014; Phase 2 took place in May and June 2015. All testing and data collecting took place at the families' residences. Each phase (spring 2014 and spring 2015) was divided into two separate visits consisting of 2–3 hours of testing each day. The testing sessions were separated into two different days in order to prevent fatigue.

At the initial visit, information regarding informed consent for a minor child and oral informed assent was reviewed with the primary caregiver. Participants and their primary caregivers were given the opportunity to ask questions related to the study and

required documentation. Signed informed consent and oral assent of the child were obtained.

All participants were residents of Ontario, living in the Greater Toronto Area and southwestern region. All participants came from two-parent households with some level of postsecondary education. The families' income ranged from \$30,000 to greater than \$130,000.

For seven children, simultaneous bilateral CI surgery was at the Hospital for Sick Children, Toronto, with the Cochlear Nucleus device, and one child was implanted at the London Health Sciences Centre with the MED-EL device. The age at which the children were implanted ranged from 0:8 to 2:3 years old. All participants received some form of services post-implant that included speech and language services and/or auditory verbal therapy with speech-language pathologists through the Infant Hearing Program, and services from a TODHH through the Home Visiting Program. Pre-implant, five of the families used aural/oral as their form of communication, and three families used visual/gesture/sign to communicate. All families used oral communication with their child post-implantation. Table 3 summarizes the audiological and amplification history for each participant.

Table 3. Participant Audiological and Amplification History

Participant	Age of identification of hearing loss	Etiology	Length of time using hearing aids	Length of time using CIs	Device
Lucia	4.5 mo.	Genetic	6 mo.	8:7	Nucleus 5
Sophia	13 mo.	Genetic	4 mo.	7:3	Nucleus 5
Steven	21 mo.	Genetic	2 mo.	6:7	Nucleus 5
William	1 day	Genetic	4.5 mo.	6:0	Nucleus 5
Robert	4 mo.	Genetic	2 mo.	5:8	MED-EL
Andrew	3 mo.	Unknown	6 mo.	5:0	Nucleus 5
Gregory	10 days	Unknown	13 mo.	4:6	Nucleus 5
Kevin	3 mo.	Ototoxicity	9 mo.	4:3	Nucleus 5

Source: Parent Questionnaire (see Appendix A)

Participant 1: Lucia

Lucia was born to hearing parents, a 36-year-old mother and a 44-year-old father. Lucia has an older sister by 3 years and a twin, who are both hearing. Both parents were born and raised in Canada, and English is the primary language of the immediate and extended family. Mother has a degree in music and education and is a high school teacher. Father has a degree in engineering and works as a mechanical engineer.

Lucia’s mother had no unusual illnesses, conditions, or accidents during the pregnancy, gaining 30 pounds and deeming it a normal pregnancy. The twins were carried to 37.5 weeks gestation, just a half-week shy of full term for twins (38 weeks), and they were therefore not considered premature. They were born with no complications by Caesarean section, with Lucia weighing 6 pounds 15 ounces, in a normal weight range.

Through the Ontario IHP, Lucia was screened for hearing loss in the hospital within one day of her birth. Lucia received a refer result on the initial hearing screening as well as the two follow-up screenings, 6 weeks and 8 weeks later. Auditory brainstem testing diagnosed a bilateral profound sensorineural hearing loss at the age of 4.5 months. Subsequent genetic testing indicated that the hearing loss was hereditary in nature.

Lucia underwent a CT scan to determine any abnormalities or malformations of the ear structure with no detection of such. Lucia received trial hearing aids in July 2005 and wore them for 2–4 hours per day. As it was a struggle to keep the hearing aids on, the parents reported that there was no apparent difference in Lucia’s communication or listening skills after they began using the hearing aids. The family communicated with Lucia through visuals and gestures.

Three days before Lucia’s first birthday, on February 9, 2006, she underwent simultaneous cochlear implant surgery at the HSC in Toronto. On March 6, 2006, at 1;1 years of age, the implant was activated. Mapping of the implants happened over 3 days in March 2006.

Lucia attended weekly 1-hour AVT sessions in addition to weekly home visits by a TODHH through the Home Visiting Program. The teacher and auditory verbal therapist worked with Lucia and the family to carry out ongoing assessments and establish language and listening goals.

In the home, there were many language models and a rich language environment, with conversation during shared meals, family discussions, and lots of books read throughout the day. Parents were both at home for the first year after Lucia’s birth.

Mother returned to work just short of a year while father continued to care for the children with occasional assistance from the paternal grandmother. Their father brought the girls for walks around the neighbourhood and spent time playing at the neighbourhood park, the library, and home, and spent time reading and interacting throughout daily routines such as feeding and bathing. Father returned to work when the twins were 15 months old. At this time, they were enrolled in daycare 3 days per week (Monday, Tuesday, and Wednesday), and for the other 2 days their grandmother looked after them in their home, implementing suggestions from parents, therapist, and teacher.

Lucia attends her local school where she is mainstreamed with same-aged peers, following the Ontario curriculum with no direct support, only monitored by a TODHH. The home environment continues to be a rich language environment with discussions on topics found in the everyday life of three preteen girls (e.g., cafeteria food, likes/dislikes of food, clothes, activities). Besides being very artistic, Lucia has been playing soccer every summer on a league since the age of 4. She has also been taking dance lessons for the past 4 years which have included ballet, acro, tap, and hip hop. This past school year, Lucia made it onto the junior level volleyball and basketball school teams while still in Grade 4. In the winter months, skating, skiing, and tobogganing keep her busy.

Participant 2: Sophia

Sophia was born to hearing parents when her mother was 38 years old. Sophia has two older sisters by 6:5 and 7:5 years who are both hearing. Both parents were born and raised in Canada, and English is the primary language in the home. Father has a diploma

in electrical engineering. Mother has a degree in social work and chose to stay at home once her children were born.

Sophia was born weighing 9 pounds 3 ounces with no complications after a normal pregnancy. While she was still in the hospital, parents were notified that Sophia had passed the hearing screening test. It was not until Sophia was 13 months of age that parents suspected a hearing loss. Genetic testing indicated that the cause of hearing loss was genetic, related to the gene connexion 26. Hearing aids were used for 2 months with no obvious benefits. In October 2006, auditory verbal therapy was tried, but because no responses with hearing aids were seen, this intervention was put on hold until after implantation. Communication development services were provided by a TODHH through the Home Visiting Program biweekly. On January 30, 2007, Sophia received simultaneous bilateral cochlear implants at 20.5 months of age. The devices were activated by 22 months of age.

Post-implant, auditory verbal therapy was put in place once a week, continuing for a year and a half (March 15, 2007, to September 2008). As a result of lack of progress in speech and language development, Sophia was transferred to a speech and language pathologist, who implemented a total communication approach. All services were terminated once school commenced.

Sophia has had a language-rich environment supported by her family. With a stay-at-home mother who implemented suggestions from the support services (AVT and TODHH), many routine events became ideal learning opportunities. Family interactions

through meaningful experiences assisted Sophia in developing her communication and language skills.

Sophia attended a daycare program for 6 months when she was 3:7 years old, where she received support from a resource teacher. After the 6 months of daycare, it was recommended that Sophia receive SLP services for articulation, which occurred once a week for 6 weeks during the summer, repeated again in the fall.

Sophia attended full-day JK and SK twice a week and every other Friday. She was supported by a full-time educational assistant and a TODHH twice a week, 3 hours per week, with a mixture of in-class support and withdrawal and the resource teacher (SERT). In Grades 1 and 2, support from the TODHH became weekly, in Grade 3 biweekly, and in Grade 4 monthly. Sophia has always had a personal FM system in the classroom. During Grades 3 and 4, Sophia has attended Kumon for academic support three times a week. Sophia continues to attend her local school in a mainstreamed class with peers following the Ontario curriculum.

Sophia has been taking piano lessons and dance lessons for 3 years. She performs in ballet, modern dance, and acro, but hip hop is her favourite. She performs so well in hip hop that she has been invited to join the precompetitive level this year.

Participant 3: Steven

Steven was born to hearing parents. He has an older brother by 1:8 years who is hearing and a younger brother by 2:4 years who has a hearing loss. Steven was born weighing 8 pounds 9 ounces at full term with no complications. He passed a hearing screening at birth. When he was 1:9 years of age, a family member questioned the

possibility of hearing loss. Steven was subsequently identified with a profound bilateral sensorineural hearing loss. It was determined that the cause of hearing loss was genetic. Three months after identification, Steven was fitted with bilateral hearing aids. In August 2007, Steven was implanted simultaneously with bilateral Freedom cochlear implants at the HSC in Toronto. At the age of 2:2 years, the implants were activated.

Both parents are physically active, providing exposure to a variety of sports, activities, and events. Steven began riding a two-wheel bicycle at the age of 4 years. Steven has enjoyed playing hockey since he was 5 years old, participates in swimming, long-distance running, high jump, and ball hockey, and recently finished third in his age group in a biathlon regional final.

Both parents hold university degrees with English as the primary language in the home. With a stay-at-home mother, Steven was engulfed in a rich environment of physical and mental activities. Pre-implant, Steven was not demonstrating any benefit from hearing aids. Mother was proactive and used gestures and visuals to communicate with Steven. Support services through IHP and OME began after the hearing loss was identified. When he was 3, parents were advised to place Steven in a preschool program to interact with peers to be exposed to age-appropriate language. Steven attended preschool twice per week for half the day.

Steven began junior kindergarten at his local school in a mainstreamed class with peers, where he continues his education. Support from the school board TODHH and access to a personal FM system began when Steven entered Grade 1. Beginning in Grade 2, Steven received support from the school board SLP services and the school SERT.

Participant 4: William

William was a healthy 8-pound-7-ounce child born to hearing parents and the youngest of three. Both parents were born and raised in Canada, and English was the primary language of the immediate and extended family. Mother had a normal pregnancy with no reported illnesses, conditions, or accidents. Parents had knowledge of the connexion 26 gene being present in the family but were surprised when William was born deaf.

William was fitted with bilateral hearing aids at the age of 3.5 months and was immediately placed on the cochlear implant candidacy list at the HSC in Toronto. He was simultaneously bilaterally implanted at exactly 8 months of age, becoming the youngest implanted infant in Canada.

Provincial services through IHP and OME were in place after William was born. AVT continued until school entry and services from the Home Visiting Program for 2 years. At the age of 3 years old, William attended preschool half days twice a week to interact with peers. William enjoyed a language-rich environment with two older siblings and well-educated parents through interactive experiences of meals, daily routines, sports, and activities (e.g., crafts and family trips).

William began junior kindergarten at his local school in a mainstreamed class with peers, where he continues his education. Beginning in Grade 1, William began to receive school board SLP services for articulation, was fit with a personal FM system, and was monitored by the school board TODHH.

Both parents are physically active, providing exposure to a variety of sports, activities, and events. William has enjoyed playing hockey since he was 4 years old, and is now playing competitive rep hockey. He has been playing ball hockey in a league since he was 3 years old. At school, he enjoys playing all sports, even training in running in order to prepare and try out for the track team this school year. In his spare time, William enjoys swimming and drawing.

Participant 5: Robert

Robert was born to hearing parents when mother was 31 years old and father was 32 years old. Robert was born via Caesarean section a week past his due date, weighing 7 pounds 12 ounces, with no complications after a normal pregnancy.

Robert received a refer result on newborn hearing screening. Follow-up screenings were delayed because of illness, but Robert's hearing loss was confirmed at 4 months of age and was subsequently identified as being genetic in origin. At 6 months of age, Robert was fitted with bilateral hearing aids. At this time, parents used gestures, visuals and oral language to communicate. At nine months of age, Robert received simultaneous bilateral cochlear implants.

Both parents were born and raised in Canada, and English was the primary language in the home. Parents are college graduates working in professional environments. The family had support services from weekly home visits by a TODHH from the PSB and weekly 1-hour AVT sessions through the IHP. Both services continued for 3 years.

Robert was exposed to and surrounded by language from the first day he was born. Having books read to him, listening activities, and speaking to him provided rich, meaningful interactions throughout daily routines. As Robert grew, high-frequency words were placed on a wall to be seen and practised reading. Robert's home environment continues to be a rich language environment through daily discussions, conversations, and bedtime stories, but now Robert gets the pleasure of reading books to his family.

After Robert's birth, mother stayed home for 14 months. After she returned to work, Robert attended a home daycare for 6 months. At the age of 2 years, Robert attended a preschool program full-time until entering school. Robert attends his local school where he is mainstreamed with same-aged peers. Robert receives biweekly support from a TODHH.

Robert is extremely active outside of school. He has been swimming since he was a baby and tried soccer for 1 year when he was 3 years old. Robert has continued to play baseball since he was 4 years old. At the age of 5 he began tennis and hockey, and this year he began playing golf. Robert took 2 years of piano lessons. Since SK, he has enjoyed taking art classes once a week after school.

Participant 6: Andrew

At the time of Andrew's birth, mother was 24 years old and father was 27 years old. Both parents were born and raised in Canada. Parents, immediate family, and extended family are hearing. Parents come from a bilingual Arabic- and English-speaking family but the primary language in the home is English. Grandparents speak Arabic to Andrew and parents also codeswitch when speaking to each other. Andrew demonstrates

his understanding of Arabic and is now beginning to use utterances in Arabic ranging from one word to very simple sentences when communicating with his grandparents.

Andrew was born weighing 6 pounds 12 ounces with no complications after a normal pregnancy. Andrew's hearing was screened 2–3 days after birth, with inconclusive results. At 3 months he was diagnosed with a profound hearing loss, of unknown etiology. At 7 months old, Andrew was fitted with bilateral hearing aids. The family had support services from weekly home visits by a TODHH from the PSB and weekly one-hour AVT sessions through the IHP. In the second and third year, services went to biweekly, for approximately 3 years.

At the age of 1:3 years, April 17, 2009, Andrew received simultaneous bilateral MED-EL cochlear implants at London Health Sciences Centre. Parents were supportive in keeping the implants on Andrew all his waking hours along with using spoken English to communicate. Mother remembers being told by the TODHH to “be a newscaster” and provide as much language during the day throughout daily routines as possible. Andrew was read a story every night. Now Andrew is asked to read a story to his parents, which he enjoys. Parents report that Andrew enjoys telling fiction and nonfiction stories, recounting events, and sharing in conversation about what the family maybe doing.

Mother stayed home with Andrew until he was 2 years old. He then attended a preschool full-time with the occasional time at his grandparents' home. Andrew attends his local school in a mainstreamed class with peers. He receives 45 minutes of direct support weekly from a TODHH and group support from the school resource teacher. The teacher reported Andrew to be reading at grade level. For Grade 1, Andrew attended a

French Immersion school but he will begin attending an English-speaking school for Grade 2.

Outside of school, Andrew has been taking swimming lessons since he was 5 years old. This past year, Andrew began playing tee-ball.

Participant 7: Gregory

Gregory was born to 31-year-old hearing parents. Both parents were born and raised in Canada, English being their primary language. Gregory has a younger brother by 2 years. All family members are hearing. Mother has a high school diploma, working as an administrator. Father has a college diploma in trades, where he currently works.

Gregory was carried to 35 weeks gestation after a normal pregnancy, and was born with no complications through a natural birth, weighing 5 pounds 14 ounces.

Gregory received a refer result on newborn hearing screening. A bilateral profound hearing loss with an unknown etiology was diagnosed 10 days later. Gregory was fitted with hearing aids 2.5 months after identification. Parents communicated via spoken English.

Upon identification of a hearing loss and hearing aid fitting, Gregory was placed on the cochlear implant candidacy list at the HSC. He received bilateral cochlear implants on May 19, 2009, at the age of 1;1 year. Following implantation, Gregory received AVT for a total of 3 years: in the first year, 1-hour sessions weekly, and in the second and third years, 1-hour sessions biweekly. He also received educational and language support delivered by a TODHH through the OME—Home Visiting Program weekly for 1 year. Gregory's mother remained home with him for the first year following his birth. He then

attended a daycare centre full-time. Gregory's home environment was filled with one-to-one interaction, and he was exposed to literacy through play and enjoying a story at bedtime.

Gregory attends his local school where he is mainstreamed with same-aged peers with direct support from the school board TODHH. His family interaction and home environment continue to be filled with conversations between parents and sibling. Gregory has been involved in karate since he was 5 years old. He currently holds an orange belt.

Participant 8: Kevin

Kevin was born to hearing parents. He has an older brother and sister who are hearing. Both parents were born and raised in Canada, and English is the primary language of the immediate and extended family. Both parents are college graduates working as professionals in their field. Age of parents was not disclosed.

Kevin received a refer result on newborn hearing screening and was subsequently identified with a hearing loss, fitted with bilateral hearing aids, and referred to the cochlear implant program. He was simultaneously bilaterally implanted with a Nucleus 5, 10 days before his first birthday.

Parents had services through IHP: 1 hour AVT sessions for 3 years. They also had services from the OME: PSB 1–2 hour visits by a TODHH for three years. Both services for the first year were weekly, while the second and third years moved to biweekly.

Kevin has been cared for by his parents and a nanny, who have all been involved in maintaining a language-rich environment. All members consistently followed through

on language, speech, and educational suggestions and goals provided by the AVT and TODHH. Kevin attends his local school, where he is mainstreamed with same-aged peers with direct support from the school board TODHH.

Measures

Language

The *Clinical Evaluation of Language Fundamentals* (Fifth Edition) (CELF-5) (Wiig, Semel, & Secord, 2013) is a standardized assessment of language performance and everyday communication interactions for individuals from 5 to 21 years old. It includes 16 tests: Observational Rating Scale (ORS), Sentence Comprehension, Linguistic Concepts, Word Structure, Word Classes, Following Directions, Formulated Sentences, Recalling Sentences, Understanding Spoken Paragraphs, Word Definitions, Sentence Assembly, Semantic Relationships, Pragmatics Profile, Reading Comprehension, Structured Writing, and Pragmatics Activities Checklist (PAC). The ORS, Pragmatics Profile and the PAC tests were not administered in this study as the skills and behaviours assessed in these tests were evaluated through parent interviews, parent questionnaire, observation during testing, the Speech Intelligibility Rating, and the Categories of Auditory Performance. The Reading Comprehension and Structured Writing subtests were also not included, as these domains were assessed using other tests and processes.

A brief description of each subtest is provided. In the Sentence Comprehension subtest, the examiner provides a sentence orally, and the child points to one picture out of four that reflects the statement (e.g., point to “the boy has a ball”). In the Linguistic Concepts subtest, the child is asked to follow spoken directions related to pictures (e.g.,

“point to the flower in the middle,” where there is a row of three flowers). The Word Structure subtest assesses understanding and use of morphology and pronouns. The child is asked to finish the sentence/statement the examiner begins (e.g., “here is one mouse, here are two ____”). The Word Classes subtest assesses understanding of relationships between words. The child is presented with three or four pictures to a page. The examiner says the words and the child points to the two pictures that go together (e.g., “tell me the two words that go together best—cat, cow, kitten”). In the Following Directions subtest, the child is presented with shapes on a page. The examiner reads a direction and the child is to point to the pictures in the order they were told (e.g., “point to the black circle and the white square”). The Formulated Sentences subtest requires the child to say a grammatically correct sentence using a word provided by the examiner related to the scene in the picture (e.g., “make a sentence about the picture and use the word *reading*”). The Recalling Sentences subtest assesses the child’s ability to remember and repeat sentences of increasing length and complexity. The Understanding Spoken Paragraphs subtest requires the examiner to read a paragraph/short story and then ask the child questions about what was read to him/her. The Word Definitions subtest assesses the ability to define and describe vocabulary words. The examiner says a word, uses it in a sentence, then asks the child to give the definition of the word. In the Sentence Assembly subtest, the examiner provides a sentence with the words out of order, and asks the child to make a sentence from those words. The child is then asked to make a second sentence if possible (e.g., “make a sentence with these words—is, on, the chair, the kitten”). The child would be expected to create “The kitten is on the chair” and then asked to make

another sentence, i.e., “Is the kitten on the chair?”). The Semantic Relationships subtest assesses the ability to understand sentences with complex linguistic relationships (e.g., “Teenagers are younger than . . . Infants? Adults? Grandparents? Children?”).

Scores provided include individual subtest standard scores, as well as composite scores (Core Language Score, Receptive Language Index, Expressive Language Index, Language Content Index, and Language Structure Index). Specific guidelines for administering the assessment to students with sensory disabilities are included in the manual.

The CELF-5 was standardized on more than 3,000 individuals (stratified by geographic location, age, gender, race/ethnicity, and education of primary caregiver) by 459 examiners in 47 states. Measures of reliability range from 0.75 to 0.98. Reliability for all composite scores range from 0.95 to 0.96. Test-retest reliability of the CELF-5 was evaluated in a study with a sample size of 137 participants in a range of ages from 5:0 to 16:11. The average corrected stability coefficients ranged from in the 0.70s to the 0.90s for subtests and from 0.83 to 0.90 for composite scores. Furthermore, inter-rater reliability measures ranged from 0.91 to 0.99 on subtests requiring examiner judgment and interpretation of scoring rules.

The *Peabody Picture Vocabulary Test, Fourth Edition* (PPVT-4 Scale) (Dunn & Dunn, 2007) is an individually administered, norm-referenced test of receptive vocabulary. The age norms are based on a representative sample of 3,540 individuals aged 2:6 through 90+ years, by over 450 examiners at 320 sites. The sample was stratified

by U.S. geographic location, age, gender, race/ethnicity, and SES and special-education status.

The PPVT-4 has two parallel forms, Form A and Form B, each with four training items (for administering the test) and 228 test items grouped into 19 sets of 12 items each arranged in order of increasing difficulty. In the test, the examiner says a word and the child points to the picture that shows the meaning of the word. The examiner administers the item sets until the child's "basal" and "ceiling" sets are found. The basal set is the item set in which the child makes one or no errors and the ceiling is the item set in which the child makes eight or more errors.

Measures of reliability of the PPVT-4 indicate internal consistency of 0.94 or 0.95 on each form. The coefficient alphas averaged 0.97 and 0.96 for Form A and B respectively. Test-retest reliability (with an approximately 1-month interval between tests) correlation coefficients for 340 examines in five age groups (ranging from 2 years to 60 years) were in an average range of 0.92 to 0.96.

Phonological Processing

The Comprehensive Test of Phonological Processing (CTOPP) (Wagner, Torgesen, & Rashotte, 2001) is a standardized, norm-referenced test of phonological processing for individuals aged 5 to 24 years. Subtests for ages 5–6 years include: Elision, Rapid Colour Naming, Blending Words, Sound Matching, Rapid Object Naming, Memory for Digits, Nonword Repetition, Blending Nonwords, Rapid Digit Naming, and Rapid Letter Naming. Composite scores can be calculated for the domains of Phonological Awareness, Phonological Memory, and Rapid Naming. Subtests for ages 7–

24 years include: Elision, Blending Words, Memory of Digits, Rapid Digit Naming, Nonword Repetition, Rapid Letter Naming, Rapid Colour Naming, Phoneme Reversal, Rapid Object Naming, Blending Nonwords, Segmenting Words, and Segmenting Nonwords. Composite scores can be calculated for the domains of Phonological Awareness, Phonological Memory, Rapid Naming, Alternative Phonological Awareness, and Alternate Rapid Naming.

A brief description of each subtest follows. In the Elision subtest, the examiner says a word, directing the child to say the word back without a specific word or letter (e.g., “tell me *cup* without the *p* sound”). In the Blending Words subtest, the examiner provides a word in “segmented” form and asks the child to blend them into a word (e.g., /b/a/t). In the Memory for Digits subtest, the child is asked to repeat a list of numbers in correct order, with the length of the list increasing as the child is able to do the task correctly. In the Rapid Digit Naming subtest, the child is shown a page with four rows of nine numbers. The examiner has the child say the numbers on the page as fast as they can without missing any numbers. In the Nonword Repetition subtest, a child is to listen to nonsense words, then say them back exactly as they were heard. The Rapid Letter Naming subtest is similar to Rapid Digit Naming, but with graphemes instead of numbers. Similarly, Rapid Colour Naming uses colours instead of numbers or graphemes. The Rapid Object Naming subtest uses pictures of objects instead of colours, numbers, or graphemes. In the Phoneme Reversal subtest, the child listens to words that are said backwards and he/she are to reverse the word and say it correctly. The Blending Nonwords subtest is similar to Blending Words, but uses nonsense words. In the

Segmenting Words subtest, the examiner will say a word, the child is to repeat the word, then say it one sound at a time. The Segmenting Nonwords subtest is similar but uses nonsense words.

Scores which can be obtained include individual subtest standard scores and/or percentiles and composite scores (Phonological Awareness Composite Score, Phonological Memory Composite Score, Rapid Naming Composite Score, Alternate Phonological Awareness Composite Score and Alternate Rapid Naming Composite Score). The normative sample of the CTOPP included 1,656 individuals in 30 states. Measures of internal consistency exceeded 0.80 and test-retest coefficients ranged from 0.70 to 0.92.

Academic Achievement

The *Woodcock-Johnson Test of Achievement—III* (WJ-III) (Schrank, Mather, & Woodcock, 2004) is a standardized, norm-referenced test of academic achievement, including phonological awareness, phonics knowledge, reading achievement, and oral language ability. It can be administered to individuals 2 to 90 years old. Guidelines for administering the assessment to students with hearing loss in their primary mode of communication (e.g., American Sign Language, sign-supported speech/English, and aural/oral English) are outlined in the manual.

Normative data for the WJ-III were collected from 8,818 individuals in over 100 geographically diverse communities representing the overall U.S population, with 4,784 subjects being drawn from students in kindergarten through Grade 12. The battery contains 10 tests: Letter-Word Identification, Passage Comprehension, Word Attack,

Reading Vocabulary made up of three subtests (Synonyms, Antonyms, Analogies), Reading Fluency, Spelling of Sounds, Sound Awareness made up of three subtests (Rhyming, Deletion, Substitution), Sound Blending, Oral Vocabulary made up of three subtests (Synonyms, Antonyms, Verbal Analogies), and Oral Comprehension. Eight cluster scores can also be obtained, to describe the domains of Basic Reading Skills, Reading Comprehension, Phonics Knowledge, Phonemic Awareness, Oral Language Comprehension, Brief Reading, Broad Reading, and Total Reading.

In the Letter-Word Identification subtest, the child is asked to read a list of print words. The Passage Comprehension subtest is a cloze activity in which the child is asked to fill in the missing word in a print sentence. The Word Attack subtest assesses decoding skills by asking the child to read a list of letters and nonsense words. The Reading Vocabulary subtest requires the child to provide a synonym or antonym for a print word or finish an analogy (e.g., summer hot, winter . . . ; dog walks, bird . . .). In the Reading Fluency subtest, the child is asked to read sentences and indicate whether they are true or false by circling Yes or No in the test booklet. In the Spelling Sounds subtest, the examiner dictates letters and words and asks the child to write them down. The Sound Awareness subtest assesses phonological and phonemic awareness. In the Deletion section of the Sound Awareness subtest the examiner says a word and instructs the child to repeat the word leaving off one part (e.g., “say *cup* without the *p* sound”). In the Substitution section of Sound Awareness, the child listens to a word with instructions to change one sound and say the new word. In Sound Blending, the examiner gives a word segmented into its component phonemes and the child has to blend them into a spoken

word. In Oral Vocabulary—Synonyms the child is shown words on a page which the examiner reads and the child is to say another word that means the same. In Oral Vocabulary—Antonyms, the child is shown words on a page which the examiner reads and the child is to say a word which means the opposite. In Oral Vocabulary—Verbal Analogies, the examiner says a statement and the child is to finish it with the correct word. In Oral Comprehension, the child listens to a sentence and is asked to finish the sentence with the correct word.

Test scores obtained include standard scores (including percentiles and age/grade equivalents) and composite scores.

Writing

Because there are few standardized tests available to assess writing, the Ontario writing curriculum was used as the basis for assessment. Uncorrected writing samples were obtained from each child. All writing samples were graded separately by three elementary teachers unknown to the participants and from different school boards than the participants, as well as by the researcher. The samples were graded according to *A Guide to Effective Instruction in Writing, Kindergarten to Grade 3 (GEW)* (Ontario Ministry of Education, 2005) and *The Ontario Curriculum: Exemplars, Grades 1–8—Writing* (Ontario Ministry of Education and Training, 1999).

A Guide to Effective Instruction in Writing, Kindergarten to Grade 3 (GEW) (Ontario Ministry of Education, 2005), is designed to provide classroom teachers of kindergarten to Grade 3 with practical approaches and resources for delivering an

effective writing program. The guide provides a developmental continuum for the initial stages of writing.

The Ontario Curriculum: Exemplars, Grades 1–8—Writing (Ontario Ministry of Education and Training, 1999), provides illustrations of each of the four levels of student achievement in writing for students at the end of each grade based on the Ontario curriculum expectations. A rubric—a scale that describes levels of achievement for a particular complex task and guides the scoring of that task according to relevant criteria—is used for each writing task to provide an effective means of assessing the particular type of student performance, to allow for consistent scoring of student performance, and to provide information to students on how to improve their work. The achievement levels for writing focus on four categories of knowledge and skills: reasoning, communication, organization, and conventions. Each rubric contains the following components: the framework, the descriptions of student learning, the expectations for the provincial standard or grade level, and the required components specific to various writing tasks.

Speech and Auditory Skills

The *Speech Intelligibility Rating scale* (SIR) (Cox & McDaniel, 1989; Ear Foundation, 2004) is a practical and reliable clinical measure of speech intelligibility of everyday spontaneous speech. The SIR consists of a five-point rating scale, with a rating of 1 described as “*Connected speech is unintelligible. Pre-recognizable words in spoken language*” up to a score of 5 representing “*connected speech that is intelligible to all listeners. The child is easily understood in everyday contexts.*” The SIR provides a baseline of speech intelligibility skills as well as monitoring changes in speech over time.

Inter-rater reliability was evaluated by Wilkinson and Brinton (2003)The interclass correlation coefficient showed that agreement between raters was high (ICC (2,1) values = 0.80 and 0.81, both $p < 0.001$), and that ratings were consistent (ICC (3,1) values = 0.82 and 0.97, both $p < 0.001$).

Categories of Auditory Performance (CAP) (Archbold, Lutman, & Marshall, 1995) is an index consisting of eight performance categories relating to auditory perception, which reflect everyday auditory performance in a realistic way. It is arranged as a hierarchy of skills that increase in difficulty from the ability to perceive environmental sounds right up to using the telephone with a familiar talker. Inter-user reliability were evaluated by Archbold, Lutman, and Nikolopoulos (1998) using ratings from 23 children followed up at various intervals after implantation. Analysis relating scores by local teachers of the deaf and the teachers of the deaf at the implant centre revealed very high inter-user reliability (correlation coefficient 0.97). This result establishes the reliability of CAP as an outcome measure for use in cochlear implant programs. It is widely used in the range of current research on children with cochlear implants and is an easy-to-use tool for monitoring progress.

The SIR and the CAP were completed during the parent interview with the researcher asking the parent each question.

Procedures for Administering Standardized Tests

All four assessment tools—CELF-5, CTOPP, WJ-III, and PPVT-4—were administered by the researcher. Testing took place in a quiet room in the participant's home with few visual distractions. Breaks were provided as necessary during the testing

periods. All participants wore both cochlear implants which were in full working condition. Researcher and participant were seated at a table, facing each other, with approximately three feet in distance between. The work area contained pencils, eraser, stopwatch, and testing material. The researcher administered the assessments in the same order for both phases. The first testing day, PPVT-4 and the CELF-5 were administered; the second testing day, CTOPP and the WJ-III were administered. Two writing samples, one in Phase 1 and the second in Phase 2, were obtained from all participants either on the first or second testing day depending on time and energy of the participant. The participants were supplied with paper, a pencil, and an eraser with instructions to write on the topic of their choice.

Inter-Scorer Reliability

Scoring reliability was assessed by the researcher in both Phase 1 and Phase 2. Inter-scorer reliability measures were performed for all CELF-5 results by a second person, a licensed speech-language pathologist. A comparison of the first 25 scores on the CELF-5 by SLP and researcher were compared with 96% reliability. All writing samples were double scored by three elementary teachers. Again, very little discrepancy e.g. research scored 2, the teachers scored 2+. In both instances, the researchers score was used.

Family Observations: Questionnaire and Interview

A questionnaire was completed by parents to assist in obtaining background details relevant to the study (see Appendix A). The questionnaire consisted of 40 questions, 35 multiple-choice and 5 fill-in-the-blanks, segmented into six areas: child

information, hearing background, early intervention, informal education, formal education, and family information. The first section, child information, asked questions related to the child's hearing loss, age of onset, hearing technology, and mode of communication. The second section, hearing background, gathers information about etiology, age aided, age of implantation, implantation facility, how and when the children used implants, and implant model. Early intervention support services were the third section which focused on any support services the family chose to receive. The fourth section focused on the early-years learning environments (e.g., Montessori, daycare). The fifth section elicited information about formal education through the Ontario education system: program, grade, support services, etc. The last section, family background, gathered information regarding parents' spoken language, education, employment, and family income.

Interview

A semi-structured interview which elaborated on the questionnaire was conducted one-to-one with each participant's mother. The interview of 29 questions was grouped into eight sections: family demographics, medical history, hearing loss identification, CI surgery, services, home literacy environment, education, and extracurricular activities (see Appendix B).

Procedures for Parent Questionnaire and Interview

The primary caregivers were provided with a paper copy of the parental questionnaire to complete while their child was being assessed. The primary caregiver in

every case was the participant's mother. The questionnaire was provided in hard copy (paper form), and mothers had the opportunity to ask for clarification during completion.

At the completion of the second day of testing, a semi-structured interview was conducted by the researcher with the participant's mother in the family home. The interview was audio recorded with some written notes by the researcher for later transcription and analysis.

In July 2015, at the completion of all testing and scoring of all assessments, each family received a package through the mail containing the test results and summary reports for Phase 1 and Phase 2.

Ethics

This research has been reviewed and approved by the Human Participants Review Committee (HPRC) within the context of York University's Senate policy on research ethics. All caregivers were provided with the research proposal that detailed the research project and the commitment it would entail, and informed consent by parents and assent by children were obtained. Each participant received a \$50.00 Chapters Bookstore gift card for their participation in the study.

CHAPTER FOUR

RESULTS

In Phase 1 of the study, there were eight participants assessed; Kevin withdrew from the study prior to Phase 2 testing. Therefore, Kevin's results are not included in the quantitative data described in this chapter.

Observations of Participants During Testing

All the participants have had extensive experience with testing in general. Participants in this study were observed speaking comfortably with their family members at various distances. The researcher had no difficulty understanding the participants as they exchanged basic personal information such as favourite pastimes, experience of attending a baseball game, etc.

Lucia

Lucia was very comfortable throughout all the testing, asking for no breaks (eating her lunch at times), and maintaining attention throughout test taking. She demonstrated advocacy skills for herself by telling siblings to lower their voices as they were being too loud and disruptive for her. Lucia breezed through the assessment, seeming to have no difficulties with the directions or questions or providing the correct answers. She rarely asked for repetition of questions. For the Spelling of Sounds test, Lucia preferred to have the researcher say the words rather than listen to the recorded words (an acceptable test accommodation), in order to look at the researcher's face. Before and after testing, during discussions with family members and the researcher, it

was observed that Lucia often said “what?” when she didn’t understand the meaning of a word.

Sophia

Sophia was always eagerly awaiting the researcher’s arrival with appropriate and efficient social language. She is a social, expressive child with a great imagination which she expressed in her written samples. Sophia had a positive and cooperative attitude towards test taking. Sophia maintained attention throughout test taking with immediate response time. She often asked for questions to be repeated throughout testing.

Steven

Steven was not always eager to give up playing outdoors on summer days but once he did he was cooperative during test taking. Steven maintained attention throughout test taking with immediate response time. He occasionally asked for questions to be repeated throughout testing.

William

William was very comfortable throughout all the testing, asking for no breaks, sometimes even enjoying a snack while continuing to test, and maintaining attention throughout. William was confident, calm, and at ease completing the assessments, seeming to have no difficulties with the directions, the questions, or providing quick answers, and rarely asking for questions to be repeated. Before and after testing, in conversation with the researcher or parent or overhearing parent and researcher conversing, it was observed that William is attentive to the content without having to make eye contact or even be in the same room.

Robert

Robert was gracious in giving up a few hours of outdoor play during the summer. He maintained a positive and cooperative attitude before, during, and after testing. Exhibiting a bit of shyness, Robert engaged in social conversation with the researcher before testing, sharing his activities of golf, tennis, and other sports. Robert maintained focus for the duration of testing; responding without delay, requiring some repetition of questions only, not directions. When unsure of an answer, Robert attempted a response regardless.

Andrew

It was difficult to test Andrew in all sessions. He was eager to see the researcher for social purposes. Being a very social and talkative child, he was prepared to share all sorts of stories, but struggled to settle down for test taking. Andrew required a lot of repetition because he was often distracted and not attentive. This inattentiveness affected what he heard, resulting in his either asking for the researcher to repeat or mishearing (e.g., instead of *hot* he heard *pot*). Andrew responded immediately to questions and was able to follow directions on the first presentation.

Gregory

Gregory was cooperative during Phase 1 testing. He was observed trying to perform his best and stay attentive and required only one break. However, during Phase 2, he required many more frequent timed breaks in order to complete the testing for that day. He tended to say “I don’t know” or “I’m tired” throughout the testing in Phase 2. Gregory demonstrated less enthusiasm and cooperation for the reading assessment tasks in Phase

2. Gregory would begin to hesitate and show signs of anxiety when he was given anything with a lot of text. He refused to sound out words and would just give up, saying he “got tired of reading.”

Overall Group Performance

Table 4 provides an overall summary of average performance for the standardized, norm-referenced tests administered in the areas of reading, language, receptive vocabulary, and phonological awareness, as well as achievement levels for writing samples. Results for all standardized tests are reported as percentile ranks. Data are reported for Phase 1 and Phase 2 in two different ways, as average scores for the group and as the percentage of participants scoring in the typical range (defined as scoring within 2 standard deviations of the mean). When interpreting percentile ranks, it is important to note that the expectation for typically developing children is that their percentile rank (i.e., their relative rank in a group compared to their peers) would be expected to remain similar over time when retests are conducted. For example, if a child is found to score above average in language and reading in Grade 2, we would anticipate that he/she would continue to score above average in Grades 3, 4, etc. (all other things being equal). This is not always the case, of course, but it would be generally unlikely for a child to demonstrate a dramatic increase or decrease in an area over the course of a year (for example, to go from being an A student in math one year to being a D student in math the next year, or vice versa).

Results which show *no change* in percentile rank over time indicate that the student is progressing at the *same rate* as his/her peers. Results which show an increase in

percentile rank indicate that a student is learning/progressing at a *faster rate* than his/her peers, while results showing a decrease in percentile rank indicate that the student is still progressing, but at a *slower rate* than his/her peers. This may mean that a gap is starting to emerge between the student’s skills and those of his/her peers and suggests that a closer look at the child’s performance is warranted to determine if an educational intervention, or additional support, is needed.

Table 4. Overall Group Performance on Standardized Tests of Reading, Writing, Language, and Phonological Processing Skills

Test	Phase 1		Phase 2	
	Mean percentile rank	% at age/grade level	Mean percentile rank	% at age/grade level
Woodcock-Johnson— Total Reading Score	70.1	100%	70.6	100%
Writing	N/A	28.5% (defined as Level 3 or 4)	N/A	14.3% (defined as Level 3 or 4)
CELF-5 Core Language Score	48.2	85.7%	46.7	71.4%
PPVT-4	45.3	85.7%	55	85.7%
CTOPP—Phonological Awareness	75.9	100%	85.9	100%
CTOPP—Phonological Memory	37.4	57.1%	38.6	85.7%
CTOPP—Rapid Naming	52.3	85.7%	57.3	100%

Overall, as a group, on standardized tests of reading, language, receptive vocabulary and phonological awareness, participants in this study scored in the typical range compared to hearing peers in all areas assessed, in both Phase 1 and Phase 2.

Overall reading, phonological awareness, and rapid naming emerged as areas of particular strength for these children as a group, while phonological memory appeared to be an area of comparative weakness (although average scores still fell well within average compared to hearing peers). It is significant to note that the task of phonological memory is essentially auditory memory with no visual support for this subtest.

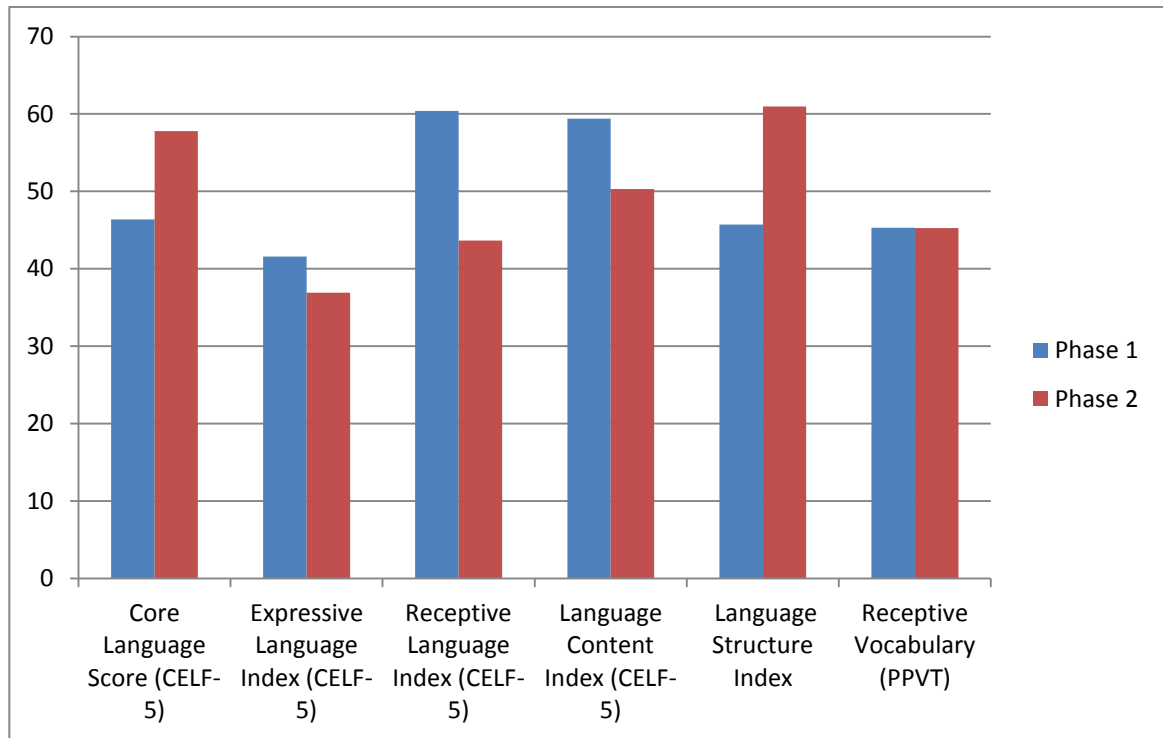
Overall results demonstrate no change from Phase 1 to Phase 2 in reading, indicating that participants are progressing at the same rate as their peers. In the area of receptive vocabulary, phonological awareness, phonological memory, and rapid naming show an increase in percentile results, meaning that the participants are progressing at a faster rate than their peers. Overall results for participants progressing at a slower rate than their peers are writing and language.

Writing was clearly an area of weakness for almost all participants, with only two of seven children able to produce a writing sample which met the benchmark for their grade in Phase 1, and only one of seven seeming to be writing at grade level in Phase 2. Overall, letter-sound relationship and spelling were areas of strength, while the use of vocabulary, the use of conventions, formulating complete sentences, and formulating a well-developed written story appeared to be areas of relative weakness.

Oral Language

Oral language skills were assessed using the CELF-5 and the PPVT-4. Results for composite scores on the CELF-5 and for the PPVT-4 are summarized in Figure 1.

Figure 1. Oral Language Results



Note: The Language Structure Index score includes scores for 5 of the 7 participants (ages 5–8).

Results indicate average percentile scores within the typical range for hearing children. Expressive language appeared to be weaker than receptive language, although still within the average range. The Language Structure Index score is calculated only for ages 5–8 years; for older children (age 9 years and up), it is replaced by the Language Memory Index. In this study, two participants were old enough to be administered the Age 9–12 version of the CELF in Phase 2. Their Language Memory Index scores indicated that one participant was above average (81st percentile) and one was below average (5th percentile).

As discussed previously, competence in face-to-face language underpins competency in reading. The results summarized in Figure 1 confirm previous research

(Geers, 2002; Moog, 2002; Watson, 2002) showing that strong spoken language assists with reading skills.

While overall, the group of participants performed in the typical range for oral language skills, participants did differ in their profiles and relative strengths and weaknesses. A summary of each participant’s skills as a user of spoken language is provided below.

Table 5. Phase 2 Individual Overall Phase 2 Scores

	Lucia	Sophia	Steven	William	Robert	Andrew	Gregory
Core (Total) Language Score	86	5	1	94	91	23	30
Expressive Language Score	96	7	23	99	84	34	68
Receptive Language Score	93	19	7	91	86	19	19
Receptive Vocabulary (PPVT)	50	82	6	63	92	47	45
Phonological Awareness	95	92	92	99	89	35	92
Phonological Memory	84	16	16	98	35	5	16
Rapid Naming	35	92	35	89	42	50	58
Total Reading	71	91	73	96	69	36	85
Spelling	96	90	91	95	91	11	94
Writing	3	1	2	2+	2	1	2

Lucia: Overall, Lucia scored in the above average to superior range for all language skills assessed, including overall language score, expressive language, receptive vocabulary, language comprehension, and understanding and use of syntax. Lucia's expressive language score and receptive language score fell at the 96th and 93rd percentiles at the end of the study, slightly higher than in Phase 1.

Sophia: Overall, Sophia demonstrated great leaps in percentiles across the board from Phase 1 to Phase 2. In relation to all the index scores, her expressive language was weaker than the rest at the 19th percentile. Sophia's receptive language skills on the PPVT showed quite significant growth from Phase 1 to Phase 2 (with scores improving from the 39th percentile to the 82nd percentile).

Steven: Overall, Steven's scores were the weakest in oral language, of all areas assessed. There was growth seen in expressive language, however. Overall, Steven's language skills did not show evidence of closing the language gap (i.e., faster growth than would be the case for typical hearing children).

William: Overall, William demonstrated above average skills in most areas of language assessed by Phase 2, showing significant growth in expressive language and vocabulary over the course of the study. Receptive language scores were particularly strong for this participant, at the 91st percentile in Phase 1 and 2.

Robert: Robert was also a very competent spoken language user, with scores in all areas of language assessed falling in the above average to superior range (e.g., in the 91st percentile for overall language scores, and in the 92nd percentile for receptive vocabulary).

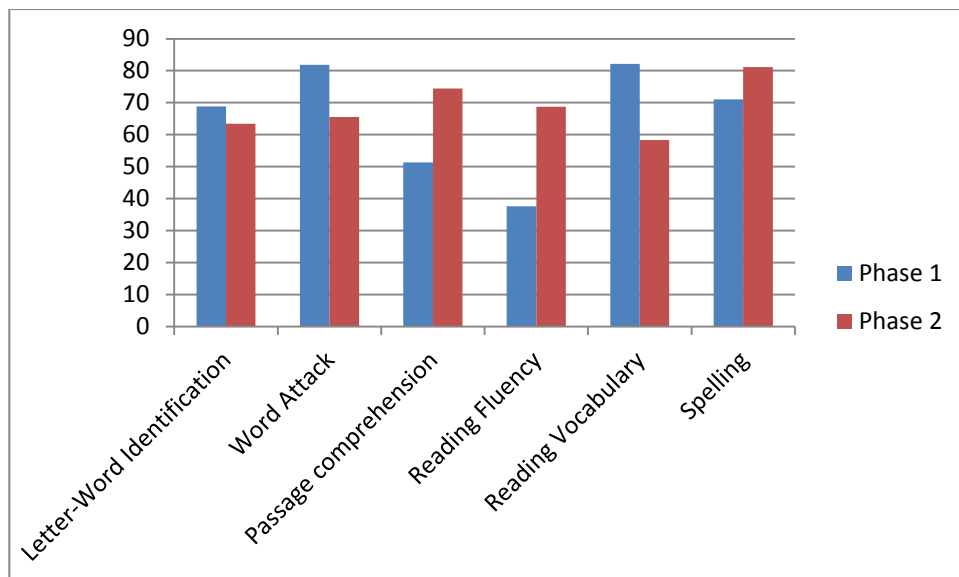
Andrew: Overall, Andrew’s language scores fell in the average range, with some relative weaknesses in receptive language, which showed slowed growth in Phase 2 of the study.

Gregory: Gregory’s scores also fell more in the average range overall, although with relative strengths in receptive language over expressive language. Scores showed growth in all areas at a typical developmental rate compared to hearing peers.

Performance in Reading

Being an effective reader requires a child to demonstrate competency in a variety of skills, including phonological awareness, decoding, vocabulary knowledge, reading comprehension, reading fluency, and spelling. Figure 2 provides a summary of average performance in each of these areas (as assessed by composite scores of the WJ-III), in Phase 1 and Phase 2.

Figure 2. Performance in Reading



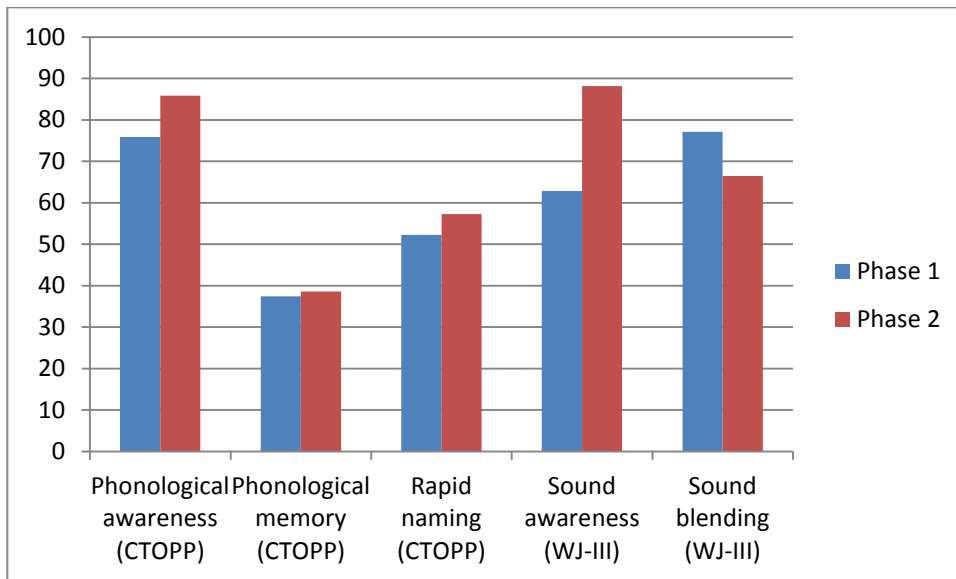
Note: Composite scores in WJ-III for reading

In Phase 2, average results indicated growth in the areas of passage comprehension, reading fluency, and spelling which exceeded that expected for typical hearing children (as evidenced by improvements in average percentile ranks). In the second year, for most participants, decoding (as measured by the Letter-Word Identification and Word Attack subtests) and reading vocabulary showed slower growth than would be expected for typical children. In this study, the sample size was too small to report on statistical significance of these differences; however, it is worth noting that despite a somewhat small slowing down of the growth rate for decoding skills, average scores still fell well within the typical range. As described previously, the subtest of Reading Vocabulary consists of knowledge of synonyms, antonyms, and analogies (more complex skills than simply being able to read a word out loud or give a definition). All children demonstrated the most difficulty with analogies.

Phonological Processing

Phonological processing as described on the CTOPP comprises three skills: phonological awareness, phonological memory, and rapid naming. Average results for performance in these areas are provided in Figure 3. Figure 3 also includes results for two subtests from the WJ-III which also assesses aspects of phonological awareness. Mean phonological processing scores fell within the typical range for all areas assessed on both the CTOPP and the WJ-III. Phonological memory emerged as an area of relative weakness.

Figure 3. Phonological Processing



Vocabulary

It is interesting to note that, while mean reading vocabulary scores in Phase 2 still fell within the typical range, they clearly show slower growth in this area for these participants than for typical hearing children. The subtest of reading vocabulary used in this study was from the WJ-III, and assessed knowledge of synonyms, antonyms, and analogies (rather than simply being able to define or identify a vocabulary item). The simpler, beginning items on this subtest consist of examples such as “what is another word for big?” However, the items quickly increase in complexity and sophistication, so it may be the case that in Phase 2, these results reflect an area of concern for these participants in being able to understand the more complex vocabulary typically found in text as compared to oral language.

Reading Comprehension and Reading Fluency

Overall results show decoding, reading comprehension, and reading fluency to be average or above, with particular growth in reading comprehension and fluency in Phase 2.

Lucia: Overall, Lucia scored in the above average range for all reading skills assessed, including phonological awareness, reading vocabulary, overall reading score, decoding, reading comprehension, and reading fluency. Spelling scores fell in the above average range as well. Lucia's scores showed growth in these areas consistent with that of hearing peers over the course of the study.

Sophia: Overall, Sophia demonstrated average to above average reading scores, with particular strengths in decoding and spelling, and weaknesses in the area of phonological memory. Sophia demonstrated significant growth in some areas which exceeded that of hearing peers, particularly in decoding and phonological awareness.

Steven: Overall, Steven's scores were in the average range for all skills assessed, and he demonstrated a growth rate consistent with that of hearing peers over the course of the study. Steven appeared to demonstrate some difficulty with subtests related to the understanding and use of syntax or grammar.

William: Overall, William demonstrated above average skills to superior skills in reading, spelling, and phonological awareness. Scores in phonological awareness, phonological memory, total reading score, decoding, reading comprehension, and spelling all fell above the 90th percentile.

Robert: Robert was also a very competent reader, with scores in all areas of language assessed falling in the above average to superior range for most skills (e.g., in

the 90th percentile for reading comprehension). Scores which were relatively weaker (such as rapid naming) still fell at the 50th percentile, or average level.

Andrew: Overall, Andrew's reading, phonological awareness, and spelling scores fell in the average range, with some relative weaknesses in phonological memory. Spelling was an area of relative weakness, falling in the low average range (although still well within the average range for hearing peers).

Gregory: Gregory's scores also fell more in the average range overall, although with relative strengths in decoding and phonological awareness. Reading comprehension was an area of relative weakness, with Phase 2 scores at the 49th percentile, in comparison to decoding scores which fell at the 81st percentile. Scores showed his growth in all areas at a typical developmental rate compared to hearing peers.

Writing

All participants provided writing samples in both phases that were graded by three certified teachers currently working in the Ontario education system. The three senior kindergarten students were graded using the *Guide to Effective Instruction in Writing: Kindergarten to Grade 3*. The grading is based on stages of writing development: emergent, early, and developmental fluency. Samples from students in Grade 1 or higher were graded using the Ontario Curriculum Writing Exemplars and awarded a level of achievement between 1 and 4, level 3 being the provincial standard.

Table 6 provides a summary for writing performance in Phase 1 and Phase 2 for all participants.

Table 6. Participants' Writing Performance

Participant	Grade		Writing level	
	Phase 1	Phase 2	Phase 1	Phase 2
Andrew	SK	1	1	1
Gregory	SK	1	2+	2+
Robert	SK	1	3+	2
William	1	2	2	2+
Steven	3	4	1	2
Sophia	3	4	2	1
Lucia	4 (Sept)	4 (June)	3	3+

In Phase 1, the three senior kindergarten participants varied greatly in ability. Andrew was in the emergent stage. He recognized that writing was an act of recording oral language in print to communicate a message, but did not show interest in writing. Andrew's writing consisted of an assortment of upper-case letters, but he was unable to use familiar words or two-letter words. Gregory was an early writer, demonstrating spelling of five high-frequency words, inventive spelling, some letter-sound relationship, and a clear idea in a complete sentence. Robert was also an early writer, but further along than Gregory. Robert demonstrated a good understanding of letter-sound relationships. He was able to correctly spell familiar words, inventive spelling, and compound sentences. He overused the conjunction *and* rather than using punctuation marks.

The Grade 1 participant, William, wrote at Level 2, showing the use of letter-sound relationships, inventive spelling, punctuation, and writing a complete thought.

The two participants in Grade 3 also varied in writing ability. Steven proved that he was a strong speller, but was scored as a Level 1 because of the use of incorrect

sentence structures, limited development of ideas, and incorrect use of punctuation marks. Sophia wrote at Level 2, demonstrating good development of ideas, a flow of thought, punctuation, and correct spelling. Lucia, the oldest participant in Grade 4, produced a Level 3 writing sample by staying on topic and having good development of details and reasons, a beginning, middle, and end of a story, compound sentences, and punctuation. However, she did have run-on sentences and overused the conjunction *and*.

In Phase 2 improvement was seen in all the participants' writing samples. Three in particular showed significant changes, as seen in Table 5. Andrew sounded out words and applied inventive spelling. He included a few simple ideas connected to his topic with some supporting details, but lacked a clear thought-out topic. Gregory improved in spelling (i.e., applying letter-sound relationships) and he used past tense verbs. He continued to struggle with some of the basic conventions of writing. Robert improved in connecting multiple ideas to the topic, and provided supporting description to create his story. William enhanced his writing by forming a thought-out, well-developed story using a variety of connective words.

Steven continued to struggle with using the basic conventions of writing. He continued to develop ideas with supporting details, but had limited vocabulary and sentence types. Sophia and Lucia remained consistent in writing skills from Phase 1 to Phase 2, showing no real change.

Students in kindergarten to Grade 2 in this study were seen using a greater quantity of personal pronouns than the students in Grade 4. The shift to using fewer pronouns occurred with the move into Grade 2.

There was a significant improvement in five of the seven students' writing samples from Phase 1 to Phase 2. Even though the use of nouns, verbs, adjectives, adverbs, conjunctions, articles, and prepositions remained the same, the length and complexity of sentences increased. The mean length of words per sentence ranged from 6 to 14 in this study. These same students produced compound complex sentences. The attempt to have a main idea with a beginning, middle, and end was more present in Phase 2. The weaknesses manifested by the students' skills in this study are similar to features often identified as areas of growth for hearing writers: simple text structure, lacking supporting details and information, and absence of clear opening and closing statements.

It is important to note that, while only two out of the seven are writing at the provincial grade level for their respective grades, no participants demonstrated the use of nonstandard English syntax and grammar with an overdependence on simple sentence patterns, and formulaic structures in their writing that was typical of deaf pupils in the past (Mayer, 2010).

Spelling was a relative strength for these participants, as evident in the Spelling subtest of the WJ-III and analysis of writing samples. Five children scored average or above, one low average and only one below average on the Spelling subtest. In their writing samples and on formal testing, students used typical strategies such as inventive spelling (e.g., *baceball* for *baseball*, *picher* for *pitcher*, *pratis* for *practise*) and often used phonemic awareness to guide their spelling.

At the completion of the writing sample in both test phases, participants read their stories aloud to the researcher. The recording of this reading was immediately played

back to the participant. Two participants recognized that they had made an error in their writing when reading to the researcher. The remaining five participants did not recognize their errors (e.g., periods, word omissions, etc.) while reading their stories to the researcher or hearing the recording.

Tables 7 to 13 provide a summary of comments on writing performance for each participant.

Andrew

Illustration 1. Andrew's Writing Sample in Phase 1

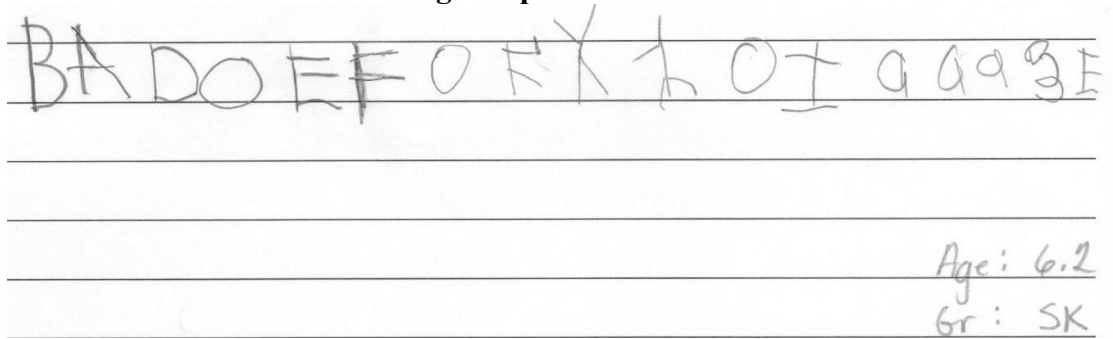
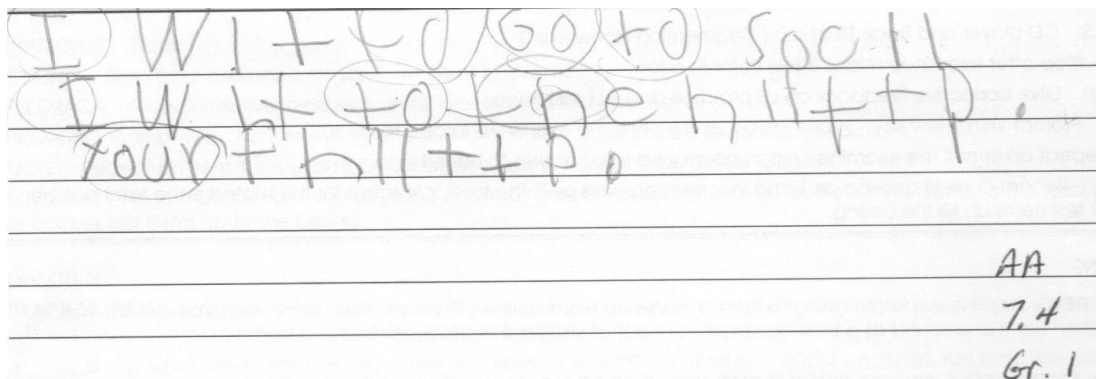


Illustration 2. Andrew's Writing Sample in Phase 2



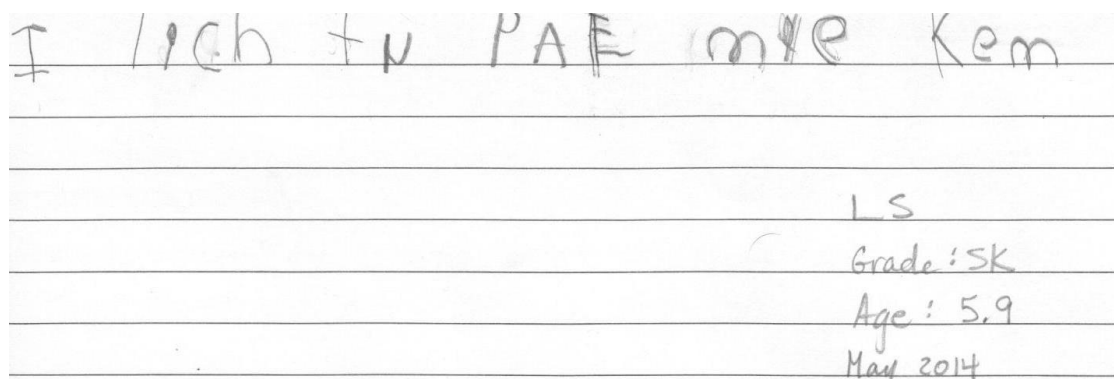
Note: "I want to go to school/ I went to the field trip. Your field trip."

Table 7. Comments on Andrew’s Writing Performance

Andrew	Phase 1	Phase 2
	Level 1, Kindergarten	Level 1, Grade 1
	<p>Was not eager to write. He tried to manipulate the exercise by telling stories, wanting to do other things.</p> <p>Required encouragement, topic ideas to write about as he didn’t know what to write. Very negative towards writing. Read story aloud. Made no alterations.</p> <p>Can write upper-case letters, no use of familiar words to convey clear meaning, no simple complete sentences.</p>	<p>Was not eager to write. At the first visit, he was given the choice to write about something or to be prepared to write something when researcher returned for visit 2. He quickly chose to write at second visit.</p> <p>Again, required encouragement regarding topic ideas and to try his best. Would rather tell an oral story then write it. Read story aloud, made no alterations.</p> <p>Has letter-sound relationship, attempted punctuation, a sense of sentences, use of period to end sentence.</p>

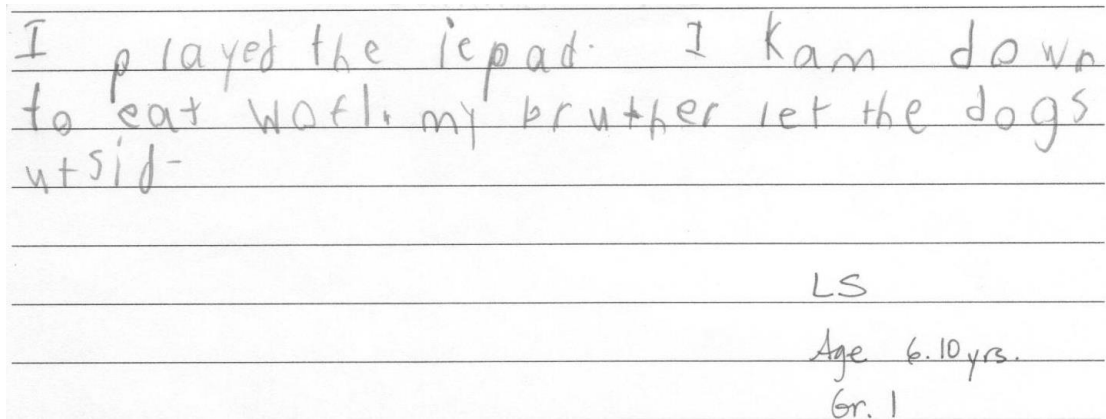
Gregory

Illustration 3. Gregory’s writing sample in Phase 1



Note: “I like to play.”

Illustration 4: Gregory's Writing Sample in Phase 2



Note: "I played the ipad/ I came down to eat waffles. My brother let the dogs outside."

Table 8. Comments on Gregory's Writing Performance

Gregory	Phase 1	Phase 2
	Level 2+, Kindergarten	Level 2, Grade 1
	Reluctant to write. Required encouragement and topic ideas. Asked for spelling of words. Read story aloud, made no alterations.	Reluctant to write. Required encouragement and topic ideas. Mother would ask participant "what happened next" to have him orally tell, and then he could write it down. Asked for spelling of words. Read story aloud. Had difficulties reading a word or two of own story.
	Clear idea, no punctuation, some letter-sound relationship.	Completed a simple sentence that makes sense, spells some high-frequency words, punctuation marks are missing but does use period, good letter-sound relationship.

Robert

Illustration 5. Robert's Writing Sample in Phase 1

today I played tennis and
I hit the ball hard and
my name is Reed and
I like to play baseball
and I hit the ball and I
catch the ball and throw the ball
to first base fast.

July 7, 2014
RF Age: 6.4
Grade: SK

Note: "Today I played tennis and I hit the ball hard and my name is Reed and I like to play baseball and I hit the ball and I catch the ball and throw the ball to first base fast."

Illustration 6. Robert's Writing Sample in Phase 2

I want to the Baseball
game I want on
a train to it
We got a hot
dog we wshst
Bad ing prat is
and than we wash
The game.

4.1 yr
Gr. 1

June 2015

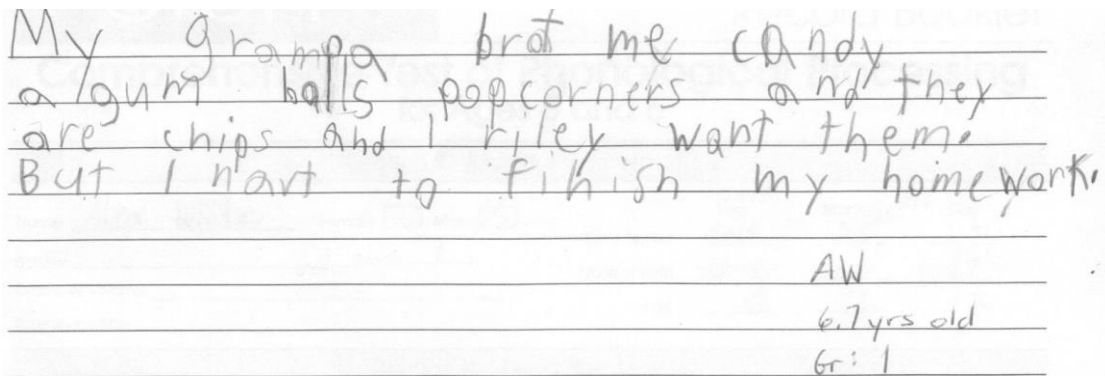
Note: "I went to the baseball game I went on a train to it we got a hot dog we watched batting practice and then we watched the game."

Table 9. Comments on Robert’s Writing Performance

Robert	Phase 1	Phase 2
	Level 3+, Kindergarten	Level 2, Grade 1
	Began to write immediately after being asked to write a story, topic of his choice. Researcher offered topics but participant went ahead with his idea.	Began to write immediately after being asked to write a story, topic of his choice. Researcher offered topics but participant went ahead with his idea. Could see participant trying to correct spelling.
	Good understanding of letter-sound relationship, unrelated sentences, aware of new ideas, compound sentences, overuse of the conjunction word <i>and</i> .	Contains flow in story, spells some high-frequency words, good letter-sound relationship, but lacks conventions.

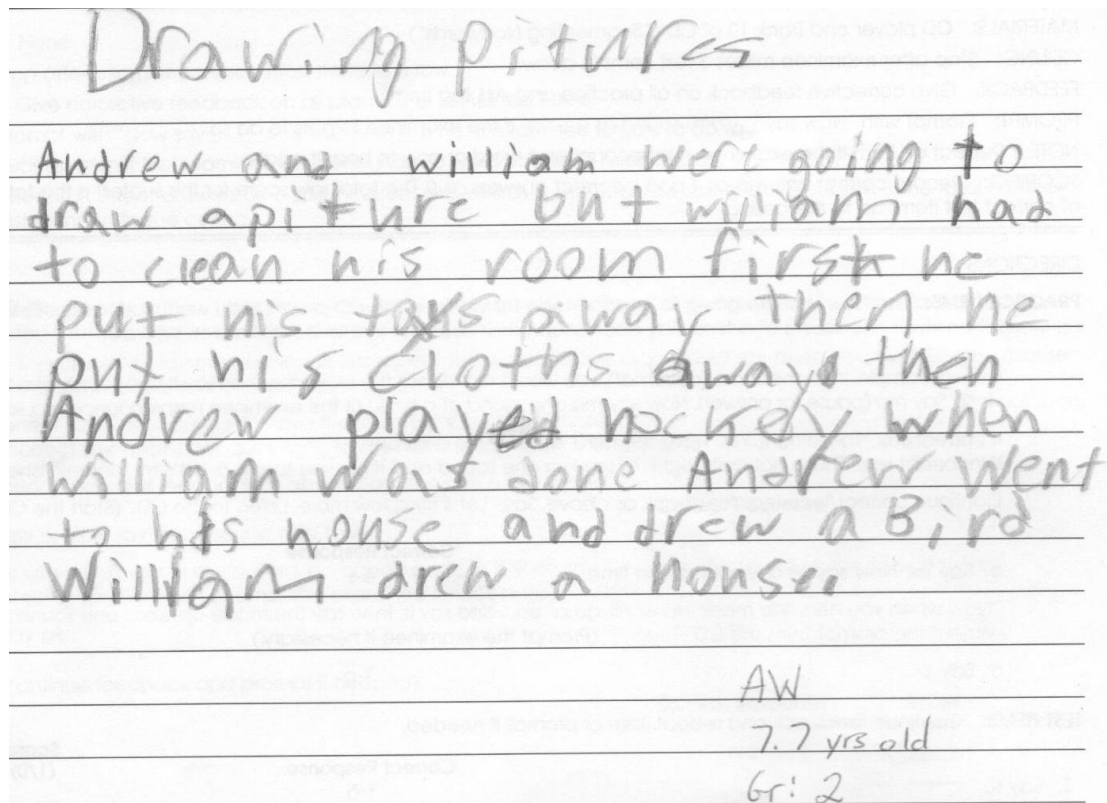
William

Illustration 7. William’s Writing Sample in Phase 1




Note: “My grandpa brought me candy a gum balls popcorn and there are chips and I really want them. But I need to finish my homework.”

Illustration 8. William's Writing Sample in Phase 2



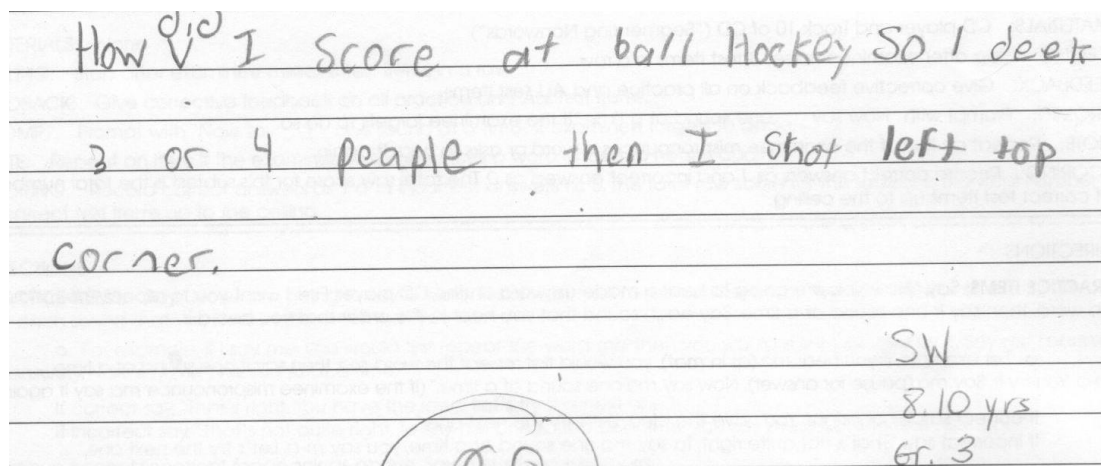
Note: "Andrew and William were going to draw a picture but William had to clean his room first he put his toys away then he put his clothes away. Then Andrew played hockey when William was done Andrew went to his house and drew a bird William drew a house."

Table 10. Comments on William’s Writing Performance

William	Phase 1	Phase 2
	<p>Level 2, Grade 1</p> <p>When asked by researcher to write a story of choice, participant hesitated, thinking of a topic. Researcher encouraged he could write about anything. Participant began to write. Did not ask for spelling. He also read his story aloud and made no changes.</p> <p>Good letter-sound relationship, attempted punctuation, but was not always sure when to use period, resulting in run-on sentences.</p>	<p>Level 2+, Grade 2</p> <p>Researcher asked participant to write about a topic of his choice. Participant immediately began writing. He asked for no spelling. He read story aloud and made no corrections.</p> <p>Good generation of ideas about a potential topic, spelled many words correctly, punctuation (not always in correct place).</p>

Steven

Illustration 9. Steven’s Writing Sample in Phase 1



Note: “How did I score at ball hockey so I deek 3 or 4 people then I shot left top corner.”

Illustration 10. Steven's Writing Sample in Phase 2

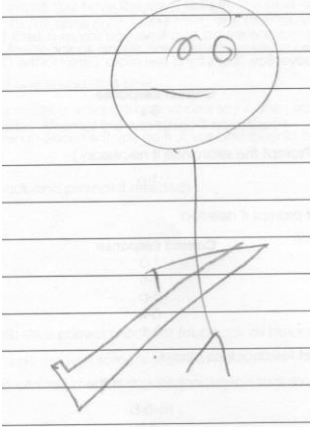
One day there was a boy name Nate and he had a friend name Chad and they were playing base ball and Chad was the pitcher and Nate was a batter. So Chad threw the ball and Nate hit the ball and it hit Nate's mom bedroom window and Nate and Chad were not talking and there faces were red and they needed to tell Nate's mom. So they did and they told every about it. But Nate's mom did get mad because they were already ^{get} ^{the} knew window and she said thank for telling me.

The End

SW
10.0 yrs
gr. 4

Note: "One day there was a boy name Nate and he had a friend name Chad and they were playing baseball and Chad was the pitcher and Nate was a batter. So Chad threw the ball and Nate hit the ball and it hit Nate's mom's bedroom window and Nate and Chad were not talking and there faces were red and they needed to tell Nate's mom. So they did and they told every about it. But Nate's mom did get mad because they were already getting a knew window and she said thank you for telling me."

Table 11. Comments on Steven's Writing Performance

Steven	Phase 1	Phase 2
	<p data-bbox="646 420 1003 451">Level 1, Grade 3</p> <p data-bbox="646 483 1003 766">Seemed willing to write for researcher. Came up with topic idea rather quickly. Did not ask for spelling; instead sounded out and tried on his own. Wanted to read story aloud.</p> <p data-bbox="646 808 1003 1050">Incorrect sentence structure, limited development of ideas, incorrect use of punctuation (?/.), good spelling of words.</p>	<p data-bbox="1027 420 1383 451">Level 2, Grade 4</p> <p data-bbox="1027 483 1383 850">Seemed willing to write for researcher. Came up with topic idea quickly. Wanted to draw an illustration and read story aloud. Made corrections after reading his story aloud and hearing the errors.</p> <p data-bbox="1027 892 1383 1050">A story that somehow relates, limited development of ideas, missing many conventions.</p>

Sophia

Illustration 11. Sophia's Writing Sample in Phase 1

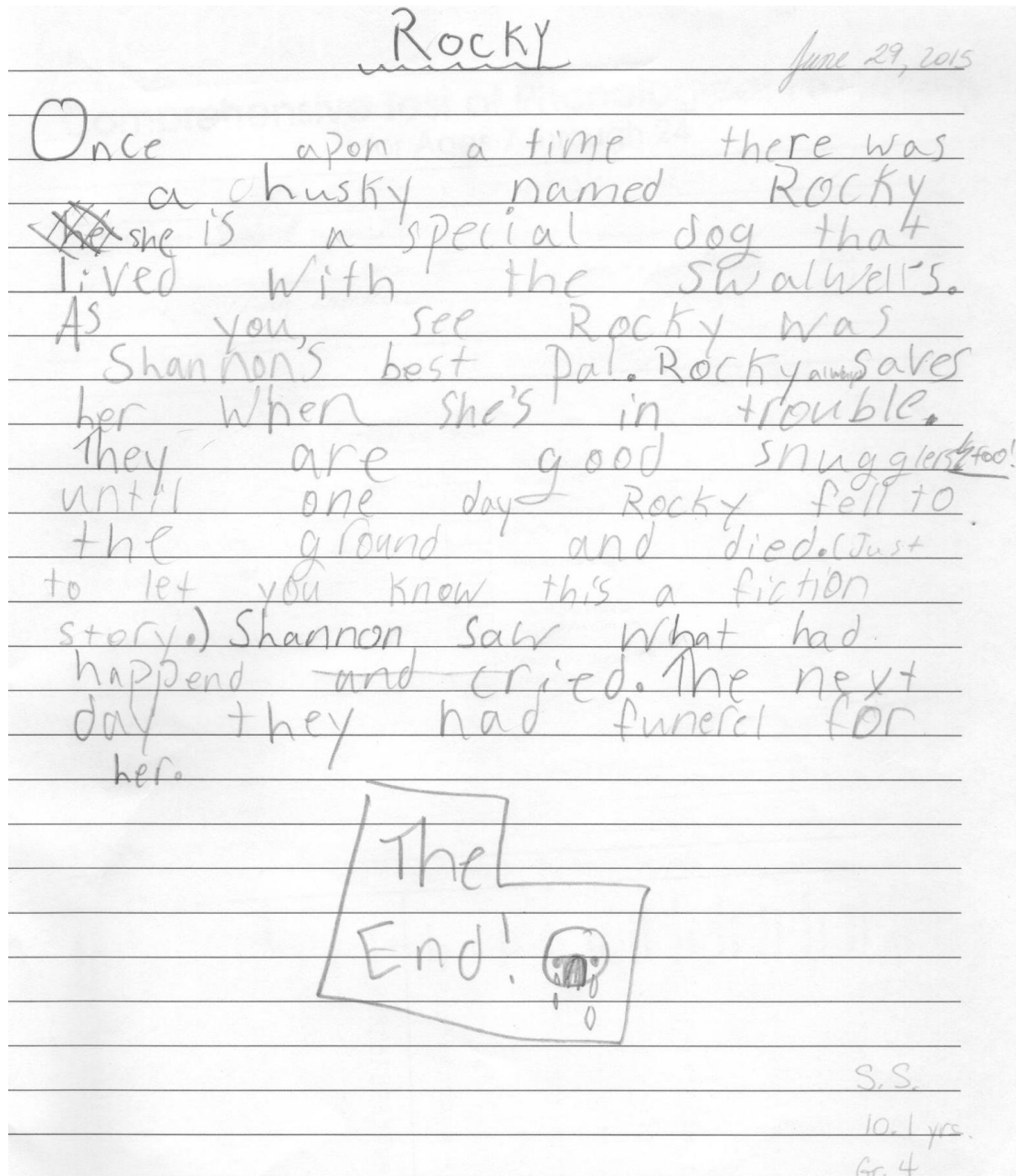
Once upon a time there was
a girl named Cathy Ruggirello. She was a
wonderful ballet dancer. She performed for a
concert before, the concert was called
the "Swan Lake" and she played as "Odette"
Jane Swalwell was her mom. Cathy was 17
years old but Jane was a thousand
years old and Jane was jealous.
Cathy became famous. In 1909,
Cathy had a hot, cute, handsome
husband named, "Glenn".

The
End!!

SS
Age 9 yrs
Lw: 3

Note: "Once upon a time there was a girl named Cathy Ruggirello. She was a wonderful ballet dancer. She performed for a concert before, the concert was called the "Swan Lake" and she played as "Odette" Jane Swalwell was her mom. Cathy was 17 years old but Jane was a thousand years old and Jane was jealous. Cathy became famous. In ? Cathy had a hot, cute, handsome husband names, "Glenn"."

Illustration 12. Sophia's Writing Sample in Phase 2




Note: "Once upon a time there was a husky named Rocky she is a special dog that lived with the Swalwell's. As you see Rocky was Shannon's best pal. Rocky always saves her when she's in trouble. They are good snugglers too! Until one day Rocky fell to the ground and died. Just to let you know this was a fiction story. Shannon saw what had happened and cried. The next day they had a funeral for her."

Table 12. Comments on Sophia’s Writing Performance

Sophia	Phase 1	Phase 2
	Level 2, Grade 3	Level 1, Grade 4
	Enthusiastic to write a story. Came up with topic idea quickly. Did not ask for spelling. Enjoyed sharing her story.	Enthusiastic to write a story. Came up with topic idea quickly. Did not ask for spelling. Enjoyed sharing her story.
	Good development of ideas, flows, punctuation and spelling is good.	Missing many conventions, lack of flow in information to the story, limited development of ideas, tense change.

Lucia

Illustration 13. Lucia's Writing Sample in Phase 1

The thing I am going to be writing about is my dog. My dog's name is Rosie and she is super cute she is like the adorablest puppy on the planet. Rosie is two years old and she is very energetic and she loves dog biscuits. For halloween Rosie is going to be Wonder Woman. She is going to come trick or treating with us too. Some facts about Rosie are when we picked her up from the OSPCA in Barrie she looked very sad and lonely in her cage and she looked so cute. I really wanted Rosie but my older sister Olivia and my twin sister Samantha wanted another dog named Bruce. But then another family was interested in Bruce and we asked them about Rosie but there her name was Bianca but we changed it to Rosie when we got her. They said Rosie was about one and a half years old but now she is two. They also said Rosie was a stray dog which means that she was found on the streets with no collar and no chip and no one said Rosie was there so we adopted Rosie. Also our mom made Rosie's birthday the day after my birthday. Rosie is the right dog for our family and she loves everyone. This is the reasons I love my dog Rosie. 

Note: "The thing I am going to be writing about is my dog. My dog's name is Rosie and she is super cute. She is like the adorablest putty on the planet. Rosie is two years old and she is very energetic and she loves dog biscuits. For Halloween Rosie is going to be Wonder Woman. She is going to come trick or treating with us too. Some facts about Rosie are when we picked her up from the OSPCA in Barrie she looked very sad and lonely in her cage and she looked so cute. I really wanted Rosie but my older sister Olivia and my twin sister Samantha wanted another dog named Bruce. But then another family was interested in Bruce and we asked them about Rosie but there her name was Bianca but we changed it to Rosie when we got her. They said Rosie was

about one and a half years old but now she is two. They also said Rosie was a stray dog which means that she was found on the streets with no collar and no chip and no one said Rosie was theirs so we adopted Rosie. Also our mom made Rosie's birthday the day after my birthday. Rosie is the right dog for our family and she loves everyone. This is the reason I love my dog Rosie."

Illustration 14. Lucia's Writing Sample in Phase 2

Slimy Soup!
One day in the cafeteria of Thornlea Suzy the cafeteria lady was serving the students the new soup. It was tomatoe soup. All the students loved it. Even the school's master pranker Josh! Suzy was so happy that all the kids loved her soup. The next day when Suzy was serving the students the tomatoe soup she looked around the room and saw everyone looking disgusted. Suzy wondered what was going on. When lunch was over Suzy tasted some of the soup and it was terrible. Suzy thought it tasted like slime. All of a sudden Suzy noticed some green slime leading to the cool kids table under the chair Josh always sits in. She knew the soup sabatogor was Josh. That night Suzy set up the cameras in the cafeteria. The next day lunch didn't go so well. After lunch Suzy checked the cameras and saw Josh sabotoshing the soup. She told the principal and showed her the footage so Josh was banned from the cafeteria!

THE END!

SL
10.3 yrs
Gr. 4

Note: "Slimy Soup! One day in the cafeteria of Thornlea Suzy the cafeteria lady was serving the students the new soup. It was tomato soup. All the students loved it. Even the school's master pranker Josh! Suzy was so happy that all the kids loved her soup. The next day when Suzy was

serving the students the tomato soup she looked around the room and saw everyone looking disgusted. Suzy wondered what was going on. When lunch was over Suzy tasted some of the soup and it was terrible. Suzy thought it tasted like slime. All of a sudden Suzy noticed some green slime leading to the cool kids table under the chair Josh always sits in. She knew the soup saboteur was Josh. That night Suzy set up the cameras in the cafeteria. The next day lunch didn't go so well. After lunch Suzy checked the cameras and saw Josh sabotaging the soup. She told the principal and showed her the footage so Josh was banned from the cafeteria!"

Table 13. Comments on Lucia's Writing Performance

Lucia	Phase 1	Phase 2
	Level 3, Grade 4	Level 3, Grade 4
	Enthusiastic to write a story. She came up with topic immediately. Read story aloud. Did not ask for spelling.	Enthusiastic to write a story. She came up with topic immediately. Did not ask for spelling. Read story aloud. Made correction after reading story aloud.
	Run-on sentence, overuse of conjunction <i>and</i> , good development of details and reasons, stays on topic, has a conclusion.	Excellent description, well organized, good use of punctuation, gap in the story.

Speech and Auditory Skills

All participants scored 5 out of 5 on the Speech Intelligibility Rating, indicating that all had intelligible speech that was easily understood by listeners in everyday contexts. With respect to auditory skills, all participants were tested in Phase 1, scoring 7 out of 7 on the Categories of Auditory Performance. Participants were active contributors in everyday family conversations and events (e.g., food, clothes, activities, likes/dislikes) without speechreading. Each one is also able to enjoy conversation over the telephone

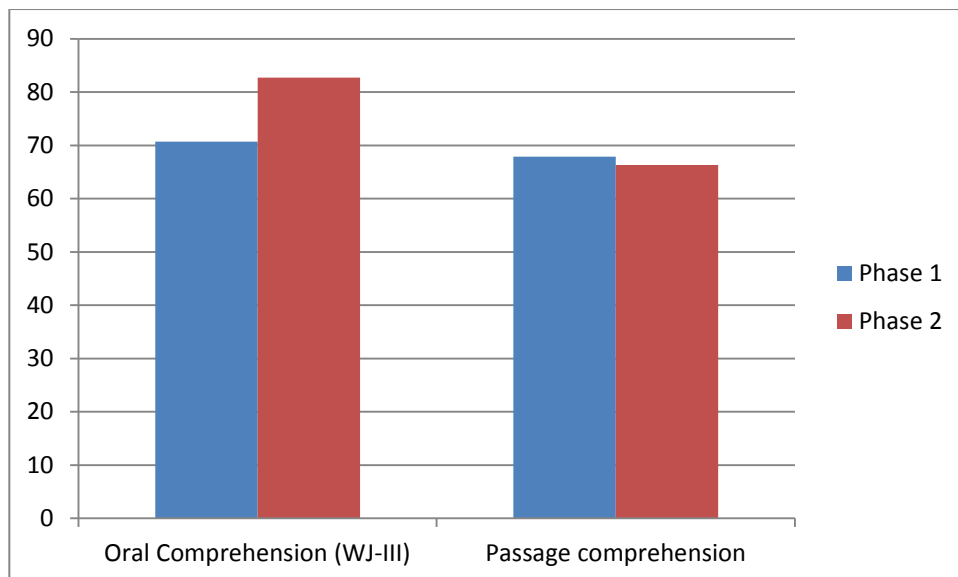
with family members such as grandparents. All participants are involved in some form of sports (e.g., swimming, dance, soccer, hockey, etc.) with hearing peers and coaches, some since they were as young as 3 years old.

Connections Between Oral Language, Reading, and Writing

Overall, the participants in this study performed in the average range for language and reading skills compared to hearing peers, with a range of abilities and profiles similar to what would be expected in a group of hearing peers. Some participants had areas of relative strength and weakness, but no consistent patterns emerged in terms of common areas of difficulties in language or reading.

Given that face-to-face language competence underpins reading competence, mean scores in spoken language comprehension and reading comprehension as assessed by the WJ-III were analyzed and are presented in Figure 4.

Figure 4. Spoken Language Comprehension and Reading Comprehension



Results showed that oral comprehension was slightly better than reading comprehension in both phases of the study. In analyzing individual participant data, in all cases oral comprehension scores were higher than reading comprehension scores. There were no cases in which participants demonstrated better reading comprehension than spoken language comprehension.

Table 14 provides a comparison of reading and writing performance for each participant in Phase 2, at the end of the study. While all participants achieved reading scores that were at or above grade level, performance in writing was much more variable and, overall, poorer.

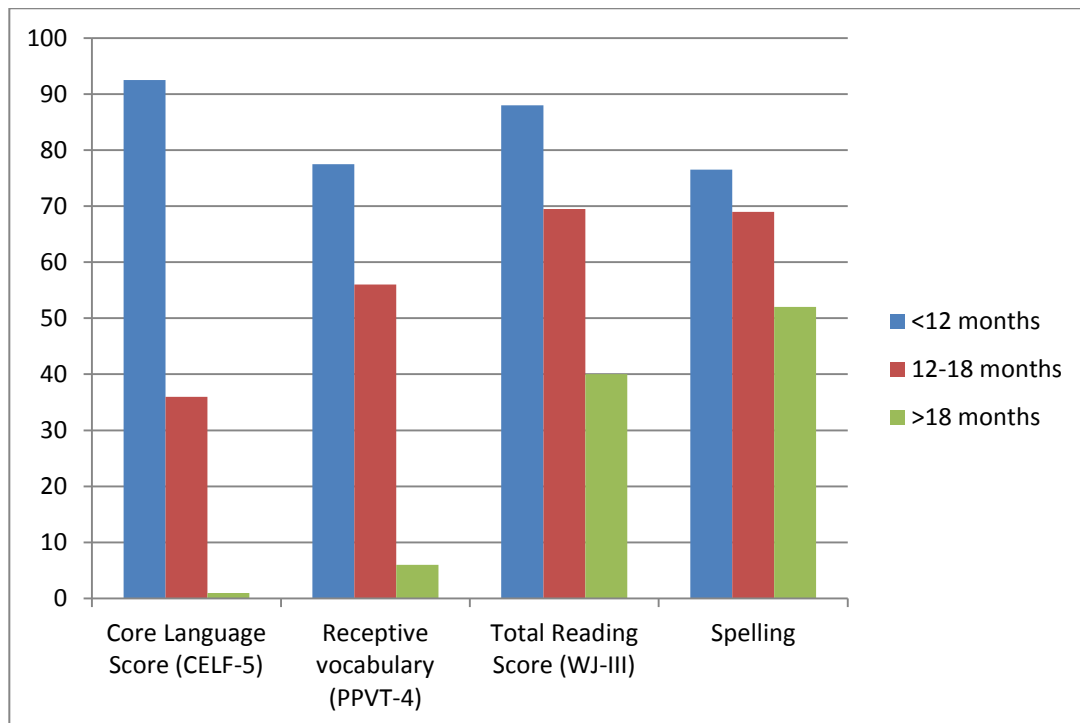
Table 14. Reading and Writing Performance

Participant	Grade in Phase 2	Reading Level (Total Reading Score, WJ-III)	Writing Level
Andrew	1	Average (52nd percentile)	Below average (Level 1)
Gregory	1	Above average (75th percentile)	Below average (Level 2)
Robert	1	Above average (86th percentile)	Below average (Level 2)
William	2	Above average (97th percentile)	Average (Level 3)
Steven	4	Average (45th percentile)	Below average (Level 1)
Sophia	4	Average (64th percentile)	Below average (Level 1)
Lucia	4	Above average (80th percentile)	Above average (Level 3+)

Age of Implantation

Given the small sample size of this study, relationships between age of implantation and performance in language and reading are difficult to examine statistically. However, as an exploratory question, results were analyzed with respect to three categories: implantation under 12 months, implantation between 12 and 18 months, and implantation after 18 months (recognizing that only one participant was implanted after 18 months). Figure 5 summarizes results with respect to overall language scores, receptive vocabulary, total reading scores, and spelling scores according to by age of implantation.

Figure 5. Age of Implantation



CHAPTER FIVE

DISCUSSION

Given the increasing number of simultaneous bilaterally implanted children in Canada now entering the school system, it would be important to examine their academic achievement, particularly with respect to literacy development as this is an area where deaf children have faced singular challenges in attaining age-appropriate outcomes. Therefore, the primary focus of this study was to investigate whether, and the extent to which, reading and writing outcomes have improved with the use of simultaneous bilateral cochlear implants. Given the current context in the field, such an investigation is both warranted and timely, as the research evidence on this question remains relatively thin, particularly for those who have been bilaterally implanted. The discussion in the chapter will be guided and framed by the research questions that underpinned the study with a focus on how these findings have implications for both future research and practice.

The primary research questions driving this study were to document the reading and writing outcomes of a cohort of school-aged children implanted bilaterally and simultaneously before the age of 2, to compare these outcomes to those of hearing age-peers, and to identify areas of relative strength and weakness (e.g., phonological abilities, language, vocabulary) that could have an impact on literacy outcomes. Overall the results of the study indicate that this cohort of seven students demonstrates achievement in reading, receptive and expressive language, vocabulary, and phonological awareness that

is within age norms. It is only in the area of writing that age-appropriate outcomes are not being achieved. It is also worth noting that of the children in this group, those who received their implants before 12 months showed the strongest performance in all areas. Given the very small sample size in this study, this finding must be interpreted with caution; however, it is suggestive and consistent with findings from previous studies that show earlier-implanted children performing better than later-implanted children (Hammes et al., 2002; Miyamoto et al., 2003).

Language, Reading, and Writing Outcomes

Almost all participants exhibited strong receptive and expressive language abilities with overall results in the average range on the CELF-5, despite some decline in the second year of the study. Five of the seven participants had core language scores that were age-appropriate. In both years, receptive language results were stronger than expressive outcomes, although outcomes were age-appropriate in both areas. More specifically, six of the seven children scored within the average range in receptive language in the first and second years of the study. Six of seven had expressive language in the typical range in both years. Vocabulary was also an area of strength. On the basis of the results of the PPVT-4, six out of seven children scored within the average range in both the first and the second year of the study. Perhaps the best indication of the strength of language performance in this cohort is provided by the scores on the Understanding Spoken Paragraphs subtest of the CELF-5. It could be argued that this task most closely approximates the use of language in real-life situations. On this subtest, all seven participants were functioning at age-appropriate levels. The findings in all these areas are

consistent with other studies of early bilaterally implanted children (Geers et al., 2009; Miyamoto et al., 2003; Spencer et al., 2003).

Overall with respect to phonological awareness, phonemic awareness, and phonological memory, all the children in this study obtained average results in both years of testing as assessed by the CTOPP and the WJ-III. Although there was some variability among the children, they all evidenced the ability to segment and blend—the two skills most strongly associated with decoding in reading and encoding in writing. Interestingly, phonological memory was the weakest of the three skills assessed with an average at the 38th percentile. This finding is worth noting as Pisoni, Cleary, Geers, and Tobey (1999) found that implanted children who had achieved higher levels of spoken language made greater use of phonologically based working memory and were faster in global information processing. In addition, all children achieved average scores on the rapid naming tasks as measured on the CTOPP.

Reading outcomes, as measured on the WJ-III, revealed that these seven participants were all performing within the age-appropriate range in both years (i.e., an overall average at the 70th percentile). While reading fluency was relatively weaker than reading comprehension and decoding, it was still within age norms and improved in the second year. These findings of impressive performance in reading are consistent with previous studies of implanted students (e.g., Archbold et al., 2008; Spencer et al., 2003; see Mayer & Trezek, 2015, for a review).

Outcomes in writing were not nearly as strong as the outcomes in reading, with only two students performing in the average or above average range. Weaknesses were

especially evident in the use of written conventions, vocabulary, coherence, and the development of ideas. That being said, as noted in the previous chapter, the children did not write using the nonstandard English syntax and grammar that was typical of deaf pupils in the past (Mayer, 2010; Mayer et al., 2016).

Interestingly, stronger readers were not necessarily found to be strong writers, although it would be important to note that the two students who were achieving age-appropriate levels in writing were also reading at age-appropriate levels. In other words, while it is not possible to argue that the better readers in this study were the better writers, it is fair to say that no children who were strong writers were poor readers. This finding is consistent with research showing that reading and writing are interdependent processes for all learners (McCardle, Chhabra, & Kapinus, 2008).

It was also the case that the two students with the strongest expressive language abilities (i.e., expressive language composite score on the CELF-5) were the strongest writers. Mayer et al. (2016) also found that average or above average scores on expressive vocabulary were related to average to above average performance in writing; This relationship between expressive language and writing parallels that found between receptive language and reading (Geers, 2002; Moog, 2002; Watson, 2002).

This relative strength in expressive language for the majority of the participants in the study (i.e., six of seven) could also account for their ability to write in correct English word order and grammar. Just as hearing children do, they are relying on their command of spoken language to “talk their way into text” by writing down what they are saying as they are composing (Mayer, 2007). This reliance on their knowledge of spoken language

is also evident in their use of invented spelling (e.g., *basball*, *bading*, *pratis*) where they were “sounding out” words in order to encode them. This use of invented spelling has not been typical of deaf writers, who have generally relied on rote memorization for encoding (i.e., remembering the word visually as a whole unit). This can be characterized as writing by “sight words” as children can only write those words they have already seen and memorized. In contrast, these children are employing a strategy that allows them to write down any word they know and can say to create a spelling. Research has consistently shown that use of invented spelling in the early years is predictive of success in a phonological training curriculum and learning to read (Torgesen & Davis, 1996). In fact, invented spelling is associated with skill in learning to read and write (Pressley, 2006).

For most of the participants’ significant development was evident in their writing between Phase 1 and Phase 2 of the study. Five of the seven children showed an increase in the length and complexity of sentences used in their written work, and there was more evidence of structure (i.e., stories with a beginning, middle, and end). The weaknesses in the writing are similar to those often identified as areas of growth for hearing writers: use of simple text structure, lack of supporting details and information, and absence of clear opening and closing statements (Singer & Bashir, 2004).

Speech and articulation were not assessed in this research but it is worth noting that all participants were fluent users of the English language with intelligible spoken language, communicating with ease in their everyday life.

Implications for Research

This study adds to the nascent body of literature on the literacy development of children with cochlear implants, and more specifically the cohort of users who are bilaterally implanted at an early age (i.e., under 2 years) where there is still relatively scant research. It provides additional support for the argument that children with cochlear implants can achieve reading and writing outcomes comparable to those of their hearing age-peers. The results of this study show levels of attainment not previously seen, as it is important to remember that this is a group of children (i.e., those with profound hearing loss) that historically struggled to achieve age-appropriate language and literacy outcomes.

That said, there is clearly a need for additional research on this population of students. While the available evidence is compelling and persuasive, it remains limited in several respects. The most obvious recommendation is a call for additional studies of literacy outcomes. Even though this is a critical outcome for all learners, it has not warranted a commensurate amount of research attention (Mayer & Trezek, 2015). Longitudinal studies consisting of larger pools of participants would offer evidence of whether early gains are maintained in secondary grades and allow more complex skills to be evaluated. There is some suggestion that students can plateau and then fall behind their hearing age-mates in the later school years (Blamey et al., 2001; Geers, 2005; Thoutenhoofd, 2006). In this regard, it would be important to conduct an investigation considering whether BSCI children who receive intense support in the areas of phonological awareness, vocabulary, and syntax during the primary grades could be

associated with greater improvements in levels of literacy achievement. Further research with a more diverse group of participants in both age and ability may assist in determining which factors support development for different children with different academic placements and family settings. There appears to be evidence that implants assist with language skills, but few if any studies have examined the perception of spoken language in real-world settings—social pragmatics and social registers. Studies of academic achievement beyond language and reading are rare, with the literature on writing skills in CI students remaining extremely limited, making this an area that requires further attention.

Implications for Practice

1. *All the children had well-managed equipment that was on and working and used consistently. This is one of the reasons they were successful.*

This is a key factor in their success, one which must be recognized by parents, teachers and other professionals working with these children. Supporting families and parents after early diagnosis in their commitment to early implantation really means education around the importance of consistent use of the child's equipment, allowing for exposure in quality and quantity, an accessible language, and engagement in meaningful activity with others who are already capable users of the language (Mayer, 2007).

2. *All the children showed ease in casual conversation before and after testing as well as during testing.*

It is important for teachers, parents, and other professionals working with these children to understand the difference between listening to a known speaker verses an

unknown speaker, listening in a familiar environment verses an unfamiliar environment, and listening to casual conversation verses new material (vocabulary, concepts). The teachers in a mainstream classroom need support around understanding the students' hearing and the capability of their technology. Implementing the accommodations that exist for a student with a hearing loss (e.g., having the student sit away from distractions, clear view of the teacher and the board/information, etc.) apply to a student with BCIs. TODHH also need to keep current in technology and deaf education to better support the student and the mainstream classroom teacher.

3. The CI is a piece of equipment and we cannot forget the learner.

While the management of the device is key, this does not guarantee performance commensurate with hearing peers. While overall the children in this study demonstrated age appropriate outcomes in reading, areas of relative strength and weakness could be identified among the participants. This suggests that they may need additional support to continue not only to develop, but to maintain the literacy levels they have achieved. This is consistent with reports that as children grow older the demands of the curriculum increase, their rate of progress may slow, and learning difficulties may become more apparent (Blamey et al., 2001; Geers et al., 2008; Thoutenhoofd, 2006).

4. Consistent monitoring (assessment) is needed to ensure that the students maintain their level of performance over time, especially in the transitions to middle school and high school, and that instruction meets the needs of the learner.

In this study three of the participants transitioned into Grade 4, and all available evidence suggests that they were successful (i.e., did not show a decline in performance).

That said, the move from Grade 3 to Grade 4 can place greater demands on students as they transition from a focus on learning to read and write to reading and writing to learn.

Therefore, ongoing monitoring via assessments is critical as a means for both tracking progress and identifying students and needs. This allows TODHH and classroom teachers to work together to differentiate instruction as needed for each learner to maintain achievement over time (Mayer & Trezek, 2014), in an approach that can be characterized as prevention rather than intervention.

5. There should be more focus on teaching writing.

All the children demonstrated weaker writing skills with limited vocabulary, use of conventions, coherence, and the development of ideas. Teachers, parents, and professionals working with these children must be made aware of these areas of need. Consistent assessment, intense support, and teaching in the area of writing and professional development for the TODHH may facilitate greater student success in this area.

Limitations

The primary limitation of this study is the small sample size, and therefore caution should be exercised when generalizing. As well this cohort represents the children who were being implanted at the time and will not be representative of the population in future studies in bilaterally implanted children.

As more children receive CIs and the benefits are documented, the cochlear implant candidacy criteria have expanded including the availability and practice of providing pediatric CI has varied throughout Canada, with different programs being

introduced and funded at various times. Today, in contrast to the earlier years of bilateral implantation, candidates for CIs include individuals having widely diverse characteristics regarding age, etiology, hearing history, quantity of residual hearing and medical conditions (Peters et al., 2010).

It must be acknowledged that all participants were consistent and effective users of their implants. At the time of testing, no participant was diagnosed with any additional disability, so this would be considered a cognitively able group. All participants came from two-parent households with supportive families who volunteered to participate in the study and received support services from outside agencies. These are all factors that have been identified as very significant in positively influencing outcomes (Mayer et al., 2016; Sarant & Bennet, 2015).

It would also be important to note that the researcher had prior relationships with several of the participants. In her capacity as a TODHH who did homevisiting, she met three of the participants while they were very young (3 months – 18 months of age). She worked in partnership with their parents, developing strategies to enhance communication, language and learning. One participant was involved in Masters research project (Ruggirello & Mayer, 2010). Three participants were involved in PhD research project.

Concluding Thoughts

The research outcomes reported in this thesis suggest that simultaneous BCIs provide significant benefits in phonological awareness, oral language, receptive vocabulary, reading, and writing as compared to a single CI or, in some cases, sequential

BCIs in achieving age-appropriate academic achievement. The outcomes of this study also show that early identification followed by early implantation with simultaneous BCIs allows children to demonstrate levels of attainment not previously seen, both in reading and writing, at levels similar to those of their hearing peers. These are positive results for a group that has struggled to achieve age-appropriate language and literacy outcomes in the past.

Findings of a practical nature include the importance of consistent use of the devices, parental involvement, and more focus on writing. Further investigation and support are needed to assist in contributing to further student success. Therefore, it is paramount for researchers and professionals in the field to continue research that tracks the academic outcomes of students with BCIs as this cohort continues to expand.

REFERENCES

- Advanced Bionics Corporation. (2004). *Hearing with two ears: Technical advances for bilateral cochlear implantation*. Valencia, CA: Author. Retrieved from https://www.advancedbionics.com/content/dam/ab/Global/en_ce/documents/candidate/AB_Tech_Advances_for_Bilateral_Cochlear_Implantation_article.pdf
- Alamargot, D., Lambert, E., Thebault, C., & Dansac, C. (2007). Text composition by deaf and hearing middle-school students: The role of working memory. *Reading and Writing, 20*(4), 333–360.
- Alberta College of Speech-Language Pathologists and Audiologists. (2008). *Endorsement of Universal Newborn Hearing Screening (UNHS) in Alberta*. Edmonton, AB: Author. Retrieved from <https://acslpa.ab.ca/download/college/UNHS.pdf>
- Albertini, J. A., & Schley, S. (2003). Writing: Characteristics, instruction, and assessment. In M. Marschark & P. E. Spencer (Eds.), *Handbook of deaf studies, language, and education* (pp. 123–135). New York, NY: Oxford University Press.
- Ambrose, S. E. (2009). *Phonological awareness development of preschool children with cochlear implants* (Doctoral dissertation). University of Kansas, Lawrence, KS. Retrieved from https://kuscholarworks.ku.edu/bitstream/handle/1808/6008/Ambrose_ku_0099D_10589_DATA_1.pdf?sequence=1&isAllowed=y

- Ambrose, S. E., Fey, M. E., & Eisenberg, L. S. (2012). Phonological awareness and print knowledge of preschool children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, 55(3), 811–823.
- Archbold, S. M. (2010). *Deaf education: Changed by cochlear implantation?* (Doctoral dissertation). Radboud University Nijmegen, Nijmegen, Netherlands.
- Archbold, S. M., Harris, M., O'Donoghue, G., Nikolopoulos, T., White, A., & Richmond, H. L. (2008). Reading abilities after cochlear implantation: The effect of age at implantation on outcomes at 5 and 7 years after implantation. *International Journal of Pediatric Otorhinolaryngology*, 72, 1471–1478.
- Archbold, S. M., Lutman, M. E., & Marshall, D. H. (1995). Categories of Auditory Performance. *Annals of Otology, Rhinology & Laryngology Supplement*, 166, 312–314.
- Archbold, S. M., Lutman, M. E., & Nikolopoulos, T. (1998). Categories of auditory performance: Inter-user reliability. *British Journal of Audiology*, 32(1), 7–12.
- Archbold, S. M., & Mayer, C. (2012). Deaf education: The impact of cochlear implantation? *Deafness and Education International*, 1(14), 2–15.
- Bagatto, M., Scollie, S. D., Hyde, M., & Seewald, R. (2010). Protocol for the provision of amplification within the Ontario infant hearing program. *International Journal of Audiology*, 49(S1), S70–S79.
- Barker, B. A. (2012, Spring). Editor's corner: Focus on early identification and intervention in deaf children with cochlear implants. *LSHA News*, 16, 1–2.

- Bess, F. H., Tharpe, A. M., & Gibler, A. M. (1986). Auditory performance of children with unilateral sensorineural hearing loss. *Ear and Hearing, 7*, 20–26.
- Blamey, P. J., Sarant, J. Z., Paatsch, L., Barry, J. G., Bow, C. P., Wales, R. J., . . . Tooher, R. (2001). Relationships among speech perception, production, language, hearing loss, and age in children. *Journal of Speech, Language and Hearing Research, 44*(2), 264–285.
- Bochner, J., & Albertini, J. (1988). Language varieties in the deaf population and their acquisition by children and adults. In M. Strong (Ed.), *Language learning and deafness* (pp. 3–48). New York, NY: Cambridge University Press.
- Brown, K. D., & Balkany, T. J. (2007). Benefits of bilateral cochlear implantation: A review. *Current Opinion in Otolaryngology & Head and Neck Surgery, 15*, 315–318.
- Canadian Infant Hearing Task Force. (2015). Report card on early hearing detection and intervention. Retrieved from http://www.infanthearingcanada.ca/wp-content/uploads/2015/09/Report-Card-2015-08_EN.pdf
- Ching, T. Y., van Wanrooy, E., & Dillon, H. (2007). Binaural-bimodal fitting or bilateral implantation for managing severe to profound deafness: A review. *Trends in Amplification, 11*, 161–192.
- Cole, E., & Flexer, C. (2007). *Children with hearing loss: Developing listening and talking birth to six*. San Diego, CA: Plural Publishing.
- Connor, C. M., Craig, H. K., Raudenbush, S. W., Heavner, K., & Zwolan, T. A. (2006). The age at which young deaf children receive cochlear implants and their

- vocabulary and speech-production growth: Is there an added value for early implantation? *Ear and Hearing*, 27(6), 628–644.
- Connor, C. M., & Zwolan, T. (2004). Examining multiple sources of influence on the reading comprehension skills of children who use cochlear implants. *Journal of Speech, Language and Hearing Research*, 47, 509–526.
- Conrad, R. (1979). *The deaf school child*. London, England: Harper & Row.
- Cox, R. M., & McDaniel, D. M. (1989). Speech Intelligibility Rating. *Journal of Speech and Hearing Research*, 32(2), 347–352.
- Crosson, J., & Geers, A. (2001). Analysis of narrative ability in children with cochlear implants. *Ear and Hearing*, 22, 381–394.
- Dillon, C. M., & Pisoni, D. B. (2006). Nonword repetition and reading skills in children who are deaf and have cochlear implants. *Volta Review*, 106(2), 121–145.
- Dillon, C. M., de Jong, K., & Pisoni, D. B. (2012). Phonological awareness, reading skills, and vocabulary knowledge in children who use cochlear implants. *Journal of Deaf Studies and Deaf Education*, 17(2), 205–226.
- Dreyfuss, J. H. (2010, June 9). Double benefit? The case for bilateral cochlear implants. *ENTtoday*. Retrieved from <http://www.enttoday.org/article/double-benefit-the-case-for-bilateral-cochlear-implants/>
- Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, fourth edition*. Upper Saddle River, NJ: Pearson Education.
- Ear Foundation. (2004). *The Speech Intelligibility Rating Scale*. Retrieved from <http://www.earfoundation.org.uk>

- Ear Foundation. (2007). *Cochlear implants*. Retrieved from <http://www.earfoundation.org.uk/hearing-technologies/cochlear-implants>
- Fagan, M. K., Pisoni, D. B., Horn, D. L., & Dillon, C.M. (2007). Neuropsychological correlates of vocabulary, reading, and working memory in deaf children with cochlear implants. *Journal of Deaf Studies and Deaf Education*, *12*, 461–471.
- Firszt, J. B., Reeder, R. M., & Skinner, M. W. (2008). Restoring hearing symmetry with two cochlear implants or one cochlear implant and a contralateral hearing aid. *Journal of Rehabilitation Research & Development*, *45*(5), 749–767.
- Fitzpatrick, E. M., Whittingham, J., & Durieux-Smith, A. (2013). Mild bilateral and unilateral hearing loss in childhood: A 20-year view of hearing characteristics, and audiologic practices before and after newborn hearing screening. *Ear and Hearing*, *35*(1), 10–18.
- 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 the Schools*, *33*, 172–183.
- Geers, A. E. (2003). Predictors of reading skills development in children with early cochlear implantation. *Ear and Hearing*, *24*, 59S–68S.
- Geers, A. E. (2004). Speech, language, and reading skills after early cochlear implantation. *Archives of Otolaryngology Head and Neck Surgery*, *130*, 634–638.
- Geers, A. E. (2005). *Factors associated with academic achievement by children who received a cochlear implant by 5 years of age*. Preconference workshop on

Development of Children with Cochlear Implants at biennial meetings of the Society for Research in Child Development, Atlanta, GA.

- Geers, A. E. (2006). Spoken language in children with cochlear implants. In P. E. Spencer & M. Marschark (Eds.), *Advances in the spoken language development of deaf and hard-of-hearing children* (pp. 244–269). New York, NY: Oxford University Press.
- Geers, A. E., Brenner, C., & Davidson, L. (2003). Factors associated with development of speech perception skills in children implanted by age five. *Ear and Hearing, 24*, 2–14.
- Geers, A. E., Brenner, C., Nicholas, J., Uchanski, R., Tye-Murray, N., & Tobey, E. (2002). Rehabilitation factors contributing to implant benefit in children. *Annals of Otology, Rhinology and Laryngology, 111*(5), 127–130.
- Geers, A. E., & Hayes, H. (2010). Reading, writing, and phonological processing skills of adolescents with 10 or more years of cochlear implant experience. *Ear and Hearing, 32*, 49S–59S.
- Geers, A. E., Moog, J. S., Biedenstein, J., Brenner, C., & Hayes, H. (2009). Spoken language scores of children using cochlear implants compared to hearing age-mates at school entry. *Journal of Deaf Studies & Deaf Education, 14*, 371–385.
- 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., Tobey, E., Moog, J. S., & Brenner, C. (2008). Long-term outcomes of cochlear implantation in the preschool years: From elementary grades to high school. *International Journal of Audiology, 47*(2s):21S–30S.
- Gordon, K. A., Deighton, M., Abbasalipour, P., & Papsin, B. C. (2014). Perception of binaural cues develops in children who are deaf through bilateral cochlear implantation. *PLOS ONE 9*(12), e114841. doi:10.1371/journal.pone.0114841
- Gordon, K. A., Jiwani, S., & Papsin, B. C. (2013). Benefits and detriments of unilateral cochlear implant use on bilateral auditory development in children who are deaf. *Frontiers in Psychology, 4*, 1–14.
- Gordon, K. A., & Papsin, B. C. (2009). Understanding hearing loss in children: What is known and what remains to be learned? *Otorinolaringologia, 59*(4), 221–227.
- Gordon, K. A., Tanaka, S., Wong, D. D. E., & Papsin, B. C. (2008). Characterizing responses from auditory cortex in young people with several years of cochlear implant experiences. *Clinical Neurophysiology, 31*, 202–211.
- Gordon, K. A., Valero, J., & Papsin, B. C. (2007). Binaural processing in children using bilateral cochlear implants. *NeuroReport, 18*(6), 613–617.
- Gordon, K. A., Wong, D. D. E., & Papsin, B. C. (2010). Cortical function in children receiving BCI simultaneously or after a period of interimplant delay. *Otology & Neurotology, 31*(8), 1293–1299.
- Graham, J., Vickers, D., Malky, G. A., Martin, J., Henderson, L., Mawman, D., . . . Bray, M. (2009). Bilateral sequential cochlear implantation in the congenitally deaf child: Evidence to support the concept of a ‘critical age’ after which the second

ear is less likely to provide an adequate level of speech perception on its own.

Cochlear Implants International, 10(3), 119–141.

Hammes, D. M., Novak, M. A., Rotz, L. A., Willis, M., Edmondson, D. M., & Thomas, J. F. (2002). Early identification and cochlear implantation: Critical factors for spoken language development. *Annals of Otolaryngology, Rhinology & Laryngology Supplement*, 189, 74–78.

Harrington, M., DesJardin, J. L., & Shea, L. C. (2010). Relationships between early child factors and school readiness skills in young children with hearing loss. *Communication Disorders Quarterly*, 32(1), 50–62.

Harris, M., & Terlektsi, E. (2011). Reading and spelling abilities of deaf adolescents with cochlear implants and hearing aids. *Journal of Deaf Studies and Deaf Education*, 16(1), 24–34.

Harrison, R. V., Nedzelski, J., Picton, N., Papsin, B. C., Russell, S., Margar-Bacal, F., . . . Barnett, S. (1997). The paediatric cochlear implant program at the Hospital for Sick Children, Toronto. *Journal of Otolaryngology*, 26, 180–187.

Hayes, H., Treiman, R., & Geers, A. E. (2014). Spelling in deaf children with cochlear implants: Implications for instruction. In B. Arfé, J. Dockrell, & V. Berninger (Eds.), *Writing development in children with hearing loss, dyslexia, or oral language problems: Implications for assessment and instruction* (pp. 45–54). New York, NY: Oxford University Press.

Hearing Foundation of Canada. (2011). *Annual report 2010/2011*. Toronto, ON: Author.

- Hearing Foundation of Canada. (2016). *Newborn hearing screening*. Retrieved from www.hearingfoundation.ca
- Hoff, E. (2009). *Language development* (4th ed.). Belmont, CA: Wadsworth Cengage Learning.
- Holt, J. A. (1993). Stanford Achievement Test—8th edition; Reading comprehension subgroup results. *American Annals of the Deaf*, 138(2), 172–175.
- Holt, J. A., Traxler, C. B., & Allen, T. E. (1997). *Interpreting the scores: A user's guide to the 9th edition Stanford Achievement Test for education of deaf and hard-of-hearing students*. Washington, DC: Gallaudet University, Gallaudet Research Institute.
- Holt, R. F., & Kirk, K. I. (2005). Speech and language development in cognitively delayed children with cochlear implants. *Ear and Hearing*, 26, 132–148.
- Holt, R. F., & Svirsky, M. A. (2008). An exploratory look at pediatric cochlear implantation: Is earliest always best? *Ear and Hearing*, 29, 492–511.
- Holt, R. F., Svirsky, M. A., Neuburger, H., & Miyamoto, R. T. (2004). Age at implantation and communicative outcome in pediatric cochlear implant users: Is younger always better? *International Congress Series*, 1273, 368–371.
- Hospital for Sick Children. (2010). *Cochlear implant program*. Retrieved from <http://www.sickkids.ca/cochlearimplant/>
- Hospital for Sick Children. (2014). *Cochlear implant program*. Retrieved from <http://www.sickkids.ca/cochlearimplant/>

- Houston, D. M. (2002). What infants learn about native language sound organization during their first year, and what may happen if they don't. In K. Schauwers, P. J. Govaerts, & S. Gillis (Eds.), *Language acquisition in very young children with a cochlear implant* (pp. 11–22). Antwerp Papers in Linguistics 102. Retrieved from http://www.eargroup.net/wwwuploads/manuscripts/1364982072_publi057.pdf
- Houston, D. M. (2011). Infant speech perception. In R. Seewald & A. M. Thapre (Eds.), *Comprehensive handbook of pediatric audiology* (pp. 47–62). San Diego, CA: Plural Publishing.
- Houston, D. M., Beer, J., Bergeson, T. R., Chin, S. B., Pisoni, D. B., & Miyamoto, R. T. (2012). The ear is connected to the brain: Some new directions in the study of children with cochlear implants at Indiana University. *Journal of the American Academy of Audiology, 23*, 446–463.
- James, A. L., & Papsin, B. C. (2004). Cochlear implant surgery at 12 months of age or younger. *The Laryngoscope, 114*(12), 2191–2195.
- James, D., Rajput, K., Brinton, J., & Goswami, U. (2008). Phonological awareness, vocabulary, and word reading in children who use cochlear implants: Does age of implantation explain individual variability in performance outcomes and growth? *Journal of Deaf Studies and Deaf Education, 13*(1), 117–137.
- Johnson, C., & Goswami, U. (2010). Phonological awareness, vocabulary, and reading in deaf children with cochlear implants. *Journal of Speech, Language, and Hearing Research, 53*(2), 237–261.

- Johnston, J. C., Durieux-Smith, A., Angus, D., O'Connor, A., & Fitzpatrick, E. (2009). Bilateral paediatric cochlear implants: A critical review. *International Journal of Audiology, 48*, 601–617.
- Kimura, M. Y. T., & Hyppolito, M. A. (2013). Reflections on bilateral cochlear implants. *International Journal of Clinical Medicine, 4*, 171–177.
- King, C., & Quigley, S. (1985). *Reading and deafness*. San Diego, CA: College-Hill Press.
- Krishnan, L. A., & Van Hyfte, S. (2014). Effects of policy changes to universal newborn hearing screening follow up in a university clinic. *American Journal of Audiology, 23*, 282–292.
- Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science, 255*, 606–608.
- Kuhn-Inacker, H., Shehata-Dieler, W., Muller, J., & Helms, J. (2004). Bilateral cochlear implants: A way to optimize auditory perception abilities in deaf children? *International Journal of Pediatric Otorhinolaryngology, 68*, 1257–1266.
- Kushalnagar, P., Mathur, G., Moreland, C. J., Napoli, D. J., Osterling, W., Padden, C., & Rathmann, C. (2010). Infants and children with hearing loss need early language access. *Journal of Clinical Ethics, 21*(2), 143–154.
- Lieberman, A. M., Hatrak, M., & Mayberry, R. I. (2014). Learning to look for language: Development of joint attention in young deaf children. *Language Learning and Development, 10*(1), 19–35. doi:10.1080/15475441.2012.760381

- Litovsky, R. Y., Goupell, M. J., Godar, S., Grieco-Calub, T., Jones, G. L., Garadat, S. W., . . . Misurelli, S. (2012). Studies on bilateral cochlear implants at the university of Wisconsin's binaural hearing and speech lab. *Journal of the American Academy of Audiology*, 23(6): 476–494.
- Litovsky, R. Y., Johnstone, P. M., & Godar, S. P. (2006). Benefits of bilateral cochlear implants and/or hearing aids in children. *International Journal of Audiology*, 45, 78–91.
- Litovsky, R. Y., Johnstone, P. M., Godar, S. P., Agrawal, S., Parkinson, A., Peters, R., & Lake, J. (2006). Bilateral cochlear implants in children: Localization acuity measured with minimum audible angle. *Ear and Hearing*, 27(1), 43–59.
- Lou, M. W. (1988). The history of language use in the education of the Deaf in the United States. In M. Strong (Ed.), *Language learning and deafness* (pp. 75–98). Cambridge, England: Cambridge University Press.
- Lyxell, B., Sahlén, B., Wass, M., Ibertsson, T., Larsby, B., Hallgren, M., & Maki-Torkko, E. (2008). Cognitive development in children with cochlear implants: Relations to reading and communication. *International Journal of Audiology*, 47(2), 47–52.
- Lyxell, B., Wass, M., Sahlén, B., Samuelsson, C., Asker-Arnason, L., Ibertsson, T., . . . Hallgren, M. (2009). Cognitive development, reading and prosodic skills in children with cochlear implants. *Scandinavian Journal of Psychology*, 50, 463–474.

- Manrique, M., Cervera-Paz, F. J., Huarte, A., & Molina, M. (2004). Advantages of cochlear implantation in prelingual deaf children before 2 years of age when compared with later implantation. *The Laryngoscope, 114*, 1462–1469.
- Markman, T. M., Quittner, A. L., Eisenberg, L. S., Tobey, E. A., Thal, D., Niparko, J. K., . . . The CDaCI Investigative Team. (2011). Language development after cochlear implantation: An epigenetic model. *Journal of Neurodevelopmental Disorder, 3*, 388–404.
- Marschark, M., Rhoten, C., & Fabich, M. (2007). Effects of cochlear implants on reading and academic achievement. *Journal of Deaf Studies and Deaf Education, 12*, 269–282.
- Marschark, M., Sarchet, T., Rhoten, C., & Zupan, M. (2010). Will cochlear implants close the reading achievement gap for deaf students? In M. Marschark & P. E. Spencer (Eds.), *The Oxford handbook of deaf studies, language and education* (Vol. 2, pp. 127–143). New York, NY: Oxford University Press.
- Marschark, M., & Spencer, P. E. (2005). Spoken language development of deaf and hard-of-hearing children: Historical and theoretical perspectives. In P. E. Spencer & M. Marschark (Eds.), *Advances in the spoken language development of deaf and hard-of-hearing children* (pp. 3–21). New York, NY: Oxford University Press.
- Marschark, M., & Spencer, P. (2009). *Evidence of best practice models and outcomes in the education of deaf and hard-of-hearing children: An international review*. Trim, Co. Meath, Ireland: National Council for Special Education. Retrieved from

http://www.nabmse.org/wp/wp-content/uploads/downloads/2012/07/1_NCSE_Deaf.pdf

- Mayer, C. (2007). What really matters in the early literacy development of deaf children. *Journal of Deaf Studies and Deaf Education, 12*(4), 411–431.
- Mayer, C. (2010). The demands of writing and the deaf writer. In M. Marschark & P. E. Spencer (Eds.), *The Oxford handbook of deaf studies, language, and education* (Vol. 2, pp. 144–155). New York, NY: Oxford University Press.
- Mayer, C., & Moskos, E. (1998). Deaf children learning to spell. *Research in the Teaching of English, 33*(2), 158–180.
- Mayer, C., Papoulidis, P., & Millett, P. (2012, April 15). Literacy achievement of deaf learners with cochlear implants. In T. P. Horejes & Y. Wang (Chairs), *Research on the education of deaf persons*. Symposium conducted at the Annual Meeting of the American Educational Research Association, Vancouver, BC.
- Mayer, C., & Trezek, B. J. (2011). New (?) answers to old questions: Literacy development in D/HH learners. In D. F. Moores (Ed.), *Partners in education: Issues and trends from the 21st International Congress on the Education of the Deaf* (pp. 62–74). Washington, DC: Gallaudet University Press.
- Mayer, C., & Trezek, B. J. (2014). Is reading different for deaf individuals?: Reexamining the role of phonology. *American Annals of the Deaf, 159*(4), 359–371.
- Mayer, C., & Trezek, B. J. (2015). *Early literacy development in deaf children*. New York, NY: Oxford University Press.

- Mayer, C., Watson, L., Archbold, S., Yen Ng, Z., & Mulla, I. (2016). Reading and writing skills of deaf pupils with cochlear implants. *Deafness & Education International*, 18(2), 71–86.
- McCardle, P., Chhabra, V., & Kapinus, B. (2008). *Reading research in action: A teacher's guide for student success*. Baltimore, MD: Paul H. Brookes.
- Miller, P. (2005). Reading comprehension and its relation to the quality of functional hearing: Evidence from readers with different functional hearing abilities. *American Annals of the Deaf*, 150, 305–323.
- Miyamoto, R. T., Hay-McCutcheon, M. J., Kirk, K. I., Houston, D. M., & Bergeson-Dana, T. (2008). Language skills of profoundly deaf children who received cochlear implants under 12 months of age: a preliminary study. *Acta Otolaryngologica*, 128, 373–377.
- Miyamoto, R. T., Houston, D. M., Kirk, K. I., Perdew, A. E., & Svirsky, M. A. (2003). Language development in deaf infants following cochlear implantation. *Acta Otolaryngologica*, 123, 241–244.
- Moog, J. (2002). Changing expectations for children with cochlear implants. *Annals of Otolaryngology, Rhinology & Laryngology Supplement*, 189, 138–142.
- Murphy, J., & O'Donoghue, G. (2007). Bilateral cochlear implantation: An evidence-based medicine evaluation. *The Laryngoscope*, 117, 1412–1418.
- National Institute on Deafness and Other Communication Disorders. (2011). *Cochlear implants*. Bethesda, MD: Author.

- National Reading Panel. (2000). *Report of the National Reading Panel: Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. NIH Publication No. 00-4769. Washington, DC: U.S. Government Printing Office.
- Nicholas, J. G., & Geers, A. E. (2006). The process and early outcomes of cochlear implantation by three years of age. In P. E. Spencer & M. Marschark (Eds), *Advances in the spoken language development of deaf and hard-of-hearing children* (pp. 271–297). New York, NY: Oxford University Press.
- Nikolopoulos, T. P., Archbold, S. M., & O’Donoghue, G. M. (2006). Does cause of deafness influence outcome after cochlear implantation in children? *Pediatrics*, *118*(4), 1350–1356.
- Nittrouer, S., Caldwell, A., & Holloman, C. (2012). Measuring what matters: Effectively predicting language and literacy in children with cochlear implants. *International Journal of Pediatric Otorhinolaryngology*, *76*, 1148–1158.
- Nittrouer, S., Caldwell, A., Lowenstein, J. H., Tarr, E., & Holloman, C. (2012). Emergent literacy in kindergarteners with cochlear implants. *Ear and Hearing*, *33*(6), 683–697.
- Nittrouer, S., Caldwell-Tarr, A., Sansom, E., Twersky, J., & Lowenstein, J. H. (2014). Nonword repetition in children with cochlear implants: A potential clinical marker of poor language acquisition. *American Journal of Speech and Language Pathology*, *23*(4), 679–695.

- Ontario Ministry of Education. (2005). *A guide to effective instruction in writing, Kindergarten to Grade 3*. Toronto: Queen's Printer for Ontario.
- Ontario Ministry of Education and Training. (1999). *The Ontario curriculum: Exemplars, Grades 1–8—Writing*. Toronto: Queen's Printer for Ontario.
- Papsin, B. C. (2005). Cochlear implantation in children with anomalous cochleovestibular anatomy. *The Laryngoscope*, *115*, 1–26.
- Papsin, B. C., & Gordon, K. A. (2007). Cochlear implants for children with severe-to-profound hearing loss. *New England Journal of Medicine*, *357*(23), 2–9.
- Papsin, B. C., & Gordon, K. A. (2008). Bilateral cochlear implants should be standard for children with bilateral sensorineural deafness. *Otolaryngology & Head and Neck Surgery*, *16*, 69–74.
- Patel, H., & Feldman, M. (2011). Universal newborn hearing screening. *Paediatrics & Child Health*, *16*(5), 301–305.
- Paul, P. V. (1998). *Literacy and deafness: The development of reading, writing, and literate thought*. Needham Heights, MA: Allyn & Bacon.
- Paul, P. V. (2001). *Language and deafness* (3rd ed.). San Diego, CA: Singular Thomson Learning.
- Peng, S. C., Spencer, L. J., & Tomblin, J. (2004). Speech intelligibility of pediatric cochlear implant recipients with 7 years of device experience. *Journal of Speech, Language, and Hearing Research*, *47*, 1227–1236.
- Peters, R. B. (2003). Rationale for studying bilateral cochlear implantation in children. *Contact*, *17*(3), 12–16

- Peters, R. B., Lake, J., Litovsky, R., & Parkinson, A. (2007). Importance of age and postimplantation experience on speech perception measures in children with sequential bilateral cochlear implants. *Otology & Neurotology*, *28*, 649–657.
- Peters, R. B., Wyss, J., & Manrique, M. (2010). Worldwide trends in bilateral cochlear implantation. *The Laryngoscope*, *120*(5), 17–44.
- Picard, A. (2011, May 9). Doctors' orders: A hearing test for every newborn. *The Globe and Mail*. Updated August 24, 2012. Retrieved from <http://www.theglobeandmail.com/life/parenting/doctors-orders-a-hearing-test-for-every-newborn/article4263272/>
- Pisoni, D. B., Cleary, M., Geers, A. E., & Tobey, E. A. (1999). Individual differences in effectiveness of cochlear implants in children who are prelingually deaf: New process measures of performance. *Volta Review*, *101*, 111–164.
- Pressley, M. (2006). *Reading instruction that works: The case for balanced teaching*. New York, NY: Guilford.
- Qi, S., & Mitchell, R. E. (2012). Large-scale academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. *Journal of Deaf Studies and Deaf Education*, *17*(1), 1–18
- Quigley, S. P., & Paul, P. V. (1984). *Language and deafness* (1st ed.). San Diego, CA: College-Hill Press.
- Quigley, S. P., Power, D., & Steinkamp, M. (1977). The language structure of deaf children. *Volta Review*, *79*, 73–83.

- Ramsden, J. D., Papaioannou, V., Gordon, K. A., James, A. L., & Papsin, B. C. (2009). Parental and program's decision making in paediatric simultaneous bilateral cochlear implantation: Who says no and why? *International Journal of Pediatric Otorhinolaryngology*, *73*, 1325–1328.
- Ramsden, J. D., Papsin, B. C., Leung, R., James, A. L., & Gordon, K. A. (2009). Bilateral simultaneous cochlear implantation in children: Our first 50 cases. *The Laryngoscope*, *119*, 2444–2448.
- Ruggirello, C. and Mayer, C. (2010). Language development in a hearing and a deaf twin with simultaneous bilateral cochlear implants. *Journal of Deaf Studies & Deaf Education*, *15*(3), 274-286.
- Sammeth, C. A. (2007). *Bimodal devices and bilateral cochlear implants: A review of the literature*. Centennial, CO: Cochlear Americas. Retrieved from [http://www.sd47.bc.ca/auditoryoutreach/resources/reading/Documents/Bilateral Cochlear Implants.pdf](http://www.sd47.bc.ca/auditoryoutreach/resources/reading/Documents/BilateralCochlearImplants.pdf)
- Sampaio, A. L. L., Araújo, M. F. S., & Oliveira, C. A. C. P. (2011). New criteria of indication and selection of patients to cochlear implant. *International Journal of Otolaryngology*, *2011*, 573968. doi:10.1155/2011/573968
- Sarant, J. (2012). Cochlear implants in children: A review. In S. Naz (Ed.), *Hearing loss* (pp. 331–382). Rijeka, Croatia: In Tech. Retrieved from <http://www.intechopen.com/books/hearing-loss/cochlear-implants-in-children-a-review>

- Sarant, J., & Bennet, L. (2015). Academic outcomes for school-aged children with severe-profound loss and early unilateral and bilateral cochlear implants. *Journal of Speech, Language, and Hearing Research*, 58(3), 1017–1032.
- Sarant, J., Harris, D., Bennet, L., & Bant, S. (2014). Bilateral versus unilateral cochlear implants in children: A study of spoken language outcomes. *Ear and Hearing*, 35(4), 396–409.
- Schrank, F. A., Mather, N., & Woodcock, R. W. (2004). *Woodcock-Johnson III (r) Diagnostic Reading Battery*. Rolling Meadows, IL: Riverside.
- 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, 218–223.
- Sherman, L. W., & Cruse, T. L. (2004, October). *Literacy achievement and early cochlear implantation in deaf children*. Presentation to the Midwest Educational Research Association, Columbus, OH. Retrieved from http://www.users.miamioh.edu/shermalw/cruse_mwera2004.htm
- Simonsen, E., Kristoffersen, A., & Hyde, M. B. (2009). Great expectations perspectives on cochlear implantation of deaf children in Norway. *American Annals of the Deaf*, 154(3), 263–273.
- Singer, B. D., & Bashir, A. S. (2004). Developmental variation in writing composition skills. In C. Stone, E. Silliman, B. J. Ehren, & K. Apel (Eds.), *Handbook of*

- language and literacy: Development and disorders* (pp.559–582). New York, NY: Guilford Press.
- Snow, C., Burns, S., & Griffin, P. (Eds.), (1998). *Preventing reading difficulties in young children*. Washington, DC: National Academy Press.
- Sparreboom, M., van Schoonhoven, J., van Zanten, B. G. A., Scholten, R. J. P., Mylanus, E. A. M., Grolman, W., & Maat, B. (2010). The effectiveness of bilateral cochlear implants for severe-to-profound deafness in children: A systematic review. *Otology & Neurotology*, *31*, 1062–1071.
- Spencer, L. J., Barker, B. A., & Tomblin, J. B. (2003). Exploring the language and literacy outcomes of pediatric cochlear implant users. *Ear and Hearing*, *24*, 236–247.
- Spencer, L. J., Gantz, B. J., & Knutson, J. F. (2004). Outcomes and achievement of students who grew up with access to cochlear implants. *The Laryngoscope*, *114*(9), 1576–1581.
- Spencer, L. J., Tomblin, J. B., & Gantz, B. (1997). Reading skills in children with multichannel cochlear-implant experience. *Volta Review*, *99*, 193–202.
- Spencer, P. E., & Marschark, M. (2010). *Evidence-based practice in educating deaf and hard-of-hearing students*. New York, NY: Oxford University Press.
- Stacey, P. C., Fortnum, H. M., Barton, G. R., & Summerfield, A. Q. (2006). Hearing impaired children in the UK, I: Auditory performance, communication skills, educational achievements, quality of life, and cochlear implantation. *Ear and Hearing*, *27*, 161–186.

- Stockley, T. L., Stanton, S. G., & Brown, C. (2012). Genetic testing as an adjunct to newborn hearing screening in Ontario Canada.
- Thoutenhoofd, E. (2006). Cochlear implanted pupils in Scottish schools: 4-year school attainment data (2000–2004). *Journal of Deaf Studies and Deaf Education*, *11*, 171–188.
- Tomblin, J. B., Barker, B. A., Spencer, J. E., Zhang, X., & Gantz, B. (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*, 853–867.
- Tomblin, J. B., Spencer, L. J., Flock, S., Tyler, R., & Gantz, B. J. (1999). A comparison of language achievement in children with cochlear implants and children using hearing aids. *Journal of Speech, Language, and Hearing Research*, *42*(2), 497.
- Tomblin, J. B., Spencer, L. J., & Gantz, B. J. (2000). Language and reading acquisition in children with and without cochlear implants. *Advances in Otorhinolaryngology*, *57*, 300–304.
- Torgesen, J. K., & Davis, C. (1996). Individual difference variables that predict response to training in phonological awareness. *Journal of Experimental Child Psychology*, *63*, 1–21.
- Torres, S., Rodriguez, J. M., García Orza, J., & Calleja, M. (2008). Reading comprehension of an inferential text by deaf students with cochlear implants using cued speech. *Volta Review*, *108*, 37–59.

- Traxler, C. B. (2000). The Stanford Achievement Test, ninth edition: National norming and performance standards for deaf and hard-of-hearing students. *Journal of Deaf Studies and Deaf Education*, 5(4), 337–348.
- Trezek, B. J., Wang, Y., & Paul, P. V. (2010). *Reading and deafness: Theory, research, and practice*. Clifton Park, NY: Delmar Cengage Learning.
- Trezek, B. J., Wang, Y., & Paul, P. V. (2011). Process and components of reading. In M. Marschark & P. E. Spencer (Eds.), *The Oxford handbook of deaf studies, language, and education* (Vol. 1, 2nd ed., pp. 99–114). New York, NY: Oxford University Press.
- United States Food and Drug Administration. (2015). *Premarket to postmarket shift in clinical data requirements for cochlear implant device approvals in pediatric patients*. Washington, DC: Author.
- Vavatzanidis, N. K., Murbe, D., Friederici, A., & Hahne, A. (2015). The basis for language acquisition: Congenitally deaf infants discriminate vowel length in the first months after cochlear implantation. *Journal of Cognitive Neuroscience*, 27(12), 2427–2441.
- Vermeulen, A. K., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with children implants. *Journal of Deaf Studies and Deaf Education*, 12(3), 283–302.
- Wagner, R., Torgesen, J., & Rashotte, C. (2001). *Comprehensive test of phonological processing*. San Antonio, TX: Pearson Education.

- Wass, M. (2009). *Children with cochlear implants: Cognition and reading ability*. Linköping Studies in Arts and Science No. 503, Studies from the Swedish Institute for Disability Research No. 30. Linköping, Sweden: Linköping University, Department of Behavioural Sciences and Learning. Retrieved from http://barnplantorna.se.space2u.com/UserFiles/file/rapporter/MalinWass_ChildrenWithCI-CognitionAndReadingAbility_Nov09.pdf
- Watson, L. (2002). The literacy development of children with cochlear implants at age seven. *Deafness and Education International*, 4, 84–98.
- Webster, A. (1986). *Deafness, development and literacy*. London, England: Methuen.
- Werker, J. F., & Tees, R. (1999). Influences on infant speech processing: Toward a new synthesis. *Annual Review of Psychology*, 50(1), 509–535.
- Wie, O. B. (2010). Language development in children after receiving bilateral cochlear implants between 5 and 18 months. *International Journal of Pediatric Otorhinolaryngology*, 74, 1258–1266.
- Wiig, E. H., Semel, E., & Secord, W. A. (2013). *The clinical evaluation of language fundamentals* (5th ed.). San Antonio, TX: Pearson Clinical.
- Wilkinson, A.S., & Brinton, J.C. (2003). Speech intelligibility rating of cochlear implanted children: Inter-rater reliability. *Cochlear Implants International*, 4(1), 22–30.
- Wolff, K. (2011). *An analysis of grammatical errors by children with cochlear implants* (Master's thesis). Program in Audiology and Communication Sciences, Washington University School of Medicine, St. Louis, MO. Independent Studies

and Capstones, Paper 617. Retrieved from

http://digitalcommons.wustl.edu/cgi/viewcontent.cgi?article=1634&context=pacs_capstones

World Health Organization. (2010). *Newborn and infant hearing screening: Current issues and guiding principles for action*. Geneva, Switzerland: Author.

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

Yoshinaga-Itano, C., Snyder, L., & Mayberry, R. (1996). Examining written language assessment and intervention links to literacy: Can lexical/semantic skills differentiate deaf or hard-of-hearing readers and non-readers? *Volta Review*, *98*(1), 39–61.

APPENDIX A
PARENTAL QUESTIONNAIRE

Please print to complete the information below. If you have any questions, please ask.

Today's date: ____ ____ / ____ ____ / ____ ____
mm dd yy

A. Child Information

1. Your child's full name: _____
2. Child's gender (check one):
 - Male
 - Female
3. Child's date of birth: ____ ____ / ____ ____ / ____ ____
4. Please indicate your child's primary mode of communication **pre-implant** (check one):
 - Oral/Spoken Language
 - Total Communication/Spoken and Sign Language
 - Visual/Sign Language

5. Please indicate your child's primary mode of communication **post-implant** (check one):

- Oral/Spoken Language
- Total Communication/Spoken and Sign Language
- Visual/Sign Language

6. Please indicate your child's primary mode of communication **at school** (check one):

- Oral/Spoken Language
- Total Communication/Spoken and Sign Language
- Visual/Sign Language

7. Please indicate your child's primary language spoken/signed (check one):

- English
- French
- ASL
- Other, _____ (specify)

8. How old was your child when his/her hearing loss was identified:

_____ years, _____ months

9. The onset of hearing loss identified by (check one):

- UNHS
- Trauma
- Illness
- ENT
- Other, _____

10. What was the cause of your child's hearing loss (check one):

- Genetic
- Unknown
- Syndrome _____
- Other (specify): _____

11. How old was your child when he/she was first fitted with hearing aids:

- Right Ear: _____ years, _____ months
- Left Ear: _____ years, _____ months

12. When did your child undergo cochlear implant surgery: ____ ____/ ____ ____/ ____

13. Where did your child undergo his/her cochlear implant surgery:

- Toronto
- London
- Ottawa

14. What type of implants does your child have (check one):

- Nucleus _____ #
- MED-EL
- Advanced Bionics
- I don't know

15. On average, how many hours a day does your child wear his/her cochlear implant

(check one):

- 0–4 hours
- 5–9 hours
- 10–14 hours
- More than 14 hours

16. On average, how many days a week does your child wear his/her cochlear implant

(check one):

- 1 day/week
- 2 days/week
- 3 days/week
- 4 days/week
- 5 days/week
- 6 days/week
- 7 days/week

17. Does your child use the telephone (check one):

- Yes
- No

B. EARLY INTERVENTION

18. After confirmation of your child's hearing loss, what services did you accept/receive

(check all that apply):

- Provincial Schools Branch—Homevisiting Program
- Auditory Verbal Therapy
- Infant Hearing Program—AVT, SLP, Social Worker, Family Support Worker

19. What was the duration of the service:

- Homevisiting _____
- AVT _____
- IHP _____ service, _____ duration

C. INFORMAL EDUCATION

20. Did your child attend daycare, home daycare or other _____

- Yes
- No

21. Did your child attend formal preschool/Montessori:

- Yes
- No

22. If yes, how many hours per week (on average): _____ hours

23. If yes, how long did your child attend daycare before attending formal school:

- 1 year
- 2 years
- 3 years
- Other (specify): _____

D. FORMAL EDUCATION

24. In the past year, has your child received individual speech and/or auditory verbal therapy outside the school or home (check one):

- Yes, (please specify average hours per week): _____ hrs/wk
- No

25. What type of educational program does your child currently attend (check one):

- Fully mainstreamed in a general education classroom with hearing peers
- Partially mainstreamed, spends time between general education and resource room/self-contained classroom
- Full-time self-contained classroom for children with hearing loss or additional needs

26. Where does your child receive his/her primary literacy instruction in school (check one):

- General education classroom with hearing peers
- Self-contained classroom for children with a hearing loss or additional needs
- Other (specify): _____

27. Please identify any additional reading support your child received in the past year either at school or outside of school (check all that apply):

- No additional reading support received
- Reading recovery
- Outside-school services (e.g., Kumon)
- Other (specify): _____

28. Please identify any additional writing support your child received in the past year either at school or outside of school (check all that apply):

- No additional writing support received
- Resource Teacher Support (LRT, SERT, RT)
- Outside-school services (e.g., Kumon)

29. Does your child currently receive education support services through an Individual Education Plan (IEP) at school:

- Yes
- No
- I don't know

30. Who are the support personnel who work directly with your child on a regular basis in

his/her educational setting (check all that apply):

- Educational Audiologist
- Occupational Therapist
- Physical Therapist
- School Psychologist
- School Social Worker
- Sign Language Interpreter
- Learning Resource Teacher/Special Education Resource Teacher
- Speech-Language Pathologist
- Auditory Verbal Educator/ Therapist
- Educational Assistant
- Teacher of the Deaf/Hard-of-hearing
- Other (please specify): _____

E. FAMILY INFORMATION

31. What is your relationship to the child (check one):

- Mother
- Father
- Step-parent
- Grandparent
- Guardian (but not parent)
- Other (specify): _____

32. What is your ethnicity (check one):

- White
- Indian
- Italian
- Chinese
- Other (specify): _____

33. What is the primary language spoken in your home:

- English only
- French only
- English primary plus some second language (specify the second language):

- Bilingual (specify languages): _____
- Other (specify language): _____

34. Please indicate the highest educational level you have attained (check one):

- Some high school
- Graduated high school
- GED/Adult Education
- Some college including community college and technical training
- Graduated two-year college
- Graduated four-year university
- Graduate school (e.g., MA, MS, MD, PhD, MBA)

35. What is your primary occupation (Be as specific as possible i.e. title and major duties:

36. Is there another adult living in your household (check one):

- Yes
- No

If yes, what is his/her relationship to the child (check one):

- Mother
- Father
- Step-parent
- Grandparent
- Guardian (but not parent)
- Other (specify): _____

37. Please indicate the highest educational level attained by the other adult (check one):

- Some high school
- Graduated high school
- GED/Adult Education
- Some college including community college and technical training
- Graduated two-year college
- Graduated three/four year university
- Graduate school (e.g., MA, MS, MD, PhD, MBA)

38. What is his/her primary occupation (be as specific as possible, i.e., title and major duties): _____

39. To help us characterize the economic status of study participants, please indicate which category best describes the combined annual income, before taxes, of all members of your household for last year (check one):

- Less than \$15,000
- \$15,000–\$29,000
- \$30,000–\$49,000
- \$50,000–\$74,000
- \$75,000–\$99, 999
- \$100,000–\$129,000
- More than \$130,000
- Decline to answer

40. How often do you or other members of the family read with your child in a typical week (check one):

- Never
- 1 or 2 times per week
- 3 or 4 times per week
- 5 or 6 time per week
- 7 or more times per week

APPENDIX B

PARENT/CAREGIVER INTERVIEW QUESTIONS

Demographics

1. Age of mother and father at time of child's birth
2. All family members hearing?
3. Where parent born (Canada)?
4. Primary language for each parent

Pregnancy

5. Any illnesses, conditions or accidents during pregnancy? Or normal?
6. Weight gained?
7. How many weeks carried?
8. Natural birth, c-section?
9. Child's birth weight?

Hearing Identification

10. Was hearing screening done at the hospital?
11. How many hours or days after birth?
12. Did your child fail or pass?
13. When was the follow-up?
14. How and when did you discover the cause of the hearing loss?

CI surgery

15. Do you have any record of the CI process? Surgery, fitting, activation?

Services

16. AVT was 1 hr sessions every week for 1 year, then biweekly for the second and third year?
17. Homevisits from TODHH for 3 years
18. Any SLP sessions?

Home Literacy Environment

19. Can you share a bit of the family atmosphere during meals, week-ends, bedtime?
Discussions/conversations, reading and writing exposure from the time your child was a toddler.
20. How long were you at home after your child's birth?
21. Did the father/mother stay home at all?
22. Family members involved to help care for your child?
23. If parents back to work, who looked after your child and for how long?

Education

24. Your child attends their local school which is hearing?
25. They are in the appropriate grade with like peers?
26. They follow the Ontario curriculum
27. They receive services/support from? (TODHH, SLP, LRT)

APPENDIX C

REQUEST FOR INFORMED CONSENT (PARENT)

Date: May 1, 2013

Study Name: Literacy Development in School-Aged Children with Bilateral Cochlear Implants

Researcher: Caterina Ruggirello

Dear (names of parents),

The purpose of this study is to learn more about the literacy development of deaf children who have received bilateral cochlear implants. Deaf children often have delays in their language development. However, the evidence to date indicates that the majority of children who have implants develop language at the same level as their hearing age peers. The expectation is that there should be a similar benefit in reading and writing. By looking at the literacy skills of your child, I hope to be able to learn more about how this happens.

To provide background information, I will be asking you to complete a short questionnaire, participate in an interview and provide your child's reports cards, assessments, and writing samples.

I do not foresee any risks or discomfort for you as a consequence of your participation in this study. It may even be the case that the information I gather may be helpful to you in thinking about the best educational placement, academic support or intervention for your child.

Participation in the study is completely voluntary for the time period of spring 2014 to the spring 2015. You may choose to withdraw from the study at any time. Upon withdrawal from the study, all associated data collected will be immediately destroyed wherever possible. If you should choose to stop participating or refuse to answer certain questions, your relationship with myself, the researcher, and with York University will not be affected. All information you supply during the research will be held in confidence and pseudonyms will be used in any reporting or publication of the study. Your data will be safely stored in a locked facility and only research staff will have access to this

information. The collected data will be stored for 2 years, and destroyed once the research has been completed. Confidentiality will be provided to the fullest extent possible by law.

If you have questions about the research in general or about your role in the study, please feel free to contact me.

This research has been reviewed and approved by the Human Participants in Research Committee, York University's Ethics Review Board and it conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process or about your and your child's rights as a participant in the study, please contact the Graduate Program Office, Faculty of Education at S865 Ross Building, 4700 Keele Street, Toronto ON M3J 1P3 (telephone 416 736 5018 or e-mail GradProgram@edu.yorku.ca) or Ms. Alison Collins-Mrakas, Manager, Research Ethics, 309 York Lanes, York University (telephone 416-736-5914 or e-mail acollins@yorku.ca).

I/We _____ agree to participate in the study, Literacy Development in School-Aged Children with Bilateral Cochlear Implants. I/We understand the nature of this project and wish to participate. I/We am/are not waiving any of my/our legal rights by signing this form. My/Our signature(s) below indicate my/our consent.

Signature _____

Date _____

I/We agree

Signature _____

Date _____

Principal Investigator

APPENDIX D

REQUEST FOR INFORMED CONSENT (FOR MINOR CHILD)

Date: May 1, 2013

Study Name: Literacy Development in School-Aged Children with Bilateral Cochlear Implants

Researcher: Caterina Ruggirello

Dear (names of parents),

The purpose of this study is to learn more about the literacy development of deaf children who have received bilateral cochlear implants (CIs). Deaf children often have delays in their language development that result in delays in their reading and writing skills. However, the evidence to date indicates that the majority of children who have implants develop language at the same level as their hearing age peers. The expectation is that there should be a similar benefit in reading and writing skills. By looking at the literacy skills of your child, I hope to be able to learn more about how this happens.

By participating in this study, your child will be required to participate in three assessment sessions. These assessments will take place in Spring 2014 and late Fall 2014. In the Spring, there will be three visits, each with a duration of 1 hour and 30 minutes. This process would be repeated in late Fall. During these three sessions I will be giving standardized tests to your child to assess their reading and writing abilities. This will include activities such as: asking your child to read aloud, listening to stories comprehension, and completing some paper and pencil tasks.

I do not foresee any risks or discomfort for your child as a consequence of their participation in this study. It may even be the case that the information I gather may be helpful to you in thinking about the best types of educational placements or supports for your child.

Participation in the study is completely voluntary and you may choose to withdraw your child from the study at any time. All information you supply during the research will be held in confidence and pseudonyms will be used in any reporting or publication of the study. Your data will be safely stored in a locked facility and only research staff will have access to this information. The collected data will be stored for 2 years, and destroyed once the research has been completed. Confidentiality will be provided to the fullest extent possible by law.

If you have questions about the research in general or about your role in the study, please feel free to contact me.

This research has been reviewed and approved by the Human Participants in Research Committee, York University's Ethics Review Board and it conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process or about your and your child's rights as a participant in the study, please contact the Graduate Program Office, Faculty of Education at S865 Ross Building, 4700 Keele Street, Toronto ON M3J 1P3 (telephone 416 736 5018 or e-mail GradProgram@edu.yorku.ca) or Ms. Alison Collins-Mrakas, Manager, Research Ethics, 309 York Lanes, York University (telephone 416-736-5914 or e-mail acollins@yorku.ca).

I/We give permission for my/our child _____ to participate in the study, Literacy Development in School Aged Children with Bilateral Cochlear Implants. I/We understand the nature of this project and wish for my/our child to participate. I/We am/are not waiving any of my/our legal rights by signing this form. My/Our signature(s) below indicate my/our consent.

Signature _____

Date _____

Parent

Signature _____

Date _____

Principal Investigator