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The Effects of Early Identification and Intervention on Language Outcomes of Children Born with Hearing Loss

Catherine A. Callow-Heusser
Utah State University

THE EFFECTS OF EARLY IDENTIFICATION AND INTERVENTION ON

LANGUAGE OUTCOMES OF CHILDREN BORN WITH HEARING LOSS

by

Catherine A. Callow-Heusser

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Approved:

Karl R. White, Ph.D. Major Professor	Lisa K. Boyce, Ph.D. Committee Member
Timothy A. Slocum, Ph.D. Committee Member	Patricia S. Moyer-Packenham, Ph.D. Committee Member
Carol J. Strong, Ph.D. Committee Member	Mark R. McLellan, Ph.D. Vice President for Research and Dean of the School of Graduate Studies

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ABSTRACT

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Catherine A. Callow-Heusser, Ph.D.

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Major Professor: Karl R. White, Ph.D.
Department: Teacher Education and Leadership

This study adds to the existing body of research by (a) including a comprehensive analysis of published reviews and primary studies investigating the effects of early identification of hearing loss and intervention on language outcomes; and (b) using advanced statistical techniques to further examine existing data on nearly 5,200 children with hearing loss.

Analysis of reviews of primary studies showed these reviews exhibited severe sampling bias, lacked systematic methods for analyzing studies, and did not include a common metric for comparing results across studies nor a mechanism for analyzing how findings from primary studies covaried with other important factors such as parental involvement, fidelity of intervention, or study quality. Without a more rigorous analysis of primary studies, the conclusions drawn from these reviews are questionable.

The review of primary studies revealed many methodological problems including weak experimental designs, small sample sizes, attrition or questionable sample selection methods, differences in length of treatment and characteristics of the participants, and inadequate reporting. Many researchers unjustifiably concluded that earlier intervention produced better developmental outcomes. However, almost half of the studies in which children were assessed at older ages showed no relationship between age at identification or intervention and language outcomes.

Use of structural equation modeling (SEM) with the SKI*HI National Data Set did not result in models that adequately fit the underlying data. As such, these methods did not result in findings from which we can draw strong conclusions regarding the relationship between age at identification of hearing loss or intervention and child outcomes.

To conclude, we know too little about whether earlier identification and intervention is better for children born with hearing loss or who acquire it at young ages. In addition to stronger research designs with sufficient sample sizes, use of reliable measures to collect a broader array of data related to important covariates, better collection of data, and measurement of intervention characteristics, perhaps we should also be asking different questions. We need to know more about what interventions, in which order, provided by whom, and in what ways are most effective for improving developmental outcomes for children with hearing loss.

(276 pages)

PUBLIC ABSTRACT

The Effects of Early Identification and Intervention on Language Outcomes
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Catherine A. Callow-Heusser, Ph.D.

This study included a comprehensive review of the literature in which the effects of early identification of hearing loss and intervention on language outcomes were investigated. Previous reviews of studies were not comprehensive in their coverage and did not include a common measure for comparing results across studies. Without a more rigorous analysis of the primary research, conclusions drawn from these reviews are tenuous. The review of primary studies showed they exhibit many methodological problems including weak experimental designs, small sample sizes, attrition or questionable sample selection methods, differences in length of treatment and characteristics of the participants, and inadequate reporting. Many researchers unjustifiably concluded that earlier intervention produced better developmental outcomes. Additionally, almost half of the studies in which children with hearing loss were assessed at older ages showed no or small relationships between age at identification or intervention and language outcomes.

Structural Equation Modeling (SEM), a statistical method that can be used to explore relationships among variables, was used with a large existing database to further investigate the relationship between age at identification of hearing loss or intervention and child outcomes. Characteristics of the data, including large amounts of missing data and data that did not meet other conditions needed for the SEM, made the data unsuitable for this statistical method. Analyses resulted in inadequate model fit indices and unreasonable parameter estimates. As such, these statistical analysis techniques did not result in findings from which we can draw conclusions to contribute to the research.

To conclude, we know too little about whether earlier identification and intervention improves later language outcomes for children born with hearing loss. In addition to stronger research designs with sufficient sample sizes, use of reliable measures to collect a broader array of data related to important factors that may affect outcomes, and better measurement of intervention characteristics, perhaps we should also be asking different questions. We need to know more about which interventions, in what order, provided by whom, and in what ways to have the greatest impact on language outcomes. These children with hearing loss, like so many other struggling children, do not have the luxury of time. In order to help them maximize their potential and be successful and productive in our society, we need to conduct better research on the efficacy of interventions now. For them, time is of the essence.

ACKNOWLEDGMENTS

Many people have been crucial to this journey. First and foremost, I want to thank Karl White for being one of my most life-changing guardian angels—may you never have to use that cattle prod again! Thank you for believing in my skills, providing direction, and always supporting me in this effort to finish climbing the mountain.

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I have had many other strong supporters on this journey—those who provided the shoulders of Atlas to help me carry the weight along the way. While I cannot possibly mention all of you here, please know I appreciated your support and friendship, and I look forward to being able to answer, "Yes! I finished!"

- Collaborators in educational research and evaluation and dear friends and colleagues: Tamara Walser and Ken Wareham. Few others understand what we do, enjoy constantly talking shop in social settings, and still manage to have as much fun playing as we have done time after time.

- Supportive friends who helped me keep my head on straight and reminded me to breathe: Terry Barnes, who has changed my life in many ways more times than she realizes; Mary Collins, who was and is always there when I need her; Pam King, who helped me get through this last few months; and Margaret Lubke, with whom I have spent innumerable hours working and exercising.

- Other important people in my life who have encouraged me: my children, Jenny, Jimmy, Bryan, and Caleb, who continually remind me I can accomplish whatever I set my mind to; my bonus children, John G, Jeff, Angie, Jennifer, Brandon, Valerie, and Jared, whose love and acceptance reminds me that life is good; John Elwell, the father of my children, who participated in a substantial part of this journey; Cy Freston, who never ceased asking me if I was done yet and why the heck not? And Jim Altschuld, a wonderful colleague who inspires me and makes me laugh.

- My parents, Phil and Robin Callow, to whom this dissertation is dedicated. Ha-ha, Dad, I beat you!

- And of course my husband, Val, who has never known marriage to me without this elephant in the room. Thanks for enduring patience and the strength of love. Now let's get on with living!

On a personal note, I want to acknowledge my sons, Caleb and Bryan, who taught me so much about language and children who start out behind. When Caleb joined our family at age 2½, he had an eight-word expressive vocabulary. When he was 3, we

enrolled him in a special needs preschool with an outstanding speech and language teacher, and I spent my time holding him, helping him feel loved, and managing his explosive expressions of anger. The time he spent at preschool was respite time for me. If I had also needed to learn how to better communicate and promote language skills with him during that time, and serve as his "teacher" to help him catch up with those skills, the stress and sense of being overwhelmed may have done us all in. He is now a responsible and well liked 18-year-old with a great sense of humor, whose language skills are on par with his same-age peers. In fact, as a senior in high school, he just achieved the highest level of proficiency in language arts on Utah's state assessment!

Thankfully, "later" can still be "not too late," as Ann Dejardins showed us so well with Caleb's brother, Bryan. Bryan had the literacy skills of an entry-level kindergartener when he joined our family at the end of second grade. By the end of third grade, Ann and her colleagues helped Bryan achieve a fifth-grade reading level. He's been reading voraciously ever since!

Access to trained professionals, a strong support system, respite time, and a focus on building nurturing relationships helped us help Bryan and Caleb become successful and productive adults of whom I am proud. Invested teachers, strong training, solid implementation, and powerful interventions can work miracles. Thank you, Sara Krebs, for pointing us in the right direction, and Chris Flores, Anne Dejardins, Tim Slocum, and teachers at CVLC for providing rich language and learning environments for my sons, as well as breaks for us, so his father and I could focus on other important things with them.

For this dissertation, I investigated the question, "Is earlier intervention better?"

While we all believe the answer is, “Of course!” I would urge us to question our beliefs for the sake of both parents and children and ask, “WHAT is better if it happens earlier?” Yes, it seems intiuitive that earlier should be better, but the right interventions can build success and change lives, even when it seems “too late.”

Catherine A. Callow-Heusser

DEDICATION

This effort is dedicated to my most important early teachers:

Mrs. Vinetti, my 2^{nd} grade teacher
who nurtured my voracious love of reading,

Mrs. Piper, my high school technical writing teacher,
who demanded exemplary writing—the most important skill in my toolbox,

Mrs. Bowen, my high school calculus teacher,
who instilled confidence with numbers and calculations,

Mrs. Bare (deceased), my high school chemistry teacher,
who was my "strong woman" role model and encouraged me to question,

and of course, my parents:

Phil Callow, who taught me I could solve any problem, and

Robin Callow, who showed me there is good in everything
and gave me wings to dream.

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LIST OF ABBREVIATIONS

AASD	Atlanta Area School for the Deaf
AFGI	Adjusted Goodness of Fit Index
AIC	Akaike Information Criterion
AMOS	Analysis of MOment Structures
ANOVA	Analysis of Variance
ASHA	American Speech-Language-Hearing Association
CDC	Centers for Disease Control
CHL	Children with Hearing Loss
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CHAC	Children's Hearing Assessment Center, Nottingham
CHIP	Colorado Home Intervention Program
CI	Cochlear Implant
CI	Confidence Interval
DEIP	Diagnostic Early Intervention Program
DP	Deaf Parent or Parent with severe or profound hearing loss
ECHI	Early Childhood Home Instruction
EHDI	Early Hearing Detection and Intervention
EHS	Early Head Start
ES	Effect Size
FDA	Food and Drug Administration
FIML	Full Information Maximum Likelihood
GFI	Goodness of Fit Index
GLS	Generalized Least Squares
HL	Hearing Loss
HP	Hearing Parents
ID	Identification
IDEA	Individuals with Disabilities in Education Act
INT	Intervention
KSZ	Kolmogorov-Smirnov Z or KSZ Test of Normality
LDS	Language Development Scale
LISREL	LInear Structural RELations (and companion software, PRELIS)
LONG	Longitudinal Study
LSD	Lexington School for the Deaf
MANCOVA	Multivariate Analysis of Variance
MCAR	Missing Completely at Random
MAR	Missing at Random
MNAR	Missing Not at Random
NCES	National Center for Education Statistics
NCHAM	National Center for Hearing Assessment and Management
NFI	Normed Fit Index

NICE	National Institute for Health and Clinical Excellence (UK)
NIDHD	National Institute of Deafness and Hearing Disorders
NIH	National Institutes of Health
NNFI	Non-Normed Fit Index (also called TFI)
NTID	National Technical Institute for the Deaf
OSEP	Office of Special Education Programs
PCA	Principal Components Analysis
PCHL	Permanent Congenital Hearing Loss
PCFI	Parsimonious Comparative Fit Index
PCI	Proportional Change Index
PHL	Parents with Hearing Loss
PNFI	Parsimonious Fit Index
PRATIO	Parsimony Ratio
PROSP	Prospective Study
RCT	Randomized Controlled Trial
REEL	Receptive-Expressive Emergent Language Scale
RETRO	Retrospective Study
RMR	Root Mean Square Residual
RMSEA	Root Mean Square Error of Approximation
SD	Standard Deviation
SEM	Structural Equation Modeling
SKI*HI	SKI*HI Home-Based Program for Children with Hearing Loss
SMDES	Standardized Mean Difference Effect Size
STEP*HI	New Mexico STEP*HI Program
TLI	Tucker Lewis Index (see NNFI)
UNHS	Universal Newborn Hearing Screening
USPSTF	United States Preventive Services Task Force
USU	Utah State University
XSEC	Cross Sectional Study

CHAPTER I

INTRODUCTION

Use of Universal Newborn Hearing Screening (UNHS) to detect hearing loss in infants has increased dramatically over the last decade, resulting in substantively earlier identification of hearing loss in infants. One reason often cited to provide support for expanding UNHS programs is the widespread belief that early intervention following the earliest possible identification of hearing loss improves later developmental outcomes—and in particular, language outcomes.

As shown in the review of the literature, many researchers have examined the relationship between language outcomes for children born with hearing loss and the age at which hearing loss was diagnosed or early intervention began. Most conclude that earlier identification and intervention leads to better child outcomes, particularly when interventions include use of hearing aids or other hearing devices, a strong focus on communication skills, and family support and training. Unfortunately, published reviews of this body of research—many of which recommend earlier identification and treatment of hearing loss—exhibit severe sampling bias and lack systematic review of the evidence. Additionally, most of the primary research studies cited in reviews suffer from serious methodological weaknesses. These weaknesses include small sample sizes, selection bias, baseline differences between groups, limited reporting of effect size metrics, inadequate consideration of confounding factors that may affect results, and failure to implement research designs that address threats to validity. Studies exhibiting these weaknesses are so prevalent in the primary research literature that it is difficult to be confident about the conclusions from reviews or primary studies regarding the effectiveness of earlier intervention for children born with hearing loss.

To extend what is known about the degree to which early identification of hearing loss coupled with early intervention impacts developmental outcomes, experimental designs that better control for threats to validity are needed. The ideal design would be a prospective longitudinal randomized controlled trial (RCT; White & Pezzino, 1986), where infants whose hearing loss was identified at an early age are randomly assigned to a group that receives early intervention or one that does not, or to randomly assign children to begin intervention at differing ages. However, finding families with infants born with hearing loss who agree to be involved in research and randomly assigned, potentially to a nontreatment or later treated group, would be difficult and possibly viewed by many as being unethical given current legislation and "evidence-based" recommendations for early intervention. Additionally, support for RCTs from political, professional, and advocacy groups is unlikely, particularly given the widespread belief that intervention must be provided as early as possible to children born with hearing loss. This widespread belief is based on empirical and considerable experiential evidence, although many researchers call for higher quality research and stronger evidence.

Given the barriers to conducting RCTs, an alternative source of evidence for evaluating the relationship between early identification and later developmental outcomes are data that include the naturally occurring variation in the age at which children with hearing loss are identified and provided services. Additionally, large data sets that include contextual and environmental factors that affect language outcomes for children with hearing loss provide an avenue for investigating models of complex systems and the interrelated factors that influence outcomes. If a large enough data set with sufficient variation in age of identification and intervention, and that included data for other factors that could affect language outcomes, could be analyzed using statistical methods that support modeling of complex systems, the results could substantively contribute to what we know about the effects of earlier intervention on the developmental outcomes of young children with hearing loss.

One data set that seemed to be appropriate for such analyses was collected by the SKI*HI project. As described in more detail in Chapter III, the SKI*HI program provided early identification services to identify children with hearing loss, home-based parent support and training, and program management support to early intervention providers at sites throughout the US beginning in 1972. From 1979 through 1991, data were systematically collected and maintained by SKI*HI staff for nearly 5,200 children with hearing loss. These data included a range of demographic, program, and child and family outcome data that appeared, based on a preliminary analysis, to be appropriate for evaluating the effects of early identification and intervention on later developmental outcomes of children with hearing loss.

Problem Statement

Research investigating the effects of early identification and intervention on later developmental outcomes for children born with hearing loss suffers from serious methodological weaknesses that make conclusions drawn from findings questionable.

Purpose Statement and Research Questions

This study adds to the existing body of research by (a) including a comprehensive analysis of published reviews and primary studies investigating the effects of early identification of hearing loss and intervention on language outcomes; and (b) using advanced statistical techniques, for which software has become more recently available, with an existing data set that included data on nearly 5,200 children with hearing loss to further investigate the effects of early identification, intervention, and other factors on language outcomes. The purpose of the study was to answer the following questions.

1. What is the relationship between language outcomes for children born with hearing loss and the age at which hearing loss was diagnosed or early intervention began?
2. Which of the following factors affect the relationship between age of identification of hearing loss or intervention and language outcomes?
    a. Child characteristics (e.g., degree of hearing loss, gender, ethnicity, presence of additional disabilities)
    b. Parent characteristics (e.g., hearing status, language used at home, communication method selected)
    c. Intervention characteristics (e.g., planned frequency of home visits, actual frequency of home visits, length of treatment)
    d. Parent communication skills with child born with hearing loss
3. Are these factors different for children who have a parent with severe or profound hearing loss than for those who do not?

CHAPTER II

REVIEW OF THE LITERATURE

This review includes the following: (a) reasons why UNHS has expanded so rapidly over the past decade and the impact on early identification of hearing loss; (b) an analysis of previously completed reviews and primary research studies that have examined the relationship between language outcomes of children with hearing loss and the age at which hearing loss was diagnosed or early intervention was begun; (c) a review of methodological issues that are central to correctly interpreting the results of previous research about whether early identification of hearing loss and intervention leads to better developmental outcomes; (d) a summary of contextual and environmental factors that have been identified as affecting outcomes for children born with hearing loss; and (e) how advanced statistical methods can help account for the complex systems in which children develop, and contribute to what we know about the effects of earlier identification and intervention on language outcomes for children born with hearing loss.

Earlier Identification of Hearing Loss Through UNHS Programs

The number of UNHS programs in the United States has increased dramatically in the past decade, and the percentage of infants screened for hearing loss has similarly grown—from 3% in 1995 to over 97% in 2009 (see Figure 1; Centers for Disease Control [CDC], 2011; White, Forsman, Eichwald, & Munoz 2010). In addition, UNHS programs have been implemented in many countries around the world (White, 2010). The reasons most frequently cited to support expansion of UNHS are the incidence of children born

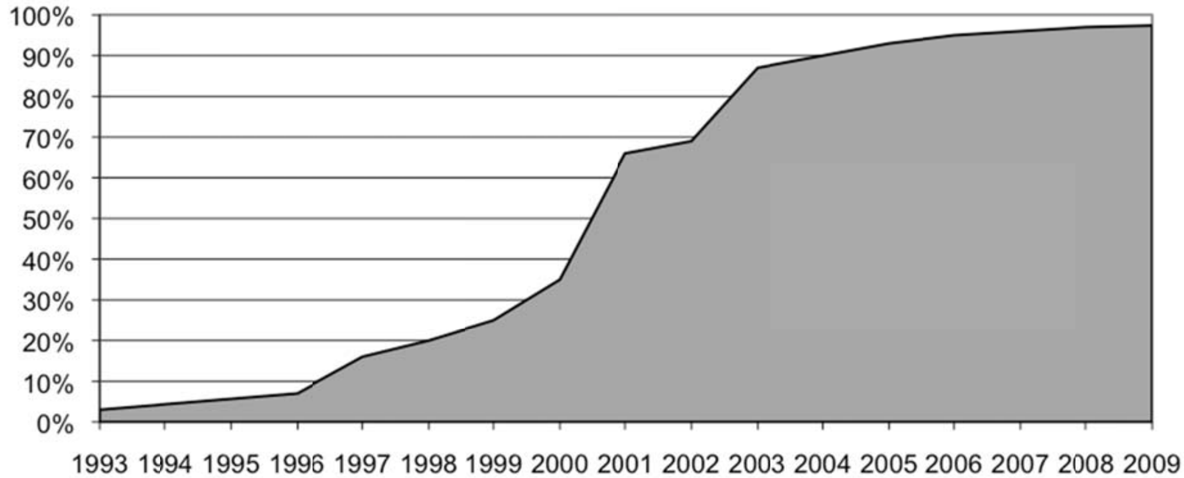

Figure 1. Percentage of newborns screened for hearing loss in the US.

with hearing loss; the emotional and ethical issues surrounding early identification and intervention for children born with hearing loss; and evidence from behavioral research on the efficacy of early intervention for children with hearing loss.

Hearing loss is the most frequent congenital condition in the United States, with about 3 per 1,000 infants born with hearing loss (White, 2004). The US Preventive Services Task Force (USPSTF, 2008) reported that children with hearing loss face greater communication challenges, resulting in more frequent behavior problems, poorer emotional and social well-being, and lower educational attainment than same age peers with normal hearing. Similar findings have been reported repeatedly since Congress commissioned the Babbidge Report (Babbidge, 1965) over 40 years ago. Since then, the US government has advocated for earlier identification of children born with hearing loss to ameliorate poor outcomes (CDC, 2011).

While some infants (mostly those with high levels of risk factors) were screened for hearing loss subsequent to the Babbidge Report (CDC, 2003), screening technologies for identifying infant hearing loss have become acceptably accurate, inexpensive, and available in more recent years (White, 2003). Given current technologies for early detection of hearing loss, many professional groups and organizations that are heavily invested in children's well-being have issued position statements in support of UNHS for earlier identification of hearing loss and the possibility of earlier intervention, asserting that "the research" justifies their claims. As shown in Table 1, these organizations make strong statements about the importance of early identification and intervention. In response to this high level of support and lobbying efforts, 43 states have legislated UNHS since the early 1990s (National Center for Hearing Assessment and Management, [NCHAM], n.d.). The support for and growth of UNHS is based partly on the widespread belief that early intervention following the earliest possible identification of hearing loss leads to better developmental outcomes, which advocates claim is supported by findings from the research on early identification and intervention for young children with hearing loss.

Effectively implemented UNHS has reduced the average age at which hearing loss was identified from 24 or 36 months of age (Harrison & Roush, 1996; Toward Equality, 1988) to 2 or 3 months (White et al., 2010). However, the growth of UNHS has not been without high profile opposition. For example, two very prominent medical researchers (Bess & Paradise, 1994) argued that research demonstrated that the widespread implementation of UNHS was "not simple, not risk free, not necessarily beneficial, and not presently justified" (p. 330).

Table 1

Position Statements Supporting Early Identification of Hearing Loss

Agency	Position statement
American Academy of Pediatrics Task Force on Newborn and Infant Hearing (1999)	"Significant hearing loss is one of the most common major abnormalities present at birth and, if undetected, will impede speech, language, and cognitive development." (p. 527) "Regardless of the age of onset, all children with hearing loss require prompt identification and intervention by appropriate professionals with pediatric training and expertise" (p. 529)
American Speech-Language-Hearing Association (ASHA, 2010)	"Late identification of hearing loss or lack of early intervention services can negatively impact speech and language development, academic achievement, and social-emotional development.7 The most critical time for stimulating the hearing centers in the brain is during the first few months of life." (p. 2)
Centers for Disease Control (CDC, 2011)	"Hearing loss can affect a child's ability to develop communication, language, and social skills. The earlier children with hearing loss start getting services, the more likely they are to reach their full potential…All babies should have a hearing screening no later than 1 month of age."
Joint Committee on Infant Hearing (2007)	"The hearing of all infants should be screened at no later than 1 month of age…Without appropriate opportunities to learn language, these children [with hearing loss] will fall behind their hearing peers in communication, cognition, reading, and social-emotional development." (p. 10)
National Institutes of Health (NIH, 1993)	"We strongly recommend that universal screening be implemented for all infants within the first 3 months of life…The first 3 years of life are the most important for speech and language acquisition. Consequently, if a child is hard of hearing or deaf at birth or experiences hearing loss in infancy or early childhood, it is likely that child will not receive adequate auditory, linguistic, and social stimulation requisite to speech and language learning, social and emotional development, and that family functioning will suffer. The goal of early identification and intervention is to minimize or prevent these adverse effects." (p. 9)
US Department of Health and Human Services (Hager & Giannini, 2006)	"It is difficult if not impossible for hearing-impaired children to acquire the fundamental language, social, and cognitive skills that provide the foundation for later schooling and success in society. When early identification and intervention occur, hearing-impaired children make dramatic progress, are more successful in school, and become more productive members of society."
US Preventive Services Task Force (USPSTF, 2008)	"Children with hearing loss have increased difficulties with verbal and nonverbal communication skills, increased behavioral problems, decreased psychosocial well-being, and lower educational attainment compared with children with normal hearing...Because half of the children with hearing loss have no identifiable risk factors, universal screening has been proposed to detect children with permanent congenital hearing loss (PCHL). There is good evidence that newborn hearing screening testing is highly accurate and leads to earlier identification and treatment of infants with hearing loss…The USPSTF recommends screening for hearing loss in all newborn infants." (p. 143)

A firestorm of protest ensued in response to the Bess and Paradise claim that no empirical evidence justified the widespread use of UNHS to insure access to earlier intervention for children born with hearing loss (Dennis, 1994; Downs, 1994; Grandori, 1994; Gravel, 1994; Hall, 1994; Hayes, 1994; Koop, 1994; Miller, 1994; Nierenberg, 1994; Northern, 1994; Raffin, 1994; Robinette, 1994; Stewart, 1994; Vohr, 1994; Von Almen, 1994). Researchers and practitioners have continued to publish articles opposing the Bess and Paradise assertion (ASHA, 2001; Berg & Spivak, 1999; Gravel, 2005; Lueterman, 2000; Mehl & Thomson, 1998; White & Maxon, 1995; Windmill, 1998; Yoshinaga-Itano, 2002). Most of these authors cited the cost-effectiveness, efficiency, and accuracy of UNHS, and the importance of intervention prior to six months of age for improving developmental outcomes for children with hearing loss.

In their reviews of the research to provide recommendations for evidence-based practice, the US Preventive Services Task Force (USPSTF, 1996, 2001) continued to question the widespread justification of UNHS programs for early identification and intervention, asserting that the evidence to support the claim that earlier treatment promotes better developmental outcomes and leads to higher levels of functioning later in life was inconclusive. However, in their most recent review of the evidence, the USPSTF (Nelson, Bougatsos, & Nygren, 2008) claimed that the "net benefit of screening all newborn infants for hearing loss is moderate" (p. E266) and as such, they recommended UNHS of all newborns to promote earlier identification. Additionally, the USPSTF claimed, "Good-quality evidence shows that early detection improves language outcomes" (p. E266). However, this assertion was based on only one "good-quality" longitudinal study (Kennedy, McCann, Campbell, Kimm, & Thorton, 2005) conducted in England in which earlier identified children had moderately higher receptive language scores at 8 years of age, as well as three “fair-quality” retrospective cohort studies (Calderon & Naidu, 2000; Moeller, 2000; Wake, Hughes, Poulakis, Collins, & Rickards, 2004) in which researchers reported mixed results. For example, in one of these fair quality studies (Wake et al., 2004), researchers found positive results for receptive vocabulary but not for other language, speech, or reading measures. Further, given that all of these studies suffered from serious methodological weaknesses, it is not surprising that the USPSTF pointed to the lack of high quality research, particularly with regard to the conclusion that earlier identification improved later academic outcomes. The authors stated, “Further research will be required to demonstrate effectiveness for the entire process that UNHS initiates” (p. E275).

Unfortunately, advocates both for and against UNHS, and whether earlier identification of congenital hearing loss leads to early intervention and better developmental outcomes, cite research that exhibits severe methodological problems. Reviews of the research provide evidence of methodological problems such as small samples, sampling bias, and lack of systematic review. Additionally, most of the primary research studies in which outcomes of early identification of hearing loss and intervention were investigated suffer from serious methodological weaknesses that call their findings into question. Carney (1996; see also Bess and Paradise, 1994) presented a “comprehensive and rather damning list of problems with the research” (p. 185) and suggested that researchers who concluded that earlier identification leads to better outcomes were “criticized justifiably” (p. 193) for their lack of scientific rigor. Methodological weaknesses of primary research include inadequate descriptions of interventions and populations studied, selection bias and attrition, small sample sizes, lack of a comparison group, nonequivalent groups, neglecting effects based on maturation and other confounding factors, outcome measures with insufficient reliability and validity, failure to implement research designs that better address threats to validity, evaluations of interventions conducted only by those who developed and/or implemented the interventions rather than by independent evaluators, inappropriate use of statistics, and improper reporting. Additionally, advocates expounding support for UNHS through their position statements and investigators reporting findings from studies of the effects of early identification on subsequent intervention and improved developmental outcomes almost universally neglect to identify the theories or prior evidence upon which their research is based. In the following section, studies are reviewed in which the impact of early identification and intervention for children with hearing loss on developmental outcomes was investigated.

Evidence Supporting Early Identification of Hearing Loss and Early Intervention

What follows is (a) a brief review of some language and human development theories that provide support for early identification of hearing loss and early intervention, (b) a systematic analysis of (1) reviews of prior research and (2) primary research studies in which investigators studied the effects of age of identification or intervention on language outcomes for children born with hearing loss who did not receive a surgical intervention (e.g., cochlear implants), (c) a discussion of the methodological problems of prior research, and (d) conclusions drawn from the combined body of research investigating early identification of hearing loss and intervention, and their impact on language outcomes.

Theories of Language Development

The ways in which language is acquired has long been debated among theorists, researchers, and others with knowledge about language development. This debate frequently rests on differences in stances between nurture and nature: Is language learned by imitation and reinforcement? Or are our abilities to learn language "hard-wired" such that humans have an innate ability to understand grammar and syntax?

Bloomfield (1933) argued that the rules of language are learned though imitation and reinforcement, a stance later expanded by Skinner (1957) in his seminal book on verbal behavior. Skinner's view promoted behavioral learning on the basis of a learner's experiences: an adult or "more expert" language user models verbal behavior, for which language learners are rewarded for imitating. This behaviorist view of language learning was cited to provide the historical context for theories of language development mentioned in some studies included in the subsequent review of the literature (e.g., Ashby, 1995; Brasel & Quigley, 1977; Clark, 1979; Marschark, 1993). However, behavioral theories were cited as the underlying guide for developing and conducting research on early intervention programs and program components in only one of the studies reviewed subsequently (Greenstein, 1975).

Chomsky (1959) argued that Skinner's explanation for language development was overly simplistic and did not account for much of the complexity in language and language learning. Rather, he argued that language with all of its complexity and subtleties could only develop on innate biological grounds (Chomsky, 1965). He later proposed that humans have a Universal Grammar (Chomsky, 1980), or a tacit knowledge of linguistic structure, with which they are born. However, few researchers reviewed in the subsequent review of the literature cited Chomsky's theories as underpinnings for their early intervention programs and research, with the exception of a few studies published in the 1970s (Greenstein, 1975; Liff, 1973).

Another "nativist" (i.e., a person who purports that nature has a larger impact than environment on behavior) who believed that language acquisition was largely driven by biological mechanisms was Lenneberg, who developed the "critical period hypothesis" (Lenneberg, 1964, 1967) with regard to language acquisition. The concept of a "critical moment" was first introduced in the field of embryology by Stockard around 1920 and carried further by Lorenz in his research on imprinting in birds (Bruer, 2001). Lorenz labeled a critical period as a period of very short duration during which a process occurs that results in an irreversible behavior or reaction. Lorenz's observations about critical periods stimulated decades of research, from which Lenneberg derived his "critical period hypothesis" for language development. Lenneberg claimed that language was a species-specific, biologically determined behavior for which a critical period existed if language understanding and use were to be fully functional. Lenneberg asserted that this period for language learning in humans occurred between birth and 12 years of age.

Bruer (2001) stated that "scientists now know that critical periods are rarely brief and seldom sharply defined" (p. 8), leading him to propose that the term "sensitive periods" be used instead. Bruer described sensitive periods where "an experience (or lack of it) during a given period in development has a more pronounced effect (positive or negative) on the organism than exposure to that same experience at any other time during the organism's development" (p. 12). He suggested that experimental evidence to support sensitive periods needed to "show that the *same* experience at *different* stages of development results in significant long-term differences in performance, behavior, or brain structure" (p. 24). the critical period hypothesis and related concepts, including sensitive periods, have continued to provide implicit support for much of the research on early intervention for children, particularly those born with hearing loss. Yet, the argument for critical periods points to the need for further research that varies time of intervention to investigate differences in outcomes.

Theories of Human Development and Their Role in Early Intervention

None of the theorists or researchers discussed so far would likely claim that language development occurs in isolation, including the nativists who argued for the innateness of grammatical and syntactical structures. Rather, language learning occurs in a complex environment of social interaction and communication among infants, their caregivers and others with whom they interact, and the contexts in which they interact and develop. Yet, as stated by Marschark (1999), "the blooming interest in deaf children's psychological development seems to be lacking in theoretical discussions concerning the complex interactions of language, cognitive, and social development" (p. 7). The authors of *From Neurons to Neighborhoods* (National Research Council and Institute of Medicine, 2000) claimed that developmental theories must take into account the complexities of the multiple nested contexts in which development occurs: families, communities, and societies, each of which is influenced by the values, beliefs, and practices of the cultures in which they are embedded. Additionally, these authors wrote, "children are active participants in their own development" (p. 27), each affecting "their environments at the same time that their environments are affecting them" (p. 24), physiologically adapting and behaviorally responding to their experiences in ways unique to each individual. One theory that accounts for human development in these complex environments is Bronfenbrenner's Bioecological Theory (Bronfenbrenner, 1979, 1989; Bronfenbrenner & Ceci, 1994; Bronfenbrenner & Evans, 2000). The Bioecological Theory of Development includes three main propositions.

1. Development occurs through "proximal" (nearby in terms of developmental progress) processes of complex reciprocal interactions between an evolving individual and persons, objects, and symbols in the immediate environment. To affect development, these interactions must occur on a fairly regular basis over extended periods of time. (Bronfenbrenner & Morris, 1998, p. 996)

2. Development results from the interaction of numerous entities: the form, intensity, and content of the proximal processes; the environmental context—both immediate and more remote—in which the processes are taking place; the characteristics of the developing person; the social contexts and changes occurring over time; the historical period during which development occurs; and the nature of the developmental outcomes considered. (Bronfenbrenner & Evans, 2000, pp. 118-119)

3. To develop along cognitive, emotional, social, and moral dimensions, a person, regardless of age, requires active participation in progressively more complex reciprocal interaction with individuals for whom the child or adult develops a strong, mutual attachment, becoming committed over time to each

other's well-being and development. (Bronfenbrenner & Evans, 2000, p. 122)

Additionally, Bronfenbrenner and his colleagues identified the environmental contexts in which these interactions occur (Bronfenbrenner, 1979, 1989; Bronfenbrenner & Ceci, 1994) as follows:

1. Microsystem: the most immediate and earliest influence that includes the family; local neighborhood and community institutions such as the school, religious institutions and peer groups; and specific cultures with which the family identifies,

2. Mesosystem: an intermediate level of influences that includes societal norms and expectations; political influences; local, state, and national events, and

3. Macrosystem: the most removed influences, such as international or global changes; economic structures; religious traditions; and historical influences such as the shift from the industrial age to the technological age.

The bioecological theory propositions and Bronfenbrenner's definitions of environmental contexts can be combined as follows (Bronfenbrenner & Evans, 2000): A developmental outcome observed at some future time is a joint function of

1. Proximal (i.e., nearby) processes occurring during interaction with persons, objects or symbols,

2. Characteristics of the developing individual,

3. The nature of the microsystem—which is shaped by other systems surrounding the microsytem—in which an individual develops, and

4. The lengths and frequencies of the time intervals during which the developing individual is exposed to the particular processes under consideration and to the multiple levels of the environmental contexts in that setting.

Considered together, the theories of language development discussed previously combined with Bronfenbrenner's bioecological theory of development suggest that

1. Sensitive periods for language acquisition exist, and during these periods, it is crucial that infants and young children are involved in appropriate and developmentally timed processes that assist them in language learning;

2. Language acquisition does not occur in isolation—many factors in the contexts in which an individual develops may affect both the methods through which language is best acquired and the degree to which language is learned and used;
3. Language acquisition and other developmental outcomes (e.g., cognitive, social, emotional) are interdependent and related to each other and to other factors within the environmental contexts in which development occurs; and
4. Amount of exposure over time affects developmental outcomes.

These theoretical explanations for child and language development make logical and intuitive sense. Yet, developers and implementers of intervention programs for children with hearing loss and researchers investigating the effectiveness of early identification of hearing loss and early intervention rarely describe the relationship between developmental theories, the development and implementation of interventions, the hypothesized relationships between specific intervention activities and outcomes, and the evaluation of impacts.

Analysis of Prior Reviews and Research on Early Identification of Hearing Loss and Intervention

Deafness and hearing loss have been researched for centuries, and attitudes towards hearing loss and early intervention have changed dramatically over time. In a few generations, treatment of children with profound hearing loss has changed from isolated, institutional environments to mainstreamed public education (Lane, 1984). The published literature about deafness and hearing loss is extensive, particularly for research conducted since the mid-twentieth century. However, dramatic changes in the past few decades have occurred in (a) the technology used for identifying hearing loss, (b) laws governing services for children identified with hearing loss, and (c) theories and evidence-based practices underlying intervention services. For these reasons, the literature reviewed here will be limited to research findings that have been published since Public Law (P.L.) 92-142, the Education of All Handicapped Children Act, was passed in 1975. This law changed approaches to early intervention by establishing national goals for developing and implementing effective programs and services for early intervention, and requiring states to eliminate laws that excluded children with disabilities—including hearing loss—from a free and appropriate public education (US Department of Education, 2000).

The Education of All Handicapped Children Act and successive legislation changed the nature and availability of intervention services for all children with disabilities from ages 5 to 21. At the same time, additional federal funding enabled states to establish preschools and infant programs to serve children younger than five who were identified with a disability. The nature of intervention changed again in 1986 when P.L. 99-457 was passed, which reauthorized the earlier act and added provisions for early intervention services to infants, toddlers, and preschoolers with disabilities, greatly increasing the number of younger children served (Craig, 1992).

Despite the limited funds available to serve children less than five years old prior to the passing of P.L. 99-457, researchers reported findings from many privately and publicly available intervention programs serving infants and toddlers during the decade between the two acts, and many of those studies continue to be widely cited. The few studies published prior to 1975 and included in this review were those most frequently cited as providing evidence in support of early intervention in the decade following the passing of P.L. 94-142.

Reviews and primary studies for this review were located through a variety of sources, including the following.

- Reference lists from all potentially relevant studies that were located.
- Tables of Contents of bound journals held in Utah State University's (USU) library.
- Electronic journal databases available through USU's library, including the following: Digital Dissertations (Digital Abstracts), ERIC Document Reproduction Service, Exceptional Child Education Resources, PsychInfo, Psychological and Behavioral Sciences Collection, Social Sciences Citation Index, Sociological Abstracts, EBSCOhost, and Web of Science.
- Google, the internet search engine, and Google Scholar.
- PubMed (http://www.pubmed.org), an online service of the US National Library of Medicine that includes citations from MEDLINE and biomedical articles as far back as the 1950s.
- Websites of prominent researchers and publishers of literature about children with hearing loss (e.g., Moeller, Yoshinaga-Itano, White).
- Websites of relevant organizations (e.g., Alexander Graham Bell Association for the Deaf and Hard of Hearing, Boys Town National Research Hospital, CDC, Gallaudet University, Marion Downs National Center, NCHAM, National Institute on Deafness and other Hearing Disorders [NIDHD], Office of Special Education Programs [OSEP]).
- Journal websites (e.g., Pediatrics, Volta Review).

The reviews and primary studies that were selected to be analyzed reported relationships between age of early identification of hearing loss or intervention and outcomes for children in at least one of the following three categories: expressive and receptive language (i.e., includes sign language), spoken language production, or written language (e.g., reading, writing).

Analysis of Prior Reviews Linking Earlier Intervention to Language Outcomes

A review of the literature on early identification of hearing loss and intervention conducted by the US Preventive Services Task Force (USPSTF, 2001; see also Hefland et al., 2001; Thompson et al., 2001) again raised the issue published by Bess and Paradise (1994) almost a decade earlier: without higher-quality studies to investigate the effects of early intervention and to link early short-term improvements through intervention to longer-term outcomes, the impacts of earlier intervention on children's developmental outcomes remains unclear. Other reviews published in the past two decades show mixed but more positive support for early identification and intervention on language outcomes for children born with hearing loss. Twelve reviews located through the literature search were analyzed here. Table 2 lists a summary of conclusions from the reviews and includes ratings of quality for each of the reviews based on criteria established by White, Bush, and Casto (1986; see also Glass, McGaw, & Smith, 1981).

In reviewing the literature, Bess and Paradise (1994) cited no primary studies of the effects of early identification and intervention, because they claimed that

> Although supported by theory and belief, no empirical evidence, to our knowledge, supports the proposition that outcomes in children with congenital hearing loss are more favorable if treatment is begun early in infancy rather than later in childhood. (p. 333)

While Bess and Paradise (1994) would have been correct in stating that no RCTs had been implemented to support a claim for earlier rather than later intervention for hearing loss, their definition of 'empirical' seems limited given the evidence available at that time. In fact, as shown in a subsequent section, almost 50 studies had been published

Table 2

Summary of Conclusions and Quality of Reviews

Review	Number of studies cited related to earlier intervention and language outcomes	Adequacy of review: 1. Representative or comprehensive sample	Adequacy of review: 2. Common metric for comparing results	Adequacy of review: 3. Systematic method for studying covariates	Adequacy of review: 4. Explicit, replicable methods for study selection and analysis	Overall quality of review	Is earlier better?
Meadow-Orlans (1987)	11	No	No	No	No	Poor	YES
Goppold (1988)	12	No	No	No	No	Poor	YES
Marschark (1993)	16	No	No	No	No	Poor	YES
Bess & Paradise (1994)	0	No	N/A	N/A	Yes	Poor	Insufficient evidence
USPSTF (1996)	11	No	No	No	No	Poor	Insufficient evidence
Calderon & Greenberg (1997)	10	No	No	No	No	Poor	YES
Davis et al. (1997)	17	No	No	No	No	Poor	YES
Carney & Moeller (1998)	30	No	No	No	No	Poor	YES
Helfand et al. (2001); Thompson et al. (2001); USPSTF (2001)	8	No	No	No	Yes	Fair	Insufficient evidence
Yoshinaga-Itano (2003a)	15	No	No	No	No	Poor	YES
Yoshinaga-Itano (2003b)	20	No	No	No	No	Poor	YES
USPSTF (2008)	6	No	No	No	No	Poor	YES

prior to Bess and Paradise's review that addressed the question of whether earlier identification of hearing loss leads to better developmental outcomes. As discussed in successive sections, quasi-experimental (e.g., cohort comparison, pre/post comparison, correlational) studies on the effects of earlier identification and intervention abound, although most have serious methodological shortcomings. The USPSTF has conducted three reviews of UNHS in the past 15 years. These reviews were federally funded and conducted by a committee charged with systematically reviewing the evidence for newborn hearing screening. In their first review, USPSTF members (1996) concluded that evidence for the efficacy of early intervention was insufficient to draw conclusions. Though they felt the evidence was inconclusive, these reviewers recommended that high-risk infants be screened prior to leaving the hospital after birth or before three months of age, with the goal of providing intervention by six months of age. In the 1996 review, the USPSTF did not include a description of the selection methods for the studies reviewed or the quality of the studies. Additionally, the 1996 USPSTF review included few publications that explicitly addressed the question of whether earlier intervention was better or whether language outcomes were related to intervention. Yet, based on what they claim is insufficient evidence, the reviewers concluded, "Recommendations to screen high-risk infants may be made on other grounds, including the relatively high prevalence of hearing impairment, parental anxiety or concern, and the potentially beneficial effect on language development from early treatment" (pp. 401-402).

In their next update (USPSTF, 2001; see also Helfand et al., 2001; Thompson et al., 2001), the USPSTF reviewed eight cohort studies that addressed the effects of earlier versus later identification of hearing loss and intervention. Three intervention programs were represented. The studies were selected by searching publication databases from 1994 to 2000, contacting experts, and reviewing reference lists. Note that nearly 30 studies of the effect of early intervention on language outcomes, based on at least nine programs, were published during that time period, as summarized in Appendix A, though these researchers included only eight in their review.

The USPSTF (2001) reviewers included sample characteristics and a cursory analysis of study quality, measures, and results, but did not compute effect sizes using a common metric. They rated the quality of three of the studies as fair and the other five as poor. While the authors of all eight of the studies included in this USPSTF review claimed that earlier intervention was better, the USPSTF concluded that results from seven of the studies indicated more positive language outcomes for earlier identified children, while they stated that one study (Yoshinaga-Itano, Coulter, & Thomson, 2000) was designed so poorly that conclusions about age effects could not be drawn. In answering the question, "Does identification and treatment prior to six months improve language and communication?" Thompson and colleagues (2001; USPSTF, 2001) concluded that the strength of evidence based on these eight studies was "inconclusive" and the quality of the evidence fair to poor.

In 2008, the USPSTF (USPSTF, 2008; Nelson et al., 2008) updated their previous recommendations. For this review, they included four additional studies. They rated one study, Kennedy et al. (2006), as good quality and stated that this study provided support that earlier was better for receptive language when children were tested at age 8, but not for other language outcomes. The other three studies were rated fair quality with positive outcomes for language. Based on these four studies, the reviewers claimed, "Good-quality evidence shows that early detection improves language outcomes" (p. 143). Again, the number of other published studies that could have been included were substantially more than four, as shown in Appendix A.

In contrast to these more recent claims that prior research provides insufficient evidence for earlier intervention, Meadow-Orlans (1987) reviewed 13 reports, eight of which addressed the influence of earlier versus later intervention. She claimed these were all that could be located through a systematic search, though in the next sections, many other studies published before Meadow-Orlans' review are listed. Meadow-Orlans described interventions, settings, sample characteristics, study design, outcome measures, and results, but did not include an analysis of study quality, statistical methods, or effect sizes. Ages when intervention started varied; the youngest children were 16 months. Authors of six of the eight studies reported that children with hearing loss who received intervention earlier scored better on language outcomes, while authors of two studies showed no statistically significant differences. Meadow-Orlans' goals were not to determine whether earlier intervention was better than later intervention, but rather to assess the effectiveness of early interventions and make recommendations for effective early intervention programs. She stated that "the balance of evidence…points to the importance of very early intervention for improving later achievement levels of hearing impaired children" (p. 348). She cautioned that, given conflicting evidence, studies providing more definitive evidence were needed.

Goppold (1988) claimed to review the efficacy of early intervention on longitudinal academic outcomes with respect to mode of communication: oral only or total communication. The twelve publications she reviewed reported outcomes of eight independent studies. One study comprising three of the publications compared two groups of children taught to communicate orally. One group attended a preschool using oral communication and the other group did not receive preschool education. Goppold wrote that the authors of the three publications reported no differences in achievement outcomes between the two groups. Four of the studies compared children in oral only or manual programs. Goppold reported that the outcomes of these studies favored the manual groups. However, she indicated that only one of the studies included age at intervention as a variable. Academic outcomes from two studies investigating children with hearing parents or deaf parents were reported in four publications, with children of deaf parents performing better. Finally, Goppold reviewed one study of earlier intervention in which academic achievement of children who were hearing impaired and who attended preschool was higher than a comparison group of children who did not attend preschool. Overall, Goppold claimed that 8 of the 12 publications, representing 6 of 8 studies, favored early intervention with total communication, and one other favored early intervention independent of communication mode. She claimed that only 1 of the 8 studies, resulting in three publications based on the same samples of children, showed no difference in language outcomes for children who received early intervention through preschool attendance when compared to those who did not attend preschool. Overall, this review was poor in quality, as Goppold did not report how she located or selected studies, use a common metric for comparing study results, analyze the quality of the studies, or consider confounding factors such as differences in parental support or attitudes, or early communication differences between deaf and hearing parents of infants with hearing loss.

Marschark (1993) has been frequently referenced as providing evidence that supports the benefits of early intervention for children with hearing loss. Yet, his stated purpose in this chapter of his book was to examine “the substance of deaf children’s language development and its relation to other domains” (p. 101). The only studies he reviewed that related to earlier intervention were 16 studies mostly comparing children with hearing parents or deaf parents. Of the 16 studies he referenced, he claimed that six provided support for earlier manual communication, although support for this claim was based on the supposed earlier intervention provided by deaf parents to their deaf children. He stated that six studies did not provide sufficient evidence for earlier intervention, and the remaining four studies he did not categorize. However, he did not describe how he selected the studies, and study quality and magnitude of effects were not discussed. Yet, Marschark concluded that “all evidence from deaf and hearing children alike points to the need for effective early communication between children and those around them” (p. 237), a claim he did not sufficiently support with research-based evidence from the studies he reviewed.

The Calderon and Greenberg (1997) publication lacked a comprehensive review of the existing literature and a systematic examination of the evidence. Calderon and Greenberg claimed that of the ten studies they reviewed, nine showed positive language outcomes for children who received earlier intervention. Interventions included hearing aid fitting and oral communication. Age cutoffs for early versus late intervention groups were 16 and 18 months for two of the nine studies; ages at intervention for the other studies were not mentioned. The authors cited one study (Watkins, 1987) that showed no statistically significant differences on language outcomes between groups when the age cutoff was 30 months. No descriptions of selection criteria, sample size or characteristics, study design, study quality, measures, or effect sizes were included. Based on the studies reviewed, Calderon and Greenberg concluded, “Very early intervention, including amplification [using hearing aids] and manual communication, appears to be associated with greater progress and a more successful outcome” (p. 462).

Davis and colleagues (1997) reviewed 17 “key” published and unpublished studies, but the authors did not describe criteria for selecting “key” studies. Although they rated the adequacy of the statistical analysis conducted in each study, the reviewers did not rate overall study quality or design. They claimed that while ten of the studies showed at least a slight advantage for those children identified earlier, 5 of the 17 studies did not address whether earlier was better. One study’s findings indicated that those who were identified earlier were more likely to be placed in schools for the deaf rather than mainstreamed—although this finding was not linked to other outcomes. Authors of another study raised the possibility that the effects of early identification and intervention could be short-lived, and that most of the effects “washed out” between ages 3 and 9. Despite small or inconsistent results, differing definitions of “early,” varied outcome measures, and lack of comparison groups in most of the studies they reviewed, Davis et al., concluded that “there is a definite indication that, in terms of language and communication outcomes, earlier identification may be beneficial" (p. 28), and the evidence "points to early sensitive periods for aspects of language acquisition, that suggest earlier intervention to be better than later intervention" (p. 32). Again, these strong conclusions were not sufficiently supported by research-based evidence.

Carney and Moeller (1998) included 30 publications that they claimed provided support for the efficacy of intervention on language outcomes. Rather than review each article individually, the authors stated a claim and listed publications that supposedly provided support for that claim. However, few of the studies referenced included (a) the relationship between age of intervention and language outcomes, (b) comparison groups that included other children born with hearing loss, or (c) study designs that controlled for threats to validity, particularly maturation. Additionally, the review included no description of study selection, study quality, or magnitude of effects. Yet, the authors claimed, "early intervention may be considered effective, based on current research" (p. S68) and an "analysis of the available research suggests that early intervention for children who are deaf or hard-of-hearing has long-term positive effects on overall development" (p. S61). Given the methods used to select and review the literature, and the quality of the evidence, the strength of these conclusions was not warranted.

The two Yoshinaga-Itano (2003a, 2003b) reviews provided summaries of findings from the Colorado Home Intervention Program (CHIP), with some comparison of CHIP findings and results from studies of other intervention programs. In the two reviews, Yoshinaga-Itano referenced 20 CHIP publications for which she was one of the authors, and she was highly involved in and received funding for the intervention program. She cited another 13 studies investigating the effects of early intervention through other programs. Not all of the studies she reviewed included the relationship between age of identification or intervention and child outcomes. For a few of the CHIP studies, Yoshinaga-Itano reported that the amount of variance explained in a regression analysis with blocks of variables that included age at identification varied from 3% to 66%, depending on the variables included in the blocks. In studies in which age at identification was entered separately in a regression analysis, age at identification accounted for 3% to 4% of the variance in language outcomes. Based on her reviews, Yoshinaga-Itano claimed that the CHIP studies and others she cited provided support for early intervention which "results in significantly better language, speech, and social-emotional development" (2003a, p. 26).

While Yoshinaga-Itano claimed that she summarized findings from all CHIP studies, the only criteria for selecting publications of other studies was the alignment of reported outcomes with CHIP findings. Additionally, she did not address study quality or provide a means of comparing effects across studies. On the other hand, she did make the following statement with regard to sample sizes of participants in the CHIP studies:

> These children…represent 70% of all the children with the specified characteristics identified in Colorado during the period from 1992…. No children who met the criteria for inclusion with developmental outcome data were eliminated…. Participation of 70% of the possible population is more than just a selective sample and represents population rather than sample statistics. (2003b, p. 253)

However, this claim was questionable. Yoshinaga-Itano does not report—in any of the studies cited—an analysis of the differences between participants and non-participants. So although 70% of the population participated in the intervention, we don't know how non-participants differed. Additionally, selection criteria were not described for samples used for different analyses in the publications—yet samples were clearly not "all inclusive" given varying sizes across publications. Without descriptions of sample selection criteria nor an analysis of differences between participants and non-participants, claims that a subset of the population represents the entire population are questionable.

In summary, even though authors of eight of the eleven reviews concluded that earlier identification and intervention were better, all eight of these reviews lacked systematic review methods and provided insufficient evidence to draw strong conclusions about the effects of age of identification and intervention on outcomes for children born with hearing loss. In particular, the reviewers did not (a) include a comprehensive or representative sample of studies addressing the effects of earlier intervention when compared to later intervention (as shown in Table 2), (b) quantify the results of the studies using a common metric with which to compare differences in effects, (c) include a mechanism for analyzing how study findings covary with other important factors such as parental involvement, length of intervention, or study quality, and (d) describe the review process—including procedures for selecting studies, analyzing results, determining study quality, and drawing conclusions—in sufficient detail to replicate the reviewers' efforts. Without a more rigorous analysis of primary studies, the conclusions drawn from these reviews are questionable.

The three reviews in which authors claimed there was insufficient evidence to justify concluding that earlier intervention was better also lacked rigor. The 2001 USPSTF review received the highest quality rating in this summary; yet, it was only rated fair, did not include a comprehensive or representative sample, lacked a common metric for comparing intervention effects, and lacked a systematic method for studying covariates. However, the authors reported how they located studies, analyzed the studies according to several criteria (e.g., selection of participants, comparability of groups, adjustments for confounders), rated study quality, and questioned the conclusions drawn from studies of insufficient quality. Overall, the USPSTF (1996, 2001, 2008) reviews and the Bess and Paradise (1994) review provide inconclusive results concerning the effects of earlier identification and intervention on outcomes for children born with hearing loss.

Because of the limited inclusion of the existing literature and lack of systematic analysis in the reviews analyzed here, the authors' conclusions are unjustified given the evidence provided, making a more complete analysis of primary studies necessary. A systematic analysis of primary studies follows in a subsequent section. First, another group of reviews will be considered.

Analysis of Reviews of Cochlear Implants and Language Outcomes

Research with cochlear implants began in the 1950s, and the Food and Drug Administration (FDA) approved them for surgical implantation in adults in the mid-1980s (http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/ImplantsandProsthetics/CochlearImplants). In 1990, cochlear implants were approved for children age two and older. Ages were lowered to 18 months in 1998 and 12 months in 2000, although some babies have received cochlear implants as young as 6 months of age. In 1995, the National Institute on Deafness and Other Communication Disorders

(NIDCD; NIH, 1995) issued a consensus statement in which they claimed the following.

> Cochlear implants have also been shown to result in successful speech perception in children. Currently, the earlier age of implantation is 24 months, but…a younger age of implantation may limit the negative consequences of auditory deprivation and may allow more efficient acquisition of speech and language.

The consensus development panel claimed these conclusions were based on scientific literature and scientific evidence presented at a consensus development conference sponsored by the NIH.

The NIDCD (http://www.nidcd.nih.gov/health/hearing) reported that as of December 2010, approximately 28,400 children in the US have received cochlear implants. Stern, Yueh, Lewis, Norton, and Sie (2005) reported that approximately 10% of children in the US identified with profound hearing loss were implanted (based on 2000 census data). Hyde and Power (2005) reported (based on personal communication with Marschark) that it was estimated that 50-60% of children born with profound hearing loss in the US were implanted. Based on current rates of incidence of infant hearing loss (http://www.asha.org/public/hearing/disorders/children.htm), these numbers would indicate that, at most, 2,600 young children per year receive cochlear implants out of the 12,000 (http://nichcy.org/disability/specific/hearingloss) born annually with hearing loss. While cochlear implants are now being widely used with children who have bilateral profound losses, they are not appropriate with other levels of hearing loss.

Because (a) cochlear implants, as a technology intervention, are affecting language outcomes for children born with hearing loss, and (b) over 200 articles published since the mid-1990s were located that address research on cochlear implants and language outcomes, recent reviews of research on language outcomes and earlier intervention for children with cochlear implants are summarized here. However, because the vast majority of children born with hearing loss are not eligible for cochlear implants, implants require substantial additional intervention, and most publications do not describe the additional intervention children receive, only reviews and not primary studies were summarized.

Four reviews of studies linking earlier intervention through cochlear implants were reviewed using the same criteria as the previous section. The quality of these four reviews is shown in Table 3. The studies cited in the four reviews are shown in Table 4. As was the case in the previous section, these reviews lacked systematic review methods and provided insufficient evidence to draw strong conclusions about the effects of cochlear implants and age at intervention on outcomes for children born with hearing loss. In particular, the reviewers did not (a) include a comprehensive or representative sample of studies addressing the effects of earlier intervention when compared to later intervention (as shown in Table 3), (b) quantify the results of the studies using a common metric with which to compare differences in effects, (c) include a mechanism for analyzing how study findings covary with other important factors such as parental involvement, length of intervention, or study quality, and (d) describe the review process—including procedures for selecting studies, analyzing results, determining study quality, and drawing conclusions—in sufficient detail to replicate the reviewers' efforts. Without a more rigorous analysis of primary studies, these conclusions drawn from these reviews are questionable.

Table 3

Cochlear Implants: Summary of Conclusions and Quality of Reviews

Review	Number of studies cited related to earlier intervention and language outcomes	5. Representative or comprehensive sample	6. Common metric for comparing results	7. Systematic method for studying covariates	8. Explicit, replicable methods for study selection and analysis	Overall quality of review	Is earlier better?
		Adequacy of review					
Niparko & Blankenhorn (2003)	6	No	No	No	No	Poor	YES
Marschark, Rhoten, & Fabich (2007)	16	No	No	No	No	Poor	YES
Bond et al. (2009)	2	No	No	No	No	Poor	YES
National Institute for Health and Clinical Excellence (NICE, 2009)	33	No	No	No	No	Poor	YES

Niparko and Blankenhorn (2003) included six studies in their review that related age at implantation to language outcomes. The authors cited research to demonstrate that children with cochlear implants had better access to education and increased opportunities for entering mainstream classrooms. They claimed many variables including hearing history, age at onset of hearing loss, age at implantation, and "presence of a motivated system of support of oral language development" (p. 267) created variability in outcomes. Yet, the studies they described do not include all these variables as covariates. Niparko and Blankenhorn do not draw strong conclusions about the benefits of cochlear implants on later academic success; they merely describe the studies.

Table 4

Effect of Age at Implant of Cochlear Implants on Language Outcomes: Studies Cited in Reviews

Publications of primary studies of the effects of cochlear implants (as an early intervention) on language outcomes in children born with hearing loss		Reviews			
Author	Year	Niparko & Blankenhorn (2003)	Marschark, Rhoten, & Fabich (2007)	NICE (2009)[a]	Bond et al. (2009)
Tait & Lutman	1994	X			
Robbins, Svirsky, & Kirk	1997	X			
Koch, Wyatt, Francis, & Niparko	1997	X			
Francis, Koch, Wyatt, & Niparko	1999	X			
Bollard, Chute, & Parisier	1999		X		X
Svirsky, Robbins, Kirk, Pisoni, & Miyamoto	2000	X			
Pisoni & Geers	2000	X			
Connor, Hieber, Arts, & Zwolan	2000		X		
Geers	2002		X		
Moog	2002		X		
Rhoten & Marschark	2003		X		
Geers	2003		X		
Nikolopoulos, Dyar, Archbold, & O'Donoghue	2004		X		X
Connor & Zwolan	2004		X		
Geers	2004		X		
Sherman & Cruse	2004		X		
Fabich	2005		X		
Geers	2005		X		
Johnson & Goswami	2005		X		
Willstedt-Svensson, Sahlén, Maki-Torkko, Lyxell, & Ibertsson	2005		X		
Ibertsson, Vass, Á rnason, Sahlén, & Lyxell	2006		X		
Archbold, Nikolopoulos, & O'Donoghue	2006		X		
Nicholas & Geers	2006		X		

[a] The NIHCE systematic review did not include a list of references, though the authors stated they reviewed 33 articles. See http://www.nice.org.uk/ta166

Marschark and colleagues (2007) reviewed “available evidence” (p. 269) about the impact of cochlear implants on reading outcomes and academic achievement. They described seven studies (including three by the same author) and claimed the other studies they cited had similar results. In all, they cited 16 sources of evidence. In the descriptions of studies they described, Marschark and colleagues claimed that most did not provide evidence that earlier implantation demonstrated more positive reading outcomes for children. Additionally, Marschark and colleagues criticized the quality of the studies they summarized, and called for research with better methodological designs. However, the reviewers concluded “research to date has provided strong evidence that pediatric cochlear implantation can provide many deaf children with significant advantages in reading and other outcomes” (p. 280).

Bond and colleagues (2009) conducted a systematic review of the effectiveness of cochlear implants in children with profound hearing loss. They located 15 studies that met their criteria out of the nearly 1,600 reviewed, and claimed these 15 studies were moderate to poor quality. However, they did not describe the metric used to judge quality. The authors concluded, “All studies reported that unilateral cochlear implants improved scores on all outcome measures” (p. 199); however, only two of the studies they cited addressed age at implantation. The authors claimed that there had been no systematic reviews prior to this one, and that “the heterogeneity of the studies means that meta-analysis was not possible” (p. 209).

The National Institute for Health and Clinical Excellence (NICE, 2009; http://guidance.nice.org.uk/TA166) in the United Kingdom seems to be similar to the

USPSTF with respect to their role in providing summaries of evidence. The NICE review of hearing impairment and cochlear implants suggests everyone with profound hearing loss who does not benefit from a hearing aid after three months should consider a cochlear implant. They claimed that two of the eight studies they reviewed that investigated cochlear implants and children suggested, "Children who have devices implanted earlier may have better outcomes." Yet, their document does not include citations or references, so the reader cannot locate the primary studies upon which their review was based.

Overall, the quality of these reviews was poor and conclusions drawn from them questionable. Given over 200 studies located that investigated cochlear implants and language outcomes for children with profound hearing loss, these reviewers lacked representative or comprehensive samples. Clearly, there is a need for a more comprehensive review of the research investigating the impact of earlier cochlear implantation and language outcomes for children with hearing loss. Because the questions investigated with the SKI*HI data set in this dissertation are based on a data set that does not include children with cochlear implants, such a review is beyond the scope of this dissertation, but consideration of the impact of cochlear implants on early intervention for children with profound hearing loss will clearly be important in the future. The following section reviews primary research studies that have addressed the effects on language outcomes of differing ages at which children with hearing loss were identified or educational interventions began.

Review of Primary Research Studies

Primary studies considered for review were located as previously described. Overall, more than 1,300 publications were located and considered for review, with 86 published studies selected for review based on criteria subsequently described. Table 5 lists the 86 primary studies in the left column. The column headings show the 12 reviews, with the studies that were reviewed by the authors and that included an analysis of the effects of early identification or intervention on language outcomes marked with an "X." Publications included in prior reviews that did not include language outcomes, or that made claims that earlier intervention was better but did not provide evidence to justify those claims, were not included in Table 5. Dark gray cells across the row indicate studies that were not included in any reviews, but that they were published prior to a review. Note that other than the almost complete overlap (10 of 11 publications) in the studies reviewed by Calderon and Greenberg (1997) and Meadow-Orlans (1987), there is surprisingly little overlap in studies cited in the 12 reviews, and none of the reviews included a substantial number of the studies available prior to the publication date and that related early identification or intervention to language outcomes.

Data collection and analysis of the primary studies were completed using a coding system to record study characteristics falling into the following four general categories. Each article was coded initially, followed by at least a 3-month lapse before recoding each article again using a blank coding sheet. Discrepancies were resolved by reviewing articles and documenting evidence for the choice selected.

1. Subject characteristics: selection criteria, degree of hearing loss, age at

Table 5

Effect of Early Identification and Intervention on Language Outcomes: Reviews and Publications from Primary Studies

Publications of primary studies of the effects of early identification or intervention on language outcomes in children born with hearing loss		Reviews (Publications included in reviews marked by X)											
		Meadow-Orlans (1987)	Goppold (1988)	Marschark (1993)	Bess & Paradise (1994)	USPSTF (1996)	Calderon & Greenberg (1997)	Davis et al. (1997)	Carney & Moeller (1998)	Thompson et al. (2001); USPSTF (2001)	Yoshinaga-Itano (2003a)	Yoshinaga-Itano (2003b)	USPSTF (2008)
Meadow	1967		X										
Meadow	1968		X	X									
Vernon & Koh	1971		X	X									
Liff	1973	X					X						
Balow & Brill	1975	X											
Greenstein	1975								X				
Greenstein, Greenstein, McConville, & Stellini	1975	X					X						
Horton	1975	X					X						
McConnell & Liff	1975												
Weiss, Goodwin, & Moores	1975			X		X							
Horton	1976	X					X						
Brasel & Quigley	1977	X		X			X						
Moores, Weiss, & Goodwin	1978		X	X									
Clark	1979								X				
Greenberg	1980												
Messerly & Aram	1980												
Sisco & Anderson	1980		X										
Greenberg	1983		X						X				
Kusche, Greenberg, & Garfield	1983			X									
Parasnis	1983			X									
Watkins	1983												
Greenberg, Calderon, & Kusche	1984			X					X				
White	1984								X				
Watkins	1984	X					X						
Davis, Elfenbein, Schum, & Bentler	1986											X	
Markides	1986							X					
Levitt	1987	X					X						
Levitt, McGarr, & Geffner	1987	X					X				X	X	
Watkins	1987	X					X		X				
White & White	1987	X					X					X	
Zwiebel	1987			X									

(*table continues*)

Publications of primary studies of the effects of early identification or intervention on language outcomes in children born with hearing loss		Reviews (Publications included in reviews marked by X)											
		Meadow-Orlans (1987)	Goppold (1988)	Marschark (1993)	Bess & Paradise (1994)	USPSTF (1996)	Calderon & Greenberg (1997)	Davis et al. (1997)	Carney & Moeller (1998)	Thompson et al. (2001); USPSTF (2001)	Yoshinaga-Itano (2003a)	Yoshinaga-Itano (2003b)	USPSTF (2008)
Geers & Schick	1988			X									
Levitt & McGarr	1988												
Musselman, Lindsay, & Wilson	1988												
Musselman, Wilson, & Lindsay	1988							X	X			X	
Theisen-Washburn	1988												
Weisel	1988												
Geers & Moog	1989								X		X	X	
Musselman, Wilson, & Lindsay	1989												
Weisel	1989								X				
Weisel & Reichstein	1989												
Markowitz & Larson	1990								X				
Musselman	1990												
Geers & Moog	1992					X			X				
Ramkalawan & Davis	1992							X					
Strong & Clark	1992								X				
Strong, Clark, Barringer, Walden, & Williams	1992												
Strong, Clark, Johnson et al.	1994												
Apuzzo & Yoshinaga-Itano	1995									X	X	X	
Ashby	1995												
Naidu	1995												
Robinshaw	1995							X				X	
Moeller	1996								X				
Musselman & Kircaali-Iftar	1996							X					
Ramkalawan	1997												
Yoshinaga-Itano	1997								X				
Calderon	1998												
Calderon, Bargones, & Sidman	1998												
Moeller	1998												
Snyder & Yoshinaga-Itano	1998										X	X	
Yoshinaga-Itano & Apuzzo	1998a									X		X	
Yoshinaga-Itano & Apuzzo	1998b									X		X	
Yoshinaga-Itano, Sedey, Coulter, & Mehl	1998							X		X	X	X	
Yoshinaga-Itano, Snyder & Day	1998										X	X	
Cunningham	1999												
Downs & Yoshinaga-Itano	1999												
Yoshinaga-Itano	1999												
Calderon	2000										X	X	
Calderon & Naidu	2000									X	X	X	X

(*table continues*)

		Reviews (Publications included in reviews marked by X)											
Publications of primary studies of the effects of early identification or intervention on language outcomes in children born with hearing loss		Meadow-Orlans (1987)	Goppold (1988)	Marschark (1993)	Bess & Paradise (1994)	USPSTF (1996)	Calderon & Greenberg (1997)	Davis et al. (1997)	Carney & Moeller (1998)	Thompson et al. (2001); USPSTF (2001)	Yoshinaga-Itano (2003a)	Yoshinaga-Itano (2003b)	USPSTF (2008)
Mayne, Yoshinaga-Itano, & Sedey	2000										X	X	
Mayne, Yoshinaga-Itano, Sedey, & Carey	2000									X	X	X	
Moeller	2000									X	X	X	X
Yoshinaga-Itano	2000												
Yoshinaga-Itano & Sedey	2000										X	X	
Yoshinaga-Itano et al.	2000									X	X	X	
Yoshinaga-Itano, Coulter, & Thomson	2001										X		
Yoshinaga-Itano, Sedey, Apuzzo, et al.	2001												
Pipp-Siegel, Sedey, Van Leeuwen, & Yoshinaga-Itano	2003										X	X	
Wake et al.	2004												X
Wake, Poulakis, Hughes, Carey-Sargeant, & Rickards	2005												
Kennedy et al.	2005												X
Kennedy et al.	2006												X
Fitzpatrick, Durieux-Smith, Eriks-Brophy, Olds, & Gaines	2007												
Worsfold, Mahon, Yuen, & Kennedy	2010												
Harris & Terlektsi	2011												
Holzinger, Fellinger, & Beitel	2011												

Note. All citations listed were reviewed in this dissertation.

Light grey cells: Study was published subsequent to review. Dark gray cells: Publication was reviewed in this dissertation but not in prior reviews.

identification/intervention, family and demographic variables

2. Intervention characteristics: program and its components, type of intervention (home-based, center-based), duration, frequency

3. Methodological characteristics of study: research design, sample sizes, covariates, dependent variables, statistical methods

4. Outcomes:

    a. Effect sizes (*ES*), where positive *ES* represents a desirable outcome, or the *voting method* (Glass, 1977; Light & Smith, 1971), which indicates the relationship between the independent and dependent variables: statistically significantly positive (+), no statistically significantly relationship in either direction (0), statistically significantly negative (-)

b. Conclusions of researchers based on study findings

c. Rating of study quality as shown in Appendix B.

Studies Inappropriately Cited in Support of Earlier Intervention

Many of the studies reviewed for this dissertation were cited by other authors as providing support for the hypothesis that earlier intervention resulted in better language outcomes. However, a number of these studies did not actually include an investigation of whether age at identification or intervention affected language outcomes, or did not include data that could be used to address this issue. Despite this, the studies were cited in numerous publications as providing research support for the effects of earlier intervention. For example, the purposes of two studies frequently cited in support of earlier intervention are shown in Table 6. Because these studies were so frequently cited, they were included in Table 5, but they will not be further analyzed in this section, as these studies did not include an analysis of the relationship between age of identification or intervention and language outcomes.

Analyzing the Quality of Primary Studies

The quality of a reported study is particularly important in drawing conclusions from a body of research, because findings from a poor quality study cannot be trusted. In

Table 6

Examples of Studies Cited in Support of Earlier Is Better, but That Do Not Include an Analysis of Age at Identification or Intervention

Authors (Date)	Purpose of study
Calderon et al. (1998)	To identify characteristics of families with deaf children (no analysis based on differences in age at identification or intervention)
Greenberg et al. (1984)	To investigate the effects of a systematic, comprehensive intervention when compared to less systematic, less comprehensive intervention

particular, quasi-experimental designs most often overestimate effects (Shadish & Clark, 2006). A strong determinant of study quality is the type of research design used to answer the research questions, with the highest rating given to randomized controlled experiments that account for most threats to validity and that include complete and appropriate reporting of study characteristics and findings. Not a single completed study was located that that met this level of quality; however, one such study was described in Rittenhouse, White, Lowitzer, and Shisler (1990), where infants identified with hearing loss prior to 9 months of age were randomly assigned to either a group receiving SKI*HI home-based services or a group that did not receive direct services until 18 months of age. Parents in the second group were telephoned regularly by a specialist to discuss answers to questions.

As an example of how judgments were made about the quality of a study, consider the following two studies: Watkins (1983) and Yoshinaga-Itano, Coulter, and Thomson (2000). Some of the methodological problems that constitute threats to internal and external validity and that could have affected the findings of these studies are shown in Table 7. As described in Appendix B, without random selection or assignment to help control for threats to validity, the highest quality rating a study could receive was good. The Yoshinaga-Itano, Coulter, and Thomson study was a pre-experimental design (Campbell & Stanley, 1966; Shadish, Cook, & Campbell, 2002) that could have earned a quality rating no higher than fair, and the Watkins investigation, with its matched comparison group design, could have earned, at best, a quality rating of good.

Participants in these studies shared many characteristics. Both studies included participants whose hearing losses ranged from mild to profound, and some participants had additional disabilities. Both intervention programs were family-centered, home-based, and included multiple communication modes (e.g., oral, manual). However, Yoshinaga-Itano and colleagues (2000) investigated participants from CHIP and included only children with hearing parents, while Watkins (1983) studied SKI*HI participants

Table 7

Methodological Problems of Primary Research: Comparing Two Primary Studies

Publication	Poor intervention description	Poor population description	Selection bias, nonrepresentative sample	Nonequivalent groups	Problems with matching	Treatment length differences	Maturation a confounding variable	Sample, group, or cell sizes are small or unequal	Attrition, missing data	Instrumentation reliability, validity questionable	Continuous variables converted to categorical	Questionable use of statistics	Reporting errors or omissions
Yoshinaga-Itano, Coulter, & Thomson (2000)	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
Watkins (1983)		✓	✓						✓				

who had both normally hearing and hearing-impaired parents.

Yoshinaga-Itano and colleagues (2000) compared the speech and language development of children born in hospitals with UNHS to that of their peers who were born in hospitals without UNHS. However, the researchers did not collect data concerning whether or not a child was actually screened, or the results of that screening, in either setting. Researchers reported that some participants born in UNHS hospitals may not have been screened and others born in hospitals where no UNHS was implemented were screened through the high-risk registry or newborn intensive care units, so assignment to groups was potentially inaccurate. Additionally, researchers did not include a description of the population or the settings of the hospitals (e.g., urban, rural), raising questions such as the following. Did only the larger hospitals in metropolitan areas have UNHS programs? Did more of the unscreened children live in rural areas, where access to services was limited? Did SES affect the parents' choice of hospitals, particularly if families with lower SES did not have maternity insurance?

Participants were matched on hearing loss, cognitive ability, and chronological age at testing, but not on other relevant factors such as disability status, hearing status of parents, or age at intervention. Children ranged from 9 to 61 months old at time of language testing, so treatment lengths varied and findings were based on short-term outcomes of intervention. Language outcome measures based on parent report were used, as well as independent coding of language from videotaped parent and child interactions, but no report of measurement reliability was provided. Additionally, many of the comparisons did not include the entire sample, indicating that data were missing and not accounted for in statistical analyses. Overall, the number and severity of methodological problems in this study make drawing conclusions questionable. Yet, Yoshinaga-Itano and colleagues (2000) strongly concluded that “children born in hospitals with a universal newborn screening program for hearing loss performed much better than their peers who were born in hospitals that did not have the screening program” (p. S137). For these reasons, the study quality was rated as very poor.

The Watkins (1983) study was based on a matched comparison group design and included children who participated in the Clark (1979) study. Although the population from which these children were selected was not described, which limits generalization of the study findings, participants were matched on a variety of characteristics and other relevant variables were included as covariates in the analysis to control for differential selection. Matching variables and covariates included hearing loss, chronological age at time of testing, existence of other disabilities, preschool attendance (e.g., amount of treatment), lapsed time since treatment, current school placement, parental occupation and education, number of parents, and age and hearing status of parents. Other threats to validity were controlled through the design and discussed in the report, with participant attrition from the Clark study remaining as an uncontrolled threat that was accounted for through careful matching and analysis of group differences.

Participants ranged from 6 to 13 years old at testing to provide evidence for the long-term outcomes of early intervention. Watkins included a description of the intervention, multiple outcome measures with appropriate reporting of tests of reliability, an analysis of covariates, a thorough description of the statistical analysis, effect sizes for all outcome measures, and justification for the conclusions drawn. Although descriptive statistics for all independent and dependent variables were not included in this publication, they were reported in Watkins (1984), along with an additional review of the relevant literature and more complete descriptions of procedures. Watkins (1983) listed a number of findings, including “hearing impaired children in this study who received home intervention earlier...performed better...on the majority of dependent [language] variables” (p. 151) and “many factors, particularly child and parent characteristics, account for the majority of the variance of the dependent variables if not controlled in the analysis” (p. 153). Implications drawn from the findings were attributed to this study with cautious recommendations for generalizing the findings to other settings. Overall, this study design and reporting sufficiently controlled for most threats to validity, which earned this quasi-experimental study a good quality rating.

Early Intervention Based on Hearing Status of Parents

To support claims for earlier intervention, authors who report investigations of the effects of having deaf parents compared to hearing parents for children born with hearing loss are often cited. Researchers who conducted studies comparing these two groups reported that deaf parents provided earlier intervention than hearing parents, who must first accept that their child has been born with hearing loss and then learn how to communicate with their child. Some of these researchers stated that study findings provide support for total communication when compared to oral communication, but others claimed this “earlier intervention” supported the earliest possible identification and intervention to improve long-term outcomes for children with hearing loss.

While basing support for earlier intervention on studies with noncomparable groups such as those with deaf parents (with researchers assuming deaf parents know that their child is deaf at birth) and those with normally hearing parents may be spurious (i.e., we cannot duplicate the effect of having deaf parents at birth for children born to hearing parents), these studies are cited so frequently as evidence for earlier identification and intervention for hearing loss that they were included in this review. The sample of studies reviewed in this section was not comprehensive. Rather, the review in this section included all studies published since 1975 that compared hearing parents and deaf parents for children born with hearing loss, and that were cited either by the reviews discussed previously or in the primary studies reviewed in the next section.

Table 8 summarizes the characteristics and findings of these studies, grouped alphabetically by author within type of intervention program. Overall, the mostly poor or very poor qualities of these studies and the wide range of effect sizes provide inconclusive support for improved language outcomes for children born with hearing loss who have deaf parents when compared to hearing parents. Yet, Balow and Brill (1975), Brasel and Quigley (1977), Geers and Schick (1988), and Vernon and Koh (1971) are widely cited in support of earlier identification and intervention for children born with hearing loss, particularly in the reviews discussed previously and the primary studies analyzed in the next section. Two of these studies (Balow & Brill, 1975; Vernon & Koh, 1971) are rated as very poor quality while the other two are rated as poor quality, which makes it difficult to have confidence in the findings. Additionally, generalizing findings based on children of deaf parents to children born with hearing parents is questionable. While the authors of these studies attributed the “competent parent language model” or “manual communication” to deaf children’s higher communication scores, innumerable confounding factors could also account for these differences. Finally, several authors described results counter to these (Messerly & Aram, 1980; Parasnis, 1983; Weisel & Reichstein, 1989), although the quality of these studies was also rated poor or very poor. These researchers reported that deaf children of hearing parents outperformed deaf children with deaf parents. Overall, findings from the studies shown in Table 8 are inconclusive, and study quality makes the validity of findings questionable.

As shown in Table 9, the overall average effect size of the 15 studies listed in Table 8 was positive, but the standard deviation was quite large in comparison. When considered with ratings of study quality, one might wonder if factors other than whether a child had hearing or deaf parents likely played a greater role in language outcomes—and study quality and range of effect sizes preclude drawing strong conclusions about the impact of deaf parents and earlier intervention on language outcomes for children born with hearing loss.

However, even if research provided sufficiently strong evidence to support claims that children with hearing loss are better served through intervention provided by deaf parents, we would be unlikely to remove children born with hearing loss from their normally hearing biological parents and place them with adults with hearing loss. In essence, this naturally occurring experimental design cannot be used—for ethical reasons—to change options available to children born with hearing loss. Rather, this

Table 8

Summary of Review of Primary Studies (Grouped by Intervention): Early Intervention Based on Having a Parent with Hearing Loss (HL)

Publication(s) and intervention program	*N*	Definition of earlier (*n*)	Design	Posttest Age (yr-mo)	Expressive receptive	Speech production	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Balow & Brill (1975) CA Schools for the Deaf, Riverside	590	INT PHL (34)	Retrospective Cohort comparison	18 approx.			✓	Vote = + (*n*, avg, $p < 0.05$)	Yes	Children with hearing loss (CHL) with PHL scored higher on paragraph meaning, IQ than those with hearing parents (HP)	Very poor
Kusche et al. (1983) CA Schools for the Deaf	78	INT PHL (39)	Retrospective matched group comparison	17-0			✓	1.02 SMDES	Yes	CHL/PHL: "The younger the subjects reported learning sign, the higher the achievement scores" (p. 464)	Poor
Meadow (1967) Meadow (1968) CA School for the Deaf, Berkeley	118 (500)	INT PHL (59)	Retrospective two group Comparison	5-6 to 21-0	✓	✓	✓	Vote = +	Yes	"Children...exposed to early manual communication performed at a higher level by almost every measure employed" (p. 39)	Poor
Vernon & Koh (1971) CA School for the Deaf, Riverside (John Tracy Clinic)	69	INT PHL (23)	Retrospective multiple group comparison	18-6 avg		✓	✓	0.26 SMDES	Yes	"Early exposure to manual communication results… achievement superior to that of extensive oral preschool education." (p. 572)	Very poor
Greenstein et al. (1975) Greenstein (1975) LSD	30	INT PHL 16 mo (11)	Retrospective cohort comparison	3-4	✓	✓		0.30 SMDES	Yes	Earlier intervention benefits language outcomes	Poor
White & White (1987) LSD	46	INT PHL (9)	Retrospective cohort comparison	3-0	✓	✓		0.22 SMDES	Yes	Earlier is better for children with HL with HP, and earlier is more important for children with HL with HP than PHL	Fair
Messerly & Aram (1980) Mayfield Public Schools	16	INT PHL (8)	Retrospective two group Comparison	17-7 avg			✓	- .80 SMDES	No	Students with HL with HP were found to have higher academic achievement than students with HL with PHL	Very poor

(table continues)

Publication(s) and intervention program	*N*	Definition of earlier (*n*)	Design	Posttest Age (yr-mo)	Expressive receptive	Speech production	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Brasel & Quigley (1977) Multiple programs	72 (470)	INT PHL (36)	Retrospective Group Comparison	10-0 to 18-11	✓		✓	0.74 SMDES	Yes	Earlier exposure to a more competent parent language model influences language outcomes	Poor
Geers & Moog (1992) Multiple programs (manual language)	127	INT PHL (64)	Retrospective Group Comparison	15-10 to 17-2	✓	✓		Vote = --	No	Few differences found between hearing-impaired children with PHL and those with HP	Poor
Geers & Schick (1988) Multiple programs (manual language)	100 (200)	INT PHL (50)	Retrospective Two Group Comparison	5-0 to 8-11	✓			0.42 SMDES	Yes	"Hearing impaired (HI) children of HI parents demonstrate linguistic advantage over HI children of HP." (p. 53)	Poor
Parasnis (1983) Multiple programs, subjects attending NTID	38 (286)	INT PHL (13)	Retrospective Two Group Comparison	19-9 avg	✓		✓	- .25 SMDES	No	College students with HP who signed later performed better than those with PHL who signed early	Poor
Sisco & Anderson (1980) Multiple programs	1228	INT PHL (106)	Retrospective Group Comparison	6-0 to 16-11	✓			0.50 SMDES	Yes	Children with HL with PHL performed better than those with HP	Poor
Weisel (1988) Multiple programs, Israel	124 (328)	INT PHL (31)	Retrospective Two Group Comparison	5-0 to 14-0			✓	0.34 SMDES	Yes	"HI children with PHL performed significantly better than HI children" with HP (p. 358)	Very Poor
Weisel & Reichstein (1989) Multiple programs, Israel	257 (327)	INT PHL (32)	Retrospective Cohort Comparison	7 to 16		✓		- .53 SMDES	No	"Children with two PHL had lower scores than children with HP" (p. 5)	Very Poor
Zwiebel (1987) Multiple programs, Israel	167 (403)	INT PHL (23)	Retrospective Multiple Group Comparison	6 to 14	✓	✓		0.56 SMDES	Yes	"PHL provide, through early manual communication,...the language base that leads to...more advanced levels of thinking" (p. 19)	Poor

[1] Effect Size (ES): Standardized Mean Difference Effect sizes (SMDES) are reported. Some SMDES were estimated from other statistics (e.g., X2, F). When no effect sizes could be calculated from data provided in a report, a vote was reported indicating that the study provided support (+) or lacked support (--) for early intervention based on deaf parents.

Abbreviations: Age of identification of hear loss (ID); Retrospective (Retro); Hearing loss (HL); Hearing parents (HP); Lexington School for the Deaf (LSD); Cross-sectional (Xsec); Months (mo); Longitudinal (Long); Effect Size (ES); National Technical Institute for the Deaf (NTID); Age at entry to intervention (INT); Prospective (Prosp); Parents with hearing loss (PHL); California (CA)

Table 9

Average Effect Sizes for Studies Comparing Hearing Status of Parents

Category	Number of studies	Average SMDES	*SD*
Average for studies that have effect sizes[a]	12	.23	.52
ES for very poor quality studies	4	- .18	.57
ES for poor quality studies	7	.47	.39
ES for fair quality studies	1	.22	na
Vote = +	2		
Vote = -	1		
Children over 60 months old at posttest	10	.23	.58

[a] Based on 12 studies reported in 17 publications

design can only be used to provide, at best, weak and confounded evidence for the impact of earlier intervention on long-term outcomes. Because deaf parents differ from normally hearing parents on many characteristics relevant to language outcomes, conclusions drawn by differences in outcomes are confounded by variables that remained uncontrolled in all of these quasi-experimental studies. These differences include language spoken in the home, level of parent education, occupational status (e.g., unemployed, employed full or part time), socioeconomic status, marital status, reason for hearing loss (e.g., illness after birth or premature birth), availability of or proximity to intervention, and time from identification to intervention, among others.

Finally, as age of identification continues to decrease with the advent of newer technologies and the implementation of UNHS, children born with hearing loss who have normally hearing parents—and their families—receive intervention services much sooner after birth. As a result, the delay between birth and initiation of services is much shorter now than when the studies listed in Table 8 were conducted, which lessens the potential advantage for children born with hearing loss who have deaf parents. For these reasons, the studies comparing children with deaf parents or hearing parents were not included in a further analysis of study characteristics of primary studies of early intervention.

Primary Studies in Which Hearing Status of Parents Was Not the Key Independent Variable

To be included in the following review of primary studies, authors of studies had to include age of identification or intervention and language outcomes in the data analysis and reporting, and hearing status of parents was not a key factor for determining group membership. In many of the studies reviewed here, the age of identification or intervention was entered into a regression model to increase the variance explained by the model in predicting outcomes. In all, 43 studies reported in 61 published articles and 3 presentations were included in the review for this section. Table 10 displays summary information for the publications grouped by intervention—alphabetically by author within program type). Narrative description of the studies by program follows. Study covariates and methodological considerations are discussed in later sections.

Analysis of Effect Sizes

The average effect sizes shown in Table 11 help summarize the effects calculated from these studies of early identification or intervention on language

Table 10

Summary of Review of Primary Studies (Grouped by Intervention): Early Intervention for Children Born with Hearing Loss

Publication Intervention Program	*N*	Definition of earlier (*n*)	Design	Posttest age (yr-mo)	Expressive/ receptive	Speech	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Ashby (1995) AASD	51 (77)	INT 12 mo (4)	Retro Xsec Cohort Comparison	5-0 to 6-0	✓			0.07 R^2 block: density, duration	Yes	Intervention duration (based on entry age), density accounted for 7% variance	Poor
Cunningham (1999) Broward County Public Schools, FL	61 (228)	INT	Retro Xsec Single Group Posttest	5 to 19			✓	0.16 SMDES	No	No significant relationship between reading/writing outcomes and age of identification or age of amplification	Poor
Vernon & Koh (1971) CA School for the Deaf, Riverside (John Tracy Clinic)	101 (123)	INT (40)	Retro Xsec Multiple Group Comparison	18-6 avg		✓	✓	- .03 SMDES	No	Negligible differences between groups who started at different ages and who have HP	Very poor
Apuzzo & Yoshinaga-Itano (1995) CHIP	69	ID 0-2 mo (14) 3-12 mo (11)	Retro Xsec Cohort Comparison	3-4 avg	✓			0.62 SMDES	Yes	"Better performance was associated with EI, the greatest benefit coming with intervention that was begun within 2 months of birth" (p. 134)	Poor
Mayne, Yoshinaga-Itano, & Sedey (2000) CHIP	168	ID 6 mo (123)	Retro Xsec Cohort Comparison	0-8 to 1-10	✓			0.11 SMDES	No	Age at ID was NOT associated with language outcomes	Very poor
Mayne, Yoshinaga-Itano, Sedey, & Carey (2000) CHIP	113	ID 6 mo (54)	Retro Xsec Cohort Comparison	2-0 to 3-1	✓			0.51 SMDES	Yes	Advantage in expressive vocabulary ability evident in early-identified group	Very poor
Snyder & Yoshinaga-Itano (1998) CHIP	180	ID 6 mo (117)	Retro Xsec Cohort Comparison	0-8 to 2-6	✓			0.06 R^2	Yes	Block with play subscale scores and age of ID accounts for a proportion of the variance in language scores	Poor
Yoshinaga-Itano & Apuzzo (1998a) CHIP	40	ID 6 mo (15)	Retro Xsec Cohort Comparison	2-1 to 5-0	✓			0.53 SMDES	Yes	Better performance was associated with early ID and early home intervention (p. 386)	Very poor

(*table continues*)

Publication Intervention Program	*N*	Definition of earlier (*n*)	Design	Posttest age (yr-mo)	Expressive/ receptive	Speech	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Yoshinaga-Itano & Apuzzo (1998b) CHIP	82	ID 6 mo (34)	Retro Xsec Cohort Comparison	2-3 avg	✓	✓		0.90 SMDES	Yes	Earlier ID and INT resulted in better language, social development, and comprehension outcomes	Very poor
Yoshinaga-Itano & Sedey (2000) CHIP	147	ID 6 mo (70)	Retro Xsec Cohort Comparison	1-2 to 5-0	✓	✓		0.18 SMDES	No	Age at identification was not highly related to language outcomes	Poor
Yoshinaga-Itano, Coulter, & Thomson (2000, 2001) CHIP	50	ID 6 mo (25)	Retro Xsec Cohort Comparison	1-2 to 5-1	✓	✓		1.07 SMDES	Yes	Hospital-based UNHS is "positively related to language and speech performance" (p. S132)	Very poor
Yoshinaga-Itano, Sedey, Apuzzo et al. (2001) CHIP	109	ID 6 mo (46)	Retro Xsec Cohort Comparison	1-1 to 3-0	✓	✓		Vote = + (given *n*, avg, no *sd*, *p*, chi-sq)	Yes	ID by six months results in "larger expressive vocabularies, higher expressive language,...language comprehension scores" (p. 3)	Very poor
Yoshinaga-Itano, Sedey, Coulter, et al (1998); Downs & Yoshinaga-Itano (1999); Yoshinaga-Itano (1997, 1999, 2000)	150 (over 400)	ID 6 mo (72)	Retro Xsec Cohort Comparison	2-2 avg	✓			1.03 SMDES	Yes	"The language difference...was so large that the mean performance of the earlier-identified children was almost a full SD higher" (p. 1169)	Poor
Yoshinaga-Itano, Snyder, & Day (1998) CHIP	170	ID 6 mo (86)	Retro Xsec Cohort Comparison	0-8 to 3-0	✓			0.03 R^2	Yes	Earlier identification accounts for 3% of the variance in language scores	Poor
Pipp-Siegel et al. (2003) CHIP and STEP*HI	188 (235)	INT	Retro Xsec Single Group Posttest	0-7 to 5-7	✓			0.03 R^2 block: communication mode, HL	Yes	"Children who began intervention earlier had higher expressive language quotients" (p. 142)	Poor
Moeller (2000) Moeller (1996, 1998) presentations DEIP	112	INT 11 mo	Retro Xsec Cohort Comparison	5-0	✓			1.09 SMDES 0.11 R^2	Yes	"Early intervention contributes to positive outcomes in language development" (p. 6) parent involvement a substantial factor	Fair

(*table continues*)

Publication Intervention Program	*N*	Definition of earlier (*n*)	Design	Posttest age (yr-mo)	Expressive/ receptive	Speech	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Calderon (1998); Calderon (2000); Calderon & Naidu (2000)	80	INT 12.5 mo (9)	Retro Long Cohort Comparison Pre/posttest	3-0	✓	✓		0.24 R^2	Yes	"provides striking evidence for the significance of age at entry for...language development" (p. 10)	Poor
ECHI	28 (44)	INT 13 mo (5)	Retro Xsec Cohort Comparison	3-9 to 7-4	✓	✓	✓	0.49 SMDES	Yes	"Results...provide further evidence for the belief that intervention at an early age is very important" (p. 18)	Very poor
Naidu (1995) ECHI	80	INT 12 mo (10)	Retro Long Cohort Comparison Pre/Posttest	3-0	✓	✓		Vote = + .543 R^2 block: age INT, pretest score, HL	Yes	"This study has demonstrated positive effects for early intervention in developing language, auditory, and speech production skills" (p. 89)	Poor
Robinshaw (1995) Hearing aids	5	INT	Prospective Longitudinal Case Study	1-9 avg	✓	✓		Vote = +	Yes	Infants "identified within the first months of life...acquired" communication "skills...more typical of their hearing peers than infants identified" later (p. 333)	Very poor
Markides (1986) Hearing aids	153 (5172)	INT 6 mo (32)	Retro Xsec Matched Group Comparison	8-0 to 12-0		✓		0.75 SMDES	Yes	"the speech intelligibility of those... who started using amplification in their first six months of life was significantly superior" (p. 166)	Very poor
Davis et al. (1986) Iowa schools	40 (112)	INT	Retro Xsec Single Group Posttest	5-0 to 18-0	✓	✓	✓	- .12 SMDES	No	"Any positive effects associated with early intervention...were not demonstrated by the data" (p.61)	Poor
Greenstein et al. (1975) Greenstein (1975) LSD	30	INT 16 mo (20)	Retro Xsec Cohort Comparison	3-4	✓	✓		0.60 SMDES	Yes	Earlier intervention benefits language outcomes, mother–child communication interactions	Fair
Levitt (1987); Levitt & McGarr (1988); Levitt et al. (1987) NY Schools for the Deaf	120 Appro x	INT 36 mo	Retro Xsec Single Group Posttest	10-6	✓	✓	✓	0.11 R^2	Yes	INT "from the age of three years or younger showed significantly higher...language scores" (p. 384)	Poor

(*table continues*)

Publication Intervention Program	*N*	Definition of earlier (*n*)	Design	Posttest age (yr-mo)	Expressive/ receptive	Speech	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
White & White (1987) White (1984) LSD, oral	46	INT 18 mo (14)	Retro Xsec Cohort Comparison	3-0	✓	✓		1.03 SMDES	Yes	Earlier is better and most important for children with HP Late-entering children with DP were slightly favored over early-entering	Fair
Liff (1973), Horton (1975, 1976) McConnell & Liff (1975) Parent teaching program	12	INT 36 mo (6)	Retro Xsec Cohort Comparison	7-6		✓		1.19 SMDES	Yes	Hearing impaired children who received earlier intervention showed more complex language use	Very poor
Clark (1979) SKI*HI	64 (108)	INT 30 mo (13-33)	Retro Long Multiple Group Comparison Pre/Posttest	3-7 avg	✓			0.02 SMDES	No	Inconclusive results concerning earlier intervention being better than later	Poor
Strong, Clark, Barringer et al. (1992), Strong & Clark (1992) Strong, Clark, Johnson et al. (1994) SKI*HI	2881 (5178)	INT	Retro Long Single Group Pre/Post	3-3 avg	✓			0.11 R^2 block: INT age, length of treatment	Yes	"only 10 to 11% of the variability in intervention developmental rates is explained by...program-start age and treatment amount." (p. 222)	Fair
Watkins (1983) Watkins (1984, 1987) SKI*HI	92	INT 30 mo (23)	Retro Xsec Matched Group Comparison	6-0 to 13-0	✓	✓	✓	0.18 SMDES	Yes	Hearing impaired children who receive intervention earlier perform better on language measures	Good
Holzinger, Fellinger, & Beitel (2011) Austria, Hospital of St. John of God	63	ID INT	Retro Xsec Population Single Group Posttest	5-1	✓			.03 R^2	Yes	Age at ID and age at INT related to language outcomes, though only small proportion of variance in language related to age at intervention when controlling for parent education, parent hearing loss, nonverbal IQ, etc.	Good
Fitzpatrick et al. (2007) UNHS	65	UNHS	Retro Xsec Single Group Posttest	5-5	✓			.07 R^2	Yes	No difference in language outcomes following UNHS when controlling for severity of HL, family education, admission to intensive care	Fair

(*table continues*)

Publication Intervention Program	*N*	Definition of earlier (*n*)	Design	Posttest age (yr-mo)	Expressive/ receptive	Speech	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Kennedy et al. (2006) UNHS	120 (168)	ID 9 mo (57)	Retro Xsec Population Study Posttest	7-11	✓	✓		0.35 SMDES	Yes	"Confirmation of hearing impairment by age nine months was associated with higher adjusted mean language z-scores" (p. unknown) Note: assessors blind to early hearing or audiologic history	Fair
Worsfold et al. (2010) UNHS	89	ID (< 9 mos)	Retro Xsec Single Group Posttest	6-6 to 10-9			✓	.21 SMDES	Yes	Early but not late ID was associated with narrative skills, some expressive aspects of syntax and morphology, but not expressive phonology	Poor
Greenberg (1980) Greenberg 1983) Multiple programs	28	ID	Retro Xsec Multiple Group Comparison	3.5 to 5	✓			0.89 SMDES (given *F*, *n*, *df*)	Yes	Differences were "more accurately conceptualized as a function of amount of school experience and age at diagnosis" (p. 469)	Very poor
Theisen-Washburn (1988) Multiple programs	29	INT	Retro Xsec Single Group Posttest	5-4 to 7-3	✓			- .08 SMDES	No	No relationship between years of intervention and language outcomes	Very poor
Harris & Terlektski (2010) Multiple programs	86	ID	Retro Multiple Group Posttest	12-0 to 16-0			✓	- .11 SMDES	No	When comparing mean scores between hearing aids (early), early cochlear implants (CI) and late CI, no age based differences	Fair
Geers & Moog (1989) Multiple programs, oral	100 (200) approx	INT	Retro Xsec Single Group Posttest	17-0	✓	✓	✓	Vote = +	Yes	Early intervention "makes a significant contribution to predicting overall literacy" (p. 83)	Poor
Moores et al. (1978) Multiple programs	60 (102)	INT	Retro Xsec Multiple Group Comparison	6-1 to 8-1	✓	✓	✓	Vote = +	Yes	"Those children who do not receive such training and communication at early ages do not catch up by age eight" (p. 935)	Very poor
Ramkalawan & Davis (1992) Multiple programs, CHAC	16 (48)	INT	Retro Xsec Single Group Posttest	2-3 to 6-8	✓	✓		0.85 SMDES	Yes	Earlier intervention results in higher language scores	Very poor

(*table continues*)

Publication Intervention Program	*N*	Definition of earlier (*n*)	Design	Posttest age (yr-mo)	Expressive/ receptive	Speech	Reading & writing	*ES*[1] (Language)	Claim EARLIER is better	Authors' conclusions	Quality
Weisel & Reichstein (1989) Multiple programs, Israel preschools	327 (327)	INT	Retro Xsec Single Group Posttest	7 to 16		✓		(-) .17 R^2 block: HL, SES, INT, age aided	No	"Children who started preschool training later had better speech production performance" (p. 8)	Very poor
Weisel (1989) Multiple programs, Israel preschools	106	INT	Retro Xsec Single Group Posttest	11-3 avg	✓	✓	✓	- .13 SMDES	No	No differences in language based on age of intervention (later intervention slightly favored with average ES)	Fair
Musselman & Kircaali-Iftar (1996) Multiple programs	20 (202)	INT	Retro Xsec High/Low Two Group Comparison	6-9 avg		✓		Vote = -- (given avg, *n* but no *sd*, *t*, *df*, *p*)	No	Age of identification not related to spoken language ability	Fair
Musselman, Wilson, & Lindsay (1988, 1989) Musselman (1990), Musselman, Lindsay, & Wilson (1988) Multiple programs, preschool	118 (202)	INT	Retro Long Single Group Pre/posttest	6-9 avg	✓			0.02 R^2	No	"The study failed to obtain evidence of lasting gains associated with intervention during infancy…Given this pattern of findings, we must ask why early intervention continues to receive widespread support within the educational community." (p. 227-8)	Fair
Wake et al. (2005) Wake et al. (2004) Population-based study, not intervention or program specific	88 (132 or 177)	ID	Retro Xsec Population study Posttest	7-11 avg	✓	✓	✓	0.03 R^2	No	Language outcomes were not related to age at diagnosis Note: Assessors blind to severity of hearing loss, age at diagnosis	Good

[1]The following types of effect sizes are reported. Some SMDES were estimated from other statistics (e.g., X^2, F): Standardized mean difference effect size (SMDES); Proportion of variance explained (R^2); Pearson correlation (r); Point biserial correlation (r_{pb})' Partial correlation (r_p).

Abbreviations:

Age of identification of hear loss (ID)
Age at entry to intervention (INT)
Months (mo)
Hearing Loss (HL)
Deaf Parents (DP)
Hearing Parents (HP)
Effect Size (ES)

Atlanta Area School for the Deaf (AASD)
Children's Hearing Assessment Center, Nottingham (CHAC)
Colorado Home Intervention Program (CHIP, includes a small percentage of children served by private and/or public centers)
Diagnostic Early Intervention Program (DEIP)
Early Childhood Home Instruction (ECHI)
Lexington School for the Deaf (LSD)

National Technical Institute for the Deaf (NTID)
New Mexico STEP*HI Program (STEP*HI)
Universal Newborn Hearing Screening (UNHS)
Cross-sectional (Xsec)
Retrospective (Retro)
Prospective (Prosp)
Longitudinal (Long)

Table 11

Average Effect Sizes for Subsets of the Primary Studies

Category for ES		Number of studies	Average *ES*	*SD*	Comments
Average for studies that have effect sizes		30	.32	.40	Based on 38 studies reported in 54 publications
Very poor quality		12	.45	.46	
Poor quality		12	.20	.33	
Fair quality		7	.27	.59	Using Moeller (2000) $ES = .11\ R^2$
Good quality		1	.18	.00	
Vote = +		7			
Vote = --		1			
R^2 effect sizes		11	.08	.11	Variance contributed by age of ID/INT, includes three R^2 effect sizes in which the block included additional variables
Children over 60 months old at posttest		12	.19	.39	
Program:	CHIP	12	.42	.42	
	DEIP	1	.11	.00	R^2, 1.09 SMDES also reported
	ECHI	3	.37	.18	
	LSD	2	.82	.30	
	SKI*HI	3	.10	.08	

outcomes for children born with hearing loss. An overall average effect size of .30 to .50 represents a moderate effect size according to Cohen's (1988) definition of effect size. However, because 11 of the 38 studies indicated no or negative effects for the relationship between age at identification or intervention and language outcomes, basing conclusions on this moderate overall average effect size would be ill advised. Additionally, as the quality of studies increases, the effect size decreases, indicating that the actual overall effect is likely smaller than findings from these studies would suggest.

The best estimate of the magnitude of the relationship between earlier identification or intervention and language outcomes would more likely be the R^2 estimate of variance explained in language outcomes by the variable representing “early.” Here, the average R^2 effect size based on 11 studies that reported results from a regression analysis, where age of identification or intervention was entered either by itself or in a block with additional variables, was $R^2 = .08$, a slightly inflated estimate for the effect of age of identification or intervention alone. This effect size indicates that 8% of the variance in language outcomes can be attributed to age of identification or intervention and any other variables included in the block. The difference between this effect size and the number of larger effect sizes calculated from data reported in the studies is likely the result of covariates or confounding variables that were not included in the statistical analyses, or other factors that were not measured in the study, such as level of parental involvement in the intervention, intervention duration or intensity, parental level of education, or one of the many factors reported in the literature to be related to children’s language outcomes.

Additionally, the average effect size of SMDES = .19, based on studies in which children were tested at ages older than five years, represents longer-term effects of early intervention on language outcomes. However, this effect size likely also includes effects that could be attributed to level of parental involvement, level of parental education, and other variables not included in analyses that could affect long-term language outcomes in children born with hearing loss.

Summary of Groups of Studies

Colorado Home Intervention Program (CHIP) studies. Twelve of the 38 studies (i.e., 17 of the 54 publications) reviewed here were based on data from CHIP and included Yoshinaga-Itano as a primary researcher who was listed as an author on all CHIP publications. Although these publications were based on the same program, they had radically different sample sizes and sample selection methods, and they were published across nine years, so they were not collapsed into a single study. In general, participants for all of these studies were selected based on complete data, matched on demographic characteristics, and divided into groups based on age of identification, most with an age cut-off of six months. No justification based on data patterns, theory, or prior research was provided for this choice of age cut-off.

As a whole, the CHIP studies portray mixed results in providing evidence for earlier intervention to improve language outcomes for children born with hearing loss. Effect sizes ranged from R^2 = .03 to SMDES = 1.07, with the average effect size for all CHIP studies being .42. Additionally, the authors' conclusions vary, with authors of two studies claiming that the studies did not provide evidence supporting earlier intervention, and the remaining claiming earlier intervention improved language outcomes for children born with hearing loss. Additionally, Pipp-Siegel and colleagues (2003) claimed an effect size of .03 R^2 was large enough to conclude that "children who began intervention earlier had higher expressive language quotients" (p. 142) while Yoshinaga-Itano and Sedey (2000) concluded that an effect size of .09 r_p indicated age at identification was not highly related to outcomes.

All CHIP studies were rated as poor or very poor in quality due to the number of methodological problems. Many of the CHIP studies reported a single outcome measure and few reported reliability of outcomes. Analyses conducted in the CHIP studies often used categorized variables when the data collected was continuous, and these categories often seemed artificially contrived and without a research or theoretical basis. Not a single published report of a study involving CHIP participants included a description of the population, so sample selection seemed a likely severe threat to validity, particularly because most of the studies did not describe the criteria used to select participants from the available population. The astute reader would wonder if participants were selected because their data provided support to the research claims. As mentioned previously, in her reviews of CHIP studies, Yoshinaga-Itano (2003a, 2003b) defended the choices of sample selection in CHIP studies by claiming that all participants who fit the study selection criteria were used for the studies. Furthermore, she stated that the 70% of the children for whom CHIP had outcome data were representative of the population of children born with hearing loss in Colorado. Yet, no report of an analysis of differences between children for whom outcome data was collected and those who did not have outcome data was located. Additionally, the authors conducted analyses to detect group differences in few of the studies, so confounding factors could reasonably explain differences found in language outcomes between groups. These confounding factors include proportion of children in the earlier identified group with deaf parents, differences between groups in parental education or socioeconomic status, treatment length or density, and differences in age at testing when age was not controlled or used as a covariate in the analyses.

Early Childhood Home Instruction (ECHI) studies. Three studies reported in four publications were conducted with participants in the ECHI program. Calderon (1998; see also Calderon, 2000; Calderon & Naidu, 2000) reported findings from two separate studies that were selected based on specific demographic characteristics. The SMDES for language outcomes in these two studies averaged .89, with an R^2 proportion of the variance explained by age at entry into intervention of .24. The investigators reported fewer behavior problems in the second study for the group receiving earlier intervention, with an effect size of .37. The authors concluded that earlier intervention resulted in greater gains in language development and fewer behavior problems. Naidu (1995) did not report an effect size or include statistics for calculating one, but she did state that the findings "demonstrated positive effects for early intervention in developing language, auditory, and speech production skills" (p. 89).

The lack of a population description which points to a selection bias, small sample sizes of the earlier intervention groups (i.e., 9, 5, and 10, respectively), and dissimilar group sizes used in comparisons resulted in poor or very poor study quality ratings, so conclusions drawn from these studies are questionable. However, in a personal communication with Karl White (date unknown), Naidu stated that all children who met selection criteria and who had outcome data were included in the studies. Additionally, she stated that families rarely dropped out of the ECHI program, although this statement does not preclude families refusing outcome testing or missing testing appointments. She claimed that results from an analyses of differences between groups did not support a systematic difference between early and late identified children that would predict different language outcomes.

Diagnostic Early Intervention Program (DEIP) study. Moeller's (2000) publication and presentations (1996, 1998) reported results of studies conducted at the Boys Town National Research Hospital that included participants enrolled in the DEIP. Although the sample sizes for the references were slightly different, data collected from the same children were used. Moeller (2000) reported a calculated SMDES of 1.09. While there was insufficient information in her presentations to judge the quality of studies, the published study was rated as fair due to selection bias and confounding factors that could account for differences between groups.

For example, in a regression analysis of her data, Moeller (2000) reported that family involvement, nonverbal intelligence, and better ear pure tone amplification account for 44.0% of the variance in children's language scores, with family involvement contributing 35.2% of the variance. Age of enrollment in intervention accounted for only 11.4% of the variance above the other three factors. These results would indicate that family involvement, measured by a 5-point scale which ranged from limited participation to ideal participation, played a larger role in the child's language development than did age at intervention. Additionally, the family involvement scale used in this study was related to treatment frequency and intensity (e.g. "Family members participate in most sessions/meetings." and "Busy schedules or family stresses may limit opportunities for carryover of what is learned." p. 8), which would support the assertion that the amount of treatment, which was likely to be partly determined by family characteristics, may have affected language outcomes more than age at which intervention was delivered. In a private communication with Karl White (2004), Moeller stated that the distributions of family involvement were similar across the age of enrollment categories, which again would support the assertion that amount of treatment may have been substantially related to language outcomes.

Lexington School for the Deaf (LSD) studies. Participants in the Greenstein and colleagues (1975; Greenstein, 1975) and White and White (1987) studies were enrolled at the LSD, an oral preschool program. Authors of both studies concluded that earlier intervention promoted better language outcomes. Additionally, these researchers reported that earlier intervention was more important for children with hearing loss who had hearing parents than for those who had deaf parents. Neither study described the population or the criteria used to select participants, and authors of both studies reported differences between groups that included the number of deaf parents, levels of parent education, and gender distributions. Given methodological concerns, the studies earned fair quality ratings, respectively, with SMDES for language outcomes of .60 and 1.03.

SKI*HI Home Intervention Program. Three of the studies reported in seven publications included children identified with hearing loss who were enrolled in the SKI*HI program. In the earliest of these studies, Clark (1979) did not directly compare earlier versus later intervention, although results of this study have been used by some (e.g., Apuzzo & Yoshinaga-Itano, 1995; Yoshinaga-Itano & Apuzzo, 1998a) to conclude that earlier is better. To explain, Clark compared a treatment group to a no treatment group, showing substantially better outcomes for the treatment group when compared to a no treatment group of the same age. But the no treatment group then received intervention initiated at later ages than the original treatment group. Clark concluded that "the total group of children receiving home intervention treatment whether early or late, improved significantly during 11 months of treatment in receptive [and expressive] language" (p. 47). However, using the numbers reported in Clark's study to determine the overall impact of earlier intervention on language outcomes shows inconclusive results, with the group treated later scoring higher on only one of three language measures, and an overall SMDES effect size of .02 for language outcomes.

Clark did not directly compare the posttest scores for the two groups with each other. However, the data reported provided sufficient information for the comparison, and indicated inconclusive results. Table 12 shows that the average REEL receptive and expressive language scores are lower for the combined group at posttesting, despite the average *AGE* being higher when the groups are combined. This indicates that the posttest scores for the group treated at a later age were quite poor, as they lowered the mean. On the other hand, the SKI*HI receptive language scores are substantially higher for the combined group, indicating that the posttest scores of the group treated at an older age were substantially higher than the scores for the group treated earlier.

However, problems with sample selection and sample sizes make comparing outcomes of the early and late intervention groups difficult given the statistics reported by Clark. In describing his population, Clark stated, "All children in the program were included in the study. Because of differing lengths of time in the program, various numbers (*N*) of children were used in the various tests and groups" (pp. 37-38). Given

Table 12

Comparison of Posttest Scores from the Clark (1979) Study

		REEL receptive			REEL expressive			SKI*HI receptive		
Source	Posttest scores	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*
From Clark (1979)	Early intervention group	69.8	31.6	33	68.2	33.6	33	50.0	38.8	13
	Both groups combined	63.6	32.0	64	62.0	34.1	62	62.0	38.9	35
	Interpretation	Mean lower with combined, so later treatment mean lower						Mean higher with combined, so later treatment mean higher		
Calculated	Late intervention group (given assumption described above)	57.0	UK	31	54.9	UK	29	69.1	UK	35
	Discrepancy (M_{early}—M_{late})	12.8			13.3			-19.1		
	Higher scoring group	Early			Early			Late		

this statement and looking at the sample sizes used throughout his report, we cannot assume that all children whose posttest scores are used for the early intervention group are included in the posttest scores for the combined group. The combined group includes only those children for whom both pretest and posttest scores were available, while the posttest scores for the intervention group were not dependent on having a pretest score.

However, if we assume that all posttest scores from the early intervention group are included in the combined group, the discrepancy between the two groups (early and late intervention) on REEL and SKI*HI measures are provided in Table 12. These mean scores for the late intervention group were calculated using the following equation:

$$M_{early}(N_{early}) + M_{late}(N_{late}) = M_{combined}(N_{combined})$$

The discrepancy indicates that Clark's data provides inconclusive evidence concerning the more positive effects of earlier intervention when compared to later intervention.

Clark's study was rated as poor quality due to methodological problems that included severe attrition, selection bias due to attrition, and sample size differences between groups. Additionally, Clark did not report the distribution of deaf parents between groups, so given the small sample sizes in group comparisons, parent hearing status could have been a confounding factor. Finally, because the early intervention cutoff age was 30 months, and the average age of testing was slightly older than 42 months, treatment length differences could have affected short-term language outcomes.

Watkins (1983, 1984, 1987) concluded that hearing impaired children who received intervention earlier performed better on language measures. Watkins (1987) also reported that age-based effects were not educationally significant, but her definition that required an effect size of .5 for educational significance was quite stringent. For children at risk of failure, an effect size smaller than .5 could be considered practically and educationally significant for language outcomes (e.g., see Borman et al., 2005). The quality of this study was rated as good, given the thorough reporting, quasi-experimental design with careful matching and analysis of group differences, statistical analysis that included variables that were correlated with outcome measures as covariates, and a complete reporting of SMDES for all outcome measures.

The Strong and colleagues (1992; Strong & Clark, 1992; Strong, Clark, Johnson et al., 1994) study was rated as fair quality due to the longitudinal design with a large sample that included all children for whom data had been collected, although almost half the original sample was eliminated because of missing outcome data. No analysis of group differences for those with and without outcome data was conducted. This study does not specifically address whether earlier intervention is better than later—instead, the purpose of the study was to estimate the impact of the SKI*HI program. The researchers showed an overall average increase per month in developmental language outcomes beyond that accounted for by maturation, but this gain was due to the treatment, and not specifically age of identification or intervention. Additionally, this gain suggests that length of treatment plays a large role in determining language outcomes. A regression analysis resulted in an R^2 of .11, indicating that 11% of the variance in expressive and receptive language scores could be attributed to the block that included age at intervention and treatment amount.

Individual studies of younger children. Greenberg (1980) assessed the expressive and receptive language skills of preschool age children as they interacted with their mothers. Fourteen of the mother-child dyads communicated using manual and oral communication while the other 14 used only oral language. The sample included only mothers who demonstrated an “active and committed” preference in using the mode of communication, although there were differences between the two groups in the number of mothers who were single. Greenberg separated the two groups further by those dyads that communicated at a high or low level. Although Greenberg did not report statistics to allow calculation of the magnitude of effect, he claimed that the differences between the groups were “more accurately conceptualized as a function of the amount of school experience and age at diagnosis” (p. 469). Overall, this study was rated very poor due to severe selection bias, reporting omissions, reliability of outcome measures, and insufficient descriptions of interventions, population, and sample.

Robinshaw (1995) conducted a longitudinal case study in which she compared observations of five children with hearing loss to observations of later-identified children reported in a different study by another author (Tait, 1987). Robinshaw claimed that children with hearing loss who were fitted with hearing aids at earlier ages transitioned to higher levels of linguistic behavior much earlier than the group reported in the Tait study. No effect sizes could be calculated, and the quality rating was very poor given the small sample size and use of a comparison group which Robinshaw did not observe. Instead, the comparison group was studied and reported by another researcher.

Individual studies of older children. Ashby (1995), Cunningham (1999), Davis and colleagues (1986), Kennedy and colleagues (2006), Theisen-Washburn (1988), Vernon and Koh (1971), and Wake and colleagues (2004, 2005) all included participants tested at older ages, ranging from 5 to 18 years old, who attended school in a variety of public and residential school settings. Authors of all of these studies except for Kennedy et al. found effects near zero for the relationship between age at identification or intervention and language outcomes. Ashby claimed the small effect size supported the importance of earlier intervention. Sample sizes ranged from 29 to 120 participants, and most of these studies were single group posttest only retrospective designs. All except the Wake et al. and Kennedy et al. publications were rated poor or very poor due to methodological concerns including severe selection bias, nonequivalent groups, attrition, single outcome measures, and measures with questionable reliability.

Wake and colleagues (2004, 2005) investigated the population of children in Australia identified between 1991 and 1993, and given the comparability of the nonresponse group, the quality of this study was rated as good. These researchers found little support for earlier intervention on language outcomes. Kennedy and colleagues (2006) located all children in Southern England with confirmed hearing loss who were identified between 1992 and 1997, although only 120 of 168 agreed to participate in the study. Non-participants were similar to participants with respect to age during study, gender, and severity of hearing loss; however, differences based on age at identification or other factors were not reported. Assessors were blind to the audiologic history of the child, and the SMDES average for receptive and expressive language assessments was .35. This study was rated as fair in quality as non-participant group differences for age of identification or other factors related to language outcomes (e.g., maternal education) were not reported.

Geers and Moog (1989), Levitt (1987; see also Levitt & McGarr, 1988; Levitt et al., 1987), and Moores and colleagues (1978) also tested children with hearing loss at later ages, but no magnitude of effect could be calculated with the data reported. These researchers claimed that earlier intervention improved language outcomes, although the quality of all three studies was poor or very poor, which makes the researchers' conclusions questionable. The methodological concerns reported for the previous studies apply to these studies as well.

Liff (1973; see also Horton, 1975, 1976; McConnell & Liff, 1975), Markides (1986), and Ramkalawan and Davis (1992) found large positive effects for age of intervention on language outcomes, with effect sizes ranging from a partial correlation of $r_p = .39$ for age at intervention to a SMDES of 1.19 between a group in which intervention began prior to 36 months and one in which participants started later. However, serious methodological problems were apparent. No population description, and attrition or selection based on complete outcome data caused a severe selection bias in all three of these studies, and Liff and Markides used single outcome measures with poor reliability and did not analyze differences between groups. Ramkalawan and Davis, and Liff, had small sample sizes and conducted many statistical analyses, resulting in questionable use of statistics. The quality ratings of all three studies were very poor.

Weisel (1989) and Weisel and Reichstein (1989) involved public school students in Israel who were tested at older ages, ranging from 7 to 16 years of age. Both studies suffered from selection bias and attrition. Weisel and Reichstein used a single outcome measure for speech production performance with questionable reliability which, combined with other methodological concerns, led to a quality rating of very poor. Weisel included a variety of assessment measures for expressive and receptive communication, speech production performance, and standardized tests of reading and writing skills with more complete reporting of study design and procedures, resulting in a fair quality rating. The findings from both studies indicate that earlier intervention resulted in poorer language outcomes.

Musselman and Kircaali-Iftar (1996) and Musselman and colleagues (1988, 1989; see also Musselman, 1990) were the highest-quality studies that included participants who had attended a variety of intervention programs and who were tested at older ages. While these studies both suffered from selection bias as only participants with complete outcome data were selected, both designs controlled for many other threats to validity.

Musselman and Kircaali-Iftar selected the 10 highest scoring and the 10 lowest scoring from a sample of over 200 students, and explored differences between the two groups. Musselman, Wilson and Lindsay conducted a single group pretest/posttest study with pretest scores as a covariate. Both studies were rated as fair quality and no relationship was found between age of intervention and language outcomes. Musselman and colleagues (1988) concluded that the findings did not support "evidence of lasting gains associated with intervention during infancy…. Given this pattern of findings, we must ask why early intervention continues to receive widespread support within the educational community" (pp. 227-228).

Studies published in the last 5 years. Five studies that report the relationship of language outcomes based on age at identification and intervention for children with hearing loss (and that are not specific to the much smaller percentage of children with profound hearing loss who receive cochlear implants, as discussed in the section describing reviews of that body of research) have been published in the past five years. These studies were all conducted outside the US, with most reporting findings from populations of children with hearing loss from those countries (e.g., Austria, Australia, United Kingdom, Canada). In the two studies from the United Kingdom (Kennedy et al., 2005, 2006; Worsfold et al., 2010), SMDES based on differences between groups that were identified at 9 months of age and less, or older than nine months, were moderate at .35 and .21, respectively. Children in these studies were assessed during elementary school years. However, differences in language skills were observed for some measures and not others (e.g., narrative skills, expressive syntax, but not expressive phonology).

No covariates were included in the analyses. In two of the studies (Fitzpatrick et al., 2007; Holzinger et al., 2011), small R^2 measures of effect size (R^2 = .07 and R^2 = .03, respectively) provided some support that earlier identification was better when controlling for other factors, such as severity of hearing loss, parent hearing status, and family education. However, the contribution to explaining variability in outcomes was only 3-7%, indicating that other—potentially unmeasured—factors played a greater role in explaining outcomes. Finally, Harris and Terlektsi (2011) reported a negative influence of earlier identification and intervention on language outcomes for post-elementary school aged children, selected by group: hearing aids (earlier), cochlear implants (earlier), and cochlear implants (later). Again, no other factors potentially related to outcomes were included in the analysis. Together, these studies provide some evidence that earlier identification was better, though average findings for the contribution of age at identification were small.

Overall, this substantial number of studies reported in a wide variety of publications across many years provide inconclusive support for the benefits of early intervention for children with hearing loss. Although authors of only 12 of the studies claimed that the evidence did not support earlier intervention, another 18 of the studies resulted in effect sizes of less than .10. Of those studies that were rated “fair” quality and children were assessed at elementary school ages, two showed positive effect sizes, two indicated zero effect, and two suggested a negative impact. The number of studies that showed no differences between those who started intervention early and those who started later when language outcomes were measured at older ages raises questions about the long term effectiveness of early intervention: Do positive effects from earlier intervention “wash out” as the children get older? Do those children who start intervention later catch up? Are there other factors such as parent involvement or duration and dosage of intervention that contribute more to long-term outcomes than does age of identification or intervention?

As Greenberg and Kusche (1987) pointed out, research on children with hearing loss has been greatly affected in the last few decades by many substantive changes in laws, education settings, communication methodologies, attitudes towards deaf culture, technology used to identify and treat hearing loss, and medical advances that have lowered infant mortality rates but increased the number of infants with multiple disabilities that include hearing losses. These many changes have resulted in cohort differences across each of the decades in the past 50 years, making comparisons between cohorts questionable and conclusions drawn from past research difficult to generalize. Table 13 provides an indication of those cohort differences by showing the numbers of studies from which researchers concluded earlier intervention was better (a) overall, (b) for those studies published before or after 1990, and (c) for those studies in which language outcomes were assessed before or after age five. Given the strong bias for support for earlier intervention from studies in which children were assessed at younger ages, recognizing that Yoshinaga-Itano has published prolifically, the concern about cohort differences expressed by Greenberg and Kusche should be considered in any review of studies investigating the effects of age of identification or intervention on

Table 13

Comparison of Researchers' Conclusions Drawn from Studies Reviewed

	Number of researchers who said			
	Yes		No	
Is earlier identification and/or intervention effective? (percentages are based on row totals)	*n*	%	*n*	%
All studies included in analysis	30	70	13	30
Studies published in 1990 or later	20	77	6	23
Studies published before 1990	10	59	7	41
Studies in which the posttest age was less than 60 months	18	86	3	14
Studies in which the posttest age was 60 months or more	12	55	10	45

language outcomes for children born with hearing loss. In particular, note that for children assessed after age five, regardless of when the study was conducted, almost half of the studies indicated that earlier age of identification or intervention was not related to better language outcomes.

Study characteristics that covary with outcomes. An analysis was conducted to identify study characteristics that covaried with outcomes. Study characteristics included the following, some of which were listed earlier in Tables 8 and 10 in Chapter II, and others of which are displayed in Appendix C: quality of the study, study design, number/severity of methodological concerns, year study was published, definition of "earlier," average age at identification or intervention, average posttest age, sample size, intervention focus (e.g., child-centered, family-centered), intervention location (e.g., school, home, center), years since graduation from early intervention, communication mode(s) of participants, degree of hearing loss of participants, whether participants had additional disabilities, hearing status of parents, and whether authors claimed the study showed evidence for early intervention.

A correlational analysis revealed few relationships between study characteristics and effect sizes. Interestingly, while study quality was not statistically significantly correlated with effect sizes, effect sizes were moderately correlated with the total number of methodological concerns identified as potentially severe threats to validity ($r = .52$, $p < .005$), and the number of methodological concerns was related to the quality of the study ($r = -.64$, $p < .005$). This relationship indicates that as effect size increased, the number of methodological concerns increased, and as the number of methodological concerns increased, study quality decreased. Additionally, effect sizes were related to researchers' answers to the question, "Does early intervention improve language outcomes?" In other words, larger effect sizes were related to "yes" answers to the question ($r = .54$, $p < .005$), while smaller effect sizes were related to "no" answers. No other study characteristics were statistically significantly correlated with effect sizes.

The only other statistically significant correlations that provide insights into research involving children with hearing loss are variables that were related to publication year: definition of "early" ($r = -.78$, $p < .000$) and average age at posttest ($r = -.53$, $p < .000$). These relationships provide an indication that the definition of "early intervention" has decreased over time and that the average age at posttesting has decreased—both an indication of the large number of studies published in the last decade that define "early" as 6 months of age, and that test children upon graduation from an early intervention programs at age 3. Previously, early intervention programs ended at age 5 or later, as was often the case prior to the passing of Public Law 95-147 in 1986.

Conclusions Based on Review of Primary Studies

Overall, findings from the 43 primary studies (which resulted in many more than 43 publications) reviewed in this section were inconclusive. While authors of 70% of the studies concluded that earlier intervention promotes later language outcomes, 30% of the studies resulted in no significant differences, including many studies in which participants were assessed at much later ages. Authors of one of the most frequently cited studies in support of early intervention (Strong et al., 1994) did not directly address the question, “Is earlier better?” but data support the conclusion that treatment length was a strong predictor of language outcomes, so earlier intervention with participation continuing over time would provide longer opportunity for language gains. Given the young age at which outcome measures were assessed in most studies (five years or younger) and the shorter treatment time experienced by those entering later, more research is needed to determine if early intervention effects produce long term developmental gains.

The fact that the quality of previous research has been mostly poor supports a need for higher quality research to determine the effects of earlier intervention. Because treatment length or intensity appears to play a role in short-term language outcomes, research that accounts for this confounding factor, as well as others, is also needed.

Additionally, a likely critical confounding factor was not mentioned or explored in greater detail in a single one of these studies—that of program dropouts. In the 24th

Annual Report to Congress on the Implementation of the Individuals with Disabilities Education Act (IDEA; US Department of Education, 2002), the authors stated that for children who were less than 26 months old when the data for the report were collected, one in five no longer received services under IDEA one year later. Who were these children—and their families—who dropped out, and how did their developmental outcomes differ from those who continued to receive services?

Those few studies reviewed in this section that mentioned attrition glossed over the effects of attrition on study findings and overall developmental outcomes for children with hearing loss. For example, Strong and colleagues (1992) stated that "All children for whom there was both pre- and posttest data were used; there is no reason to expect that SKI*HI children (a) who dropped out of the program prior to posttest or (b) who entered the program mid-year and were only assessed once during the year or (c) for whom "parent advisors" did not report posttest data differed systematically from those who had both pre- and posttest data" (pp. 240-241). Others reported that children participating in the research and for whom the researchers collected outcome data were representative of the population of children with hearing loss in the US (Musselman et al., 1988; Musselman, 1990), or that those for whom outcome data was missing were likely similar to those from whom data was collected (Clark, 1979; Naidu, 1995; Yoshinaga-Itano, 2003a, 2003b).

Despite these authors' claims, were the samples of children with hearing loss who participated in these primary studies representative of the general population of children with hearing loss who should have received early intervention services? This researcher would emphatically say, "not likely!" For example, in a recent longitudinal randomized study of Early Head Start (EHS), a program serving low-income families and their children from birth through age 3, the following differences were found between those who dropped out prior to 24 months of age and those who stayed involved in the EHS program (Roggman, Boyce, Cook, Callow-Heusser, & Hart, 2002).

- Were ethnic minorities (SMDES = .21),
- Experienced regular family unemployment (SMDES = .34),
- Had lower education levels (maternal SMDES = .75; paternal SMDES = .91),
- Moved multiple times per year (SMDES = .26), and
- Exhibited a lower incidence of clinical depression (SMDES = .20).

Families who have a child identified with hearing loss are disproportionately represented as low income, of minority ethnicity, and with lower levels of parental education (US Department of Education, 2002). Are those who dropped out of intervention programs for children born with hearing loss and their families likely to be different than similar families who dropped out of the EHS program? What happened to those children with hearing loss who did not continue to receive intervention services, and why did they drop out? How did they differ in age of identification and intervention, access to services, family and child characteristics, and developmental outcomes? How did their language skills compare to those who continued to receive services? Claims about the effectiveness of early intervention made by the researchers who published the primary studies analyzed here can only be attributed to those families who continued to participate in services—a group that is likely not representative of the population of families that included a child identified with hearing loss.

Overall, both the reviews and the primary studies analyzed here provided inconclusive evidence for the impact of early identification and intervention for children born with hearing loss, and the findings are of questionable generalizability. However, this body of literature suggested many factors and variables that should be considered in planning better studies that would provide stronger evidence for the effectiveness of early intervention for children identified with hearing loss. These factors will be discussed in more detail in another section.

Methodological Problems of Prior Research

Previous investigations of the relationships between early intervention and children's developmental outcomes have suffered from serious methodological problems (see Appendix A), which precludes drawing conclusions about the efficacy of early identification of hearing loss and intervention, or which types of learning are most appropriate at which ages to best promote the strongest outcomes for children born with hearing loss. In particular, investigators did not study individual intervention components to determine the impact of different opportunities. Also, they used small sample sizes, reported questionable sample selection methods and varying lengths of treatment, and employed poor or limited use of statistical methods. Most previous studies were based on comparison group designs using convenience samples with purposeful selection—the groups were matched based on selected demographic criteria that rarely included most relevant factors that the research literature suggests would be related to language outcomes. Correlational statistics, tests of differences of group means, analysis of variance (ANOVA), and chi-square measures of group association were the most used statistical methods, and small sample sizes limited use of covariates. While Weisel (1989) used MANCOVA as the statistical method of analysis and controlled for independent variables that were correlated with outcome measures, most researchers grouped the samples based on dichotomous or categorical factors that had no documented research support (e.g., identified before or after 6 months of age). This grouping resulted in a loss of power because a continuous variable (e.g., age in months) was treated as categorical. Stronger sampling criteria or advanced statistical methods were rarely used.

Because of the methodological weaknesses and mixed results of previous studies, many researchers and policy-makers have called for more rigorous research to provide evidence for UNHS and early intervention for children born with hearing loss (Bess & Paradise, 1994; Carney, 1996; Meadow-Orlans, 1987; NIH, 1993; Paradise, 1999; Thompson et al., 2001). In a widely cited summary of evidence, Thompson et al., stated that the efficacy of early identification and subsequent intervention in improving long term language outcomes remained uncertain due to the lack of adequate research.

While the review of the literature described previously supports that assertion, Carney (1996), as well as many other researchers (Calderon, 2000; Yoshinaga-Itano, 1995), pointed out in her response to Bess and Paradise (1994) that controlled clinical trials employing random assignment to investigate the long term effects of early identification and early intervention would be unethical—no clinician would intentionally withhold treatment from an infant identified with a disability. Furthermore, Institutional Review Boards for the protection of human research participants would probably not approve such a protocol.

Yet, as shown in the review of the literature, we do not have sufficient evidence to show which intervention, including no intervention, would be best and for which groups of individuals under what conditions. Boruch (1997) pointed out that researchers are much more likely to believe their programs will result in positive outcomes than would be supported by research employing well-executed experimental designs. In reviewing experimental research, Boruch found that only 35% of new interventions in the social sciences succeeded relative to the control groups, and a mere 20% of new medical therapies improved patient outcomes. Because early intervention for hearing loss includes both medical innovations (e.g., hearing aids) and social or educational interventions (e.g., speech, language, and hearing therapy; grief counseling; communication methods and skills), it would be surprising if all components of typical programs delivering early intervention for hearing loss showed positive and practically significant results in randomized controlled studies.

However, the difficulty and impracticality of using RCTs to research earlier versus later intervention for children with hearing loss is supported by the fact that not a single randomized experiment was included in any of the twelve reviews cited previously. Despite the continued call for RCTs to determine the long-term impacts of early intervention for children born with hearing loss and their families, substantial funding for and political interest in conducting RCTs to determine the impacts of earlier intervention is negligible—in fact, not one of the grants researching early hearing detection and intervention (EHDI) funded by the Centers for Disease control indicates an experimental research design (CDC, 2011, http://www.cdc.gov/ncbddd/hearingloss/

projects.html), despite the strong call for such research over the past decade. Without substantial funding and support from political, professional, and advocacy groups, it is likely that we will have to rely on quasi-experimental studies to provide evidence for the effectiveness of early identification of hearing loss and early intervention by systematically adding to the evidence additional studies that differentially control for threats to validity.

Prior intervention research with its multitude of methodological problems provides, at best, weak and largely inconclusive support for earlier intervention with children with hearing loss. Bruer and Greenough (2001) summed up this conundrum elegantly:

> If indeed what people learn is a function of the environments they inhabit, the larger policy challenge is to decide which living and learning environments to foster and which to discourage. This is a complex political and moral challenge that...science, no matter how far it advances, will never be able to meet alone. (p. 230)

Conclusions Drawn from Prior Research

Because of the methodological weaknesses and mixed results of previous intervention studies, many researchers and policy-makers have called for more rigorous research in support of UNHS and early intervention for children born with hearing loss (Bess & Paradise, 1994; Carney, 1996; Meadow-Orlans, 1987; NIH, 1993; Paradise, 1999; Thompson et al., 2001). While the review of the intervention literature described previously supports the need for more rigorous research, few researchers would support RCTs, and Institutional Review Boards would be unlikely to approve them if treatment were withheld from children.

Because RCTs are not likely to be supported, higher-quality research incorporating designs that better account for threats to validity is needed. A recent call for better research was issued by the Agency for Healthcare Research and Quality with the following statement (Russ, 2009; http://www.ahrq.gov/about/nac/sruss.htm):

> There are many questions regarding the best types of intervention for children with early hearing loss, and little evidence in the field on which to base decisions. It is widely believed that this dearth of research must be addressed if outcomes for children that [sic] are deaf or hard of hearing are to improve.

Contextual and Environmental Factors Related to Language Outcomes for Children Born with Hearing Loss

Bronfenbrenner's Bioecological Theory of Development (1989; Bronfenbrenner & Ceci, 1994; Bronfenbrenner & Evans, 2000; Bronfenbrenner & Morris, 1998) reminds us that the environments in which people develop are complex systems and include many interrelated factors that influence development. More complex models could provide additional evidence for early identification of hearing loss and intervention and their causal effects on developmental outcomes. Ideally, a wide variety of factors that potentially affect outcomes would need to be included in these models.

Previous research has provided evidence for many contextual and environmental factors that are related to developmental outcomes for children born with hearing loss. Factors included in the studies reviewed in this dissertation are listed in Appendix C. While the list of factors may not be exhaustive, it reveals the complexities of the developmental environments in which children with hearing loss live and interact.

Though the review of research suggests some of these factors were unrelated to developmental outcomes, studies of other at-risk populations provide support for the relationship between many of these factors and outcomes (e.g., Early Head Start Research Consortium, 2002; Mathematica Policy Research, 2002; Meadow-Orlans, Mertens, & Sass-Lehrer, 2003; Roggman et al., 2002). Given theories or evidence that these factors are likely to impact language outcomes for children born with hearing loss, strong research designs that include measurement of these factors with large enough samples to meet statistical power recommendations are needed.

Summary of the Evidence Supporting Early Identification of Hearing Loss and Intervention

Overall, the evidence supporting earlier identification and intervention for children with hearing loss provided mixed findings. While over 70% of the researchers claimed their studies provided support for "earlier is better," almost half of the studies in which children were assessed at older ages showed no relationship between age at identification or intervention and language outcomes. Additionally, most of the studies investigating whether earlier is better were rated as poor or very poor quality studies. Not one study included in the review was based on an experimental design in which children were randomly assigned to condition—the criteria for a high quality study. Of those studies that were rated "fair" quality and children were assessed at elementary school ages, two showed positive effect sizes, two indicated zero effect, and two suggested a negative impact. Results such as these draw into question the claim that earlier identification of hearing loss and intervention resulted in better language outcomes, although given the quality of many of the studies, it is hard to place confidence in findings, regardless of the magnitude and direction of effects.

Table 14 shows the magnitude of effects for various subgroups of the studies analyzed in the comprehensive review of the literature. All effect sizes were positive, indicating that, on average, the evidence supported the claim, “Earlier is better.” When “earlier” was defined categorically (i.e., children who were identified or treated before a specific age cutoff), effect sizes were larger. When age was included as a continous variable in a multivariate analysis of variance, the effect sizes were considerably smaller and other variables included the models (i.e., levels of parent involvement, language spoken at home) accounted for a proportion of variance in the outcomes. In particular, effect sizes when children were assessed at ages greater than five were smaller than effect sizes when children were assessed at younger ages. The raises questions about the longer term impacts of intervention and the need to conduct high quality research to determine which interventions have a positive impact on children beyond their enrollment in school.

Table 14

Summary of Effect Sizes for Groups of Studies

Effect sizes	Parents with severe or profound hearing loss	Hearing parents
Average SMDES	.23	.32
SMDES: Good quality study	NA	.18
SMDES: Age at posttest > 5 years	.23	.19
Average R^2	NA	.08
R^2: Age at posttest > 5 years	NA	.06

Adding to Existing Knowledge of Relationships Between Contextual Factors and Language Outcomes for Children Born with Hearing Loss

Most prior studies of developmental outcomes of children born with hearing loss have been conducted with relatively small numbers of participants. Statistical power for small sample sizes limits the numbers of variables that can appropriately be included in an analysis. As a result, much of the published research on early identification of hearing loss, intervention, and language outcomes includes few additional factors that may influence outcomes. Given the complexity of human development described with Bronfenbrenner's Bioecological Theory, more evidence is needed about the relationships between developmental outcomes of children born with hearing loss and the many contextual and environmental factors that may play a role in the efficacy of intervention on those outcomes. In particular, given the importance of communication skills on success in school and in our society at large, research that contributes to existing knowledge about relationships between language outcomes and contextual factors that affect these outcomes is crucial.

However, statistical methods used to test complex models and explore relationships between hearing loss, language outcomes, and factors affecting outcomes require data sets with (a) large sample sizes, (b) a sufficient number of measured variables to develop models to explore the relationships among variables or constructs described by those variables, (c) measures with adequate validity and reliability, (d) sufficient variability in data, and (e) data that meet requirements of the assumptions upon which the statistical methods are based. Previous research conducted using data from the SKI*HI National Data Bank suggested the data met these requirements.

Summary of the Literature Review

The literature reviewed showed UNHS is expanding rapidly in part because of the widespread belief that earlier identification of children with hearing loss and intervention results in improved developmental outcomes. Advocates of UNHS and early intervention—including advocacy groups, professionals, policy makers, and researchers—often cite "the research" in support of this belief. However, both reviews of the research on early intervention for children with hearing loss and primary studies suffer from methodological weaknesses, making their conclusions unconvincing. Reviews exhibited sampling bias and lack systematic methods for analyzing studies, and conclusions from primary studies were weakened due to the many threats to validity including weak quasi-experimental designs, selection bias, small sample sizes, poor use of statistical methods, and differences in length of treatment and characteristics of the participants. Additionally, the findings from primary studies were inconclusive—while some researchers concluded that earlier intervention produced better developmental outcomes, others claimed there were no differences, particularly when children were assessed at older ages.

Given the poor quality of most prior research, many researchers have called for research using stronger experimental designs that better control for threats to validity, such as RCTs. Because RCTs are costly and would require substantial funding and political, professional, and parental support, alternative analytical techniques are needed to investigate whether earlier identification and intervention for children with hearing loss leads to better developmental outcomes. Advanced statistical modeling tools can help provide such evidence, as they can be used in a post hoc analysis on a large data set to help provide a better accounting of the actual contributions of age of identification and intervention, as well as other factors that might influence language outcomes for children with hearing loss. The SKI*HI data set is sufficiently large and contains variables with sufficient variability that comprise a number of factors that can be tested to determine the relationships between child and parent characteristics, intervention characteristics, and language outcomes. Previously, data from the SKI*HI National Data Bank have been used to determine the impact of the SKI*HI program on children's language skills, but they have not been analyzed using more advanced statistical techniques. The purpose of this study is to use data from the SKI*HI National Data Bank to investigate, using more advanced statistical modeling tools, the relationships among early identification, intervention, and other factors on language outcomes for children born with hearing loss.

CHAPTER III

METHODS

For this study, an existing data set from the SKI*HI national data bank was used. The SKI*HI program (Strong et al., 1992) was developed in the 1970s as a model program for early identification of children with hearing loss, and for providing early intervention to those children from birth through age five and their families. The SKI*HI model was validated by the US Department of Education's Joint Dissemination Review Panel in 1978, and was revalidated in 1984 and 1990. The SKI*HI model was implemented by over 260 agencies in the US, Britain, and Canada. These programs served over 4,000 children annually using a home-based early intervention approach. The SKI*HI program was based on a theoretical model supported by the research on early intervention (Strong et al., 1992). The program was built on the assumption that earlier identification and family-focused, home-based early intervention would ameliorate the negative impacts of hearing loss on the child and family. Language and communication development were key aspects of the program, with the goal of ensuring the child was prepared to enter and succeed in school.

Although demographic and outcome data were collected through SKI*HI beginning in 1973, the SKI*HI national data bank was established in 1979. Data collection for the SKI*HI national data set was initiated as part of a national effort to better understand the demographic characteristics of children with hearing loss and their families. Prior to this funding, systematic data collection from children with hearing loss had not been conducted on a large scale. The data collection effort was funded to learn more about these characteristics so children with hearing loss and their families could be better served. The SKI*HI data set also provided information about the effectiveness of the SKI*HI program in (a) identifying children with hearing loss earlier and (b) getting them enrolled in early intervention services.

The SKI*HI national data bank and the instruments used to collect data served these purposes well. With only 40 children in the beginning, the data set increased to 2,200 children by 1987 and almost 5,200 children by 1991. Previous studies using this data set included investigation of descriptive characteristics of children with hearing loss and their families, examination of the relationships among demographic characteristics, and evaluations of the effectiveness of SKI*HI early identification and intervention (Clark, 1979; Strong et al., 1992; Strong, Clark, & Walden, 1994; Watkins, 1984, 1987). While these researchers investigated the differential effects on child outcomes of the SKI*HI home-based intervention when compared to untreated children, or to predicted outcomes based on maturation, the purpose of this dissertation was to use a structural model with the SKI*HI data set to examine how age at identification of hearing loss and intervention, child and family characteristics, treatment characteristics, and parent outcomes were related to language outcomes of children with hearing loss.

Research Design

In this study, a retrospective analysis was used to examine the relationships between earlier identification and intervention, as well as other factors, on language outcomes of children with hearing loss. The data set included all data collected from the accessible population of children with hearing loss enrolled in the SKI*HI program from 1979 through 1991. Previous research by Strong and colleagues (1992) on the effectiveness of SKI*HI home-based programming examined the theoretical model shown in Figure 2 (adapted from Strong et al., 1992). The rectangles, variable labels, and arrows are those that were included in the original model. In the present study, confirmatory factor analysis (CFA), which is the first step in structural equation modeling (SEM), and SEM were used to (a) test the fit of the theoretical model to the SKI*HI data; (b) determine the degree to which contextual and environmental characteristics were related to developmental outcomes in children born with hearing loss; and (c) determine if results were different for children with hearing parents when compared to children with at least one parent who had a severe or profound hearing loss.

Participants

The SKI*HI national data bank included data collected on young children with hearing loss served by SKI*HI from July 1979 to June 1991 (Strong et al., 1992). Data submission to the SKI*HI national data bank by SKI*HI sites was voluntary. Although SKI*HI served over 4,000 children across the US each year, the number of sites that submitted annual data varied. For example, Strong et al., reported that during the 1989-1990 program year, approximately 28% of the sites served by SKI*HI submitted data. The accessible population used for this dissertation was all those who were served from 1979 to 1991 from whom data were collected. Descriptive statistics for the data set were reported in the final report by Strong and colleagues (1992) to the US Department of

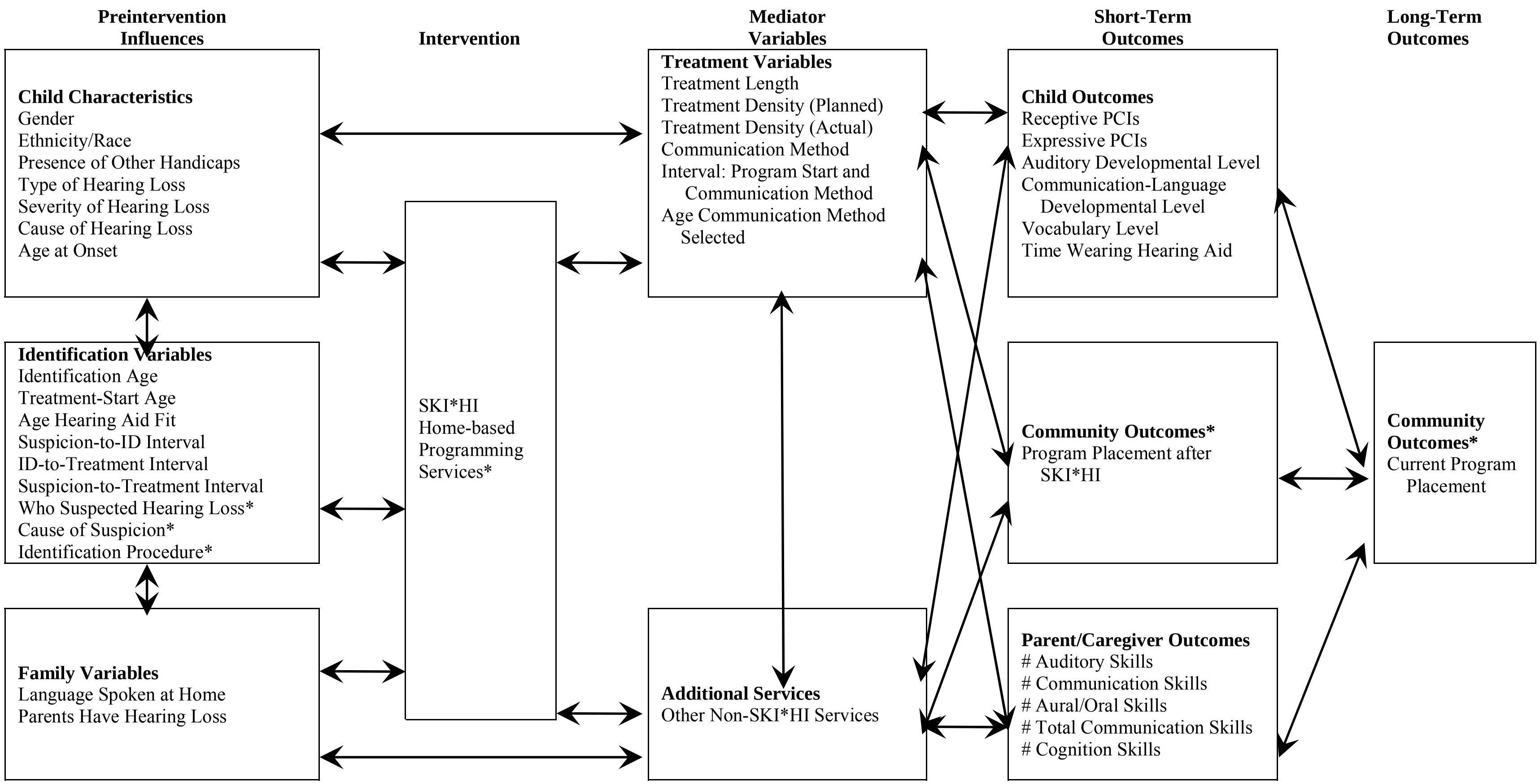

Figure 2. Model for research on the effectiveness of the SKI*HI program, adapted from Strong et al. (1992).

Education's Office of Special Education and Rehabilitative Services (contract number H023C90117). While the thorough reporting of descriptives contained in that report is not repeated here, additional analyses that were important to understanding the data set and analyzing the data with SEM were conducted and reported in the following sections.

The sample used for this dissertation was comprised of the entire accessible population, which included 5,177 children from 143 agencies in 30 states. Sample sizes and descriptive statistics for variables included in this data set are shown in Appendix D. However, some of the measures of variables included in the theoretical model were developed and piloted in 1986 and used for data collection from 1987 to 1991. These additional measures were implemented only at sites that agreed to participate. In particular, measures of SKI*HI treatment variables and parent outcomes were implemented after 1986. Given these changes in instrumentation, a subset of the data collected from 1987 through 1991 will be used for the CFA and SEM analyses. Appendix E includes descriptive statistics for that subset of data.

Measures

The SKI*HI Language Development Scale (LDS; Hope Publishers, 2004) lists the expressive and receptive language skills that a child of a particular age would typically demonstrate. Home visitors observed whether the child showed evidence of a skill, and if so, that skill was awarded two points. Scores on the LDS expressive and receptive scales ranged from zero to sixty. Reliability and validity for the LDS scales were established in previous studies (Strong et al., 1992; Tonelson, 1980). To summarize, interrater agreement was 80% and 78% for the LDS receptive and expressive scales, respectively. Test-retest reliability was .86 for the receptive scale and .92 for the expressive scale. Internal consistency coefficients were .93 and .94 for receptive and expressive scales. Concurrent validity was determined through a comparison with the Receptive-Expressive Emergent Language Scale (REEL; Bzoch & League, 1970). Coefficients were .78 for the receptive scale and .79 for the expressive scale.

Trained home visitors, or "parent advisors," recorded intervention characteristics, child and parent characteristics, and level of communication skills for child (e.g., *communication language development level*) and parent (e.g., *number of parent communication skills*) on the SKI*HI Data Sheet, which was developed and validated by Utah's SKI*HI Institute staff (Strong et al., 1992). Intercoder agreement was reported to be 87%. A copy of the SKI*HI Data Sheet and its coding key are included in Appendix F. The SKI*HI guides for completing and submitting the data (*Step-by-Step Guide to Completion and Submission of SKI*HI Data Sheet*) and coding the data (*SKI*HI Data Coding Instrument and Coding Conventions*) are also included in Appendix F.

Child outcomes (other than the LDS) and parent outcomes were measures of skill levels that were recorded by a home visitor on the SKI*HI Data Sheet either every visit or monthly, depending on site-specific procedures. Parent communication method determined which data were collected. For example, if a parent chose to communicate with their child using American Sign Language, their aural-oral skills were not measured. Because of the cost of sending two home visitors to a home, no measures of interrater reliability were collected for these measures, and no other measures of reliability were reported (Strong et al., 1992). However, CFA includes a measure of indicator reliability, or the degree to which the variability in an indicator is explained by the factor it is supposed to measure (Hatcher, 1994; Long, 1983). Indicator reliabilities are the square of the standardized beta coefficient between an indicator and the latent factor. In the "final" model presented in Chapter IV, indicator reliabilities for parent outcomes ranged from a low of $r^2 = .32$ (*number of parent cognition skills*) to a high of $r^2 = .50$ (*number of parent auditory skills*). Indicator reliabilities for child outcomes (other than the LDS scores) ranged from a low of $r^2 = .13$ (*hearing aid use*) to a high of $r^2 = .80$ (*communication language development level*). Because these CFA calculations are based on a specific measurement model, indicator reliabilities and the corresponding coefficient alpha measures of reliability for each factor will be further discussed in Chapter IV.

Some variables from the SKI*HI data set that were used in the theoretical model were calculated from other variables. For example, the number of months in the program was calculated from variables that included the month, day, and year of program entry and posttest date. *Proportional change indexes* (PCI; Strong et al., 1992) for the expressive and receptive scales of the LDS were calculated using the ratio of the average change in scores per month divided by the predicted expected change due to maturation.

Other variables included in the initial theoretical model (Strong et al., 1992; see Figure 2) were removed from the analyses because they were nonordered categorical or included substantial missing data, or recoded. For example, planned home visit frequency was reported for 96% of families, but frequency of visits actually made was reported for only 25% of these families (1,229 out of 4,984). Of the families for which actual frequency was reported, 92 were different than planned frequencies. Given this small proportion of families for whom actual frequency differed from planned frequency, and the amount of missing data for actual frequency, planned frequency was used in the model. Age at onset of hearing loss was not reported for 58% of cases. Reported value was “at birth” for another 30% of cases, and less than 1 year of age for an additional 7%, leaving only 5% of cases with other values. Hence, values of this variable were highly skewed with little variability. Thus, this variable was not included in the analyses.

Finally, some variables described in the original theoretical model were not included in the CFA or SEM analyses, because they were non-ordered categorical measures. According to Muthén (1993; see also Muthén & Muthén, 2006b) and Fox (2006, 2007), categorical variables use in SEM must be ordered categorical. Dichotomous variables can be ordered and used in CFA and SEM. However, categorical variables for which the order of values does not matter cannot be used because of the numerical calculations upon which these statistical methods are based. For this reason, type and cause of hearing loss, as well as communication method selected, were excluded from the analysis. While language used in the home could have been recoded to a dichotomous variable indicating whether the language used in the home was English, the recoding resulted in values almost identical to the variable indicating White/non-White (i.e., 98% of cases were identical). As such, this variable was excluded. Finally, all dichotomous and ordinal variables were recoded so scales started at zero, per recommendations of SEM software developers (Arbuckle, 1996; Muthén & Muthén, 2006b). Excluded and recoded variables are noted in Table 15.

Table 15

*SKI*HI Variables Used in the Theoretical Model*

Variable	Variable description	Scale	Values
sex[a]	Gender	O	1 = Male, 2 = Female,
race[b]	Race/ethnicity (recoded to white/Caucasian and non-white as variable was nonordered categorical, renamed white)	N	1 = Caucasian 2 = Black 3 = Others 4 = Asian 5 = Mexican/Latino 6 = American Indian
otherh[a]	Additional disabilities	O	1 = Yes, 2 = No,
✦	Type of hearing loss	N	1 = Not yet determined 2 = Conductive 3 = Sensorineural 4 = Mixed
sfu	Unaided hearing loss	I	0-120 decibel (dB) loss
sfa	Aided hearing loss	I	0-120 decibel (dB) loss
✦	Cause of hearing loss	N	1 = Unknown 2 = Hereditary 3 = Infections during pregnancy 4 = Meningitis 5 = Defects at birth 6 = Fevers or infection in child 7 = RH incompatibility/Kernicterus/ jaundice 8 = Drugs during pregnancy 9 = Conditions during pregnancy 10 = Middle ear problems/ENT anomalies 11 = Drugs administered to child 12 = Birth trauma 13 = Child syndrome 14 = Other 15 = Not reported
✦✦	Age at onset	I	Months (integer)
preldse	LDS expressive pretest score	I	0-60 score (integer)
preldsr	LDS receptive pretest score	I	0-60 score (integer)
ageid	Age at identification	I	Months (integer)
agehaft	Age at hearing aid fit	I	Months (integer)
progmos	Age at program start	I	Months (integer)
commtmos	Age communication method selected	I	Months (integer)
✦ ✦✦	Language spoken at home	N	1 = English 2 = ASL 3 = Spanish 4 = Other 5 = Signed English System
otfam[a]	Parent has hearing loss	O	1 = Yes, 2 = No
✦	Communication method selected	N	1 = Diagnostic-prescriptive 2 = Auditory (aural-oral) 3 = Total communication 4 = Other

(*table continues*)

Variable	Variable description	Scale	Values
prgpstdf	Treatment length (posttest—program start)	I	Months (integer)
✦✦	Planned frequency of home visits (recoded with categories 1 and 7 dropped as they are non-ordered, other values numerically reassigned in increasing order of frequency of home visits)	N	1 = Irregular 2 = Once per week or 3 times per month 3 = Every other week 4 = Monthly 5 = Bimonthly 6 = Twice per week 7 = Other
✦✦	Change in frequency of home visits	O	1 = Yes, 2 = No
✦✦	Actual treatment density	N	Same as Planned Frequency
commpmos	Program month select communication method	I	Months (integer)
✦	Additional services (non-ski*hi)	N	1 = Educational 2 = Mental health 3 = Health 4 = Social 5 = Mental retardation 6 = Other (combination services) 7 = Speech and hearing Rx 8 = Educational + speech and hearing Rx
as#	Number of parent auditory skills	O	1-11 score
cg#	Number of parent cognition skills	O	1-12 score
ao#	Number of parent aural-oral skills	O	1-9 score
cs#	Number of parent communication skills	O	1-22 score
tc#	Number of parent total communication skills	O	1-20 score
pcie	LDS expressive proportional change index	R	Ratio of change per month to expected change based on maturation
pcir	LDS receptive proportional change index	R	
postldse	LDS expressive posttest score	I	0-60 score (integer)
postldsr	LDS receptive posttest score	I	0-60 score (integer)
thaw[c]	Highest level of child hearing aid use (reassigned so lowest value = 0, highest value = 4)	O	1 = Less than ¼ time 2 = ¼ to ½ time 3 = ½ to ¾ time 4 = Over ¾ time 5 = All of the time
adl	Highest auditory development level	O	1-11 score
cldl	Highest communication language development level	O	1-12 score
vi	Highest vocabulary level	O	1-8 score

Scale: N = Nominal; O = Ordinal, including dichotomous scales; I = Interval; R = Ratio

[a] Recoded so values were 0 and 1

[b] Recoded so variable was dichotomous with values of 0 and 1

[c] Recoded as described

✦ Excluded because nonordered categorical

✦✦ Excluded for reasons described in text

The variables included in the initial theoretical model (Strong et al., 1992; see Figure 2) to examine the relationships between child, parent, and intervention characteristics, and child and parent language outcomes, are listed in Table 15. These variables were checked for outliers and inappropriate values. One case was deleted because it was clearly a test case (i.e., all values were outside allowed values and few variable values were included).

Investigating Theoretical Models Using SEM

Data analysis using SEM has become more widely used in social sciences research due to advances in software for testing structural models with latent factors. SEM is a set of statistical techniques that can be used to reduce a number of observed (i.e., measured) variables into a smaller number of latent (i.e., not observed or directly measured) factors, and to investigate the relationships among the constructs described by the latent factors. SEM can be considered analogous to combining CFA with path analysis (Hatcher, 1994) or exploratory factor analysis with multiple regression (Ullman, 2006). SEM is a two-step process whereby CFA is used to develop an acceptable measurement model, or a model that "fits" the underlying data. In a measurement model, every latent factor is allowed to covary with all other latent factors. The second step in SEM is a path analysis in which directional relationships between latent factors are specified and tested.

First Step: Develop an Acceptable Measurement Model with CFA

Using CFA to develop an acceptable measurement model is the first step in SEM. The initial measurement model tested with CFA was redrawn from Figure 2, which showed the theoretical model on which the SKI*HI program was based according to Strong and colleagues (1992). The CFA measurement model shown in Figure 3 includes curved arrows indicating covariance between factors rather than directional arrows. In the measurement model, all latent constructs are allowed to covary with all other latent constructs, as shown in the diagram. In Figure 3, the rectangles indicate the observed, or measured, variables. The ovals represent the latent constructs, or factors. Colors and bolded lines are included only to help the reader quickly identify variables associated with latent factors. Though measurement models are often drawn with additional circles representing residual terms, residual terms were not included in this diagram for the sake of readability.

The initial measurement model proposed for this study (Figure 3) was different than the model used by Strong and colleagues (1992, see Figure 2). Specifically, some of the latent factor and indicator labels were changed to better identify the contribution to the model. For example, race/ethnicity (*White*), severity of hearing loss (*unaided hearing loss*), and *additional disabilities* create the potential for *child risk* that could impact *child outcomes*. While *initial child language* may also indicate risk, initial language scores are strongly related to age of the child. For instance, a child identified with hearing loss at birth and assessed shortly after birth may score “0” on a measure of language skills because he or she is not yet old enough to register on that language measure. Hence, the

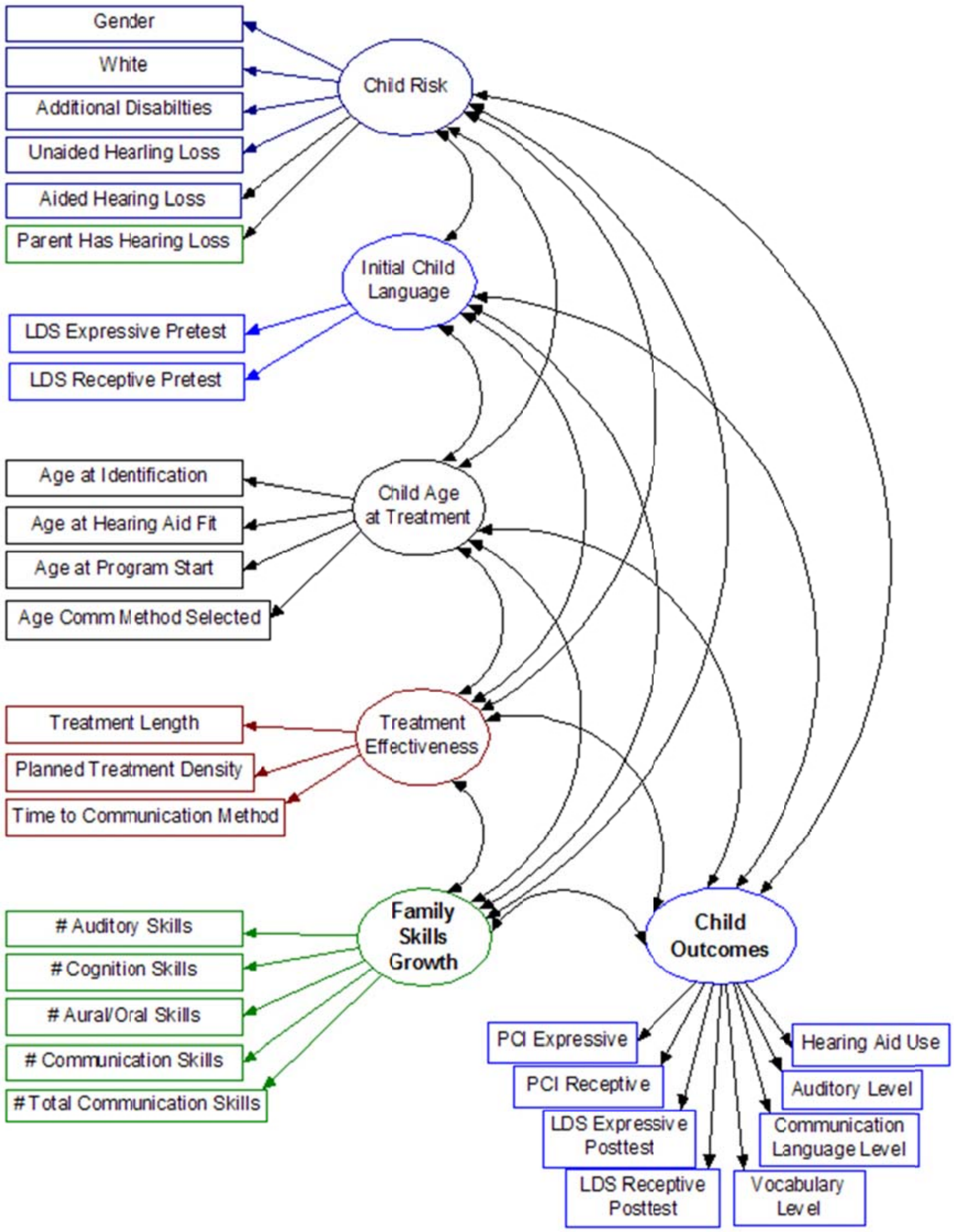

Figure 3. Initial measurement model adapted from Strong et al. (1992).

LDS pretest variables were separated from *child risk* and placed in a latent factor, *initial child language*. Because excluding nonordered categorical variables left the factor, *family characteristics*, with only one indicator, the variable, *parent has hearing loss*, was associated with the factor, *child risk.* This association seemed reasonable because, presumably, a child of a parent with severe or profound hearing loss would be more likely to be assessed for hearing loss at birth, and such a parent's behavior would likely be initially different from that of a hearing parent. *Child age at treatment* included ages at identification, hearing aid fit, program start, and communication method selection. These variables were included under a factor labeled "*treatment*" because, presumably, once a child is identified with hearing loss, behavior within the family changes. Nonordered categorical variables were excluded as described in the previous section.

Second Step: Testing Theoretical Models with SEM

When a measurement model with acceptable fit indices is identified, a structural (i.e., theoretical) model showing hypothesized directional relationships is developed. The directional relationships between factors are based on theory and empirical results from previous research. SEM estimates the magnitude and direction of relationships between theoretical constructs (i.e., factors that are not directly measured) and observed variables. For example, to determine the influence of earlier identification or intervention on outcomes for children with hearing loss, the contributions of factors such as initial child characteristics, parent growth in communication skills, and specific intervention characteristics can be calculated for the data to which a model is applied. Models should be thoughtfully specified prior to SEM analysis and should be defensible according to theory and empirical findings (Thompson, 2000). For this dissertation, theoretical models based on the CFA "best fit" measurement model were tested.

Assumptions Underlying CFA and SEM

CFA and SEM are based on a number of conditions. First, both methods require a relatively large number of cases compared to the number of parameters estimated in the model (i.e., for CFA, the sum of the numbers of variances and residuals for each indicator, and covariances between factors; for SEM, the sum of the numbers of variances and residuals for each indicator and each exogenous factor, or those with directional arrows leaving the factor, and path coefficients). Recommendations for what constitutes an adequate sample size vary, but complexity of the models, the number of measured variables associated with the factors, and multivariate normality must be considered in choosing sample sizes. One recommended heuristic is to use 5 to 10 cases per estimated parameter (Bentler & Chou, 1987; Klem, 2000). Stevens (1996) recommended 15 cases per measured variable, while Loehlin (1992) recommended at least 200 cases for 10 variables. Thompson (2000) and Mueller (1997) suggested that the ratio of sample size to the number of observed variables used in the model should be 10 to 1 at a minimum, and possibly as high as 20 to 1 for more complex models. The CFA model shown in Figure 3 includes 72 parameters that need to be estimated (i.e., 28 residuals for each observed variable, 28 variances for each residual term, and 16 covariances between latent factors). As shown in Appendix E, samples sizes for all variables included in the model are at least five times the number of parameters to be estimated, except for the *number of parent total communication skills*. All variables have at least 15 times the number of parameter estimates except for three of the five *parent skills growth* variables. Most variables used in the model approach or exceed 20 times the number of estimated parameters. Therefore, the SKI*HI sample sizes met most recommendations for CFA and SEM based on the number of cases per variable.

Second, the measurement scales of the observed variables and the distributions of those variables must be considered. SEM is based on the variance-covariance matrix of associations between observed variables (Thompson, 2000). As such, two assumptions upon which CFA and SEM are based include (a) the observed variables that are used to create the variance-covariance matrix must be based on interval scales, and (b) the variables must have a multivariate normal distribution. Muthén (1993) showed that SEM with ordered categorical variables produced unbiased estimates, while Lubke and Muthén (2004) showed that nonnormal categorically scaled data distorted factor estimates. Jöreskog and Sörbom (1989) found that for large samples sizes, ordinal data with four or more ordered categories produced poor results with some fit statistics, even when skew and kurtosis were within normal limits, while other fit indices were robust. Values of skewness and kurtosis are near zero in a normal distribution, so the further these values are from zero, the more non-normal the distribution. West, Finch, and Curran (1995; see also Curran, West & Finch, 1996; Muthén & Kaplan, 1992) found significant problems with the results from CFA if skewness was greater than two or kurtosis was greater than seven. Finney and DeStefano (2006) reviewed research and concluded that maximum likelihood estimation methods produced biased parameters for nonnormal categorical data, and that bias increased as univariate skew and kurtosis increased. Statisticians (Flora & Curran, 2004; Hu & Bentler, 1999; Yu & Muthén, 2002) recommended caution in interpreting fit indices when data are not univariate and multivariate normal, particularly with categorical variables. As shown in Table 15, the SKI*HI data set included several categorical variables that were used in the CFA and SEM models.

Another assumption underlying CFA and SEM is that data are "missing completely at random" (MCAR) or "missing at random" (MAR; Allison, 2001; Little, 1995; Little & Rubin, 2002; Schafer, 2005). When data are MCAR, the distribution of missingness does not depend on covariates or outcomes, and missing data are distributed randomly throughout the data matrix. In other words, any cell in the matrix would be as likely to have missing data as any other cell, and the probability of missing would be unrelated to characteristics of the participants. In social sciences research, data are rarely MCAR because participants are rarely completely compliant. Missing data may be related to socioeconomic status, depression, differences in education, or one of many other potentially unmeasured constructs (i.e., covariates) that affect data collection. When data are MAR, the distribution of missingness may be related to measured or unmeasured covariates (such as those previously mentioned), or to observed outcomes. MAR means the probability of missing data may be related to responses at the time of dropout or responses prior to dropout. "Missing not at random" (MNAR; Little, 1995) means the probability of missingness may be related to responses at the time of data collection and possibly afterward, such as when participants refuse to respond because survey questions about abuse trigger adverse emotions. With missing data, we can often reject MCAR in favor of MAR when previously measured characteristics of participants differ and are related to whether or not data are missing. In most cases, it is impossible to determine whether data are MAR or MNAR, because we cannot determine relationships between covariates and missing data when data are missing.

Analyzing the Data

The following software programs were used to conduct the CFA and SEM analyses: PRELIS/LISREL version 8.80, (LInear Structural RELations; Jöreskog & Sörbom, 2006; Scientific Software International, SSI, http://www.ssicentral.com/); Mplus, version 6.11 (Muthén & Muthén, 2006a, http://www.statmodel.com/); and AMOS version 7.0 (Analysis of MOment Structures, Arbuckle, 2006, http://www.ibm.com). Because many of the variables included in the model proposed for this study were dichotomous or ordered categorical, PRELIS and Mplus, version 6.11 (Muthén & Muthén, 2006a) were used to estimate tetrachoric and polychoric correlations. Tetrachoric and polychoric correlations are estimates of correlation for binomial or ordered categorical variables, respectively, as if the values of these variables were on a continuous scale. These estimates are, theoretically, invariant over changes in the number or “width” of categories (Uebersax, 2006). AMOS treats ordered categorical variables as continuous. LISREL, Mplus, and AMOS were used to test measurement and structural models. SPSS version 19 (http://www.ibm.com) was used for other statistics.

Virtually all large data sets in the social sciences have missing data, so a great deal of research has been done to decide how to best deal with missing data (Allison, 2001; Enders, 2010; Little & Rubin, 2002; McKnight, McKnight, Sidani, & Figueredo, 2007; Muthén, Asparouhov, Hunter, & Leuchter, 2011; Muthén, Kaplan, & Hollis, 1987). When "missingness" is MCAR or MAR, most researchers believe that full information maximum likelihood (FIML) estimation is the best way to deal with missingness (Arbuckle, 1996; Enders, 2006; Little & Rubin, 2002; Muthén & Muthén, 2010). FIML has been shown to be robust with large amounts of missing data when data are MCAR or MAR (Arbuckle, 1996; Muthén et al., 1987; Myrtveit, Stensrud, & Olsson, 2001). For example, Enders and Bandalos (2001) investigated the impact of various amounts of missing data on four estimation methods in SEM. Enders and Bandalos tested both MCAR and MAR data. Because the SKI*HI missing data is likely not MCAR, their results for MAR data will be discussed here. The largest percent of missing observations tested was 25%. Results indicated that with CFA, parameter estimate bias increased as the amount of missing data increased, though FIML produced the least biased estimates. Enders and Bandalos showed that SEM structural model parameter estimates were generally unbiased for FIML. Additionally, model convergence rates were higher for FIML than for the other methods, and model rejection rates based on fit indices were near expected rates with FIML. Enders and Bandalos reported that the other methods for handling missing data implemented in their study resulted in more biased parameter estimates and greater Type I error rates. These findings were consistent with research conducted by other investigators (e.g., Arbuckle, 1996; Muthén et al., 1987; Wothke, 2000). Additionally, some researchers (Enders, 2006; Muthén & Muthén, 2006b) have reported that FIML yields less biased estimates than other methods when data are MNAR. However, Thompson (2000) suggested that most research using FIML with missing data has been conducted with models that adequately "fit" the complete data set prior to removing data, and that we have insufficient knowledge of the impact of missingness on an inadmissable model.

FIML uses all available information to estimate parameters. In contrast, listwise deletion eliminates cases from the analysis that have data missing on any variable. Both Mplus and AMOS use FIML as the default missing data method (Arbuckle, 1996, 2007; Muthén & Muthén, 2006a, 2006b). Assumptions underlying FIML include (a) model residuals are normally distributed, (b) the fitted model is correct, and (c) data are MAR; however, with data MNAR, FIML is likely to yield less biased estimates (Enders & Bandalos, 2001; Schumacker & Lomax, 2004). Given the amount of missing data in the SKI*HI data set and the deduction that data were not likely MCAR, it was decided that FIML was the best method for handling missing data.

Examining Model Fit Indices

Several issues must be considered in evaluating the fit of a specified model to the underlying data in CFA and SEM. First, the calculated parameters should be assessed from theoretical and statistical perspectives under which the model was developed. In this regard, the directions and magnitudes of the coefficients generated by the software should be consistent with theory and previous research results. Additionally, parameters must be checked for statistical reasonableness. A model that does not fit the data, or one that is misspecified, may result in negative variances or correlations greater than one—situations that are impossible under the definitions of these statistics. Results should also be checked to confirm that there is a unique solution for each parameter in the model, meaning the model is identified (though SEM software provides an error message when a model is not identified). Identification problems result, for example, if a non-zero correlation is expected, but the SEM software calculates a zero correlation.

Fit indices provide an indication of the "fit" of the model to the data. A variety of model fit statistics have been developed and can be calculated by CFA and SEM software, each accounting for different aspects of the model and the data used to validate the measurement and theoretical models. Some recommended model fit indices and their characteristics are shown in Table 16 (see Hatcher, 1994; Hox & Bechger, 1998; Thompson, 2000). Thompson stated that there is no general agreement on which model fit indices are best, because a model may fit the data better according to some criteria than others. Accordingly, "a researcher should be guided by the preponderance of the evidence in reaching a conclusion about the adequacy of a model" (p. 244).

Respecifying Models That Do Not Demonstrate Acceptable Fit

As will be described in Chapter IV, the CFA did not provide an acceptable model fit for the available data, despite conducting analyses with different subsets of the data (e.g., selected by hearing status) and making numerous modifications to the measurement model. Researchers suggest several methods for modifying models to identify a model that better fits the underlying data. However, Mueller and Hancock (2008) warned that modifications "might not lead to a model that resembles reality any more closely than the one(s) initially conceptualized" (p. 491). Moreover, model respecifications too often capitalize on chance characteristics of the sample (Kline, 2005) or over fitting (i.e., by

Table 16

Some Recommended Model Fit Statistics for SEM

Model fit statistics	Characteristics	Expected value
χ^2 (Thompson, 2000)	Tests whether the variance-covariance matrix reproduced by the parameter estimates equals the original variance-covariance matrix. Sensitive to sample size.	> .05
Adjusted χ^2 (Klem, 2000)	Similar to χ^2. Takes number of estimated parameters and complexity of model into account. Sensitive to sample size.	< one less than # of factors
Goodness-of-fit index (GFI; Jöreskog & Sörbom, 1984)	Compares parameters of the model to no model in reproducing the variance-covariance matrix.	> .95
Adjusted goodness-of-fit index (AGFI; Jöreskog & Sörbom, 1984)	Evaluates the difference between the estimated and observed covariance matrices. Takes number of estimated parameters and complexity of model into account.	> .95
Root mean square residual (RMR; Byrne, 1988, 2011)	Tests the average residual value calculated from the variance-covariance matrix reproduced by the parameter estimates, and the original variance covariance matrix.	< .05
Normed fit index (NFI; Bentler & Bonett, 1980)	Compares model fit to the data assuming zero correlation of measured variables. Underestimates when samples are small.	> .95
Comparative fit index (CFI; Bentler, 1990; Fan, Thompson & Wang, 1999)	Adjusted NFI that takes sample size into account.	> .95
Root mean square error of approximation (RMSEA; Fan et al., 1999; Hu & Bentler, 1999; Steiger, 1990)	Compares the estimated covariance matrix to the observed covariance matrix. Takes model complexity into account.	< .08
Akaike information criterion (AIC; Mueller & Hancock, 2008)	Compares the estimated covariance matrix to the observed covariance matrix. Best used to compare fit of different models.	< .05
Tucker-Lewis index (TLI) or nonnormed fit index (NNFI; Schumacker & Lomax, 2004)	Similar to CFI or NFI, but adjusts for the number of parameters estimated and complexity of model.	> .95

adding unnecessary parameters to the model; Kenny, 2011). Kline stated that critical judgment based on knowledge of theory and prior research must be used rather than a specification search guided completely by model statistics. Similarly, Thompson (1998) wrote, "Never change a [model] specification without a theoretical justification" (p. 29). However, in multivariate statistics, we sometimes accept the chance of a Type I error by considering probabilities greater than $p = .05$ when justified. Additionally, in a regression model, we may try variables *a*, *c*, and *e* to predict *x*, because *a*, *b*, and *c* only accounted for 50% of the variance in *x*. Similarly, model fit statistics and parameter estimates can be used to adjust models to better fit the data. Some modification suggestions that were attempted included the following.

First, remove factors or parameters based on theoretical considerations (Hatcher, 1994; Mueller & Hancock, 2008). Theory or prior research could suggest that factors are not likely to contribute to the model and can be removed.

Second, examine multicollinearity of variables and consider combining or eliminating variables in which multicollinearity is greater than $r = .85$ (Hatcher, 1994; Kline, 2005). Variables can be combined using principal components analysis (PCA), which is a variable reduction procedure that identifies components that account for most of the variance in the observed variables. With PCA, a new variable (or variables) replaces variables that were highly correlated. Similarly, some authors (Hatcher, 1994; Kline, 2005) suggested deleting a variable from the model that is highly correlated with others, or identifying variables related to more than one factor and reassigning or eliminating them.

Third, constrain parameters to zero that demonstrate small contributions to the model, essentially eliminating them from the model (Hatcher, 1994; Kenny, 2011). However, Bentler and Yuan (2000) claimed that setting a parameter equal to zero because the correlation was small does not mean that correlation was, in fact, zero. Again, eliminating factors, indicators, or paths needs to be carefully considered with theory or prior research driving decisions.

Fourth, use a different mathematical method to estimate parameters, such as using generalized least squared (GLS) rather than maximum likelihood methods (Arbuckle, 2007; Jöreskog & Sörbom, 2006; Muthén & Muthén, 2006b). The mathematical calculations used to estimate parameters with these methods are different, and they handle characteristics of the data differently. However, as described in a previous section, some research provides evidence that FIML calculates the least biased parameter estimates when large amounts of data are missing. Also, some SEM programs (e.g., AMOS) will not calculate parameters with some estimation methods (e.g., generalized least squares) when there are missing data.

Fifth, examine the data and eliminate outliers or transform the data to increase univariate normality (Arbuckle, 2007; Kline, 2005). Transformations change the scale of variables and can make interpreting results challenging. Sometimes, variables require different transformations to increase univariate normality (e.g., log, square or cubed roots), increasing the challenge of interpreting findings. Rather than transforming data, outliers can be excluded to increase univariate normality. Eliminating outliers changes the underlying data to which we are trying to fit a model. A model is a simplified representation of "reality," and outliers may be an important part of that reality.

Next, use modification indices, such as the Wald test and Lagrange multipliers (Hatcher, 1994). These indices are a measure of the degree of change in the chi-square statistic based on removal of some parameters. However, some SEM software does not compute modification indices when data are missing (Arbuckle, 2007; Muthén & Muthén, 2006b).

Finally, develop nonrecursive models (e.g., those with feedback loops) that might better fit the data, but which more frequently fail to converge or result in unstable parameter estimates (Hatcher, 1994; Schumacker & Lomax, 2004). To the extent possible, all of these approaches were attempted. As described in Chapter IV, satisfactory fit indices could not be achieved for the numerous models tested.

Providing Evidence to Answer the Research Questions

Once an acceptable measurement model is identified through CFA, SEM is used to develop a structural model that demonstrates adequate model fit indices. These models provide answers to the research questions in the following ways.

Research question #1: Relationship between age at identification or treatment and child language outcomes. The path coefficient between the latent factors, Age at Treatment and Child Outcomes, provides an indication of the direction and strength of the relationship between these factors. For example, in the structural model shown in Figure 5 in Chapter IV, the square of the path coefficient, similar to an adjusted R^2 coefficient, describes the variability in the factor, child outcomes, accounted for by the factor, age at treatment.

Research question #2: Characteristics that affect the relationship between age at identification or treatment and child language outcomes. Factor loadings provide an indication of the direction and strength of the relationship between factors. For example, the square of the path coefficient describes the variability in the factor, *child outcomes,* accounted for by the factor, *child risk* (see Figure 5 in Chapter IV). The factor loadings between the factor, *child risk,* and individual indicators tell us the reliability of indicators for predicting *child risk.* The square of these values, β^2, provides an indication of the relative contribution of each measure to the factor, *child risk.* The larger the magnitude of a β^2 value, the more the latent factor, *child risk,* depends on that measure to account for variability in *child outcomes*. The SEM analysis also provides parameters for composite reliability, a measure of internal consistency for each indicator that is similar to coefficient alpha. Hence, the parameters for composite reliabilities provide evidence regarding the reliability of measures such as *number of parent communication skills*, which were not reported in previous research (e.g., Strong et al., 1992). Similarly, parameters for parent skills and treatment characteristics provide indications of the contribution of each of these to the model, and the reliability of each in accounting for variability in the factor, *child outcomes.*

Research question #3: Differences between children with hearing parents and those with a parent with hearing loss. The factor loading and composite reliability for the variable, *parent with hearing loss*, provide an indication of the contribution of this variable to the model. A large factor loading would provide support for differences between hearing parents and parents with hearing loss in accounting for variability in the model. In other words, the model provides evidence that child outcomes are different based on hearing status of parents. Additionally, the measurement and structural models can be analyzed with subsets of the data (i.e., selected by parent hearing status) to determine of model parameters differ for the two groups.

CHAPTER IV

RESULTS

For each variable used in the analysis for this study, sample sizes, descriptive statistics, measures of missingness, and measures of univariate normality are included in Appendix E. Although the SKI*HI data set includes data collected from 1979-1991 (see Appendix D), data on several variables that were considered essential to the model were only collected from 1987 through 1991 (see Appendix E for variable labels, descriptive statistics, and measures of univariate normality). Therefore, unless otherwise specified, all results reported here were based on the subset of data collected from 1987 through 1991. Variable correlations are included in Appendix G.

Characteristics of the Data

Missing Data

The amount of missing data in the SKI*HI data set was substantial as shown in Table 17. The percent of missing observations (i.e., empty cells) ranged from 33% to 35%, depending on the subset of data selected (e.g., parent hearing status). Using listwise deletion would have resulted in less than 2% complete cases for variables used in the model. There were no complete cases in which one or both parents had a severe or profound hearing loss. Table 18 shows the number and percent of cases for each latent factor in the model that would be retained with listwise deletion. Most of the factors included less than 50% of cases. Though the FIML estimation method was used to account for missing data, there is not enough research on the impact of estimation

Table 17

*SKI*HI Dataset Complete Cases and Missing Data*

SKI*HI dataset, 1987-1991	# Cases	# cases with complete data	% cases with complete data	% empty cells
Sites with parent skills and Treatment characteristics data[a]	2,300	32	1.4	33
Hearing parents	2,087	32	1.5	33
Parent with hearing loss	171	0	0	35

[a] Parent hearing status was not reported for all cases

Table 18

Cases with Complete Data for Latent Factors

Latent factor	# cases with complete data	% complete cases
Child risk	1,236	54
Initial child language	1,555	68
Child age at treatment	969	42
Treatment effectiveness	852	37
Family skills growth	730	32
Child language outcomes	877	38

methods on parameter bias when such large amounts of data are missing, particularly when categorical variables or variables with unequal intervals are included in the model.

Differences Between Those with LDS Posttest Scores and Those Without

There were no complete cases for children with at least one parent with severe or profound hearing loss, and few complete cases for children with hearing parents. Thus, an attrition analysis was conducted to determine whether baseline differences existed between program participants who "stayed in" (i.e., had LDS posttest scores) and dropped out. While we cannot assume that program participants who did not have an LDS score actually dropped out of the program, that is a plausible explanation for missing scores, and missing LDS posttest scores make generalizability of findings questionable. Table 19 lists variables that had at least a moderate SMDES (complete results are reported in Appendix H) between those with LDS posttest scores and those without, based on Cohen's (1988) suggestions that SMDES between .3 to .5 are moderate, and SMDES greater than .5 are large. Additionally, SMDES between those with LDS posttest scores and dropouts are shown for the two groups selected by hearing status of parents. The SMDES for *Age at Intervention* was moderate and positive across all groups, indicating that children who were older when they enrolled in the program were less likely to have LDS posttest scores. All other variables with moderate to large

Table 19

SMDES Between Those with LDS Posttest Scores and Those Who "Dropped Out"

Variable	All participants	Hearing parents	Parent with hearing loss
Age at intervention	Moderate	Moderate	Moderate
Highest level of hearing aid use	Large	Large	Large
Highest auditory development level	Moderate	Moderate	Moderate
Highest vocabulary development level	Moderate	Moderate	Large
Highest communication development level	Large	Large	Large
Number of parent auditory skills	Large	Large	Large
Number of parent aural-oral language skills	Moderate	Moderate	Large
Number of parent cognition skills	Large	Large	[a]
Number of parent communication skills	Large	Large	Large
Number of parent total communication skills	Large	Large	Large

[a] Sample size too small for SMDES to be meaningful: *N* (parent with hearing loss) = 2 and *N* (hearing parents) = 13.

SMDES were “outcome” variables for parents or children, suggesting that those with lower scores on those outcome measures did not have LDS posttest scores. Additionally, SMDES are similar across groups for most variables, indicating the pattern of missing outcomes was similar for children with hearing parents and parents with hearing loss.

Though statisticians (Allison, 2001; Little, 1995; Little & Rubin, 2002) claimed that providing evidence to show data are MNAR is untenable, the definition of MNAR indicates that the probability of missingness may be related to characteristics at the time of data collection or afterward. If outcome scores on one outcome measure are related to missingness on another outcome measure, it seems that one could infer that data are MNAR. Because CFA and SEM are based on the assumption that data are at least MAR, parameter estimates for data that are MNAR may be biased in unknown ways, making conclusions drawn from estimates questionable.

Univariate Normality and Outliers

Univariate normality is a condition of multivariate normality, though not sufficient for multivariate normality. Skewness, kurtosis and other tests of univariate normality (e.g., Kolmogorov-Smirnov Z or KSZ Test of normality, Q-Q plots) indicated several variables were not univariate normal. As shown in Appendix E, some variables had high values for skewness, kurtosis and the KSZ test. In particular, the following variables demonstrated large values of skewness, kurtosis, and KSZ tests of normality: the number of months in the program before communication method was selected, and the proportional change indices indicating average monthly growth in LDS scores. Curran and colleagues (1996; see also Muthén & Kaplan, 1992; West et al., 1995) found significant problems with CFA when skewness was greater than two or kurtosis greater than seven.

Additionally, Q-Q plots displayed univariate nonnormality and outliers in the data. Q-Q plots compare the shape of the distribution for a variable against a normal distribution. To the extent that data fall on or near the line in these plots, the data demonstrate univariate normality. The six variables plotted in Appendix I showed departures from univariate normality. While transformations to the data can increase univariate normality, transformations change the scale of the variables making it difficult to interpret results. Additionally, the variables showed both quadratic and higher order polynomial departures from univariate normality, indicating different transformations could be needed, which increases the challenge of interpreting findings. Because in social sciences research, data typically demonstrate univariate nonnormality—particularly for categorical data—analyses were conducted knowing that univariate nonnormality could bias results.

Testing Measurement Models with CFA

SEM has two components: (a) using CFA to identify a measurement model with acceptable fit indices and (b) testing structural models developed from the measurement model. Means and standard deviations for the ordinal and continuous variables included in the measurement model (see Figure 3 in Chapter III) are listed in Appendix E. Bivariate correlations between these variables are included in Appendix G.

In the first step, numerous attempts to test the CFA measurement model were unsuccessful. CFA with AMOS resulted in nonconvergence or inadmissible models, both of which stop the analysis prior to computing fit indices. Because a number of variables in the model were ordered categorical scales, PRELIS was used to create the polychoric correlation and asymptotic covariance matrices for dichotomous and ordered categorical variables. PRELIS did not calculate correlation and covariance matrices due to fatal errors that prevented the software from calculating parameter estimates. Additional attempts to create the matrices after removing the variables that caused the calculations to fail were unsuccessful. Mplus was also used to estimate parameters in the measurement model. Error warnings were generated that indicated high collinearity between several indicator variables (see Appendix G; e.g., *LDS expressive pretest score* and *LDS receptive pretest score,* r = .946, *age at identification* and *age at hearing aid fit*, r = .869, *age at program start* and *age at hearing aid fit*, r = .842, *age at program start* and *age when communication method selected*, r = .959). In short, initial analyses indicated the measurement model did not provide a good fit to the data.

Many of the calculations in CFA and SEM are not possible if measures are multicollinear (Tabachnick & Fidell, 2001) or if there are large amounts of missing data (Arbuckle, 1996). High collinearity between measures can prevent convergence of the estimated covariance matrix and terminate the analysis, or result in an inadmissible model. Often, the underlying cause of an inadmissible model is a “not positive definite” matrix. Briefly, a matrix is positive definite if the eigenvalues (total variances) are positive. Negative eigenvalues result in a not positive definite matrix (Wothke, 1993). Negative eigenvalues do not permit the matrix to be transposed, and matrix transposition is necessary to calculate parameter estimates in a CFA or SEM analysis. A not positive definite covariance matrix may result if there is perfect or near perfect linear dependency between two variables, the sample size is small, a variable has the same value across all cases, or there are large amounts of missing data (Arbuckle, 1996; Hatcher, 1994; Kline, 2005). The overall sample size in the SKI*HI data set was adequate, but error messages suggested missing values prevented calculations with some variables. Additionally, some variables were highly collinear. Clearly, the CFA analysis did not provide support for the initial model, and the characteristics of the underlying data affected parameter estimation. As described in Chapter III, researchers have suggested several strategies for modifying models to identify a measurement model that fits the underlying data. First, variables that show a high degree of highly multicollinearity can be combined (Hatcher, 1994; Kline, 2005). PCA was used to reduce variables with high collinearity for variables comprising the latent factors, *child age at treatment* and *initial child language*. Table 20 shows Pearson correlations among these variables. PCA is a large sample procedure that uses pairwise deletion to account for missing data (Hatcher, 1994). Because the PCA reduced the number of variables related to the factor, *age at treatment,* to a single combined variable that included fewer than half of the originally included cases, this combined variable was not used in subsequent analyses. The combined variable for LDS pretest scores deleted only three cases with pairwise deletion, so the combined variable for pretest scores was included in some of the subsequent models that were tested. With these changes, no admissible models with adequate fit indices were identified with Mplus or AMOS.

Table 20

Pearson Correlations Between Variables Combined Using PCA

Variable	Pretest LDS receptive score	Age at identification	Age at hearing aid fit	Age at program start
Pretest LDS expressive score	.95** (1555)			
Age at hearing aid fit		.87** (1737)		
Age at program start		.77** (1779)	.84** (1435)	
Age when communication method selected		.74** (1239)	.82** (1020)	.96** (1249)

Next, model parameters that contributed little to the model were eliminated. For example, Hatcher (1994) suggested that factors that have low correlation and covariance estimates with all other factors in the model might be considered for elimination. For one model that converged with model fit indices that approached acceptable levels, the factor, *age at treatment,* indicated low correlation and covariance with other factors (i.e., highest correlation was r = .05 for *age at treatment* ←→ *family skills growth*). However, because the key research questions addressed in this dissertation related age at identification or intervention to child language outcomes, dropping this factor would not provide evidence to answer the questions. The variable, *age at identification*, consistently yielded one of the smallest factor loadings. Yet, because the parameter estimate was not zero, and because the research questions included this variable, it was not dropped from the model. In many models, either *unaided hearing loss* or *aided hearing loss*, but not both, exhibited parameter estimates smaller than .05. When one of these variables was dropped, model estimates changed little. However, *aided hearing* *loss* typically demonstrated a larger contribution to the model or resulted in slightly better model fit indices. The amount of missing data for this variable was substantially higher (46% compared to 8% for *unaided hearing loss*), which could increase bias in parameter estimates. Overall, modifying models based on parameter estimates was unsuccessful in identifying a model with adequate fit indices.

Reviewing variable correlations with latent factors provided evidence about whether indicators might be related to more than one factor. In some models that were tested, the indicator, *LDS expressive posttest,* was highly correlated with both *child outcomes* (as expected) and *child risk*. Reassigning the outcome score to the factor, *child risk,* would not make sense given the focus on identifying the characteristics that affected outcomes. Similarly, deleting this variable would eliminate one of the most important measured outcomes. Most CFA models tested did not provide evidence that indicators were related to more than one factor, so no variables were removed from the model based on this criteria.

To help correct for univariate nonnormality, outliers in some continuous variables were excluded from the analysis. To do this, z-scores were calculated and scores that fell greater than three standard deviations from the mean were excluded. This resulted in excluding numerous data values for the following variables: *LDS expressive PCI* (over 3%), *LDS receptive PCI* (over 3%), *months in program when communication method selected* (greater than 5%), and *aided hearing loss.* A few values for other variables were excluded. While removing outliers increased model convergence rates for some models, fit statistics did not substantively improve.

Additional model modifications based on the recommendations described in Chapter III were tested, but analyses did not converge, resulted in inadmissible models, or demonstrated poor fit statistics.

Results from One CFA Model

One example of a model that converged, though fit indices suggested the fit was marginal at best, was estimated in AMOS. The measurement model is shown in Figure 4, with parameter estimates included. For this model, the LDS pretest scores were not combined; however, they were reassigned to the latent factor, *child risk*. Because lower scores on pretest measures would indicate higher risk for poor language outcomes, regardless of age, these changes seemed reasonable and aligned with theoretical models.

The chi-square fit statistic for this model was one of the lowest achieved. At $\chi^2 = 2895$ with 146 degrees of freedom, the chi-square was statistically significant at $p < .001$. A statistically significant chi-square indicates the model does not adequately fit the data, and the model should be rejected. However, many researchers (Enders, 2006; Hatcher, 1994; Fan et al., 1999; Yu & Muthén, 2002) have provided evidence that the chi-square statistic is sensitive to sample size, missingness, and nonnormality, and it is typically overinflated when categorical variables are included in the model.

Other model fit indices for the model shown in Figure 4 are included in Table 21. The CFI and RMSEA are among the measures least affected by sample size (Fan et al., 1999). The CFI compares the covariance matrix predicted by the model to the observed covariance matrix, and compares the null model with the observed covariance matrix. A CFI measure of goodness of fit varies from 0 to 1, with a CFI close to 1 indicating a very

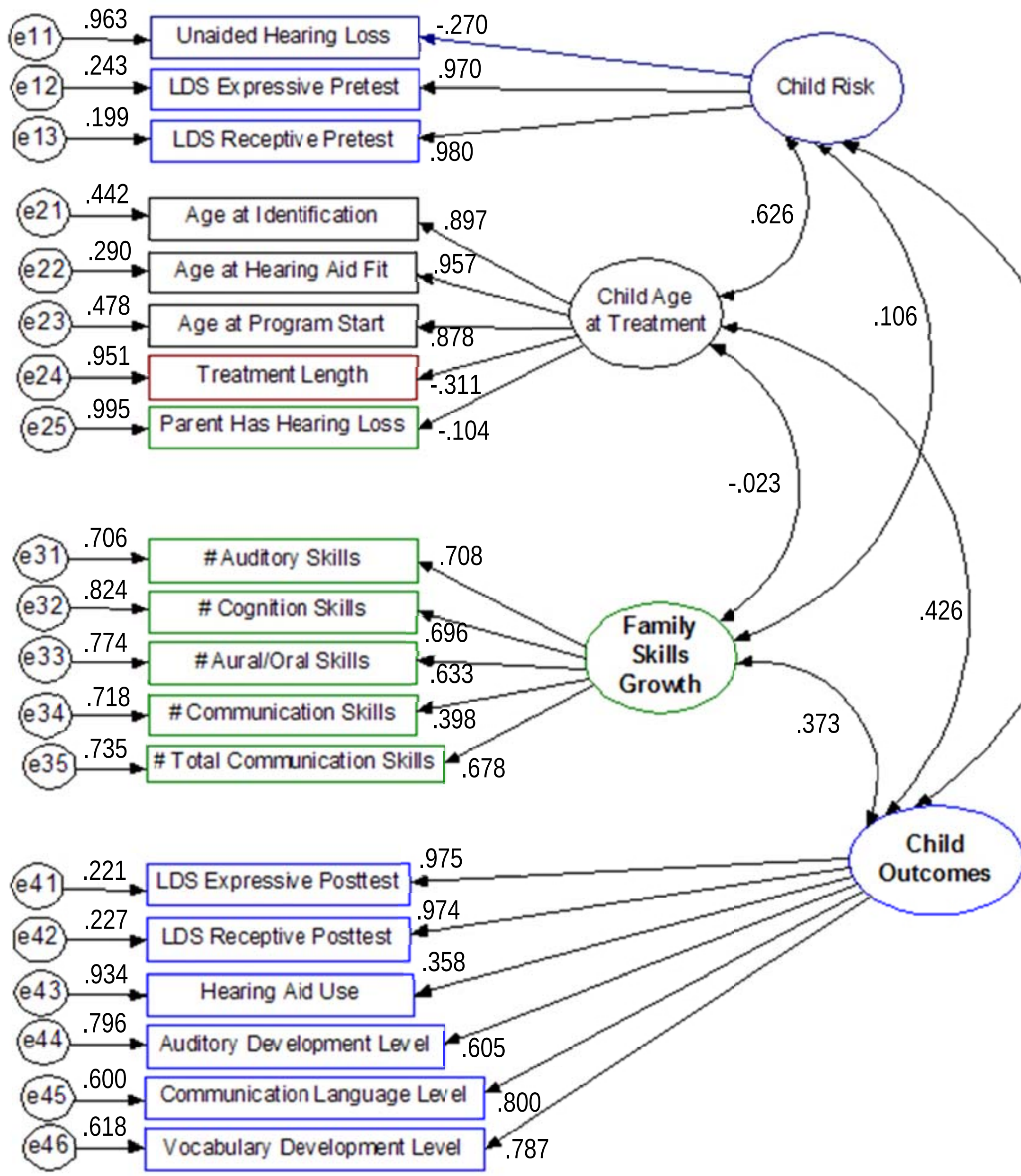

Figure 4. Example of a measurement model with “reasonable” fit indices.

Table 21

Model Fit Indices for the CFA Measurement Model

Fit index	Value	Expected value
CFI	.863	> .95
RMSEA	.091 (CI: .088-.093)	< .08 with 0 included in CI
NFI	.857	> .95
TLI	.821	> .95, but can be 0 to 1 for model acceptance
AIC	3021	Smaller is better; used to compare models

good fit. The obtained CFI = .863 did not meet recommended cutoffs for model fit. The RMSEA is a measure of the closeness of fit, with values less than .05 indicating good model fit, and values up to .08 indicating reasonable model fit (Browne & Cudeck, 1993; Hu & Bentler, 1999). Steiger (1990; also Browne & Cudeck, 1993; MacCallum, Browne, & Sugawara, 1996) suggested that a confidence interval (CI) around RMSEA should include values between 0 and .05 to indicate the possibility of good fit. The obtained RMSEA = .091 with a confidence interval from .088 to .093, which does not include the value of zero. Again, this fit index provides evidence that the model was not a good fit for the underlying data. The AIC for this model was lower than for other models that were tested, providing support for this model when compared to others. None of the other fit indices provided evidence that this model fit the data, though some are close to the recommended cutoffs. Similar to relaxing a *p* value for a statistical test and accepting the increased chances of a Type-I error, one might think these fit indices are "close enough" to be considered acceptable. As such, parameter estimates were reviewed.

Standardized and unstandardized model coefficients are included in Table 22. The *p* values for *t* tests indicating that the estimated parameter was statistically significantly different than zero (i.e., the null model) were less than *p* = .001 for all

Table 22

CFA Model Coefficients and Reliability Estimates

Latent factor and indicators	β	Reliability	*B*	*SE*	Variance extracted
Child risk		.73[a]			.65
Unaided hearing loss	-.270	.07	-7.347	.637	
LDS expressive pretest score	.970	.94	10.534	.204	
LDS receptive pretest score	.980	.96	11.313	.214	
Child age at treatment		.84[a]			.72
Age at identification	.897	.80	11.994	.227	
Age at hearing aid fit	.957	.92	12.892	.225	
Age at program start	.878	.77	12.546	.254	
Treatment length	-.311	.10	-3.081	.303	
Parent has hearing loss	-.104	.01	-.028	.006	
Family skills growth		.93[a]			.74
# Of auditory skills	.708	.50	2.198	.091	
# Of cognition skills	.566	.32	1.911	.214	
# Of aural-oral language skills	.633	.40	1.822	.115	
# Of communication skills	.696	.48	3.469	.141	
# Of total communication skills	.678	.46	3.410	.198	
Child outcomes		.96[a]			.83
LDS expressive posttest score	.975	.95	13.888	.257	
LDS receptive posttest score	.974	.95	14.285	.264	
Hearing aid use	.358	.13	.476	.036	
Auditory development level	.605	.37	2.123	.086	
Communication language level	.800	.64	2.405	.060	
Vocabulary development level	.787	.62	2.050	.055	

[a] Composite reliability

parameters. The reliability of the indicator, β^2, or the squared multiple correlation, indicates the percent of variation in an indicator that is explained by the factor it is supposed to measure, similar to R^2 in a regression model. These values seemed reasonable. The composite reliability of factors is similar to the coefficient alpha measure of internal consistency statistic. The composite reliability reflects the internal consistency of the indicators measuring a factor. Ideally, composite reliabilities should exceed .70. For this model, all composite indicators meet that criterion. Variance extracted is a measure of the amount of variance in the model that is accounted for by a factor. For this model, the variance extracted estimates are high, indicating the factors account for a substantial amount of the variance in the model.

The purpose of this dissertation was to determine if SEM techniques could be used to better understand how age at which intervention begins affects children's language outcomes. Therefore, even though the fit indices did not provide support for this model being a good fit for the underlying data, the researcher decided it would be useful to explore what results would be produced if a greater chance of a Type I error were accepted by "relaxing" the probability for rejecting the model and evaluating the results. Given parameter estimates, indicator and composite reliabilities, and variance accounted for by factors in this simplified model shown in Figure 4, the next step of testing a structural model was completed.

Testing Structural Models with SEM

Once a measurement model with acceptable fit indices and other parameter estimates has been identified, a structural (i.e., theoretical) model can be developed. The directional relationships between factors are based on theory and empirical results from previous research. SEM estimates the magnitude and direction of relationships between theoretical constructs (i.e., factors that are not directly measured) and observed variables. For this analysis, several structural models were tested that produced almost identical results. Figure 5 shows the final structural model selected based on fit indices. Table 23 summarizes the model fit indices.

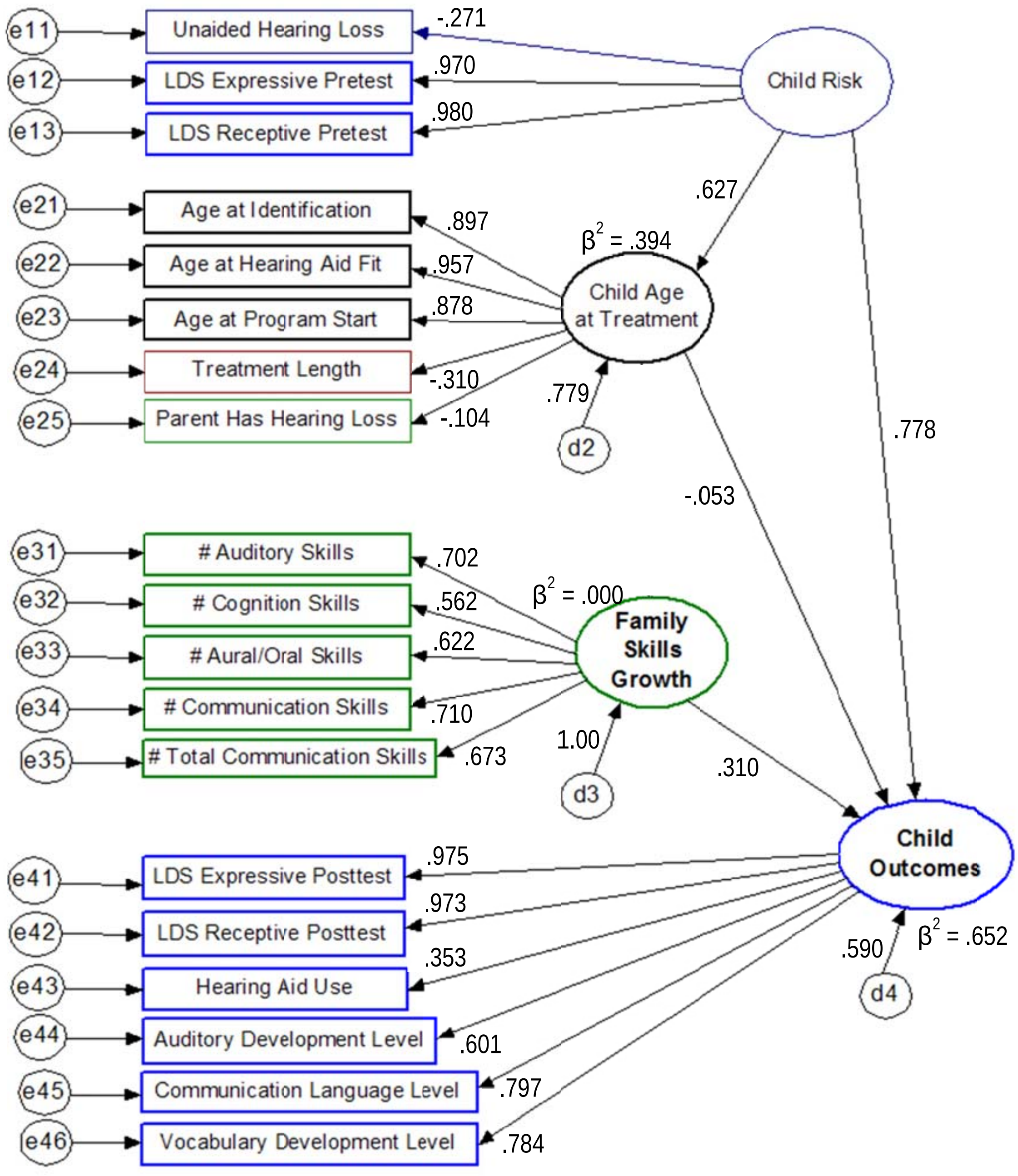

Figure 5. Structural model with standardized regression coefficients.

Table 23

Model Fit Indices for the SEM Structural Model

Fit index	Value	Expected value
CFI	.862	> .95
RMSEA	.090 (.087-.093)	< .08 (confidence interval)
NFI	.856	> .95
TLI	.823	> .95, but can be 0 to 1 for model acceptance
AIC	3034	Smaller is better; used to compare models
PRATIO	.779	Larger is better; used to compare models
PNFI	.667	Larger is better; used to compare models
PCFI	.671	Larger is better; used to compare models

The chi-square fit statistic for this model was $\chi^2 = 2912$ with 148 degrees of freedom. The chi-square was statistically significant at $p < .001$, but again, a chi-square statistic is sensitive to sample size, missingness, and nonnormality, and it is typically overinflated when categorical variables are included in the model. Other fit indices were very similar to fit indices for the CFA measurement model. Additional fit indices for a structural model include the parsimony ratio (PRATIO), the parsimonious fit index (PNFI), and the parsimonious comparative fit index (PCFI). These were used to compare models for the most parsimonious, or simple, fit. These indices changed minimally (i.e., less than .01) between the models tested. Additionally, the values were moderate to high, indicating that this structural model provided both a reasonable fit and was parsimonious.

Standardized and unstandardized model coefficients are included in Table 24. The *p* values for *t* tests indicating that the estimated parameter was statistically significantly different than 0 (i.e., the null model) were less than $p = .001$ for all parameters except for the following path estimate: *child age at treatment* → *child*

Table 24

SEM Model Coefficients and Reliability Estimates

Paths, latent factors and indicators	β	Reliability	B	SE	Variance extracted
Child risk → child age at treatment	.627	.393	.717	.024	
Child risk → child outcomes	.778	.605	.975	.029	
Child age at treatment → child outcomes	-.053	.003	-.059	.025	
Family skills growth → child outcomes	.310	.096	2.009	.158	
Child risk		NA			.97
Unaided hearing loss	-.271	.074	-.654	.056	
LDS expressive pretest score	.970	.941	.931	.010	
LDS receptive pretest score	.980	.960	1.000		
Child age at treatment		.394 [a]			.98
Age at identification	.897	.805	.931	.014	
Age at hearing aid fit	.957	.916	1.000		
Age at program start	.878	.771	.973	.017	
Treatment length	-.310	.096	-.283	.023	
Parent has hearing loss	-.104	.011	-.002	.000	
Family skills growth		.000 [a]			.86
# Of auditory skills	.702	.493	1.000		
# Of cognition skills	.562	.316	.871	.104	
# Of aural-oral language skills	.622	.386	.820	.060	
# Of communication skills	.710	.504	1.623	.088	
# Of total communication skills	.673	.453	1.552	.107	
Child outcomes		.652 [a]			.99
LDS expressive posttest score	.975	.950	.972	.009	
LDS receptive posttest score	.973	.947	1.000		
hearing aid use	.353	.125	.033	.002	
auditory development level	.601	.362	.149	.006	
communication language level	.797	.635	.169	.004	
vocabulary development level	.784	.615	.144	.003	

[a] Composite reliability.

outcomes (p = .020). This path estimate was statistically significant at the $p < .05$ level.

While fit indices and other statistics indicated that this structural model exhibited "reasonable" fit for the data, examination of reliability estimates and model coefficients raised concern about the validity of the model. For example, the reliability of the factor, *family skills growth*, was β^2 = .000, indicating that this variable did not account for variability in the model. When a directional path between *child age at treatment* and *family skills growth* was added (not shown in the structural model in Figure 7), the squared multiple correlations for both *child risk* and *family skills growth* were β^2 = .000. Given the amount of variability accounted for by these latent factors in the measurement model, these R^2 values of .000 were questionable. Similar results were observed for all models tested.

Overall, no SEM models converged with admissible solutions demonstrated adequate fit indices based on research-recommended cutoffs, and resulted in model coefficients that seemed reasonable based on theory and previous research.

Summary of SEM Analyses

Even though initial examination of the SKI-HI National Data Base suggested that the data set would be appropriate for examining how age at which intervention begins was related to language outcomes for children with permanent hearing loss, the analyses reported thus far in Chapter IV demonstrated that the data were not adequate to support the use of SEM techniques. This claim held true across the numerous models that were tested based on modifications recommended by researchers, and when estimated start values for parameters were included to allow models to converge with fewer iterations.

The characteristics of the data that likely precluded identifying a model that "fit" the underlying data included: (a) missing data, (b) multivariate nonnormality, (c) the number of categorical variables included in the models, and (d) the variability of time between important events upon which variables in the model are based. Overall, no SEM models converged with admissible solutions that demonstrated adequate fit indices based on research-recommended cutoffs, and resulted in model coefficients that seemed reasonable based on theory and previous research. When criteria for achieving adequate fit are relaxed beyond the point recommended by most researchers using SEM techniques, it is possible to test a structural model, but the results are far from satisfactory as discussed in more detail in Chapter V. Thus, other analytical approaches were pursued as described next.

Replicating Strong and Colleagues' Regression Results

SEM software can also be used to conduct regression analysis with observed variables. Because the CFA and SEM analyses discussed previously did not result in acceptable models, an analysis was conducted to determine if the regression findings reported in Strong and colleagues (1992) could be replicated. In brief, Strong et al. concluded that "With R^2 equal to .11 and .10, respectively, these [SKI*HI] data indicate that only 10% to 11% of the variability [in gains] was explained by the linear combination of program start age and treatment amount [i.e., difference between posttest date and date of enrollment in program]" (p. 222).

The models shown in Figure 6 were tested to replicate Strong and colleagues' (1992) findings with both LDS expressive and receptive scales. Figure 6 shows standardized regression coefficients as well as the squared multiple correlations, or adjusted R^2, showing the relationships between LDS rate of development gain and the linear combination of program start age and treatment amount. These R^2 values indicate

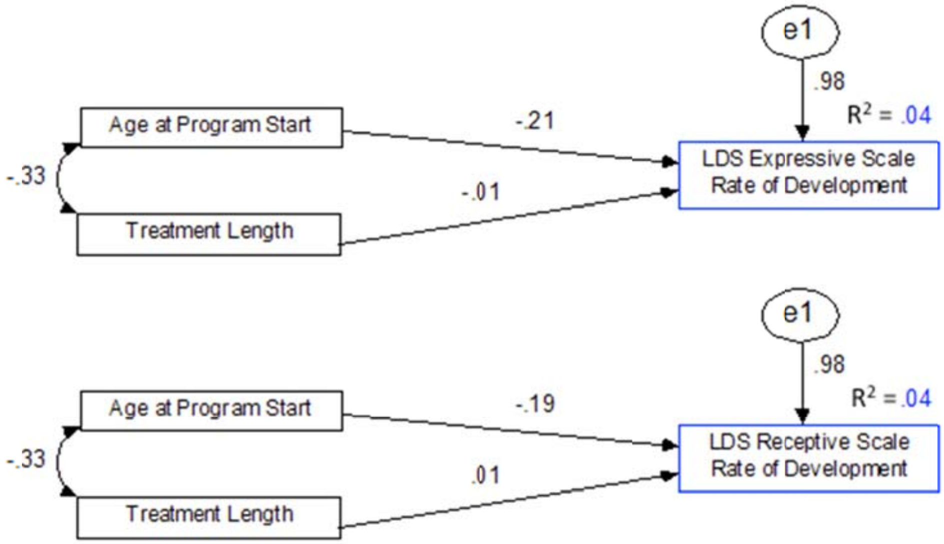

Figure 6. Regression model to replicate Strong et al. (1992) findings.

the amount of variance explained in outcomes by age at treatment is about 4%, which is somewhat lower than what was reported by Strong et al. However, Strong and her colleagues reported beta coefficients of $\beta = .216$ and $\beta = .190$ for average monthly gains in LDS expressive and receptive scales, respectively, which matched results shown in Figure 6. Strong and colleagues reported beta coefficients for treatment amount of $\beta = -.185$ and $\beta = -.202$, respectively, which differed from results shown in Figure 6, indicating a different measure of treatment length was used. Squaring these standardized regression coefficients gave $\beta^2 = .04$; the amount of variability in language scores accounted for by *age at program start* (as the contribution from *treatment length* was negligible). These results are consistent with findings from the literature review regarding the relationship between age at intervention and outcomes.

Confounding Factors That Might Help Explain Findings

To help explain the findings in these analyses, the data were further explored. Important variables in the CFA and SEM analyses included *Age at Identification*, *Age at Program Start,* LDS gains in scores, and LDS developmental rates of gain (i.e., average monthly gain). Test gains were calculated based on pretest and posttest dates. Additionally, while LDS raw scores were included in the CFA and SEM analyses, the time lapse variable used in the models was *Treatment Length.* Important but often implicit and often unrecognized assumptions about timing include the following: (a) pretest administration and either *Age at Identification* or *Age at Program Start* are close in time, and (b) posttesting occurs near the end of treatment. Table 25 shows the difference in months between some of the important events upon which analyses using the SKI*HI data were based.

The numbers showed that pretesting did not occur close in time to *age at identification* or *age at program start* for most children. In fact, the average difference between events, *age at program start* and *age at pretest*, was over 2 months, with 68% of

Table 25

Descriptives of Differences in Months Between Events

			Difference in months (Event 2—Event 1)				
First event	Second event	*N*	Min	Max	Median	Mean	*SD*
Age at identification	Age at pretesting	3,150	-30.5	100.6	6.2	9.7	10.1
Age at pretest	Age at program start	2,693	-72.8	37.7	-.7	-2.4	5.5
Age at pretest	Age at posttest	3,259	.9	60.6	9.6	12.5	8.8
Age at program start	Age at posttest	2,691	.4	79.2	12.7	15.0	10.0
Age at posttest	Age at graduation	856	-33.0	19.0	-1.0	-1.8	4.6

children assessed within the range of almost eight months before to three months after the start of the program—nearly a one year range in assessment dates around *age at program start*! Given the degree to which a typically developing young child changes in a year, the variability in time between these events could potentially “wash out” statistical findings. CFA and SEM models were tested using *age at pretest* in place of *age at program start, but* model fit indices were still not adequate. Additionally, though the available sample was smaller, the average difference in ages between *age at posttest* and *age at graduation* was nearly 2 months, with 68% of the children assessed more than 6 months before to almost 3 months after graduation. Figure 7 shows the distribution of these differences. This tremendous range between when young children were assessed and when they started the program, or graduated, may impact findings that are based on the assumption that testing occurs near intervention start and graduation dates. When analyses are based on assumptions that are not a good match with the actual data, statistical findings may be difficult to interpret.

Overall, the analyses described in this chapter indicated that characteristics of the SKI*HI data set made drawing further conclusions based on implementing more advanced statistics methods with the data implausible. In Chapter V, these results will be summarized, limitations of the study explained, and directions for further research suggested.

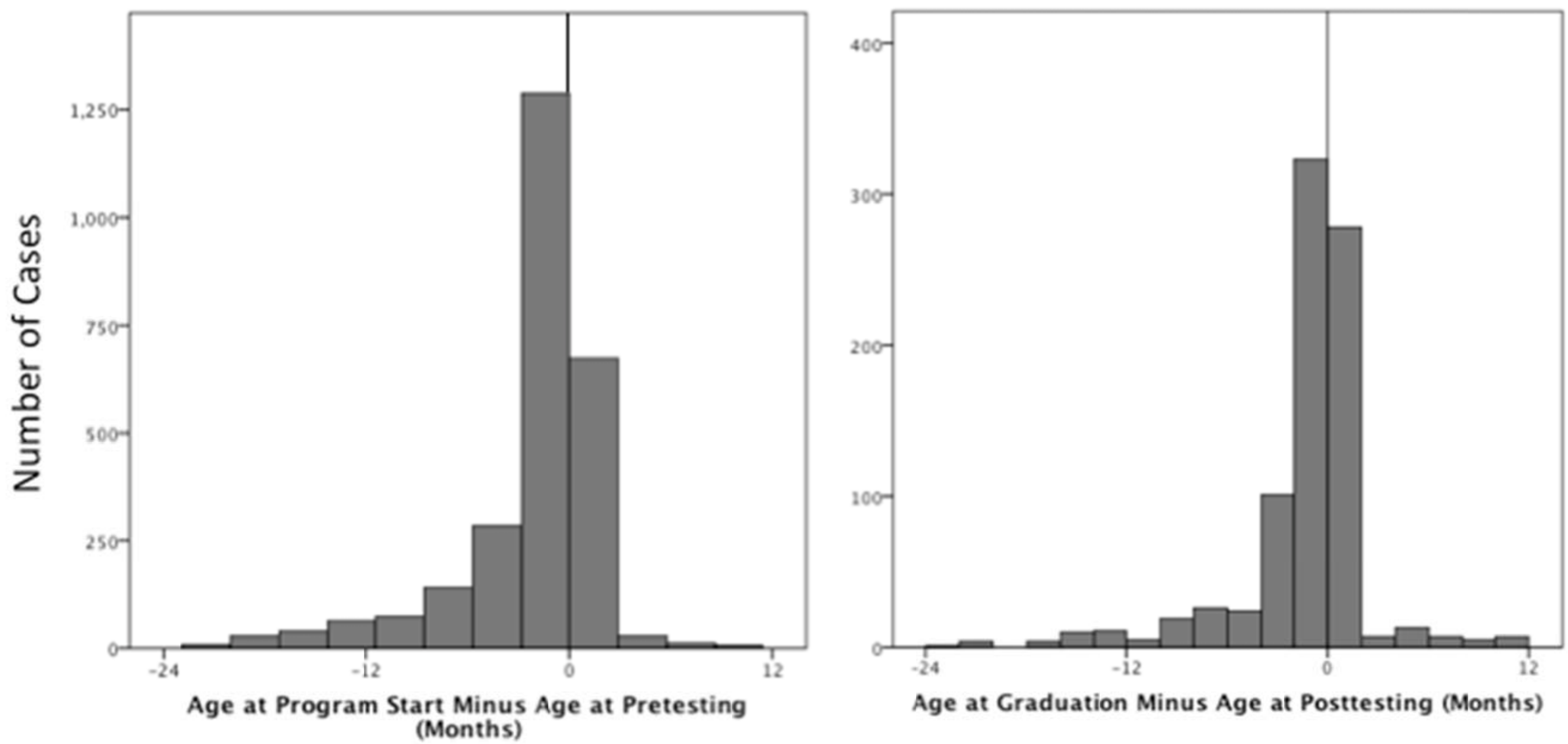

Figure 7. Distribution of differences between ages at events.

CHAPTER V

DISCUSSION AND CONCLUSIONS

During the last 25 years, there has been a dramatic increase in the number of infants in the United States who are screened for hearing loss. The expansion of newborn hearing screening programs has significantly reduced the age at which children with permanent hearing loss are identified and the age at which it is possible to enroll these children in early intervention programs. Proponents of conceptual models of child development, such as Bronfenbrenner's bioecological theory of development, have capitalized on this opportunity to urge that children with permanent hearing loss be enrolled in early intervention programs at younger and younger ages. For example, Yoshinaga-Itano (2004) wrote, "Most professionals…believe…that the age when children begin to have access to language and communication and the characteristics of the intervention are the primary cause of better outcomes" (p. 451).

Unfortunately, even though most previous researchers have concluded that earlier intervention results in greater developmental gains, particularly with regard to language outcomes, the empirical basis for concluding that children with permanent hearing loss will benefit from earlier versus later educational intervention programs is weak. Not surprisingly, most researchers have emphasized the need for better evidence.

Because there is such strong conceptual and administrative support for beginning educational intervention programs as early as possible, almost all researchers and program administrators have concluded that randomized controlled trials of early intervention with children who have permanent hearing loss are impossible. Indeed, not a single randomized experiment was found among almost 100 studies included in the review of literature for this dissertation. Given the need for better evidence about the effects of earlier versus later intervention for children with hearing loss, the purpose of this study was to determine if structural equation modeling (SEM) techniques could be used with a national data set of outcome and demographic data for a large data set of nearly 5,200 children with permanent hearing loss to better answer the following questions.

1. What is the relationship between language outcomes for children born with hearing loss and the age at which hearing loss was diagnosed or early intervention began?

2. Which of the following factors affect the relationship between age of identification of hearing loss or intervention and language outcomes?

    a. Child characteristics (e.g., degree of hearing loss, gender, ethnicity, presence of additional disabilities)

    b. Parent characteristics (e.g., hearing status, language used at home, communication method selected)

    c. Intervention characteristics (e.g., planned frequency of home visits, actual frequency of home visits, length of treatment)

    d. Parent communication skills with child born with hearing loss

3. Are these factors different for children who have a parent with severe or profound hearing loss than for those who do not?

In this chapter, the results from the statistical analysis are discussed and limitations of the study explained. Directions for future research are suggested, with regard for the legal and ethical constraints to conducting RCTs.

Summary of Analyses and Answers to Research Questions

The comprehensive review of the literature indicated that the research provides some support for earlier identification and intervention. For example, average SMDESwere about .19 for the groups of studies for which an SMDES could be calculated, and .18 for studies rated good quality. For studies in which an R^2 proportion of variance explained could be calculated, age at intervention (or identification) accounted for 8% of the variability in outcomes. When children were assessed at ages older than five years, age at intervention accounted for an average of 6% of the variability in outcomes. For the data analyzed for this study, age at intervention (i.e., program start) accounted for approximately 4% of the variability in outcomes. This finding is consistent with previous literature, indicating that a small amount of the variability in outcomes is accounted for by earlier identification and intervention. Given these small numbers, other factors—measured or unmeasured—may account for a greater proportion of the variability in language outcomes.

The conceptual model developed on the basis of prior research and theories about child development assumed that child risk, initial child language, child age at treatment, treatment effectiveness, and family skills growth were all related to each other and would impact on child outcomes (see Figure 3 in Chapter III for a graphical representation of this model). The SKI*HI National Data Base included measures of each of these variables for data from almost 5,200 children that preliminary analyses suggested would be appropriate for testing this model using SEM. These data were collected to provide greater information about the demographic characteristics of children born with hearing loss, and to assess program effectiveness in identifying children at earlier ages. As such, the measures and data collection were not designed for analyses using the structural methods employed in this dissertation.

As shown in Chapter IV, results from CFA indicated that a measurement model could not be identified that adequately fit the underlying data. Numerous models were tested based on modifications recommended by researchers. Of the models tested, fit indices were not within recommended criteria. Additional analyses suggested that the characteristics of the data, including the amount and patterns of missing data and data that were not multivariate normal, precluded identifying models that adequately described the underlying data.

Using the best model identified through CFA (even though the fit indices were only marginally adequate), further analyses were conducted to determine if additional information to answer the research questions could be garnered. This seemed reasonable given arguments for relaxing probability levels in multivariate statistics when we are willing to accept a greater chance of Type I errors (i.e., falsely rejecting a model that "fits").

When measurement models that had only marginally adequate fit indices were tested with SEM, fit indices were again outside recommended ranges. Results from the one of the best models that could be identified (although still only marginally good) were presented. While the fit indices for both the CFA and SEM analyses seemed to warrant further model testing, structural model estimated parameters were not reasonable. In particular, the contribution of the factor, *family skills growth*, to explaining variability in the model was zero. When a path between *age at treatment* and *family skills growth* was added, both *child risk* and *family skills growth* resulted in zero contributions to explaining variability in the model. Modifying models based on theory or model statistics did not result in models with more acceptable fit indices or more reasonable estimated parameters, even when estimated start values for parameters were included to allow models to converge with fewer iterations.

Because the CFA and SEM analyses did not result in findings from which plausible conclusions could be drawn to answer the research questions, additional analyses were conducted using more typical regression techniques. First, the Strong and colleagues (1992) results were replicated using the AMOS SEM software. Findings for the relationship between earlier age at intervention and language outcomes were similar to those reported by Strong and colleagues but of more modest magnitude. Analyses in the present study indicated that approximately 4% of the variability in language outcomes was accounted for by age at intervention, compared to 11% reported by Strong and colleagues. The differences are most likely attributable to different treatment length variables used in the regression analysis. Findings in the present study were also similar to other results from recent primary studies, as summarized in Table 26 (see also Tables 8 and 10 in Chapter II). For example, the Wake and colleagues (2004, 2005) studies, which were reports of good quality population-based research in Australia, provided evidence that the impact of age at identification contributed 3% to explaining the

Table 26

Summary of Results from Recent Studies Reviewed in Chapter II

Study	Location	Independent variable	Age at posttest (yr-mo)*	R^2	Quality of primary study
Holzinger et al. (2011)	Northern Austria population	ID and INT	5-1	.03	Good
Fitzpatrick et al. (2007)	Ontario, Canada selected centers	ID	6-6	.07	Fair
Wake et al. (2005) Wake et al. (2004)	Australia population	ID	7-11	.03	Good
This dissertation	Review of primary studies, Chapter II	ID and INT		.08 (average)	

ID = Identification, INT = Intervention.

variability in language outcomes several years after children entered school. This finding was echoed by Holzinger and colleagues (2011) with children who were school age. Additionally, Fitzpatrick and colleagues (2007) reported similar numbers with a study of school age children, though her results were marginally higher at R^2 = .07. Finally, the average R^2 measure of effect size from the review of primary studies discussed in Chapter II of this dissertation was R^2 = .08. These similar results across studies that had sufficient sample sizes to include other covariates suggest that earlier identification and intervention are related to better language outcomes, but the contribution was small compared to the variance in the models potentially explained by other—possibly unmeasured—factors.

The following paragraphs summarize results to answer the research questions proposed for this study.

Research Question #1: Relationship Between Age at Identification or Treatment and Child Language Outcomes

Use of CFA and SEM statistical methods with the SKI*HI data set did not result in models that adequately fit the underlying data. As such, these techniques did not result in findings from the SKI*HI national data bank from which we can draw strong conclusions regarding the relationship between age at identification of hearing loss or intervention and child outcomes. Multiple regression using AMOS and SPSS were conducted to replicate findings regarding the relationship between age at program start and child language outcomes based on LDS expressive and receptive average monthly gains in scores. Findings for the variability in outcomes explained by age at program start were similar, but somewhat smaller at $\beta^2 = .04$, to results reported by Strong and colleagues (1992) with this same data set. However, results were consistent with findings described in the literature review in Chapter II.

Research Question #2: Characteristics that Affect the Relationship Between Age at Identification or Treatment and Child Language Outcomes

Again, use of CFA and SEM statistical methods with the SKI*HI data set did not result in models that adequately fit the underlying data. Hence, conclusions drawn from these methods about characteristics that affect the relationship between age at identification of hearing loss or intervention are tenuous at best and probably unjustified. Using simplified models and other techniques recommended by SEM experts in the hopes that an appropriate model could be identified resulted in excluding many of the variables that could answer this question. However, if we presume that the measurement model shown in Figure 4 in Chapter III displayed fit statistics that were "close enough," some tentative inferences about relationships among the variables could suggest directions for future research. For example, model parameters listed in Table 23 in Chapter IV showed a positive relationships between *child risk*, and *unaided hearing loss (*about 7% of the variability shared between them); *age at hearing aid fit* and *child age at treatment* (90% of the variance in *age at hearing aid fit* in common with *child age at treatment); treatment length* and *child age at treatment* (near 10% of the variance shared); and *child outcomes* and level of *hearing aid use (*12% shared variance). While these relationships are what would be expected based on Bronfenbrenner's bioecological theory of development, drawing strong conclusions from these numbers would be unwarranted given the marginal fit that was achieved with the data. The poor fit was most likely attributable to large numbers of missing data (e.g., 33% missing cells and only 32 out of 2300 complete cases), and weaknesses in how data were collected (e.g., a large and variable range between the dates at which a child was pretested and when the child was enrolled in the program, though we expect these dates to be near in time given our expectation that pretest scores represent baseline language status when treatment begins). The fact that the model parameters mentioned above were fairly consistent across most models tested, however, suggests that these variables merit further research.

Research Question #3: Differences Between Children with Hearing Parents and Those with a Parent with Hearing Loss

Again, results from the CFA and SEM statistical analyses do not justify drawing strong conclusions about differences for children with hearing parents and children with a parent who had a permanent hearing loss. However, a preponderance of evidence from the analyses conducted for this dissertation suggests there are few differences between these groups based on the variables measured, though there were no complete cases for parents with hearing loss. For example, the attrition analysis showed few differences based on parent hearing status for children who did not have posttest scores. In all CFA and SEM models tested in which the variable, *parent has hearing loss*, was retained, the factor loading was low (i.e., typically lower than $\beta = .1$, with $\beta^2 = .01$). Model parameter estimates consistently suggested that this variable did not contribute substantively to explaining the variability in outcomes. While these results do not provide strong evidence about differences in characteristics or outcomes based on hearing status of parents, they differ from the summary of prior research in Chapter II, which suggested the average SMDES of differences in means between children with a parent with hearing loss compared to children with hearing parents was .23. These discrepancies suggest the need for more carefully planned studies to determine the extent to which differences exist, though we would never take a child with hearing loss away from hearing parents to provide intervention through an adult with hearing loss. However, including adults with hearing loss in a child's language and development experiences could be possible if supported by high-quality evidence.

In summary, more advanced statistical methods applied to an existing data set did not substantively contribute to what we know about the impacts of earlier identification and intervention on language outcomes of children born with hearing loss. However, results from a simpler regression analysis were aligned with findings from the comprehensive review of the literature, suggesting earlier age at identification or intervention accounts for a small percentage, e.g., less than 10%, of the variability in language outcomes.

Limitations of the Study

The results from CFA and SEM analyses of the SKI*HI data set indicated that the models that were tested did not adequately describe the underlying data. We cannot determine whether the lack of fit was due to (a) the wrong model even though data were available for all the right variables; (b) a model that accurately described the underlying data, but the data were inadequate for the following potential reasons, among others: not multivariate normal, non-ignorable missing data (Muthén et al., 2011), not properly collected based on underlying assumptions (e.g., pretest and program start dates not close in time; or c) data that were not available for essential elements in a model that adequately simplifies reality (e.g., parent education; economic status; density of actual treatment; fidelity of treatment). Additionally, the children who participated in this study were assessed upon exit from the SKI*HI program when they were approximately three years old; we do not have data for long-term outcomes after children have entered school.

The SKI*HI data set was designed to learn more about the demographic characteristics of children born with hearing loss and to determine if the SKI*HI program was effective in diagnosing hearing loss at earlier ages. The data set served these purposes at the time the program was funded. Data collection measures and procedures were not intentionally designed for an analysis such as the one conducted for this dissertation. In particular, the data set exhibited several characteristics that made it unsuitable for a more complex analysis of the data. For example, there were substantial missing data. While some missing data were the result of changes in the design of the research (i.e., instruments were developed during the course of the program to capture additional data to evaluate program effectiveness, so those data were not collected initially), other "missing" data stemmed from the voluntary nature of data submission from sites. Using the subset of data collected from 1987 through 1991 helped correct for changes to the research design, and excluding data from sites that did not collect treatment data or parent outcomes left 2,300 cases remaining in the sample. However, even these 2,300 cases had considerable missing data.

Fortunately, CFA and SEM methods incorporate estimation of parameters that account for and are robust to missing data (Arbuckle, 1996). For this dissertation, it was decided that FIML was the best estimator as it uses all information available to calculate parameters. Despite this, it seemed likely that missing data were at least partly responsible for preventing models from converging and calculating parameter estimates. Additionally, there was some evidence that data were MNAR, because missing on the LDS outcome variables was related to lower scores on other parent and child outcome measures. There is insufficient research on these MNAR conditions to know the impact of MNAR on SEM estimates. Wothke (2000), one of the developers of AMOS, stated, "one might summarize [missing data estimation methods] yield very precise estimates of exactly the wrong parameter" (p. 11). With large amounts of missing data, findings are tenuous, at best, and generalizing study results to a larger population would be questionable.

Additionally, there was evidence that data were not univariate normal, which is a necessary but not sufficient condition for multivariate normality—an assumption upon which multivariate statistics are based. Some researchers claimed that SEM methods are robust to nonnormality (Curran et al., 1996), but others (Enders & Bandalos, 2001; Fan et al., 1999; Thompson, 2000) suggested that nonnormality, particularly when it is combined with large amounts of missing data, result in biased parameter estimates. Hence, the SKI*HI data set had several characteristics that indicated it was not well suited for analysis using SEM.

Unfortunately, many data sets in the social sciences suffer from these same problems, and large data sets from low-incidence populations are currently difficult to locate. While we hoped that the SKI*HI data set would help contribute answers to important questions, the characteristics of the data precluded learning more than was already reported by Strong and colleagues (1992).

The fact that SEM techniques were not successful with this data set in answering the research questions posed should not lead to the conclusion that SEM is inappropriate for answering such questions. A more plausible explanation is that weaknesses in how data were defined and measured for the children in this data set were responsible for the failure to find solutions that were an adequate fit for the data. Yet, as is often the case with analysis of existing data set, these data were not collected with an eye towards the analyses described in this dissertation, as these methods were not yet widely used in social sciences research. This underscores the need to carefully plan and systematically collect appropriate data rather than assuming that a data set that includes a large number of subjects will be sufficient. There are nonetheless important lessons that can be gleaned from the analyses conducted for this study, as described in the next section.

Additional limitations to this study include the following. This data set did not include children with cochlear implants, as they had not yet been approved by the FDA for use in children when these data were collected. Cochlear implants have become a major factor in the treatment of children with profound hearing loss in the past 15 to 20 years, albeit cochlear implants are likely to affect only 15-20% of children with hearing loss, based on eligibility. Additionally, key outcomes in this study were limited to LDS expressive and receptive scores. Although this assessment demonstrates adequate reliability for children with hearing loss, and the LDS and similar measures were used in most of the research with children with hearing loss (as shown in Chapter II), better measures of language development exist. If we want to compare children with hearing loss to typically hearing children in our efforts to help children with hearing loss be on par with their same age hearing peers, additional measures normed with both typically hearing children and children with hearing loss need to be included in studies of language development. Also, an important variable in intervention research is fidelity of treatment (Kaderavek & Justice, 2010; O'Donnell, 2008). Treatment verification data in the SKI*HI data set included only treatment length and the average number of home visits per month. We do not know if intervention was delivered as intended, or the extent to which the number of home visits was aligned with children's needs rather than scheduling convenience for both families and home visitors.

Finally, though the SKI*HI National Data Set was a "national data set," it was not likely representative of the population of children with hearing loss. Almost 28% of children in the data set were not White (Caucasian), compared to census data from 1990 that indicates that non-White groups comprised less than 20% of the population (Hobbs & Stoops, 2002). This disparity indicated that data submitted by sites to the SKI*HI National Data Base included more children of minority status than would be expected by a representative group. Adequate representation of children from minority backgrounds in studies such as this is crucial, because children from minority families are disproportionately less likely to receive early intervention services despite having a greater proportion who qualify (Hebbler, Spiker, Mallik, Scarborough, & Simeonsson, 2004). In general, more high-quality research on the impacts of home languages other than English, and adequacy of intervention services for meeting the needs of minority children, and outcomes is needed. Yet, we do not know from the SKI*HI data if there were actually more non-White children identified and served, or if sites were located in less predominantly White areas. As such, geralizing findings from the SKI*HI data to the population would be problematic.

Suggestions for Future Research

While some researchers (e.g., Hart & Risley, 1995) have provided evidence that early language experiences are associated with language outcomes during later school years, other research shows those trajectories can be changed with appropriate intervention (Callow-Heusser, 2009; Carnine & Callow-Heusser, 2006; Nittrouer, 2009; Roggman et al., 2002). The research summarized in Chapter II indicates that we need to know more about how to effectively implement early intervention programs with children with hearing loss to more strongly affect language outcomes through school years and beyond, particularly for children from minority ethnicities. To explain, all studies reviewed in Chapter II for which an effect size could be calculated and in which children were assessed beyond elementary grades (e.g., age 13 and older) indicated younger ages at identification or intervention had a zero or small negative impact on long term language outcomes (Davis et al., 1986; Harris & Terlektsi, 2011; Vernon & Koh, 1971; Weisel & Reichstein, 1989) except Cunningham (1999), who reported that there were no statistically significant relationships despite a small SMDES. Additionally, other studies in which children were assessed at between the ages of 8 and 12 showed small or mixed results. Markides (1986), Watkins (1983, 1984, 1987), Kennedy and colleagues (2006), and Worsfold and colleagues (2010) showed moderate to large effect sizes; Levitt (1987; see also Levitt & McGarr, 1988; Levitt et al., 1987) and Wake and colleagues (2004, 2005) showed negligible to small effect sizes; and Weisel (1989) showed a negative impact.

Given this variation in outcomes, research should be better designed with prospective selection of groups and measures, and children should be followed longitudinally. Sample sizes should be adequate for statistical power, particularly to investigate the impact of covariates on outcomes. Yet, it may be better to conduct carefully designed studies with well-executed data collection plans, adequate sample sizes for statistical power, and validated measures sensitive enough to detect differences between groups, rather than attempt to collect data on larger samples. Additionally, data for variables that could affect outcomes should be collected, including family characteristics such as parent hearing status, education, economic status, employment, health insurance, other services, and family composition and relocation status (e.g., number of household moves), at a minimum. Treatment characteristics and fidelity of implementation also need to be measured. Outcome measures better aligned with goals (i.e., helping children with hearing loss achieve on par with typically hearing peers) should be used. Additionally, for children with profound hearing loss, cochlear implants—and the most effective age at implantation—need to be better addressed in future research. Finally, researchers outside of program developers and staff, and technology manufacturers, need to be involved to prevent conflicts of interest in data analysis and reporting.

While it is challenging and costly to include sufficient sample sizes to meet research criteria, and potentially impossible and unethical to conduct RCTs despite claims to the contrary (Mosteller & Borush, 2002; Shavelson & Towne, 2002), the review of the literature completed in Chapter II indicates that with respect to providing early intervention for children who are deaf or hard of hearing, we do not yet have sufficient evidence to be confident about what works best for whom and under what conditions. While the authors of those studies may have been heavily invested in doing what they felt was best for children with hearing loss, insufficient evidence justifies strong claims that "earlier is better." Hence, research designs that better account for confounding factors and small sample sizes should be considered. These include comparing growth from alternative interventions in strong single case design (Institute for Education Sciences, 2010); larger group studies with planned missing data to lower costs of research (Graham, Taylor, Olchowski, & Cumsille, 2006); and growth modeling (i.e., repeated measures) designs (Raudenbush & Bryk, 2002; Muthén & Asporouhov, 2010; http://www.statmodel.com/download/multilevelVersion2.pdf); and other strong designs for comparative studies (http://www.ahrq.gov/about/nac/sruss.htm).

Finally, it is clear from the research that those involved with early identification of children with hearing loss and intervention are emotionally invested in the work they do with children, as they should be. However, this researcher wonders, based on her experience working with struggling children and children with disabilities, how often we are willing to think outside the box and consider alternative interventions, or sequencing of interventions. Do we really know that a strong focus on early language for children born with hearing loss is better than an early focus on building nurturing relationships between caregivers and children that will promote strong attachment? Do we really know that home- or center-based coaching of parents is better than providing center-based care with experienced professionals many hours a day (such as Sweden does; see Gunnarsson, Korpi, & Nordenstam, 1999), particularly when families may be stressed by the financial, time, and parenting obligations needed to successfully raise a child with a disability? Do we really know if early surgical implants and the inherent risk with medical interventions are better than promoting other early experiences, implanting devices when a child is, say, three, and providing intensive audiological, speech and language training at that time? Based on the research reviewed in Chapter II, this researcher wonders to what extent we know how to best serve families of children with hearing loss, many of whom are forced to travel on a path they did not choose and about which they know very little when they begin.

Russ (http://www.ahrq.gov/about/nac/sruss.htm) sums up this conundrum in her plea to the National Advisory Council for Healthcare Research and Quality:

> There are many questions regarding the best types of intervention for children with early hearing loss, and little evidence in the field on which to base decisions. It is widely believed that this dearth of research must be addressed if outcomes for children that are deaf or hard of hearing are to improve. Suggested areas of focus include…the nature of early intervention offered to children that are deaf or hard of hearing:
>
> - the counseling strategies,
> - the characteristics of habilitative interventions,
> - the fidelity of the intervention,
> - the knowledge and skills of the intervention provider, and
> - whether or not the family gets regular progress monitoring information.
>
> These may in fact, be stronger predictor variables than the type of amplification or the age at which amplification was acquired, although these are aspects of intervention that are more challenging to measure.

Conclusions

To conclude, we know too little about whether earlier identification and intervention is better for children born with hearing loss or who acquire it at young ages. Unfortunately, the data analyses completed for this dissertation add very little to what was already known about the questions posed at the beginning of the study. However, the literature review suggests additional research that is needed, and that results from prior studies are mixed. In addition to using better research designs, reliable measures to collect a broader array of data related to important covariates, data collection plans, and analysis methods to address questions about the age at which intervention begins, perhaps we should also be asking different questions. Maybe, we could help children be more successful if we asked questions about what interventions, in which order, provided by whom, and in what ways? However, at a minimum, we need to design better studies to answer important questions for the sake of children with hearing loss, and to keep our focus on children and what's best for them, despite our often well-founded beliefs.

Finally, these children with hearing loss, like so many other struggling children, do not have the luxury of time. In order to help them maximize their potential and be successful and productive in our society, we need to conduct better research on the efficacy of interventions now. For them, time is of the essence.

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APPENDICES

Appendix A

Sample Characteristics and Methodological Problems of Prior Research

Table A-1

Sample Characteristics and Methodological Problems of Prior Research

			Independent variables				Methodological problems with study												
Publication	Year	Intervention program, type, & location	Hearing status of parents	child's hearing loss	Mode of communication	Other disabilities included	Poor intervention description	Poor population description	Selection bias, nonrepresentative sample	Nonequivalent groups	Problems with matching	Treatment length differences	Maturation a confounding variable	Sample, group, or cell sizes are small or unequal	Attrition, missing data	Instrumentation reliability, validity questionable	Continuous variables converted to categorical	Questionable use of statistics	Reporting errors or omissions
Apuzzo & Yoshinaga-Itano	1995	CHIP, parent-centered, home-based	nr	M MS P	All	Yes		✓	✓	✓	na	✓		✓		✓	✓		
Ashby	1995	AASD, parent-centered, home-based	HP	M SP	All	No		✓	✓			✓				✓			✓
Balow & Brill	1975	CA residential schools for the deaf, school-based	DP HP	nr	nr	nr	✓		✓	na	na	✓				✓	✓		✓
Brasel & Quigley	1977	Multiple programs, sign/oral	DP HP	SP	All	No	✓	✓	✓	✓	✓			✓	✓				
Calderon	1998	ECHI, family-centered, home-based	HP	M MS P	All	No		✓	✓	✓	na	✓		✓			✓		
Calderon & Naidu	1998	ECHI, family-centered, home-based	nr	SP	All	No		✓	✓	✓	na	✓		✓			✓		
Clark	1979	SKI*HI, parent-centered, home-based	mix	M MS P	All	Yes			✓	✓	na	✓		✓	✓				
Cunningham	1999	Multiple programs, hearing aids, preschool	nr	M M SP	All	nr	✓	✓	✓	na	na			✓	✓	✓			

(*table continues*)

Publication	Year	Intervention program, type, & location	Independent variables: Hearing status of parents	child's hearing loss	Mode of communication	Other disabilities included	Methodological problems with study: Poor intervention description	Poor population description	Selection bias, nonrepresentative sample	Nonequivalent groups	Problems with matching	Treatment length differences	Maturation a confounding variable	Sample, group, or cell sizes are small or unequal	Attrition, missing data	Instrumentation reliability, validity questionable	Continuous variables converted to categorical	Questionable use of statistics	Reporting errors or omissions
Davis, Elfenbein, et al.	1986	Iowa schools, hearing aids	nr	M M S	All	No	✓	✓	✓	✓	na			✓	✓		✓		
Geers & Moog	1989	High schools US, Canada, oral	nr	P	O	nr	✓	✓	✓		na								
Geers & Moog	1992	High Schools US, Canada, Total Communication	DP HP	M MS P	M	nr	✓	✓	✓	✓	na								
Geers & Schick	1988	Multiple programs, manually coded English, center-based	DP HP	SP	M	No		✓	✓	✓	✓					✓			
Greenstein, et al.	1975	LSD, parent-centered, center-based	DP HP	SP	All	nr			✓	✓	na	✓		✓					
Kennedy, et al.	2006	Earlier identification through UNHS	nr	M MS P	All	nr									✓				
Kusche, Greenberg, & Garfield	1983	CA residential schools for the deaf, school-based	DP HP	nr	M	No		✓	✓							✓			
Levitt	1987	NY schools for the deaf, school-based	nr	SP	All	Yes	✓	✓	✓	na	na			✓	✓			✓	✓
Liff	1973	Parent teaching program, hearing aids, center-based	nr	SP	O	No	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓
Markides	1986	Hearing aids	nr	SP	nr	No	✓	✓	✓	✓	✓					✓			
Mayne, Yoshinaga-Itano, & Sedey	2000	CHIP, parent-centered, home-based	HP	M MS P	All	Yes		✓	✓	✓	na	✓	✓	✓	✓	✓	✓		

(*table continues*)

Publication	Year	Intervention program, type, & location	Independent variables: Hearing status of parents	child's hearing loss	Mode of communication	Other disabilities included	Methodological problems with study: Poor intervention description	Poor population description	Selection bias, nonrepresentative sample	Nonequivalent groups	Problems with matching	Treatment length differences	Maturation a confounding variable	Sample, group, or cell sizes are small or unequal	Attrition, missing data	Instrumentation reliability, validity questionable	Continuous variables converted to categorical	Questionable use of statistics	Reporting errors or omissions
Mayne, Yoshinaga-Itano, Sedey, et al.	2000	CHIP, parent-centered, home-based	HP	M MS P	All	Yes		✓	✓	✓	na	✓	✓		✓	✓	✓		
Meadow	1968	CA school for the deaf, Berkeley, school-based	DP HP	SP	All	No		✓	✓	✓	✓				✓	✓	✓		
Messerly & Aram	1980	Multiple programs	DP HP	SP	O	No	✓	✓	✓	✓	✓			✓					
Moeller	2000	DEIP, family-centered, home/center-based	HP	M M SP	All	No		✓	✓	✓	na	✓					✓		
Moores, Weiss, & Goodwin	1978	Multiple programs, communication mode	nr	SP	All	No			✓	✓	na	✓		✓	✓				✓
Musselman & Kircaali-Iftar	1996	Multiple programs	HP	SP	All	nr	✓	✓	✓		na					✓			
Musselman, Wilson, & Lindsay	1988	Multiple programs, parent-centered	HP	SP	All	nr		✓	✓	na	na	✓					✓		✓
Naidu	1995	ECHI, family-centered, home-based	HP	M MS P	All	No		✓	✓	✓	na	✓		✓			✓		
Parasnish	1983	Multiple programs, sign language	DP HP	SP	M	nr		✓	✓	✓	na	✓							
Pipp-Siegel et al.	2003	CHIP, STEP*HI, parent-centered, home-based	HP	M M SP	All	Yes		✓	✓	na	na	✓			✓	✓	✓		
Ramkalawan & Davis	1992	Multiple programs, located through CHAC	HP	M MS	O	No	✓	✓	✓	na	na	✓		✓	✓				
Robinshaw	1995	Hearing aids	nr	SP	All	Yes		✓	✓	na	na		✓	✓		✓			

(*table continues*)

Publication	Year	Intervention program, type, & location	Independent variables				Methodological problems with study												
			Hearing status of parents	child's hearing loss	Mode of communication	Other disabilities included	Poor intervention description	Poor population description	Selection bias, nonrepresentative sample	Nonequivalent groups	Problems with matching	Treatment length differences	Maturation a confounding variable	Sample, group, or cell sizes are small or unequal	Attrition, missing data	Instrumentation reliability, validity questionable	Continuous variables converted to categorical	Questionable use of statistics	Reporting errors or omissions
Snyder & Yoshinaga-Itano	1998	CHIP, parent-centered, home-based	All	M MS P	nr	Yes		✓	✓	✓	na	✓					✓		
Strong, Clark, Barringer, et al.	1992	SKI*HI, parent-centered, home-based																	
Theisen-Washburn	1988	Multiple programs	nr	M SP	All	No		✓	✓	na	na			✓	✓	✓	✓		✓
Vernon & Koh	1971	Different interventions, communication mode	DP HP	SP	O M	nr	✓	✓	✓	✓	✓					✓			✓
Wake et al.	2005	None specified	nr	M MS P	All														
Watkins	1984	SKI*HI, parent-centered, home-based	mix	M MS P	All	Yes	⊘	✓	✓	✓	✓						✓		
Weisel	1988	Multiple programs (Israel), school-based	DP HP	SP	nr	No	✓	✓	✓	✓	na				✓	✓			✓
Weisel	1989	Multiple programs (Israel), school-based	HP	SP	O	Yes	✓	✓	✓	na	na	✓			✓				
Weisel & Reichstein	1989	Multiple programs (Israel), hearing aids, school-based	DP HP	SP	All	nr	✓	✓	✓	na	na				✓	✓	✓		✓
White	1983	SKI*HI, parent-centered, home-based		M MS P	All	Yes		✓	✓						✓				
White & White	1987	LSD, child-centered, center-based	DP HP	SP	All	nr	✓	✓	✓	✓	na	✓		✓					

(*table continues*)

Publication	Year	Intervention program, type, & location	Independent variables				Methodological problems with study												
			Hearing status of parents	child's hearing loss	Mode of communication	Other disabilities included	Poor intervention description	Poor population description	Selection bias, nonrepresentative sample	Nonequivalent groups	Problems with matching	Treatment length differences	Maturation a confounding variable	Sample, group, or cell sizes are small or unequal	Attrition, missing data	Instrumentation reliability, validity questionable	Continuous variables converted to categorical	Questionable use of statistics	Reporting errors or omissions
Yoshinaga-Itano	1999	CHIP, parent-centered, home-based	nr	M MS P	All	Yes		✓	✓	✓	na	✓			✓	✓	✓		✓
Yoshinaga-Itano & Apuzzo (a)	1998	CHIP, parent-centered, home-based	HP	M MS P	All	Yes		✓	✓	✓	na	✓				✓	✓		
Yoshinaga-Itano & Apuzzo (b)	1998	CHIP, parent-centered, home-based	All	M MS P	All	Yes	✓	✓	✓	✓	na	✓	✓	✓	✓	✓	✓		
Yoshinaga-Itano & Sedey	2000	CHIP, parent-centered, home-based	HP	M MS P	All	Yes		✓	✓	✓	na	✓				✓	✓		
Yoshinaga-Itano, Coulter, & Thomson	2000	CHIP, parent-centered, home-based	HP	M MS P	All	Yes	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓
Yoshinaga-Itano, Sedey, Apuzzo, et al.	2001	CHIP, parent-centered, home-based	HP	M MS P	All	nr	✓	✓	✓	✓	na	✓		✓			✓		✓
Yoshinaga-Itano, Sedey, et al.	1998	CHIP, parent-centered, home-based	nr	M MS P	All	Yes		✓	✓	✓	na	✓			✓	✓	✓		✓
Yoshinaga-Itano, Snyder, & Day	1998	CHIP, parent-centered, home-based	HP	M MS P	All	Yes	✓	✓	✓	✓	na	✓					✓		✓

Not Reported	nr	Severe	56-70 dB
Mild	26-40 dB	SP	71-90 dB
Moderate	41-55 dB	Profound	91 + dB

Appendix B

Criteria for Rating Quality of Primary Studies

Table B-1

Criteria for Rating Quality of Primary Studies

Rating	Criteria
Very poor	Severe threats to validity that are not controlled or discussed; inappropriate use of statistical methods to support conclusions; severe omissions in reporting. Examples include single group posttest design using single outcome measure with questionable validity; no report of sample size or criteria for sample selection. Yoshinaga-Itano and Apuzzo (1998a) is an example of a study rated “very poor.”
Poor	Severe threats to validity or omissions in reporting make drawing conclusions questionable. Examples include single group posttest design with multiple posttests; posttest-only design with nonequivalent comparison group(s); posttest-only nonequivalent comparison group design with sufficient sample sizes. Geers and Moog (1992) is an example of a study rated “poor.”
Fair	Design controls for some threats to validity; sample selection or size or other threats to validity raise concern. Examples include single group pre/posttest design with multiple dependent measures of different constructs; matched comparison group designs with sufficient sample sizes (highest rating for single group design as described by Campbell & Stanley, 1966, or Shadish, Cook, & Campbell, 2002). Moeller (2000) is an example of a study rated “fair.”
Good	Design controls for many threats to validity; sample selection and sample size are adequate; other confounding factors are controlled or addressed. Examples include population studies, carefully matched comparison group designs with multiple dependent measures (highest rating for quasi-experimental designs with matched comparison groups as described by Shadish, Cook, & Campbell, 2002). Wake, et. al (2005) is an example of a study rated “good.”
Excellent	Well-executed RCT with thorough reporting (as defined by DerSimonian, Charette, McPeek, & Mosteller, 1982; Institute for Education Sciences, 2003). No studies in the body of research reviewed here were rated “excellent.”

Appendix C

Factors Reviewed or Investigated in Primary Studies of Early Intervention for Children Born with Hearing Loss

Table C-1

Factors Reviewed or Investigated in Primary Studies of Early Intervention for Children Born with Hearing Loss

	Child characteristics												Parent/family characteristics													Intervention characteristics									
Primary study	Gender	Ethnicity	Cognitive ability	Additional disabilities	Attachment security	Degree of hearing loss	Etiology of hearing loss	Age at onset of hearing loss	Age at identification	Age at intervention	Level of hearing aide use	Child age at final assessment	Socio-economic status (SES)	Hearing status of parents (and siblings)	Age of mother/father	Language spoken in the home	Mode of communication with deaf child	Parent level/frequency of communication	Level/quality of parent-child interaction	Parent involvement in intervention	Acceptance/confidence in parenting child	Parent social support	Father involvement/father in home	Parent stress	Mother/father educational level	Treatment length	Components, sequencing of intervention	Focus of intervention (child/family)	Intensity/frequency of intervention	Intervention location (home, center, school)	School placement, access to hearing children	Service area (rural, urban, suburban)	Home visitor characteristics	Quality of relationship (family/home visitor)	Study characteristics
Apuzzo & Yoshinaga-Itano (1995)			R			±				±		R	R																						
Ashby (1995)	R	±	±	R	R	R			±	R		R	±	R			R	R	R	R		R	R	R	R	±	R	R	±	R	R	R			R
Balow & Brill (1975)			±							±				±												±				R					
Brasel & Quigley (1977)	±			S		S		S			R	S	R	±		R	±																		
Calderon (1998)	⊘	⊘	S	S		⊘	R		R	±		⊘	±	S	±	R	R		R	⊘	R	R	R	R	⊘	R		R	⊘	R	R	⊘			R
Clark (1979)				R		⊘	R		R	⊘				R		R	⊘			R	R	R		R		±	R	R	R	R	R		R	R	R
Cunningham (1999)	R		±			±	R	R	⊘	⊘	R	R		R		R	±	R		R	R				R		R	R	R	⊘	⊘				
Davis, Elfenbein et al. (1986)			S	S		R		S		±	R	R	R												R										
Geers & Moog (1989)			S			±		S		±			±				±								R						±				
Geers & Moog (1992)			S			±		S		⊘	R	S		S			S														R				
Geers & Schick (1988)	M			S		M				S		M		±		R	S										M	M		M					
Greenstein et al. (1975)						R			R	±		M	R	⊘			R	±	±	R	R					±		R	R	R	R				R
Kennedy et al. (in press)						S	S	S	S			S													S										R

(*table continues*)

	Child characteristics												Parent/family characteristics													Intervention characteristics									
Primary study	Gender	Ethnicity	Cognitive ability	Additional disabilities	Attachment security	Degree of hearing loss	Etiology of hearing loss	Age at onset of hearing loss	Age at identification	Age at intervention	Level of hearing aide use	Child age at final assessment	Socio-economic status (SES)	Hearing status of parents (and siblings)	Age of mother/father	Language spoken in the home	Mode of communication with deaf child	Parent level/frequency of communication	Level/quality of parent-child interaction	Parent involvement in intervention	Acceptance/confidence in parenting child	Parent social support	Father involvement/father in home	Parent stress	Mother/father educational level	Treatment length	Components, sequencing of intervention	Focus of intervention (child/family)	Intensity/frequency of intervention	Intervention location (home, center, school)	School placement, access to hearing children	Service area (rural, urban, suburban)	Home visitor characteristics	Quality of relationship (family/home visitor)	Study characteristics
Kusche, Greenberg, & Garfield (1983)	M	M	R	R		M	R	M	R	±	M	M	M	±			R			M			M		M						R				R
Levitt (1987)			⊘	±		±	⊘	±		±	±		±	±		±				±											±				R
Liff (1973)	R		S			S				±	S	R					R																		
Markides (1986)	M					M		M		±		M																			M				
Mayne, Yoshinaga-Itano, & Sedey (2000)	⊘	⊘	R	⊘		±			⊘	R		±	⊘	S			⊘	R	R						⊘										
Mayne, Yoshinaga-Itano, Sedey et al. (2000)	R	R	R	±		R			±			±	R	S			R	R	R						R										
Meadow (1968)	M	S	M	S		M	S	S		±		M	R	R			R								R					R	R				
Messerly & Aram (1980)			M			S	R					M	S	±		R	R				R											S			
Moeller (2000)	R	R	±	R		R				±			R	R		R	R	±	±	±	±	R				R	R	R	R	R		R			R
Moores, Weiss, & Goodwin (1978)	R		R	R		±				±	R		R				±				R				R		R			R	R				
Musselman & Kircaali-Iftar (1996)	⊘		R			R		S		⊘	±	R	⊘	S			±		±	±	±	R	±	R	±		±	R	±	R	±				R
Musselman, Wilson, & Lindsay (1988)			±			±		S		⊘		±	R	S		R	R	R	±	⊘					R	R		R	±	R					R
Naidu (1995)			R	S		±	R	R	R	±	R	R		R	R		R	R	R	R	R	R		R	R		R	R	R	R	R	R	R	R	R
Parasnis (1983)	±					R				±		S		M			S		R							R					S				
Pipp-Siegel et al. (2003)	⊘	±	R	±		±			±	±		±	⊘				⊘								⊘										R

(*table continues*)

	Child characteristics												Parent/family characteristics													Intervention characteristics									
Primary study	Gender	Ethnicity	Cognitive ability	Additional disabilities	Attachment security	Degree of hearing loss	Etiology of hearing loss	Age at onset of hearing loss	Age at identification	Age at intervention	Level of hearing aide use	Child age at final assessment	Socio-economic status (SES)	Hearing status of parents (and siblings)	Age of mother/father	Language spoken in the home	Mode of communication with deaf child	Parent level/frequency of communication	Level/quality of parent-child interaction	Parent involvement in intervention	Acceptance/confidence in parenting child	Parent social support	Father involvement/father in home	Parent stress	Mother/father educational level	Treatment length	Components, sequencing of intervention	Focus of intervention (child/family)	Intensity/frequency of intervention	Intervention location (home, center, school)	School placement, access to hearing children	Service area (rural, urban, suburban)	Home visitor characteristics	Quality of relationship (family/home visitor)	Study characteristics
Ramkalawan & Davis (1992)			S	S		±	R		±	±	R	±	±			R	S								R	±									
Robinshaw (1995)	R			R		R	R		R	±	R		R				R	R	R									R		R					
Sisco & Anderson (1980)	R	R	±			R							R	±			R	R	R		R										R	R			R
Snyder & Yoshinaga-Itano (1998)	R	R		R		R			±								R								R										
Strong, Clark, Barringer et al. (1992)	⊘	⊘	±	±		±	±	±	±	±	⊘	±		⊘		±	±									±		R	⊘	R	R				R
Theisen-Washburn (1988)	R	R	S	S	R	S	R	R	R	R			R	R	R	R	R	R	±	R	R	±		R	R	⊘				R	R				
Vernon & Koh (1971)	M		M			R	M			R		M		M			±													R	R				
Wake et al. (2005)																																			
Watkins (1983)				±		±	R			±	R	±	±	M	±		R	R	R	R	±		M		±	M		R		R	R				R
Weisel (1989)	R		R	R		R	R			±			R	S			R	R	R	R					R						R				
Weisel & Reichstein (1989)	R					±		R		±	±	R	±	±																					
Weisel (1988)	R			S			S						R	±		R	R		R		R				R										
White & White (1987)	R						R		R	±	R	R	R	±		R	R			R	R				R										
Yoshinaga-Itano & Apuzzo (1998a)			S	R		S	R		S	±		S	R	S			R		R					R			R	R		R	R				R
Yoshinaga-Itano & Apuzzo (1998b)	S	R	S	R		±			±	R		S	R	R			R								R										
Yoshinaga-Itano & Sedey (2000)	⊘	⊘		±		±			⊘			R	⊘				±								⊘					R	R				

(*table continues*)

	Child characteristics												Parent/family characteristics													Intervention characteristics									
Primary study	Gender	Ethnicity	Cognitive ability	Additional disabilities	Attachment security	Degree of hearing loss	Etiology of hearing loss	Age at onset of hearing loss	Age at identification	Age at intervention	Level of hearing aide use	Child age at final assessment	Socio-economic status (SES)	Hearing status of parents (and siblings)	Age of mother/father	Language spoken in the home	Mode of communication with deaf child	Parent level/frequency of communication	Level/quality of parent-child interaction	Parent involvement in intervention	Acceptance/confidence in parenting child	Parent social support	Father involvement/father in home	Parent stress	Mother/father educational level	Treatment length	Components, sequencing of intervention	Focus of intervention (child/family)	Intensity/frequency of intervention	Intervention location (home, center, school)	School placement, access to hearing children	Service area (rural, urban, suburban)	Home visitor characteristics	Quality of relationship (family/home visitor)	Study characteristics
Yoshinaga-Itano (1999)	⊘	⊘	R	±		±			±	±		±	⊘	R			±	±	±	R	R	±		±	R	⊘	R	R	R	R					R
Yoshinaga-Itano, Coulter, & Thomson (2000)	⊘	⊘	M	R		M			±			M					⊘								⊘										
Yoshinaga-Itano, Sedey, Apuzzo et al. (2001)			R			S			±					S			R																		
Yoshinaga-Itano, Sedey et al. (1998)	±	±	R	±		±			±	±		±	±				±								±		R	R	R	R					R
Yoshinaga-Itano, Snyder, & Day (1998)		R	R	R		R	R		±	±		R	R	S		R	R								R			R		R					

R: Reviewed or mentioned as factor that was/should be considered or that affects developmental or language outcomes
S: Factor used to select participants or control for differences in a statistical model
M: Factor used to match groups
⊘: Factor showed no differences
±: Factor was related to outcomes—no directionality implied

Appendix D

SKI*HI Data Descriptive Statistics: All Data Collected From 1979-1991

Table D-1

*SKI*HI Data Descriptive Statistics: All Data Collected From 1979-1991*

Latent variable	Variable	Variable label	*N*	% Missing	Scale	Min	Max	Median	Mean	*SD*	Skew	Kurtosis	KSZ✦
Child risk	sex	Gender	5,048	2	N	1	2	1	1.5	.50			
	race	Race/ethnicity	5,025	3	N	1	6	1	1.7	1.36			
	otherh	Additional disabilities	4,974	4	N	1	2	2	1.8	.43			
	typehl	Type of hearing loss	4,968	4	N	1	4	3	3.0	.52			
	sfu	Unaided hearing loss	4,458	14	I	0	120	75	73.9	25.37	- .31	- .41	5.62
	sfa	Aided hearing loss	2,391	54	I	1	120	45	47.2	23.25	.64	.06	4.58
	causehl	Cause of hearing loss	5,177	0	N	1	15	2	4.0	4.17			
	✦✦	Age at onset											
Initial child language	preldse	LDS expressive pretest score	3,312	36	I	0	60	12	14.6	1.79	1.50	2.45	9.47
	preldsr	LDS receptive pretest score	3,318	36	I	0	60	12	15.9	11.33	1.27	1.38	8.81
Child age at treatment	ageid	Age at identification	4,848	6	I	0	71	17	18.9	12.96	.76	.47	5.09
	agehaft	Age at hearing aid fit	4,026	22	I	0	74	22	23.8	13.08	.78	.56	4.97
	progmos	Age at program start	4,185	19	I	0	73.5	25	26.7	14.30	.61	.04	3.47
	commtmos	Age communication method selected	2,973	43	I	.2	73.7	27	28.4	14.26	.53	- .02	2.52
Family moderators	lang	Language spoken at home	5,037	3	N	1	5	1	1.2	.69			
	otfam	Parent who is deaf	5,000	3	N	1	2	2	1.9	.29			
	comm	Communication method selected	4,861	6	N	1	4	2	2.3	.83			
Treatment effectiveness	prgpstdf	Treatment length (program start to posttest)	2,691	48	I	.4	79.2	13	15.0	1.00	1.26	1.98	5.10
	freq	Planned frequency of home visits	4,984	4	N	1	7	2	2.3	.93			
	freqchg	Change in frequency of home visits	3,676	29	N	1	2	2	1.9	.26			
	✦✦✦	Actual treatment density											
	commpmos	Program month comm method selected	2,898	44	I	0	55.1	0	1.5	4.07	4.49	29.99	19.18
	other	Additional services (Non-SKI*HI)	2,525	51	N	1	8	3	3.6	2.71			

(*table continues*)

Latent variable	Variable	Variable label	*N*	% Missing	Scale	Min	Max	Median	Mean	*SD*	Skew	Kurtosis	KSZ✦
Family skills growth (parent outcomes)	as#	Number of parent auditory skills	1,327	74	O	1	11	4	4.6	3.10	.61	- .69	4.78
	cg#	Number of parent cognition skills	265	95	O	1	12	3	4.4	3.37	.93	- .16	3.12
	ao#	Number of parent aural-oral skills	702	86	O	1	9	5	4.7	2.89	.16	-1.37	3.90
	cs#	Number of parent communication skills	1,493	71	O	1	22	8	8.1	5.00	.04	-1.37	4.43
	tc#	Number of parent total communication skills	670	87	O	1	20	6	6.7	5.02	.89	.14	3.32
Child language outcomes	pcie	LDS expressive proportional change index	3,238	37	R	0	58.5	2	2.7	3.73	5.50	47.92	13.25
	pcir	LDS receptive proportional change index	3,243	37	R	0	79.3	2	2.6	3.24	7.06	113.94	12.01
	postldse	LDS expressive posttest score	3,314	36	I	2	60	28	26.3	14.06	.63	- .36	7.89
	postldsr	LDS receptive posttest score	3,312	36	I	2	60	24	28.5	14.38	.43	- .67	6.29
	thaw	Highest level of child hearing aid use	1,476	71	O	1	5	5	4.1	1.33	-1.20	.09	13.11
	adl	Highest auditory development level	1,421	72	O	1	11	7	6.4	3.49	.02	-1.44	5.16
	cldl	Highest comm language development level	1,633	68	O	1	12	8	7.2	3.01	- .25	-1.02	5.54
	vi	Highest vocabulary level	1,566	70	O	1	8	5	4.5	2.57	- .02	-1.47	5.54

N = Nominal, O = Ordinal, I = Interval, R = Ratio

Shaded cells indicate measures of univariate skewness and kurtosis that researchers have found cause significant problems in CFA, the first step in testing SEM models (i.e., skewness > 2 or kurtosis > 7, Curran, West & Finch, 1996; West, Finch, & Curran, 1995; Muthén & Kaplan, 1992)

✦ All values of the Kolmogorov-Smirnov Z (KSZ) Test of normality were significant at the $p < .001$ level

✦✦ Age at Onset was not reported for 58% of the cases. The value was "at birth" for another 30% of cases, and less than 1 year of age for another 7%, leaving only 5% of cases with other values. Hence, the values of this variable were highly skewed with little variability, and this variable was not included in analyses.

✦✦✦ See description in body of dissertation explaining why this variable was excluded from the analysis.

Appendix E

SKI*HI Data Descriptive Statistics: Data Collected From 1987-1991 From

Sites with Parent and Treatment Variables

Table E-1

*SKI*HI Data Descriptive Statistics: Data Collected From 1987-1991 From Sites With Parent and Treatment Variables*

Latent variable	Variable	Variable label	*N*	% Missing	Scale	Min	Max	Median	Mean	*SD*	Skew	Kurtosis	KSZ*
Child risk	sex	Gender	2,295	0	N	1	2	1	1.5	.50			
	race	Race/ethnicity	2,264	2	N	1	6	1	1.8	1.47			
	otherh	Additional disabilities	2,278	1	N	1	2	2	1.8	.43			
	typehl	Type of hearing loss	2,234	3	N	1	4	3	3.0	.44			
	sfu	Unaided hearing loss	2,110	8	I	6	120	75	72.4	27.16	- .27	- .56	3.56
	sfa	Aided hearing loss	1,295	44	I	1	120	45	46.4	22.24	.73	.46	3.32
	causehl	Cause of hearing loss	2,300	0	N	1	15	2	4.2	4.26			
	**	Age at onset (not available)											
Initial child language	preldse	LDS expressive pretest score	1,557	32	I	0	60	12	14.4	1.33	1.45	2.36	6.12
	preldsr	LDS receptive pretest score	1,558	32	I	0	60	12	15.8	11.02	1.25	1.48	5.64
Child age at treatment	ageid	Age at identification	2,180	5	I	0	71	17	18.4	13.24	.77	.49	3.84
	agehaft	Age at hearing aid fit	1,775	23	I	0	73	22	23.7	13.42	.81	.59	3.40
	progmos	Age at program start	1,857	19	I	0	73.5	25	26.2	14.33	.65	.21	2.16
	commtmos	Age communication method selected	1,284		I	.2	73.7	27	28.4	14.26	.51	.07	1.59
Family moderators	lang	Language spoken at home	2,249	2	N	1	5	1	1.2	.71			
	otfam	Parent who is deaf	2,258	2	N	1	2	2	1.9	.27			
	comm	Communication method selected	2,124	8	N	1	4	2	2.3	.78			
Treatment effectiveness	prgpstdf	Treatment length (program start to posttest)	1,268	45	I	.4	56.7	12	14.5	9.85	1.28	1.84	3.48
	freq	Planned frequency of home visits	2,230	3	N	1	7	2	2.3	.85			
	freqchg	Change in frequency of home visits	2,131	7	N	1	2	2	1.9	.30			
	**	Actual treatment density (not available)											
	commpmos	Program month comm method selected	1,249	54	I	0	37	0	1.7	4.10	3.58	15.85	12.29
	other	Additional services (Non-SKI*HI)	1,180	49	N	1	8	6	4.2	2.83			
Family skills growth (parent outcomes)	as#	Number of parent auditory skills	1,310	43	O	1	11	4	4.6	3.10	.61	- .69	4.78
	cg#	Number of parent cognition skills	1,475	36	O	1	22	8	8.1	5.00	.05	-1.32	4.38
	ao#	Number of parent aural-oral skills	691	70	O	1	9	5	4.7	2.89	.16	-1. 37	3.84

Latent variable	Variable	Variable label	*N*	% Missing	Scale	Min	Max	Median	Mean	*SD*	Skew	Kurtosis	KSZ*
	cs#	Number of parent communication skills	660	71	O	1	20	6	6.7	5.02	.88	.12	3.27
	tc#	Number of parent total communication skills	263	89	O	1	12	3	4.4	3.37	.92	- .18	3.13
Child language outcomes	pcie	LDS expressive proportional change index	1,542	33	R	0	42	2	2.4	3.10	5.03	39.72	8.47
	pcir	LDS receptive proportional change index	1,542	33	R	0	79.3	2	2.3	3.14	11.30	241.84	8.93
	postldse	LDS expressive posttest score	1,555	32	I	2	60	24	25.9	13.27	.63	- .20	5.05
	postldsr	LDS receptive posttest score	1,552	33	I	2	60	28	28.2	13.71	.41	- .52	4.01
	thaw	Highest level of child hearing aid use	1,455	37	O	1	5	5	4.1	1.33	-1.20	.09	12.99
	ald	Highest auditory development level	1,401	39	O	1	11	7	6.4	3.49	.01	-1.44	5.11
	cldl	Highest comm language development level	1,611	30	O	1	12	8	7.2	3.01	- .26	-1.02	5.51
	vi	Highest vocabulary level	1,546	33	O	1	8	5	4.5	2.57	- .02	-1.47	5.54

N = Nominal, O = Ordinal, I = Interval, R = Ratio

Shaded cells indicate measures of univariate skewness and kurtosis that researchers have found cause significant problems in CFA, the first step in testing SEM models (i.e., skewness > 2 or kurtosis > 7, Curran, West & Finch, 1996; West, Finch, & Curran, 1995; Muthén & Kaplan, 1992)

* All values of the Kolmogorov-Smirnov Z (KSZ) Test of normality were significant at the $p < .001$ level

** Age at Onset was not reported for 58% of the cases. The value was "at birth" for another 30% of cases, and less than 1 year of age for another 7%, leaving only 5% of cases with other values. Hence, the values of this variable were highly skewed with little variability, and this variable was not included in analyses.

*** See description in body of dissertation explaining why this variable was excluded from the analysis.

Appendix F

SKI*HI Data Sheets and Coding Instructions

Child's Name:____________________

SKI*HI DATA SHEET

DEMOGRAPHICS-I

1. Site Prefix (3 letters)_____ 2. Child ID #_____ 3. Date of birth_____ 4. Sex_____ 5. Program Start Date_____ 6. Date of ID_____ 7. Other handicaps_____
8. Date Hearing Aid Fit_____ 9. One or Both Parents Deaf: Yes / No (circle one) 10. Date of Suspicion_____ 11. Type of Loss: Sensori-neural / conductive / mixed (circle one) 12. Cause of Loss_____
13. Date of "Cause" if Occurred after Birth_____ 14. Race_____ 15. Language Spoken in the Home_____

DEMOGRAPHICS-II (Fill in at program initiation and thereafter whenever additions/changes are made):

1. Hearing Loss (dB numerical values; use best ear; circle if ave. of 2 frequencies or less):

Test Date	Unaided dB	Test Date	Aided dB

2. Communication Methodology: Date Begun:
Diagnostic/prescriptive _____
Aural-Oral _____
Total Communication _____
Other _____ _____

3. Other Non-Parent Infant Program Services: Date Begun:
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

4. Frequency of Home Visits: Date Begun:
( ) twice a week _____
( ) once a week _____
( ) every other week _____
( ) other_____ _____

5. Graduation Date _____

TEST DATA (Write down scores and dates of tests)

LDS:

Test Date	RA	EA

(highest month in age interval)

Other Tests:

Test name	Test Date	Results

CHILD DATA (Slash item if no longer reporting. Leave blank if child not yet achieved.)

(Visit #)	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__	#__
	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date
Time Hearing Aid Worn. Begin recording after H.A. Prog. Initiated. Write # of appropriate time interval. See back. Discontinue (slash) when child achieves 100%.																	
Auditory Development Begin recording after Aud. Prog. Initiated. Write highest level child achieves (1-11). See back.																	
Communication-Language Development Begin recording after Comm. Prog. Initiated. Write highest level child achieves (1-12). See back. Write # of appropriate vocabulary interval. See back. Discontinue (slash) when child has over 300 words.	Communication-Language Level:																
	Vocabulary:																

PARENT DATA (Begin recording after each program initiated. Slash item if no longer reporting. Leave blank if not yet achieved.)

Hearing Aid Skills: Visit # parent achieves 80-100% on hearing aid competency test:_____

New Auditory Skills acquired (1-11). See back.																	
New Communication Skills acquired (1-15). See back.																	
New Aural-Oral Language Skills acquired (1-9). See back.																	
New Total Communication Skills acquired (1-20). See back.																	
New Cognition Skills acquired (1-12) Optional. See back.																	

SKI*HI Data Sheet Key

CHILD DATA

Time Hearing Aid Worn

1. Less than ¼ time
2. ¼ - ½ time
3. ½ - ¾ time
4. Over ¾ time
5. All of the time

(Discontinue reporting when child wears aid 100% of time or recommended hearing aid wearing time during any week.)

Auditory Development

1. Attending
2. Early Vocalizing
3. Recognizing
4. Locating
5. Vocalizing w / inflection
6. Distances / levels
7. Producing vowels / consonants
8. Environmental discrim. and comp.
9. Vocal discrim. and comp.
10. Speech discrim. and comp.
11. Speech use

Communication-Language Development

1. Aware of surroundings, faces and / or voices
2. Pre-babbles (coos, gurgles, etc.)
3. Babbles or gestures
4. Understands single words or signs
5. Uses single words or signs
6. Uses jargon
7. Understands 2 word or sign sequences
8. Uses 2 word or sign sequences
9. Understands 3-4 word or sign sequences
10. Uses 3-4 word or sign sequences
11. Understands compound / complex sentences
12. Uses compound / complex sentences

Vocabulary Interval

1. 0-5 words
2. 6-10 words
3. 11-20 words
4. 21-30 words
5. 31-50 words
6. 51-100 words
7. 101-200 words
8. 201-300 words

(Discontinue reporting when child has over 300 words.)

PARENT DATA

New Auditory Skills

1. Attending
2. Early vocalizing
3. Recognizing
4. Locating
5. Vocalizing w / inflection
6. Distance / levels
7. Producing vowels / consonants
8. Environmental discrim. and comp.
9. Vocal discrim. and comp.
10. Speech discrim. and comp.
11. Speech use

New Communication Skills

1. Minimize background noise
2. Encourage child to explore and play
3. Serve as communication consultant
4. Use interactive turn-taking
5. Get down on child's level
6. Maintain eye contact / direct conversation
7. Use facial expressions
8. Use intonation
9. Use gestures
10. Touch child
11. Respond to child's cry
12. Stimulate babbling
13. Respond to communication intents
14. Use conversational turn-taking
15. Use meaningful conversation

New Language Stimulation Skills: Aural-Oral

1. Conversation in child care activities
2. Conversation in parent task activities
3. Conversation in child initiated activities
4. Conversation in parent directed activities
5. Selection of target words and phrases
6. Increased frequency
7. Reinforcement
8. Expansion
9. Naturalness

Total Communication

1. Use gestures (lesson 2)
2. Respond to baby's gestures (lesson 2)
3. Use t.c. telegrams (lesson 4)
4. Emphasize iconic, easily shaped, functional signs (lesson 4)
5. Increase frequency of functional signs (lesson 5)
6. Emphasizes signs appropriate for child's language and visual development (lesson 5)
7. Reinforce child's signing attempts (lesson 6)
8. Sign consistently to child in child care activities (lesson 7)
9. Sign consistently to child in parent task activities (lesson 7)
10. Sign consistently to child in child initiated activities (lesson 7)
11. Sign consistently to child in parent directed activities (lesson 7)
12. Sign consistently during home visit (lesson 8)
13. Sign consistently when child present but conversation not directed to child (lesson 9)
14. Use animation in t.c. (lesson 10)
15. Use speech effectively in t.c. (lesson 10)
16. Use affixes and noncontent signs (lesson 10)
17. Know how to get the child to watch the signer (lesson 10)
18. Know how to correct child's signing mistakes (lesson 10)
19. Know how to sign when hands are full (lesson 10)
20. Know how to involve reluctant family members, friends and relatives in t.c.

New Cognition Skills

Parent helps child:

1. Assimilate and accommodate (lesson 2)
2. Learn object permanence (lesson 3)
3. Develop goal direction (lesson 3)
4. Learn about space (lesson 4)
5. Learn about causality (lesson 4)
6. Integrate all senses (lesson 4)
7. Attach symbols to objects and mental representations (lesson 5)
8. Distance self from objects (lesson 5)
9. Engage in symbolic play (lesson 5)
10. Form concepts (lesson 6)
11. Learn about order (lesson 6)
12. Learn how to generalize (lesson 6)

Step-By-Step Guide to Completion and Submission of SKI*HI Data Sheet

Step 1

Complete Demographic Section I of SKI*HI Data Sheet at program initiation. Complete Demographic Section II at program initiation and thereafter when additions/changes are made.

Demographic Data - I. Parent advisor fills in Demographic - I (fixed data) only once at program initiation. All dates should be written in numbers: month/day/year. For example, a program start date of June 4, 1985 is written 6/4/85.

1. **Site Prefix:** Each SKI*HI replication agency is assigned a 3-letter prefix (for example, GAA is Georgia's prefix and NDX is North Dakota's prefix). Enter the site's assigned prefix.

2. **Child ID Number:** Each child in a program is assigned a 3 digit number (for example, the sixteenth child to be assigned a number in a particular program is 016). Enter the child's ID number.

3. **Birthdate:** Write birthdate in numbers. For example, a birthday of July 6, 1985 is written 7/6/85.

4. **Sex:** Write M for male, F for female.

5. **Program start date:** The program start date is the month, day and year that *any* parent-infant program services were first given by the SKI*HI program. Examples are the date the coordinator spends time on the first telephone contact, the day the parent advisor visits the home and collects background information, or the first date of any home visit.

6. **Date of ID:** Identification is defined as first report from an audiologist indicating a hearing loss.

7. **Other handicaps:** Check yes if the child has a handicap, other than a hearing loss, which has been professionally confirmed.

8. **Date hearing aid first fit:** Write the date in numbers (month,day, year) when an aid, either trial or permanent, was first fit by any agency.

9. **One or both parents deaf:** Circle yes if one or both parents living in the home are hearing impaired.

10. **Date of suspicion:** Suspicion: Record the date the parents first suspected the hearing loss. If parents did not suspect any hearing loss before formal identification, record the identification date.

11. **Type of loss:** Circle only one of the types. Mixed implies both sensori-neural and conductive types of loss.

12. **Causes of loss:** For cause write the one from the following list that best describes the cause of the hearing loss.

1) unknown
2) hereditary
3) maternal rubella, CMV, or other infections during pregnancy
4) meningitis
5) defects at birth
6) fever or infections in child
7) RH incompatibility
8) drugs during pregnancy
9) other conditions during pregnancy
10) middle ear problems or ENT anomalies
11) drugs administered to child
12) birth trauma
13) child syndrome
14) other (specify)

13. **Date of cause:** If cause occurred after birth (e.g., meningitis, infection, child's reaction to drugs, or middle ear problems), enter the date of occurrence. If hearing loss present at birth, leave blank.

14. **Race:** Write child's race from the following (parental provision of this information is optional):

1) Caucasian
2) Black
3) Oriental/Asian American
4) Spanish American
5) American Indian
6) other (specify)

15. **Language spoken in the home:** Indicate what primary language is spoken in the home from the following list:

1) English
2) Spanish
3) American Sign Language
4) Signed English System
5) other (specify)

Demographics - II.

Parent advisor fills in Demographics - II (changing data) at program initiation and thereafter whenever new information is available. Dates should be written in numbers: month/day/year.

1. **Hearing loss:** Report the hearing sensitivity of the child in numerical dB values. Do not use categorical words. Use the child's best ear. If the average of two frequencies or less is reported,

circle that number. If the average of three or more frequencies is reported, do not circle that dB value. Make sure to indicate test date in numbers: month/day/year.

2. **Communication Methodology:** When the child first enters the parent-infant program, check the communicative placement and give date. Diagnostic/Prescriptive refers to the first few months of the child's enrollment in the program when no decision has yet been made as to auditory or total communication placement. During this time, evaluation data is being collected to aid in making this decision. By the end of the Communication Program, a communication method decision should be made, if possible. The child then begins the Language Stimulation Program: Aural-Oral or the Language Stimulation Program: Total Communication. The parent advisor should be sure to note when the child changes from diagnostic-prescriptive to an aural-oral or a total communication language program. When the child is placed in or changed to a specific methodology, give the date the family begins to use that method with the child.

3. **Other Non-Parent-Infant Program Services:** List and date the initiation of other non-parent-infant program services (other than diagnostic) given to the child and family while child is in the parent- infant program. List services by category as shown below:

a. educational (e.g., preschool, day care, kindergarten)
b. speech and hearing therapy
c. mental health (e.g., parent counseling, child therapy)
d. health (e.g., free clinics, public health nurse, nutritional services)
e. social (e.g., welfare, aid to dependent children, family services)
f. services for mentally retarded
g. other (specify)

4. **Frequency of Home Visits:** Check the one that best describes the current visiting schedule.

5. **Graduation Date:** Put the date in numbers (month,day, year) of the child's graduation from the parent infant program.

Step 2

Explain parent notebook to parents (see pages 89–157). Have parents post parent notebook checklists in an obvious place and check highest level of child's behavior for preceding week. When particular checklist is completed, have parents put it back in the Parent Notebook.

Step 3

Obtain child and parent progress data and record on the SKI*HI Data Sheet during or after each home visit. It is suggested that the parent advisor take one SKI*HI Data Sheet (which becomes the parent advisor's master copy for that child) and then insert a carbon and another data sheet underneath the master for weekly submission to the supervisor. Or the parent advisor may xerox the master data sheet for the supervisor. The parent advisor retains the master copy for continued data entry.

Before recording child and parent data, the parent advisor should enter the home visit date in numbers (month/day/year) and the home visit number (1, 2, 3, 4 ... etc.). For example, the first home visit made to a home on Nov. 3, 1985 reads: Visit 1 on 11/3/85. When beginning a new data sheet, the first home visit number entered will be the next higher number after the last entry on the previous sheet. If the parent advisor goes to the home and the family is not there, date the home visit *but do not write in a new home visit number.* Then write "no show" across the blank lines below.

Child Data.

On all child data, slash the item ☒ if no longer reporting the item. Leave the item blank if the child has not yet achieved a new skill. For example, if the child has not yet begun the Auditory Program, leave the auditory development item blank. Or if the child achieves an auditory level of 4 one week but *does not achieve a new auditory level the next week* leave the next week blank.

1. **Time Hearing Aid Worn:** Begin recording weekly after initiating the Home Hearing Aid Program. Using the SKI*HI Data Sheet Key, write down the number of the appropriate time interval (as determined from the parent's entry on the Hearing Aid Wearing Time Checklist from the Parent Notebook). If the child does not achieve a new time interval during a particular week (for example, the child stays at 1/4 - 1/2 of the time), leave the current week blank. When the child wears the aid all of his waking hours or the hearing aid time recommended by the audiologist, discontinue reporting by slashing item on data sheet.

2. **Auditory Development:** Begin recording weekly after the Auditory Program is initiated. Using the SKI*HI Data Sheet Key, write down the number of the *highest* auditory level the child achieves during the week (as determined from the parent's entry on the Auditory Development Checklist from the Parents Notebook). The parent advisor will want to discuss with the parents the parent's entry on the Auditory Development Checklist and then using the guide below, make a final decision as to the auditory level that should be checked on the SKI*HI Data Sheet.

Determining The Child's Auditory Achievement Level

For Auditory Skills 1, 3, 4, and 6, achievement of a particular level is determined by the child's responding, without auditory clues (see page 394), to three or more different sound stimuli at a 50% or higher consistency level during a series of meaningful presentations of each sound. For example, the child is on the "locating" level if he can localize half the time without clues to three or more sounds (e.g., knocking, his name being called, electrical appliance) during a series of meaningful presentations of each sound (e.g., Mother knocks five times on kitchen cabinet while she is cooking and child responds three times).

For Auditory Skills 8, 9, and 10, achievement of a particular level occurs when the child is making more than 50% of his auditory responses on that level. For example, if most of the child's responses are discriminations of vocal sounds, words, or phrases, the child is on auditory level 9. For achievement of vocal skills (auditory skills 2, 5, 7, and 11), the child should be making 50% or more of his vocalizations on that level. If the child does not acquire a new auditory level (auditory level for current week is the same as the preceeding week), leave blank.

3. **Communication-Language Development:** Begin recording after *Communication Program* is initiated.

(a) **Language level:** Using SKI*HI Data Key, write down the number of the highest language level the child achieves during the week (as determined from the parent's entry on the Communication-Language Checklist from the Parent Notebook). The parent advisor should discuss the parent checklist entry with the parents and verify it if possible. If the child does not acquire a new language level (level for current week is same as preceding week), leave blank.

(b) **Vocabulary count:** Using the Key, write down the number of the appropriate vocabulary interval (as determined from the parent's entry on the Communication-Language Checklist from the Parent Notebook). The parent advisor should discuss with parents their entry on the Communication-Language Checklist. Using the following guide, the parent advisor can make a final decision as to what new vocabulary words should be counted for entry on the SKI*HI Data Sheet.

What Constitutes A New Vocabulary Word

Count as a new word, a morpheme that is distinguishable as a word and has been used spontaneously (not imitatively) by the child more than once. If the word is so misarticulated that it is not recognizable as a word (child says ma or makes an unrecognizable or unrelated sign as he points to a doggie) do not count it as a morpheme (word). If the child understands one morpheme (cat) but uses it in an over-generalized manner to refer to any furry animal with four legs and a tail, only one morpheme will be counted (the verbalized or signed cat is very different from the word dog).

If the child says a morpheme /bä-bä/ for bottle and another morpheme /bä-bē/ for baby, the parents can "hear" the differences and will note the presence of two morphemes. Similarly, if the child signs a close approximation for father and a slightly different but distinguishable approximation for boy, the parent will note the presence of two morphemes. If the child utters one morpheme /bä-bä/ in many different situations, such as when the child wants his /bä-bä/ (bottle), waving and saying /bä-bä/ (bye-bye) or pointing to a /bä-bä/ (baby), the parent will know the child has *three* morphemes if:

1. There is a close approximation of the uttered word to the real word (/bä-bä/ to bye-bye or /bä-bä/ to baby) *and,*
2. If there is a strong indication of the child's knowing the three words because of (a) gestural clues such as waving and saying /bä-bä/ or pointing or reaching for a /bä-bä/ (bottle) or (b) environmental clues (whenever mother gives the child a bottle the child says /bä-bä/ or whenever the child sees a baby the child says /bä-bä/).

This principle can also be applied when the child is using signs. For example, the child may use the same squeezing or wrist-twisting motion for milk, orange, and ice cream, but indications may be that he knows and distinguishes the three different words.

If the child utters /bä-bä/ or makes one sign indiscriminately as a generalized response to many events or objects (points to many things and makes the sign or says /bä-bä/) only one morpheme will be counted. If the child uses two words together such as /allgone/ or /allwet/ that represent one meaningful unit, only one morpheme will be counted.

6. **New Cognition Skills (optional):** Begin recording after initiation of the Home Cognition Program. Using the Key, write down the number(s) of all new skills the parent acquires during the home visit or preceding week. (See page 71 for complete description of determining parent progress.) If the parent achieves *no* new cognition skills during a particular week (for example, the parent achieves cognition skills 1 and 2 during a preceding week but achieves no new skills during the current week), leave the space for the current week blank.

Step 4

Submit the carbon or xerox copy of the SKI*HI Data Sheet weekly to the supervisor. It is possible that the copy sent to the supervisor will also contain the Lesson Plan and Lesson Narrative Report if *suggestion 1* on page 62 is being used. If *suggestion 2* is being used, the parent advisor may be required to send to the supervisor both the Lesson Plan and Lesson Narrative Report (one form) and the SKI*HI Data Sheet (another form). In some programs, submission of the Lesson Plan and Narrative Report Form may not be required or may eventually be phased out if the parent advisor and supervisor deem it appropriate. However, it is suggested that the parent advisor continue to make written lesson plans and narrative reports for her own use even if she is not submitting them to her supervisor.

Upon receipt of the carbon copies, the supervisor reviews parent and child progress, responds to any parent advisor comments, and files the report chronologically in the child's file.

Step 5

Administer LDS to child *at time of entry into the program* and twice yearly. Record date and results on SKI*HI Data Sheet. Administer and report on other tests as appropriate.

Language Development Scale (LDS): Parent advisor records LDS test scores and dates whenever the LDS is given. Children in SKI*HI replication sites should receive the test at least twice a year. More frequent administrations are encouraged. *The first administration of the LDS must take place within the first three months of the child's enrollment in the program.* This first administration constitutes the pretest. The earlier the first administration can be given, the greater the likelihood of demonstrating child progress.

Parent advisor should record the child's receptive and expressive ages (RA and EA). These ages will be the *highest* age in months of the highest interval achieved (for example, if the child's receptive age interval is 20- 22 months, the RA would be recorded as 22 months). Parent advisors should make sure to date all test administrations in numbers: month/day/year.

Other tests: Administrations of tests (other than the LDS) are optional. All test administrations must be dated. If the SKI*HI Receptive Language Test is given, enter the child's percentage scores for Parts A, B, C, and D. If the child does not respond, enter a *0*.

Step 6

By May 31 of each year, SKI*HI Data Sheets (on every child in the local program) should be submitted to the SKI*HI Institute Data Manager.

If during a particular week the child does not achieve a new vocabulary count interval (for example, child stays at 21-30 words), leave the space for that week blank. When the child has more than 300 words, discontinue recording by slashing item on the data sheet.

Parent Data.

On all parent data, slash the item ☐ if no longer reporting the item. Leave the item blank if the parent has not achieved new skills. For example, if the Language Program has not been initiated, leave the new language skills item blank. Or if the parent achieves language skills 1 and 2 during a preceding week and no new skills for the current week, leave the current week blank.

1. **Hearing Aid Skills:** Begin recording after initiation of the Home Hearing Aid Program. Write down *only once*, the *number of the home visit* during which the parent receives 80-100% on the hearing aid competency test. The competency test is in hearing aid lesson 9 and is on pages 231–234. For example, if the parent achieves 80-100% on the competency test during visit 10, write down 10. Discontinue reporting by slashing this item after the parent achieves 80-100% on the competency test.

2. **New Auditory Skills**: Begin recording after initiation of the Home Auditory Program. Using the SKI*HI Data Sheet Key, write down the number(s) of all new skills the parent acquired during the home visit or preceding week. (See page 71 for complete description of determining parent progress.) If the parent achieves *no* new auditory skills during a particular week (for example, the parent achieves auditory skills 3 and 4 during a preceding week but achieves no new skills during the current week), leave the space for the current week blank.

3. **New Communication Skills:** Begin recording after initiation of the Home Communication Program. Using the Key, write down the number(s) of all new skills the parent acquires during the home visit or preceding week. (See page 71 for complete description of determining parent progress.) If the parent achieves *no* new communication skills during a particular week (for example, the parent achieves communication skill 3 and 4 during a preceding week but achieves no new skills during the current week), leave the space for the current week blank.

4. **New Language Stimulation Skills: Aural-Oral:** Begin recording after initiation of the Language Stimulation Program: Aural-Oral. Using the Key, write down the number(s) of all new skills the parent acquires during the home visit or preceding week. (See page 71 for complete description of determining parent progress.) If the parent achieves *no* new language skills during a particular week (for example, the parent achieves language skills 2 and 3 during a preceding week but achieves no new skills during the current week), leave the space for the current week blank. Leave blank if the family is using Language Stimulation Program: Total Communication.

5. **New Language Stimulation Skills: Total Communication:** Begin recording after initiation of the Language Stimulation Program: Total Communication. Using the Key, write down the number(s) of all new skills the parent acquires during the home visit or preceding week. (See page 71 for complete description of determining parent progress.) If the parent achieves *no* new total communication skills during a particular week (for example, the parent achieves total communication skills 7 and 8 during a preceding week but achieves no new skills during the current week), leave the space for the current week blank. Leave blank if the family is using Language Stimulation Program: Aural-Oral.

Notices will come from the SKI*HI Data Bank Manager (SKI*HI Institute) to remind replication site personnel to submit copies of their SKI*HI Data Sheets in *May*. The program should *cut off the child's name at the top of the SKI*HI Data Sheet to ensure anonymity of the data,* make copies of all data sheets kept on each child since the previous May's submission, and send the copies to:

SKI*HI Data Manager
SKI*HI Institute
Department of Communicative Disorders
Utah State University
Logan, Utah 84322-9605
(801) 752-4601

In small programs that do not have a supervisor, the parent advisor will need to follow the above procedures to submit data on her children.

At the SKI*HI Data Center, all data will be analyzed. Reports will be sent to replication site personnel describing the progress of parents and children in the entire SKI*HI Network and in their particular site if more than 10 children are served. In order to help replication site personnel interpret and use these reports, the section below is given.

Data Collection and Submission Quick Reference

Step 1

Complete demographic Section I of SKI*HI Data Sheet at program initiation. Complete Demographic Section II at program initiation and thereafter when additions/changes are made.

Step 2

Explain parent notebook to parents (see pages 89–157). Have parents put parent notebook checklists in an obvious place (ex: refrigerator door) and check highest level of child's behavior for preceding week. When particular checklist is completed, have parents put it back in the Parent Notebook.

Step 3

Obtain child progress data (from parent checklists and parent advisor observation) and record highest level of child's behavior on Master SKI*HI Data Sheet during each home visit. Record parent progress data. A carbon and another data sheet may be inserted underneath the master data sheet for submission to supervisor (or a xerox copy may be submitted).

Step 4

Submit copy of SKI*HI Data Sheet weekly to supervisor (and as appropriate, Lesson Plan and Lesson Narrative Report).

Step 5

Administer Language Development Scale (LDS) to child at least twice yearly and record date and results on SKI*HI Data Sheet. Administer and report on other tests as appropriate.

Step 6

By May 31, all data sheets should be submitted to the SKI*HI Institute Data Manager.

CODER__________ DATE______
ENTERED BY_____ DATE______

CODING CKD BY__________
ENTRY CKD BY___________

SKI*HI DATA CODING INSTRUMENT

TO BE USED WITH DATA FROM 1986 TO PRESENT.

	VARIABLES	COLUMNS	
1.	SITEID	1-4	__ __ __ b
2.	RECORDN	5	1
3.	CHILDID	6-9	b __ __ __
4.	BMN	10-12	__ __ b
5.	BDA	13-15	__ __ b
6.	BYR	16-19	__ __ b b
7.	SEX	20-21	b __
8.	PROM	22-24	__ __ b
9.	PRODA	25-27	__ __ b
10.	PROYR	28-31	__ __ b b
11.	AGEID	32-34	__ __ __
12.	OTHERH	35-36	b __
13.	AGEHAFT	37-39	__ __ __
14.	OTFAM	40-41	b __
15.	RELAT	42-45	b b b b
16.	MNTHS	46-48	__ __ __
17.	SFU	49-52	b __ __ __
18.	SFUDATE	53-62	__ __ b b __ __ b b
19.	GRADM	63-65	__ __ b
20.	GRADYR	66-67	__ __
21.	ADAPT	68-69	b __

<hard return>

	VARIABLES	COLUMNS	
22.	SITEID	1-4	__ __ __ b
23.	RECORDN	5	2
24.	CHILDID	6-9	b __ __ __
25.	SFA	10-13	b __ __ __
26.	SFADATE	14-23	__ __ b b __ __ b b
27.	DXTORX	24-25	__ __

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28.	RACE	42-43	b __
29.	OTHER	44-45	b __
30.	LANG	46-47	b __
31.	FREQ	48-50	b __ b
32.	FREQCHG	51	__
33.	TYPEHL	52-53	b __
34.	CAUSEHL	54-56	b __ __
35.	DATEOC	57-66	__ __ b b __ __ b b
36.	COMMCHG	67-68	b __
37.	COMM	69-70	b __
38.	COMDATE	71-78	__ __ b __ __ b __ __
39.	YR	79-80	b 2

<hard return>

TEST DATA-POSTTEST

1.	SITEID	1-4	__ __ __ b
2.	CHILDID	5-8	b __ __ __
3.	TESTID	9-12	b b __ __
4.	LDSO1	32-41	__ __ b b __ __ b b
5.	LDSO2	42-44	__ __ __
6.	LDSO3	45-47	__ __ __

<hard return>

TEST DATA-POSTTEST

1.	SITEID	1-4	__ __ __ b
2.	CHILDID	5-8	b __ __ __
3.	TESTID	9-12	b b __ __
4.	LDSO1	32-41	__ __ b b __ __ b b
5.	LDSO2	42-44	__ __ __
6.	LDSO3	45-47	__ __ __

<hard return>

CODED BY ______________________

CHECKED BY ____________________

VARIABLES	**COLUMNS**	
40. SITEID	1-4	__ __ __ b
41. RECORDN	5	3
42. CHILDID	6-9	b __ __ __
43. S#8889	10-12	b __ __
44. S#8990	13-14	__ __
45. S#9091	15-16	__ __
46. S#8788	17-18	__ __
47. BEGTHAW	19	__
48. THAW	20	__
49. THMODAYR	21-26	__ __ __ __ __ __
50. MODAYRTH	27-32	__ __ __ __ __ __
51. ADL	33-35	b __ __
52. BEGADL	36-37	__ __
53. ADMODAYR	38-41	__ __ __ __
54. MODAYRAD	42-47	b b __ __ __ __
55. CLDL	48-50	b __ __
56. BEGCLDL	51-52	__ __
57. CLMODAYR	53-56	__ __ __ __
58. MODAYRCL	57-62	b b __ __ __ __
59. BEGVI	63	__
60. VI	64	__
61. VIMODAYR	65-70	__ __ __ __ __ __
62. MODAYRVI	71-76	__ __ __ __ __ __
63. VISIT#	77-78	__ __
64. AS#	79-80 <Hard Return>	__ __

VARIABLES	**COLUMNS**	
65. SITEID	1-4	__ __ __ b
66. RECORDN	5	4
67. CHILDID	6-9	b __ __ __
68. ASMODAYR	10-15	__ __ __ __ __
69. MODAYRAS	16-21	__ __ __ __ __
70. CS#	22-24	b __ __
71. CSMODAYR	25-30	__ __ __ __ __
72. MODAYRCS	31-36	__ __ __ __ __
73. AO#	37-38	b __
74. AOMODAYR	39-44	__ __ __ __ __
75. MODAYRAO	45-50	__ __ __ __ __
76. TC#	51-53	b __ __
77. TCMODAYR	54-59	__ __ __ __ __
78. MODAYRTC	60-65	__ __ __ __ __
79. CG#	66-68	b __ __
80. CGMODAYR	69-74	__ __ __ __ __
81. MODAYRCG	75-80 <Hard Return>	__ __ __ __ __

SKI*HI DATA CODING CONVENTIONS Revised 2/14/90

To be used for data from 1986 to present. Note: Use zero fill.

1.	SITEID	3-character label in spaces 1,2,3. Blank in space 4.
2.	RECORDN	A 1 should appear in column 5.
3.	CHILDID	Blank in 6. 3-digit ID# in 7,8,9.
4.	BMN	Month of Birth. 2 digits in 10 & 11. Blank in 12.
5.	BDA	Day of Birth. 2 digits in 13 & 14. Blank in 15.
6.	BYR	Year of Birth. 2 digits in 16 & 17. Blanks in 18 & 19.
7.	SEX	Blank in 20. 1 digit in 21. 1= male 2= female
8.	PROM	Program start month. 2 digits in 22 & 23. Blank in 24.
9.	PRODA	Program start day. 2 digits in 25 & 26. Blank in 27.
10.	PROYR	Program start year. 2 digits in 28 & 29. Blanks in 30 & 31.
11.	AGEID	Age of identification in months. Calculate. Zero fill in 32. 2 digits in 33 & 34. To calculate age in months, use the following guidelines: One month= 30 days. If child's days are greater than 15, add one to the month column. If days are less than or equal to 15, leave month column as is.

Example:

	Year	Month	Day
		15	
	87	3	33
If Date of ID equals	88	4	3
and Date of Birth equals	86	6	9
Subtract to get ID Age:	1	9	24
Since days are >15 add 1 to months:	1	10	
Multiply yrs x 12 & add to months:	(1 x 12) + 10= 22 months		

If days not specified on Date of ID, then calculate AGEID using Date of Birth (rounded up one months if days greater than 15).

12.	OTHERH	Other handicaps. If no response is provided by site, assume the answer is No, except in those instances where the entire demographic section is left blank. Blank in 35. 1 digit in 36. 1= yes, 2= no.
13.	AGEHAFT	Age of hearing aid fit in months. Calculate Zero fill in 37. 2 digits in 38 & 39. Subtract Date of Birth from date Hearing Aid Fit.
14.	OTFAM	Other Family Member with Hearing Problem. Blank in 40. 1 digit in 41. 1= yes, 2= no.
15.	RELAT	Dropped from new data sheet. Blanks in 42, 43, 44, and 45.
16.	MNTHS	Months between suspicion of loss and identification of loss. Calculate. Zero fill in 46. 2 digits in 47 & 48.
17.	SFU	Hearing loss, unaided, in dB values. Use best ear dB, if give both ears. If No Response to sound is indicated, then enter 120 dB. Also, use the following guidelines: 0 - 20 = normal hearing; 25 - 40 = mild loss; 45 - 60 = moderate loss; 65 - 90 = severe loss; 90+ = profound loss. Enter a decibel value in the middle of each range. Blank in 49. Zero fill in 50, if needed. Digits in 51 & 52.
18.	SFUDATE	Date of unaided test. Month in 53 & 54. Blank in 55. Day in 56 & 57. Blank in 58. Year in 59 & 60. Blanks in 61 & 62.
19.	GRADM	Month of graduation in 63 and 64. Blank in 65.
20.	GRADYR	Year of graduation in 66 and 67.
21.	ADAPT	Was program adapted for the child? Any data sheet with stars around the outside indicates program was adapted. Blank in 68. One digit in 69. 1= yes 2= no
22.	SITEID	3-character label in spaces 1,2,3. Blank in space 4.
23.	RECORDN	A 2 should appear in column 5.
24.	CHILDID	Blank in 6. 3-Digit ID# in 7, 8, 9.

25.	SFA	Hearing loss, aided in dB values. Blank in 10. Zero fill in 11, if needed. Digits in 12 & 13. Use best ear dB if give both ears.
26.	SFADATE	Date of aided test. Month in 14 & 15. Blank in 16. Day in 17 & 18. Blank in 19. Year in 20 & 21. Blanks in 22 & 23.
27.	DXTORX	Time span between Diagnostic/Prescription date and first communication Methodology choice. 2 digits in 24 & 25.
28.	RACE	Race/National origin. Blank in 42. One digit in 43. 1= Caucasian 2= Black 3= Others 4= Oriental American 5= Spanish American 6= American Indian
29.	OTHER	Other non-Parent-Infant Program Services. Blank in 44. One digit in 45. 1= Educational 2= Mental Health 3= Health 4= Social 5= Mental Retardation 6= Other (Combination Services) 7= Speech & Hearing Rx 8= Educational + Speech & Hearing Rx
30.	LANG	Primary language spoken in the home. Blank in 46. One digit in 47. 1= English 2= ASL 3= Spanish 4= Other 5= Signed English System
31.	FREQ	Frequency of home visits. Blank in 48. One digit in 49. Blank in 50. 1= Irregular 2= Once a week (3 x/mo. also coded as 2) 3= Every other week 4= Monthly 5= Bi-monthly 6= Twice a week 7= Other

32.	FREQCHG	Did frequency of home visits change? One digit in 51. Yes= 1 No= 2
33.	TYPEHL	Type of Hearing Loss. Blank in 52. Digit in 53. 1= Not yet determined. 2= Conductive 3= Sensorineural 4= Mixed
34.	CAUSEHL	Cause of hearing loss. Blank in 54. Digits in 55 and 56. 1= Unknown 2= Hereditary 3= Maternal Rubella, CMV or other infections during pregnancy 4= Meningitis 5= Defects at birth (Atresia) 6= Fever or infections in child 7= RH incompatibility/Kernicterus/Jaundice 8= Drugs during pregnancy 9= Other conditions during pregnancy (premature) 10= Middle ear problems or ENT anomalies (Otitis Media) 11= Drugs administered to child 12= Birth trauma 13= Child syndrome 14= Other (specify) 15= Not Reported
35.	DATEOC	Date of occurrence of hearing loss, if after birth. Month in 57 & 58. Blank in 59. Day in 60 & 61. Blank in 62. Year in 63 & 64. Blanks in 65 & 66.
36.	COMMCHG	Did communication method change from aural to total or from total to aural or to other, etc.? (<u>Note</u>: Do not mark a "Yes" if Communication Methodology has gone from Diag./Prescriptive to Aural or to Total--this does not indicate a change in Communication Methodology.) Blank in 67. One digit in 68. If still in diagnostic/prescriptive phase, leave blank. 1= yes 2= no

37.	COMM	Present Communication Method. Blank in 69. Digit in 70. 1= Diagnostic-prescriptive 2= Auditory (Aural-Oral) 3= Total Communication 4= Other
38.	COMDATE	Date family begins to use present Communication Method. Month in 71 & 72. Blank in 73. Day in 74 & 75. Blank in 76. Year in 77 & 78.
39.	YR	Blank in 79. A 2 should appear in 80.
40.	SITEID	3-character label in spaces 1,2,3. Blank in space 4.
41.	RECORDN	A 3 should appear in column 5.
42.	CHILDID	Blank in 6. 3-Digit ID# in 7, 8, 9.
43.	S#8889	Blank in 10. Actual number of sessions child received from pretest to posttest for 1988-89 year. 2 digits in 11 & 12.
44.	S#8990	Actual number of sessions child received from pretest to posttest for 1989-90 year. 2 digits in 13 & 14.
45.	S#9091	Actual number of sessions child received from pretest to posttest for 1990-91 year. 2 digits in 15 & 16.
46.	S#8788	Actual number of sessions child received from pretest to posttest for 1987-88 year. 2 digits in 17 & 18.
47.	BEGTHAW	Put number representing beginning amount of time hearing aid was worn. 1 digit in 19.
48.	THAW	Put number representing largest amount of time hearing aid is worn by child in 20.
49.	THMODAYR	Month, Day and Year of first entry for Time Hearing Aid Worn. Month in 21 & 22, Day in 23 & 24, and Year in 25 & 26.
50.	MODAYRTH	Month, Day and Year of entry for largest amount of time hearing aid is worn by child. Month in 27 & 28, Day in 29 & 30, and Year in 31 & 32.
51.	ADL	Put highest auditory development level attained by child in 34 & 35. Blank in 33.
52.	BEGADL	Beginning auditory level in 36 and 37.

53.	ADMODAYR	Month and Year of first entry for Auditory Development. If days greater than 15, round month up one. Month in 38 & 39, Year in 40 & 41.
54.	MODAYRAD	Month and Year of entry for highest auditory development level. Blanks in 42 & 43, Month in 44 & 45, Year in 46 & 47. If days greater than 15, round month up one.
55.	CLDL	Blank in 48. Put highest communication-language-development level attained by child in 49 & 50.
56.	BEGCLDL	Put beginning Communication-Language-Development Level of child in 51 and 52.
57.	CLMODAYR	Month and Year of first entry for Communication-Language Development. Month in 53 & 54, Year in 55 & 56.
58.	MODAYRCL	Month and Year of entry for highest communication-language development level. Blanks in 57 & 58, Month in 59 & 60, Year in 61 & 62.
59.	BEGVI	Put beginning Vocabulary Interval in 63.
60.	VI	Put number representing highest vocabulary interval attained by child in 64.
61.	VIMODAYR	Month, Day and Year of first entry for Vocabulary Interval. Month in 65 & 66, Day in 67 & 68, Year in 69 & 70.
62.	MODAYRVI	Month, Day and Year of entry for highest Vocabulary Interval. Month in 71 & 72, Day in 73 & 74, Year in 75 & 76.
63.	VISIT#	Visit number the parent achieves 80-100% on hearing aid competency test. 2 digits in 77 & 78.
64.	AS#	Put number of auditory skills attained by parent in 79 & 80.
65.	SITEID	3-character label in spaces 1,2,3. Blank in space 4.
66.	RECORDN	A 4 should appear in column 5.
67.	CHILDID	Blank in 6. 3-Digit ID# in 7, 8, 9.
68.	ASMODAYR	Month, Day and Year of first entry for Auditory Skill Program. Month in 10 & 11, Day in 12 & 13, Year in 14 & 15.

69.	MODAYRAS	Month, Day and Year of last entry for a new Auditory Skill attained. Month in 16 & 17, Day in 18 & 19, Year in 20 & 21.
70.	CS#	Blank in 22. Put number of communication skills attained by parent in 23 & 24.
71.	CSMODAYR	Month, Day and Year of first entry for Communication Skills Program. Month in 25 & 26, Day in 27 & 28, Year in 29 & 30.
72.	MODAYRCS	Month, Day and Year of last entry for new Communication Skill attained. Month in 31 & 32, Day in 33 & 34, Year in 35 & 36.
73.	AO#	Blank in 37. Put number of Aural-Oral skills attained by parent in 38.
74.	AOMODAYR	Month, Day and Year of first entry for Aural-Oral Skills Program. Month in 39 & 40, Day in 41 & 42, Year in 43 & 44.
75.	MODAYRAO	Month, Day and Year of last entry for new Aural-Oral Skill attained. Month in 45 & 46, Day in 47 & 48, Year in 49 & 50.
76.	TC#	Blank in 51. Put number of total communication skills attained by parent in 52 & 53.
77.	TCMODAYR	Month, Day and Year of first entry for Total Communication Program. Month in 54 & 55, Day in 56 & 57, Year in 58 & 59.
78.	MODAYRTC	Month, Day and Year of last entry for new Total Communication Skill attained. Month in 60 & 61, Day in 62 & 63, Year in 64 & 65.
79.	CG#	Blank in 66. Put number of cognition skills attained by parent in 67 & 68.
80.	CGMODAYR	Month, Day and Year of first entry for Cognition Skills Program. Month in 69 & 70, Day in 71 & 72, Year in 73 & 74.
81.	MODAYRCG	Month, Day and Year of last entry for new Cognition Skill attained. Month in 75 & 76, Day in 77 & 78, Year in 79 & 80.

TEST DATA-PRETEST

1.	SITEID	3-character label in space 1, 2, 3. Blank in 4.
2.	CHILDID	Blank in 5. 3-digit-ID# in 6, 7, 8.

3.	TESTID	Blanks in 9 & 10. 2-digit code in 11 & 12. 15= 1986-87 Pretest 16= 1986-87 Posttest 17= 1987-88 Pretest 18= 1987-88 Postest 20= 1988-89 Pretest 21= 1988-89 Postest 22= 1989-90 Pretest 23= 1989-90 Postest 24= 1990-91 Pretest 25= 1990-91 Postest 26= 1991-92 Pretest 27= 1991-92 Postest
4.	LDSO1	Date of administration of LDS. Month in 32 & 33. Blank in 34. Day in 35 & 36. Blank in 37. Year in 38 & 39. Blanks in 40 & 41.
5.	LDSO2	Receptive Age on LDS. Zero fill 42. 2-digit score in 43 & 44.
6.	LDSO3	Expressive Age on LDS. Zero fill 45. 2-digit score in 46 & 47.

TEST DATA-POSTTEST

1.	SITEID	3-character label in 1, 2, 3. Blank in 4.
2.	CHILDID	Blank in 5. 3-digit-ID# in 6,7,8.
3.	TESTID	Blanks in 9 & 10. 2-digit code in 11 & 12. 15= 1986-87 Pretest 16= 1986-87 Postest 17= 1987-88 Pretest 18= 1987-88 Postest 20= 1988-89 Pretest 21= 1988-89 Postest 22= 1989-90 Pretest 23= 1989-90 Postest 24= 1990-91 Pretest 25= 1990-91 Postest 26= 1991-92 Pretest 27= 1991-92 Postest
4.	LDSO1	Date of administration of LDS. Month in 32 & 33. Blank in 34. Day in 35 & 36. Blank in 37. Year in 38 & 39. Blanks in 40 & 41.
5.	LDSO2	Receptive Age on LDS. Zero fill 42. 2-digit score in 43 & 44.
6.	LDSO3	Expressive Age on LDS. Zero fill 45. 2-digit score in 46 & 47.

Appendix G

Pearson Correlations and Sample Sizes for Variables Included in Initial Model

Table G-1

Pearson Correlations and Sample Sizes for Variables Included in Initial Model

Variable	1	2	3	4	5	6	7	8	9	10
1. Gender	2295									
2. White (Caucasian)	.032									
	2264	2264								
3. Other disabilities	.023	- .008								
	2278	2257	2278							
4. Unaided hearing loss	-.047*	-.082**	-.126**							
	2107	2093	2104	2110						
5. Aided hearing loss	- .042	-.109**	- .022	.720**						
	1293	1286	1291	1261	1295					
6. Parent who is deaf	.033	.014	-.075**	.017	- .024					
	2258	2236	2247	2084	1279	2258				
7. Pretest LDS expressive score	.019	.103**	-.158**	-.199**	-.222**	- .001				
	1554	1547	1549	1486	981	1541	1557			
8. Pretest LDS receptive score	.033	.098**	-.132**	-.229**	-.223**	.01	.946**			
	1555	1548	1550	1487	984	1542	1555	1558		
9. Age of identification	.011	- .01	-.172**	-.185**	-.182**	-.120**	.493**	.497**		
	2180	2164	2175	2049	1262	2156	1511	1512	2180	
10. Age hearing aid fit	- .019	-.055*	-.086**	-.209**	-.204**	-.071**	.528**	.531**	.869**	
	1775	1764	1769	1679	1213	1758	1270	1272	1737	1775
11. Age in months when program started	.035	.01	-.074**	-.199**	-.172**	-.104**	.610**	.610**	.768**	.842**
	1857	1840	1852	1715	1030	1831	1266	1266	1779	1435
12. Age in months when communication method select	.019	.005	-.089**	-.185**	-.150**	-.130**	.555**	.560**	.737**	.821**
	1284	1275	1281	1198	721	1275	882	883	1239	1020
13. Months between program start and posttest	- .017	.056*	- .027	.181**	.062	.052	-.092**	-.081**	-.263**	-.214**
	1268	1264	1268	1215	785	1260	1265	1265	1237	1035
14. Planned frequency of home visits	- .01	.047*	.021	- .005	.013	- .004	.032	.028	- .04	- .028
	2229	2203	2218	2056	1275	2201	1524	1525	2128	1745

(*table continues*)

Variable	1	2	3	4	5	6	7	8	9	10
15. Months in program when communication method select	- .038	- .036	- .023	.083**	.026	-.079**	- .065	- .066	-.091**	-.083**
	1249	1240	1246	1165	694	1240	856	857	1205	988
16. Number of parent auditory skills	- .007	.126**	-.089**	-.071*	-.139**	.014	.065*	.065*	.002	- .031
	1309	1297	1300	1236	818	1292	995	996	1265	1085
17. Number of parent cognition skills	.058	.056	-.167**	- .052	- .085	.014	.128	.133	.014	.021
	263	259	257	242	166	259	214	214	250	211
18. Number of parent aural-oral language skills	-.106**	.111**	-.119**	- .012	- .03	- .027	.150**	.164**	.057	.011
	690	682	684	649	426	680	547	547	658	548
19. Number of parent communication skills	- .004	.081**	-.062*	.094**	- .001	- .015	-.088**	-.099**	- .021	- .045
	1474	1460	1464	1378	891	1452	1091	1092	1422	1200
20. Number of parent total communication skills	.059	.115**	-.085*	.125**	.032	.017	.110*	.106*	.008	.006
	660	656	655	629	432	655	526	526	638	574
21. Expressive proportional change index	.024	.012	- .049	- .003	- .011	- .045	-.186**	-.112**	.173**	.191**
	1542	1536	1539	1475	976	1530	1542	1540	1504	1265
22. Receptive proportional change index	.005	- .014	-.062*	.009	- .019	-.066**	-.121**	-.165**	.216**	.207**
	1542	1536	1539	1476	979	1530	1539	1542	1504	1265
23. Posttest LDS expressive score	.011	.166**	-.244**	-.128**	-.239**	.066**	.707**	.690**	.347**	.371**
	1552	1545	1547	1484	980	1539	1553	1553	1509	1268
24. Posttest LDS receptive score	.023	.145**	-.230**	-.140**	-.229**	.057*	.679**	.707**	.369**	.388**
	1549	1542	1544	1482	981	1536	1549	1552	1506	1266
25. Highest level of hearing aid use	- .02	.147**	-.098**	-.065*	-.237**	-.079**	.153**	.155**	.152**	.065*
	1454	1438	1445	1371	946	1432	1043	1044	1399	1307
26. Highest auditory development level	.043	.151**	-.098**	-.419**	-.480**	.032	.421**	.433**	.266**	.264**
	1400	1384	1390	1318	866	1382	1044	1045	1349	1138
27. Highest communication language development level	.006	.140**	-.179**	-.222**	-.271**	.068**	.547**	.563**	.327**	.342**
	1610	1595	1598	1496	941	1590	1152	1153	1549	1283
28. Highest vocabulary level	.01	.158**	-.197**	-.134**	-.218**	.073**	.524**	.511**	.271**	.275**
	1545	1529	1533	1442	916	1526	1126	1127	1490	1233

(*table continues*)

Variable	11	12	13	14	15	16	17	18	19	20
11. Age in months when program started										
	1857									
12. Age in months when communication method select	.959**									
	1249	1284								
13. Months between program start and posttest	-.336**	-.213**								
	1268	857	1268							
14. Planned frequency of home visits	.002	- .021	.073*							
	1815	1274	1248	2230						
15. Months in program when communication method select	-.134**	.153**	.320**	.005						
	1249	1249	857	1240	1249					
16. Number of parent auditory skills	- .018	- .027	.111**	.009	.095**					
	1094	778	847	1291	759	1310				
17. Number of parent cognition skills	.031	.047	.05	.028	.133	.334**				
	204	145	174	258	142	244	263			
18. Number of parent aural-oral language skills	.003	- .052	.123**	.04	- .009	.470**	.498**			
	563	378	453	683	368	629	166	691		
19. Number of parent communication skills	-.072*	- .055	.188**	.026	.141**	.508**	.410**	.395**		
	1250	887	933	1448	866	1244	261	652	1475	
20. Number of parent total communication skills	- .013	- .033	.096*	.009	.01	.430**	.373**	.424**	.489**	
	568	416	457	652	404	585	152	252	631	660
21. Expressive proportional change index	.181**	.193**	-.099**	-.076**	- .036	.049	- .042	- .038	.03	.065
	1262	878	1262	1514	852	990	211	544	1088	523
22. Receptive proportional change index	.218**	.227**	-.123**	- .04	- .028	.061	- .013	- .053	.054	.092*
	1262	879	1262	1514	853	989	209	542	1087	521

(*table continues*)

Variable	11	12	13	14	15	16	17	18	19	20
23. Posttest LDS expressive score	.397**	.402**	.332**	.02	.049	.190**	.197**	.256**	.075*	.251**
	1266	882	1266	1522	856	996	214	548	1093	527
24. Posttest LDS receptive score	.408**	.420**	.344**	.011	.066	.188**	.172*	.263**	.080**	.264**
	1262	879	1262	1519	853	994	213	546	1091	524
25. Highest level of hearing aid use	.111**	.142**	.115**	.053*	.098**	.274**	.151*	.238**	.204**	.220**
	1220	868	883	1427	844	1157	230	588	1290	608
26. Highest auditory development level	.295**	.291**	.022	.019	- .041	.391**	.228**	.316**	.112**	.173**
	1154	827	872	1375	802	1221	242	650	1270	601
27. Highest communication language development level	.389**	.407**	.166**	- .001	.061	.311**	.220**	.351**	.233**	.332**
	1361	975	979	1584	950	1276	261	675	1431	651
28. Highest vocabulary level	.345**	.342**	.196**	.039	.025	.239**	.188**	.291**	.197**	.344**
	1293	934	952	1521	909	1233	251	657	1370	638

(*table continues*)

Variable	21	22	23	24	25	26	27	28
21. Expressive proportional change index								
	1542							
22. Receptive proportional change index	.629**							
	1536	1542						
23. Posttest LDS expressive score	.077**	.024						
	1542	1540	1555					
24. Posttest LDS receptive score	.071**	.071**	.947**					
	1537	1542	1550	1552				
25. Highest level of hearing aid use	.051	.059	.241**	.243**				
	1038	1037	1044	1042	1455			
26. Highest auditory development level	.033	.018	.493**	.487**	.328**			
	1039	1038	1045	1043	1226	1401		
27. Highest communication language development level	.088**	.063*	.694**	.704**	.348**	.659**		
	1148	1147	1153	1151	1364	1368	1611	
28. Highest vocabulary level	.082**	.082**	.712**	.698**	.299**	.526**	.800**	
	1122	1121	1127	1125	1313	1320	1508	1546

* $p < .05$ ** $p < .01$

Appendix H

Analysis of Differences Between Groups Based on Missing Posttest Scores

Analysis of Differences Between Groups Based on Missing Posttest Scores

The following tables show differences between groups based on whether participants had a posttest score or not. The first three columns of numbers show all participants, whether or not they had posttest scores. The successive columns show differences between groups for those who have a posttest score and those who do not, with (a) all participants, (b) only hearing parents, and (c) only families with at least one parent with severe or profound hearing loss. Standardized mean difference effect sizes (*ES*) are included to show the magnitude of difference, as large samples are likely to be statistically significantly different simply because of the impact of sample size on statistical significance.

Cohen (1988) suggested that effect sizes less than .3 were small, effect sizes of .3 to .5 were moderate, and effect sizes larger than .5 were large.

Table H-1

Differences between Groups: Those Who Have Posttest Scores and Those Who Do Not, Also Disaggregated by Hearing Status

						All participants			Hearing parents			Deaf parents		
Variable		All participants (N = 5,178)	Deaf parents (N = 448)	Hearing parents (N = 4,552)	*ES*	No outcomes (N = 1,860)	One/both outcomes (N = 3,318)	*ES*	No outcomes (N = 1,605)	One/both outcomes (N = 2,947)	*ES*	No outcomes (N = 171)	One/both outcomes (N = 277)	*ES*
Is a parent deaf	*n*	5,000				1,799	,3201							
	% of *n*	97				97	96							
	M	1.91				1.9	1.91	.03						
	SD	.29				.3	.28							
Year posttest administered	*n*	3320	277	2949										
	% of *n*	64	62	65										
	M	87.3	86.62	87.44	.28									
	SD	2.82	3.05	2.78	***									
Age of identification	*n*	4848	427	4334		1693	3155		1487	2847		162	265	
	% of *n*	94	95	95		91	95		93	97		95	96	
	M	18.93	14.94	19.31	.34	2.64	18.02	- .20	21.13	18.36	- .21	16.86	13.77	- .24
	SD	12.96	12.78	12.92	***	14.06	12.24	***	14.01	12.21	***	14.02	11.83	*
Age in mos when program started	*n*	4185	380	3715		1495	2690		1291	2424		152	228	
	% of *n*	81	85	82		80	81		80	82		89	82	
	M	26.7	23.23	27	.26	29.35	25.23	- .29	29.66	25.58	- .28	26.43	21.09	- .36
	SD	14.3	14.77	14.18	***	15.49	13.37	***	15.41	13.27	***	15.56	13.85	***
Age hearing aid fit	*n*	4026	332	3637		1299	2727		1158	2479		113	219	
	% of *n*	78	74	80		70	82		72	84		66	79	
	M	23.83	21.24	24.03	.21	25.75	22.92	- .21	25.96	23.12	- .21	23.34	2.16	- .24
	SD	13.08	13.17	13.04	***	14.08	12.48	***	14	12.46	***	14.48	12.34	*
Age in mos when pretested	*n*	3261	275	2936										
	% of *n*	63	61	64										
	M	27.85	23.6	28.23	0.33									
	SD	13.84	13.96	13.75	***									

(*table continues*)

Variable		All participants (*N* = 5,178)	Deaf parents (*N* = 448)	Hearing parents (*N* = 4,552)	*ES*	All participants: No outcomes (*N* = 1,860)	All participants: One/both outcomes (*N* = 3,318)	All participants: *ES*	Hearing parents: No outcomes (*N* = 1,605)	Hearing parents: One/both outcomes (*N* = 2,947)	Hearing parents: *ES*	Deaf parents: No outcomes (*N* = 171)	Deaf parents: One/both outcomes (*N* = 277)	Deaf parents: *ES*
Age in mos when posttested	*n*	3259	275	2934										
	% of *n*	63	61	64										
	M	14.63	37.83	40.51	0.19									
	SD	10.79	13.96	13.96	***									
Mos between pre and posttest	*n*	3259	275	2934										
	% of *n*	63	61	64										
	M	12.46	14.23	12.29	- .20									
	SD	8.82	10.43	8.63	***									
Unaided hearing loss	*n*	4458	376	3984		1442	3016		1272	2712		127	249	
	% of *n*	86	84	88		78	91		79	92		74	90	
	M	73.93	71.83	74.01	0.09	73.18	74.29	0.04	73.24	74.37	0.04	70.83	72.34	0.06
	SD	25.37	24.59	25.5		26.27	24.92		26.4	25.06		25.52	24.14	
Aided hearing loss	*n*	2391	170	2184		590	1801		533	1651		39	131	
	% of *n*	46	38	48		32	54		33	56		23	47	
	M	47.19	43.69	47.44	0.17	48.19	46.87	- .06	48.38	47.13	- .05	44.49	43.46	- .05
	SD	23.25	22.02	23.34	*	23.78	23.07		23.92	23.15		23.1	21.77	
Other handicap	*n*	4974	427	4448		1774	3200		1556	2892		161	266	
	% of *n*	96	95	98		95	96		97	98		94	96	
	M	1.75	1.86	1.75	- .28	1.73	1.77	0.09	1.72	1.76	0.09	1.84	1.86	0.06
	SD	0.43	0.35	0.44	***	0.45	0.42	***	0.45	0.43	***	0.36	0.34	
Gender	*n*	5048	434	4498		1818	3230		1584	2914		165	269	
	% of *n*	97	97	99		98	97		99	99		96	97	
	M	1.45	1.43	1.45	0.04	1.44	1.46	0.04	1.44	1.46	0.04	1.42	1.44	0.04
	SD	0.5	0.5	0.5		0.5	0.5		0.5	0.5		0.5	0.5	
Race	*n*	5025	440	4487		1783	3242		1565	2922		164	276	
	% of *n*	97	98	99		96	98		98	99		96	100	
	M	1.68	1.54	1.69	0.12	1.79	1.62	- .12	1.82	1.62	- .14	1.52	1.55	0.03
	SD	1.36	1.2	1.38	*	1.48	1.29	***	1.51	1.29	***	1.16	1.22	
Beginning level of hearing aid use	*n*	1477	99	1355		417	1060		373	982		30	69	
	% of *n*	29	22	30		22	32		23	33		18	25	
	M	2.52	2.02	2.57	0.37	2.51	2.53	0.01	2.57	2.57	0.00	2.03	2.01	- .01
	SD	1.59	1.35	1.6	***	1.56	1.6		1.56	1.62		1.45	1.31	
Highest level of hearing aid use	*n*	1476	99	1354		418	1058		374	980		30	69	
	% of *n*	29	22	30		22	32		23	33		18	25	
	M	4.06	3.62	4.11	0.35	3.56	4.26	0.51	3.63	4.29	0.49	2.87	3.94	0.73
	SD	1.33	1.5	1.31	**	1.55	1.18	***	1.53	1.16	***	1.63	1.32	***

(*table continues*)

						All participants			Hearing parents			Deaf parents		
Variable		All participants (*N* = 5,178)	Deaf parents (*N* = 448)	Hearing parents (*N* = 4,552)	*ES*	No outcomes (*N* = 1,860)	One/both outcomes (*N* = 3,318)	*ES*	No outcomes (*N* = 1,605)	One/both outcomes (*N* = 2,947)	*ES*	No outcomes (*N* = 171)	One/both outcomes (*N* = 277)	*ES*
Beginning auditory development level	*n*	1423	103	1301		363	1060		325	976		27	76	
	% of *n*	27	23	29		20	32		20	33		16	27	
	M	3.23	3.36	3.2	- .05	3.6	3.1	- .16	3.61	3.07	- .17	3.56	3.29	- .08
	SD	3.09	3.29	3.07		3.39	2.98	*	3.4	2.94	*	3.61	3.19	
Highest auditory development level	*n*	1421	102	1300		363	1058		335	975		27	75	
	% of *n*	27	23	29		20	32		21	33		16	27	
	M	6.39	6.75	6.37	- .11	5.46	6.71	0.36	5.42	6.68	0.36	6	7.03	0.30
	SD	3.49	3.41	3.49		3.5	3.42	***	3.48	3.44	***	3.68	3.28	
Beginning vocabulary level	*n*	1566	113	1433		425	1141		381	1052		32	81	
	% of *n*	30	25	31		23	34		24	36		19	29	
	M	2.41	2.68	2.37	- .14	2.77	2.28	- .22	2.74	2.23	- .23	2.75	2.65	- .05
	SD	2.15	2.16	2.14		2.36	2.05	***	2.38	2.03	***	2.14	2.19	
Highest vocabulary level	*n*	1566	113	1433		425	1141		381	1052		32	81	
	% of *n*	30	25	31		23	34		24	36		19	29	
	M	4.54	5.14	4.48	- .27	3.72	4.84	0.44	3.7	4.76	0.42	3.75	5.69	0.92
	SD	2.57	2.28	2.59	***	2.51	2.53	***	2.54	2.55	***	2.1	2.12	***
Beginning communication language development level	*n*	1635	114	1500		466	1169		421	1079		32	82	
	% of *n*	32	25	33		25	35		26	37		19	30	
	M	4.04	4.17	4.01	- .05	4.39	3.9	- .16	4.37	3.88	- .16	4.44	4.06	- .12
	SD	2.92	2.98	2.91		3.16	2.81	***	3.16	2.8	**	3.22	2.9	
Highest communication language development level	*n*	1633	114	1498		466	1167		421	1077		32	82	
	% of *n*	32	25	33		25	35		26	37		19	30	
	M	7.23	7.91	7.18	- .26	6.09	7.69	0.54	6.04	7.63	0.53	6.75	8.37	0.63
	SD	3	2.62	3.02		3.15	2.82	***	3.17	2.84	***	2.75	2.43	***
Number of parent auditory skills	*n*	1327	82	1227		318	1009		285	942		22	60	
	% of *n*	26	18	27		17	30		18	32		13	22	
	M	4.63	4.82	4.65	- .05	3.23	5.08	0.65	3.26	5.07	0.63	3.41	5.33	0.64
	SD	3.1	3.18	3.09		2.62	3.11	***	2.63	3.1	***	2.77	3.19	*
Number of parent aural-oral language skills	*n*	702	44	647		146	556		131	516		8	36	
	% of *n*	14	10	14		8	17		8	18		5	13	
	M	4.67	4.39	4.69	0.10	3.59	4.95	0.49	3.6	4.97	0.49	3	4.69	0.54
	SD	2.89	3.13	2.87		2.74	2.86	***	2.71	2.85	***	3.12	3.09	

(*table continues*)

						All participants			Hearing parents			Deaf parents		
Variable		All participants (*N* = 5,178)	Deaf parents (*N* = 448)	Hearing parents (*N* = 4,552)	*ES*	No outcomes (*N* = 1,860)	One/both outcomes (*N* = 3,318)	*ES*	No outcomes (*N* = 1,605)	One/both outcomes (*N* = 2,947)	*ES*	No outcomes (*N* = 171)	One/both outcomes (*N* = 277)	*ES*
Number of parent cognition skills	*n*	265	15	246		50	215		47	199		2	13	
	% of *n*	5	3	5		3	6		3	7		1	5	
	M	4.42	4.67	4.45	- .07	2.82	4.79	0.66	2.81	4.84	0.67	4	4.77	0.31
	SD	3.37	3.29	3.38		2.55	3.43	***	2.6	3.44	***	1.41	3.52	
Number of parent communication skills	*n*	1493	97	1373		386	1107		346	1027		27	70	
	% of *n*	29	22	30		21	33		22	35		16	25	
	M	8.12	7.86	8.2	0.07	5.35	9.09	0.79	5.41	9.14	0.79	5.37	8.81	0.72
	SD	5	4.97	5		4.65	4.76	***	4.67	4.76	***	4.81	4.72	***
Number of parent total communication skills	*n*	670	51	614		134	536		114	500		17	34	
	% of *n*	13	11	13		7	16		7	17		10	12	
	M	6.69	7.04	6.7	- .07	4.19	7.32	0.70	4.17	7.27	0.70	4.88	8.12	0.68
	SD	5.02	5.06	5.02		3.81	5.09	***	3.72	5.1	***	4.53	5.02	*
Language in the home	*n*	5037	437	4496		1808	3229		1582	2914		164	273	
	% of *n*	97	98	99		97	97		99	99		96	99	
	M	1.21	1.54	1.18	- .45	1.22	1.2	- .03	1.2	1.16	- .06	1.49	1.58	0.10
	SD	0.69	0.95	0.65	***	0.69	0.69		0.67	0.64		0.83	1.02	
Latest communication method	*n*	4861	429	4333		1681	3180		1471	2862		156	273	
	% of *n*	94	96	95		90	96		92	97		91	99	
	M	2.25	2.41	2.24	- .21	2.11	2.32	0.25	2.1	2.31	0.25	2.36	2.45	0.11
	SD	0.83	0.79	0.83	***	0.87	0.79	***	0.87	0.79	***	0.83	0.76	
Communication change	*n*	3035	269	2723		869	2166							
	% of *n*	59	60	60		47	65							
	M	1.93	1.95	1.93	- .09	1.97	1.92	- .23						
	SD	0.25	0.22	0.25		0.16	0.27	***						
Planned frequency of home visits	*n*	4984	435	4446		1766	3218		1543	2903		163	272	
	% of *n*	96	97	98		95	97		96	99		95	98	
	M	2.3	2.37	2.29	- .08	2.34	2.28	- .06	2.33	2.28	- .05	2.5	2.3	- .19
	SD	0.93	1.06	0.93		1.01	0.89	*	1	0.88		1.22	0.94	
Frequency change	*n*	3676	271	3342		1162	2514							
	% of *n*	71	60	73		62	76							
	M	1.92	1.93	1.92	- .04	1.97	1.91	- .26						
	SD	0.26	0.26	0.27		0.18	0.29	***						

(*table continues*)

Variable		All participants ($N = 5,178$)	Deaf parents ($N = 448$)	Hearing parents ($N = 4,552$)	*ES*	All participants: No outcomes ($N = 1,860$)	All participants: One/both outcomes ($N = 3,318$)	All participants: *ES*	Hearing parents: No outcomes ($N = 1,605$)	Hearing parents: One/both outcomes ($N = 2,947$)	Hearing parents: *ES*	Deaf parents: No outcomes ($N = 171$)	Deaf parents: One/both outcomes ($N = 277$)	Deaf parents: *ES*
Other services provided	*n*	2525	199	2280		849	1676		759	1521		68	131	
	% of *n*	49	44	50		46	51		47	52		40	47	
	M	3.61	3.38	3.64	0.10	3.22	3.8	0.22	3.22	3.85	0.23	3.31	3.42	0.04
	SD	2.71	2.57	2.73		2.6	2.75	***	2.62	2.75	***	2.4	2.66	
Pretest EA score	*n*	3312	277	2942										
	% of *n*	64	62	65										
	M	14.63	14.64	14.62	0.00									
	SD	10.79	11.22	10.79										
Posttest EA score	*n*	3314	277	2943										
	% of *n*	64	62	65										
	M	26.32	28.76	26.09	- .19									
	SD	14.06	13.76	14.07	***									
PCIE	*n*	3238	274	2915										
	% of *n*	63	61	64										
	M	2.72	2.34	2.77	0.13									
	SD	3.73	2.83	3.82	*									
Pretest RA score	*n*	3318	277	2947										
	% of *n*	64	62	65										
	M	15.88	15.9	15.88	0.00									
	SD	11.33	11.87	11.32										
Posttest RA score	*n*	3312	277	2941										
	% of *n*	64	62	65										
	M	28.47	30.49	28.28	- .15									
	SD	14.38	14.25	14.4	*									
PCIR	*n*	3243	274	2920										
	% of *n*	63	61	64										
	M	2.6	2.14	2.64	0.17									
	SD	3.24	2.45	3.29	***									

Appendix I

Q-Q Plots of Selected SKI*HI Variables

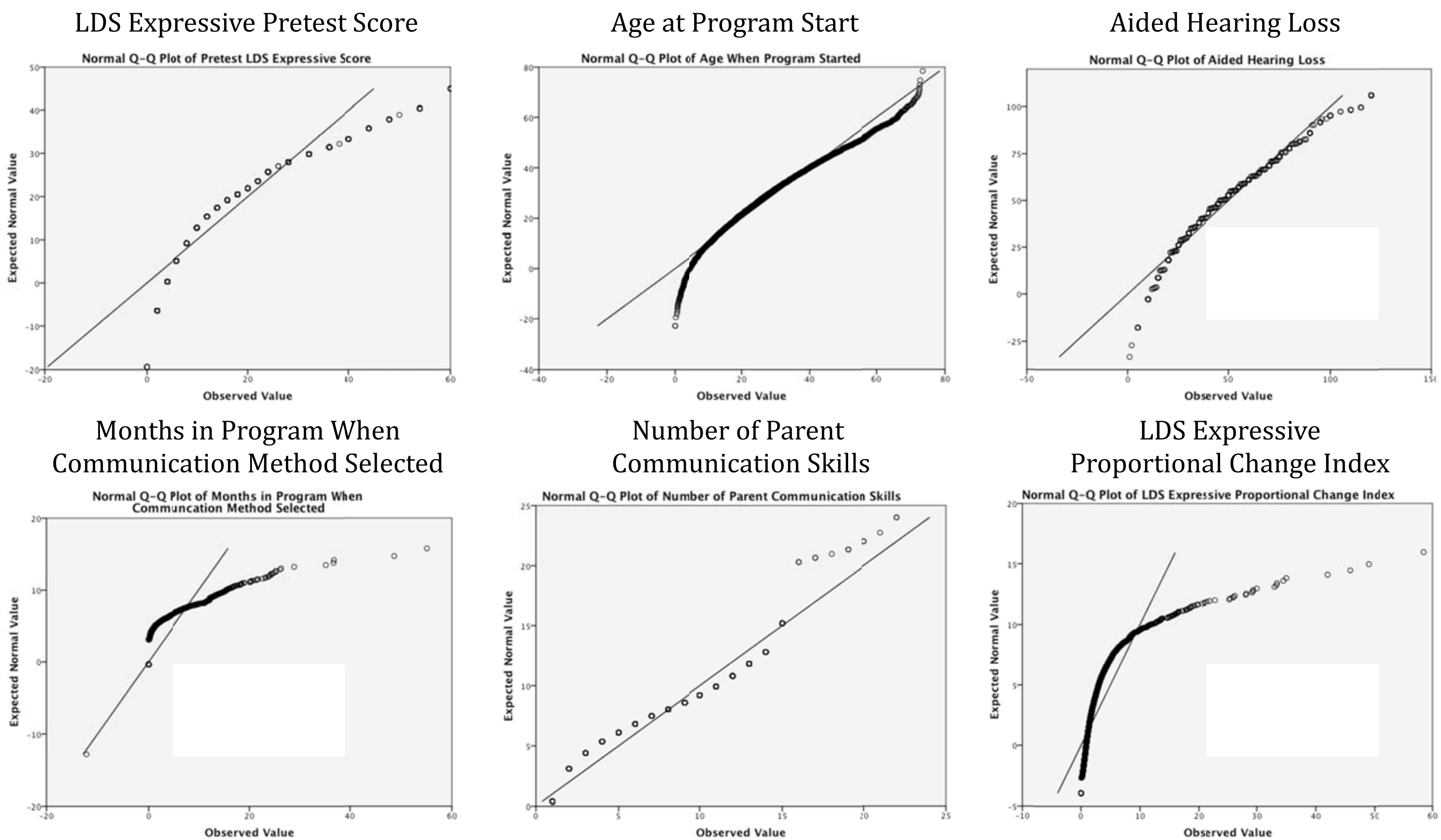

Figure I-1. Q-Q plots of selected SKI*HI variables.

VITA

CATHERINE A. CALLOW-HEUSSER

catherine.callow-heusser@gmail.com
41 E. University Blvd. #321
Logan, UT 84321
(435) 757-2724

EDUCATION

2011	**Ph.D.**, Education, Interdepartmental Specialization in Research & Evaluation, Utah State University, Logan, UT. (Major Professor: Karl White)
2000	**Secondary Teacher Licensure** (Grades 6-12): Endorsements: Math Level IV, Chemistry, Computer Science; Utah State University, Logan, UT.
1996	**M.S.**, Instructional Technology, Utah State University, Logan, UT. (Major Professor: M. David Merrill)
1984	**B.S.**, Computer Science; Minor, Chemistry, University of Utah, Salt Lake City, UT.
1976-1978 1980-1981	Undergraduate coursework, Chemical Engineering, University of New Mexico, Albuquerque, NM, and University of Utah, Salt Lake City, UT.

PROFESSIONAL EXPERIENCE

2010-present	**Senior Research Specialist**, National Center for Hearing Assessment and Management, College of Education, Utah State University, Logan, UT.
2003-2011	**President/Owner**, Callow-Heusser Associates, LLC, DUNS 141873815, dba ΣndVision Research & Evaluation, LLC, and ΣndVision Learning Systems, LLC, Logan, UT.
12/2008- 6/2009	**Mathematics Teacher**, Level 4, Bear River Middle School, Box Elder School District, Garland, UT.
2002-2007	**Principal Investigator** (2004-2007); **Project Director** (2002-2004), Building Evaluation Capacity in STEM Projects, a National Science Foundation Math-Science Partnership (MSP) Research, Evaluation, and Technical Assistance (RETA) project, Utah State University, Logan, UT.
1995-2005 About one course per year	**Instructor**, Utah State University, Logan, UT. *Psychology Department* (graduate evaluation course); *Mathematics and Statistics Department* (undergraduate and remedial mathematics courses); *Instructional Technology Department* (graduate multimedia development and evaluation, and multimedia authoring languages courses).
2000-2002 & 1996-1997	**Project Coordinator; Research Specialist**, Early Head Start Research Partnership, Utah State University, Logan, UT, and Mathematica Policy Review Inc., Princeton, NJ.
2000-2002	**Mathematics Teacher**, Level 4, Cache Alternative High School, Cache County School District, Logan, UT.

1999-2000 **Evaluation Specialist**, SUMMIT Research Lab, Utah State University Research Foundation, Logan, UT.

1996-1999 **NSF/AREA Fellow**, Evaluation Training Program Grant, Utah State University, Logan, UT.

1995-1996 **Senior Instructional Designer; Software Engineer**, ID_2 Research Group, Department of Instructional Technology, Utah State University, Logan, UT.

1987-1995 **Research Specialist; Project Coordinator; Network Administrator**, Technology Division, Center for Persons with Disabilities, Utah State University, Logan, UT.

1985-1986 **Software Engineer: Expert Systems**, Computer Systems Research & Development Group, Sperry Computer Corporation, Salt Lake City, UT.

1983-1986 **Teaching Assistant; Research Assistant**, Computer Science, University of Utah, Salt Lake City, UT.

1981-1982 **Chemist,** Peavey Flour Mill, Cereal Foods Corporation, Salt Lake City, UT.

1978-1980 **Chemical Engineering Technician**, Thiokol Chemical Corporation, Promontory, UT.

AWARDS

1997-2000 **Fellow**, National Science Foundation (NSF) / American Educational Research Association (AERA) Evaluation Training Program (ETP), Utah State University, Logan, UT.

2000 **Presidential Strand**, *Building evaluation capacity byte by byte: More computer-based and on-line resources for evaluators*, paper presented at the annual conference of the American Evaluation Society, November 1-5, 2000, Waikiki, HA.

1999 **Graduate Student Award**, *Take a byte: A growing collection of on-line resources for evaluators*, paper presented at the annual conference of the American Evaluation Association, Nov. 2-6, 1999, Orlando, FL.

1976 **Freshman Engineering Award for Best Project**, *Infant crying detector for deaf parents* [product]. University of New Mexico, December 1976.

LICENSES AND CERTIFICATIONS

2001, renewed 2009-2012 Professional Educator License for the State of Utah, Level 1, Grades 6-12. Endorsements: Math Level 4, Chemistry, Computer Science.

2011, July DIBELS Next Certified Trainer, Dynamic Measurement Group, Eugene, OR.

2005, June Consortium on Reading Excellence (CORE) Coaching for Secondary Literacy, San Jose, CA.

2005, March CORE Leadership and Coaching in Elementary Literacy, Denver, CO.

2004, July DIBELS (Version 6.0) Training, Wireless Generation, St. Louis, MO.

CONTRACTS AND GRANTS AWARDED

Co-Principal Investigator, International Initiative for Impact Evaluation (3IE) Travel Grant for Proposal Preparation in Partnership with the Ministries of Education in Ecuador. Utah State University, Logan, UT, 11/2011-3/2012, $30,000.

External Evaluator, Masters-Level, Interdisciplinary, Transition Specialist Preparation Program. Utah State University Department of Special Education, Logan, UT, 1/2011-12/2014, $25,000/year in years 1-2; $50,000/year in years 3-4.

External Evaluator, Teaching for Excellence in Science and Literacy Achievement (TESLA): Evaluation of an Idaho Math-Science Partnership Project. Lewiston School District, Lewiston, ID, 7/2010-6/2013, $25,000 per year.

Evaluator, Arizona First Things First Regional Needs and Assets Reports, subcontracted through MGT of America, Inc., Tallahassee, FL, funded through Arizona Early Childhood Development & Health Board for Salt River Pima Reservation, 3/2010-7/2010, $8,000.

External Evaluator, Oberkotter Deaf Education Personnel Preparation Grants: Technical Assistance for Proposal Writing. National Center for Hearing Management and Assessment (NCHAM)/ Oberkotter. Logan, UT. 10/2009-7/2010, $8,300.

Technical Assistance Provider: Coaching; Effective Teaching in Reading and Math; Assessment and Data Use, Bureau of Indian Education's Professional Education Consulting Services for the Educational Enhancement Initiative, including BIE READS! and Math Now Programs. Bureau of Indian Education, Albuquerque, NM, Indefinite Delivery/ Indefinite Quantity (IDIQ) Task Order Contract, 1/2008-9/2010. Approximately $220,000 per year.

School-Level Technical Assistance and Coaching, Bureau of Indian Education schools in ND, SD, AZ, NM, and MT, Bureau of Indian Education Educational Enhancement Grant, Math Counts and BIE READS! Programs, 2008-2009 (12 schools) and 2009-2010 (23 schools) school years. $150,000-$400,000 per year based on school need and funding.

External Program Evaluation, Bureau of Indian Education (BIE) Reading First Grant and BIE READS! Program, including DIBELS Benchmark Assessments of all K-3 (years 1-4) or K-6 (years 5-8) students, DIBELS and data use technical assistance to schools, and professional development at BIE Leadership and Summer Staff Institute meetings. 24 schools in 2004-2005 with additional schools annually to 86 schools in 2009-2010. Bureau of Indian Education, Albuquerque, NM, IDIQ contract, initially $400,000 per year in 2004-2005 increasing to approximately $800,000 per year in 2009-2010, 7/2004-9/2011.

External Evaluator, Teaching for Excellence in Science and Literacy Achievement (TESLA): Evaluation of an Idaho Math-Science Partnership Project. Lewis Clark State College, Lewiston, IT. $15,000 per year, 7/2007-6/2010.

Principal Investigator, McDougal Littell Small-Scale Study: McDougal Littell Literature (randomized experiment, 40 classrooms in both 7th and 10th grades). McDougal Littell, a subsidiary of Houghton Mifflin, Evanston, IL. $650,000, 1/2007-9/2008.

External Evaluator, Evaluation of Oberkotter's First Year Professionals Program, in partnership with the National Center for Hearing Assessment and Management (NCHAM), Logan, UT, $35,000, 1/2007-4/2007.

Principal Investigator, Mathematics-Science Partnership (MSP) Evaluation Summit II. Supplementary funds to hold a meeting of MSP principal investigators and evaluators to present MSP grant evaluation findings and build evaluation capacity. Building Evaluation Capacity in STEM Projects Grant. National Science Foundation (NSF), $175,000, 4/2006-12/2006.

External Evaluator, Utah State Improvement Grant Independent Evaluation. Center for Personnel Development, Utah State Office of Education, Salt Lake City, UT. $60,000 per year, 1/2005-12/2007.

Principal Investigator, Evidence: An Essential Tool. Supplemental funds to develop an evaluation policy statement for the Mathematics-Science Partnership projects, Building Evaluation Capacity in STEM Projects Grant. National Science Foundation, $150,000, 9/2004-4/2005.

External Evaluator, Participatory Evaluation of the University of New Mexico's Project LINK BANNER Enterprise-Wide Software Implementation, $50,000 per year, 9/2004-6/2008. Contract cancelled per mutual agreement after one year (change in UNM project leadership).

Principal Investigator, McDougal Littell Small-Scale Study: Middle School Science (randomized experiment, 32 classrooms in 6 districts in NY, AL, TN, UT, CA). McDougal Littell, a subsidiary of Houghton Mifflin, Evanston, IL. $330,000, 5/2004-7/2005.

Principal Investigator, McDougal Littell Small-Scale Study: Middle School Math, 7th grade (quasi-experimental design, 20 classrooms, 3 school districts in AZ, TN). McDougal Littell, Evanston, IL. $150,000, 5/2004-8/2005.

Principal Investigator, McDougal Littell Small-Scale Study: Algebra I, 9th grade (quasi-experimental design involving 20 classrooms, 3 school districts in NY, NJ). McDougal Littell, Evanston, IL. $150,000, 5/2004-8/2005.

Principal Investigator (2004-2006); **Project Director** (2002-2004), Building Evaluation Capacity in the National Science Foundation's (NSF) Mathematics-Science Partnership (MSP) Projects, a NSF MSP Research, Evaluation, and Technical Assistance (RETA) Project, Psychology Department, Utah State University, Logan, UT, $1,500,000, 10/2002-9/2005, with a 1-year no-cost extension to 9/2006.

RECENT GRANT PROPOSALS SUBMITTED

Development of a teleintervention model of service delivery for children with hearing loss, submitted in June 2011 to the US Department of Education's Institute for Education Sciences. National Center for Hearing Assessment and Management (NCHAM), Utah State University. Principal Investigator: Karl White. Project Director: Catherine Callow-Heusser. Two years, $200,000 per year. Status: Under review, anticipated award notification January 2012.

Personnel preparation for teachers of birth to five year old children who are deaf or hard of hearing, submitted in May 2011 to the US Department of Education, Office of Special Education Programs. Department of Communication Disorders and Deaf Education, Utah State University. Principal Investigator: Lauri Nelson. Evaluator: Catherine Callow-Heusser. Five years, $250,000 per year. Status: Not funded, revise and resubmit May 2012.

ILLUMIN-ED in STEM: Improving literacy and learning using media, integrated and networked for e-learning with data (Collaborative Research), submitted in January 2011 to the National Science Foundation's Cyberlearning competition. PI: Alan Hofmeister, Academic Success for All Learners. Co-PI: Andrew Hofmeister, Academic Success for All Learners. Co-PI: Catherine Callow-Heusser, Utah State University. Co-Investigator: Dale Smith, Director, Publication Design and Production, Utah State University. Two years, $275,000 per year. Status: Not funded, revise and resubmit January 2012.

Early learning in mathematics through Experience-Inquire-Revisit-Show (EIRS), submitted in January 2011 to the National Science Foundation's Developmental and Learning Sciences competition. Utah State University. Principal Investigator: Lisa Boyce, co-PI: Catherine Callow-Heusser. Four years, average $212,000 per year. Status: Not funded, revise and resubmit January 2012.

Personnel preparation for teachers of preschool children who are deaf or hard of hearing, submitted in February 2011 to the Utah State Office of Education. Utah State University, Principal Investigator, Lauri Nelson, evaluator: Catherine Callow-Heusser. One year, $100,000. Status: Not funded, resubmission requested with submission in February 2012.

Research topic of interest (RTOI): Improving loss to follow-up/loss to documentation from newborn hearing screening programs through collaboration with WIC programs, submitted in May 2011 to the Centers for Disease Control/Association of University Centers on Disabilities (AUCD). Utah State University Center for Persons with Disabilities. Principal Investigator: Richard Harward, Utah Director of Early Hearing Detection and Intervention Program (affiliated with USU's AUCD). Evaluator: Catherine Callow-Heusser. Two years, $100,000 per year. Status: Not funded.

Learning and instruction using mobile technologies: Reading for All Learners Program (RALP) + Student Assessment and Monitoring (SAM), submitted in June 2011 to the National Science Foundation's Small Business Innovation Research Program Phase I. Principal Investigator: Alan Hofmeister, Academic Success for All Learners. Co-PI: Andrew Hofmeister. Co-PI: Catherine Callow-Heusser, Utah State University. Six months, $150,000. Status: Not funded, revise and resubmit in December 2011.

ON-TRAC STTAR: ON-tablet reading adaptive curriculum with standards-based teaching and testing for all readers, submitted in April 2011 to the US Department of Education Office of Special Education Programs, Stepping Stones of Technology Innovation for Children with Disabilities. Principal Investigator: Alan Hofmeister, Academic Success for All Learners. Co-PI: Andrew Hofmeister. Co-PI: Catherine Callow-Heusser, Utah State University. Two years, $200,000 per year. Status: Not funded, revise and resubmit March 2012.

MONOGRAPH

Callow-Heusser, C.A., Torres, R.T., & Chapman, H.J. (2005). *Evidence: An essential tool. Planning for and gathering evidence using the design-implementation-outcomes (DIO) cycle of evidence.* Washington, DC: National Science Foundation. Retrieved from http://www.nsf.gov/pubs/2005/nsf0531/nsf0531.pdf

REFEREED PUBLICATIONS (previously known as Catherine A. Callow Elwell)

King, J.A., Ross, P., **Callow-Heusser**, C.A., Gullickson, A., Lawrenz, F., & Weiss, I. (2011). Reflecting on multi-site evaluation practice: A Chapel Hill conversation. *New Directions in Evaluation, 129, 59-71*.

Roseland, D., Volkov, B., & **Callow-Heusser**, C.A. (2011). MSP-RETA case study. *New Directions in Evaluation, 129, 33-38.*

Carnine, L.M., & **Callow-Heusser**, C.A. (2006). Success using Reading Mastery in Bureau of Indian Affairs' Reading First schools. *Utah Special Educator, 26*(5), 16-19.

Smith, J.A., Puhlmann, N., Jones, S.C., Moulding, L., **Elwell**, C.C., & Morgan, W. (1998). Implementing an arts education program at Edith Bowen Lab School: What we've learned. *National Association of Lab Schools*, 6-10.

Elwell, C.C., Reeve, K., & Hofmeister, A. (1992). Captioning instructional video. *Educational Technology, 32*(8), 45-50.

Elwell, C.A. (1986, May). Expert systems: Development and delivery on PCs. In *Sperry Technical Symposium—1986—Proceedings, Volume 3: Artificial Intelligence* (5-1 to 5-13). Brainerd, MN: Sperry Corporation.

SELECTED RESEARCH/EVALUATION REPORTS (over 700 submitted reports)

Callow-Heusser, C.A. (2011). *The effects of early identification and intervention on language outcomes of children born with hearing loss. Unpublished doctoral dissertation*. Logan, UT: Utah State University.

Callow-Heusser, C.A., Hoffmann, A., & Major, C. (2011). *Idaho Mathematics-Science Partnership (MSP) Teaching for Excellence in Science and Literacy Achievement (TESLA): 2010-2011 Evaluation Report*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Major, C. (2010). *Idaho Mathematics-Science Partnership (MSP) Teaching for Excellence in Science and Literacy Achievement (TESLA): 2009-2010 Evaluation Report*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A. (2010). *Bureau of Indian Education (BIE) BIE READS! summative evaluation report: 2009-2010 school year external evaluation* (also individual reports for 86 Cohorts 1, 2, 3, and 4 BIE Reading First and BIE READS! subgrant schools). Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A. (2009). *Bureau of Indian Education (BIE) Reading First summative evaluation report: 2004-2005 through 2008-2009 school years external evaluation* (also individual reports for 72 Cohorts 1, 2, 3, and 4 BIE Reading First and BIE READS! subgrant schools). Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Major, C. (2009). *Findings from the Teaching for Excellence in Science and Literacy Achievement (TESLA) workshop, August 2009*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Major, C. (2009). *Idaho Mathematics-Science Partnership (MSP) Teaching for Excellence in Science and Literacy Achievement (TESLA): 2008-2009 Evaluation Report*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A. (2008). *Bureau of Indian Education (BIE) Reading First Summative Evaluation Report: 2004-2005 through 2007-2008 school years external evaluation* (also individual reports for 66 Cohorts 1, 2, 3, and 4 BIE Reading First and BIE READS! subgrant schools). Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Jones, C.D., & Chapman, H.J. (2008). Evidence-based small-scale study final report: McDougal-Littell 7th and 10th grade Literature Program technical report, 11-17-08. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Major, C. (2008). *Findings from the Teaching for Excellence in Science and Literacy Achievement (TESLA) workshop participant survey, August 2008*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Chapman, H.J. (2008). *Idaho Mathematics-Science Partnership (MSP) Teaching for Excellence in Science and Literacy Achievement (TESLA): 2007-2008 Evaluation Report*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A. (2008). *Bureau of Indian Education (BIE) Reading First Summative Evaluation Report: 2004-2005 through 2006-2007 school years external evaluation (also individual reports for 42 Cohorts 1, 2, and 3 BIE Reading First and BIE READS! subgrant schools)*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Leonard, A.J. (2007). *Technical Report: The Relationship between Dynamic Indicators of Basic Early Literacy Skills (DIBELS) and Stanford Achievement Test, version 10 Reading First (SAT-10, RF) Data from Bureau of Indian Education Reading First Schools*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A. (2007). *Technical Report: The Relationship between Dynamic Indicators of Basic Early Literacy Skills (DIBELS) and Iowa Test of Basic Skills Data from Cache School District, 2005-2006*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Hoffmann, A. (2007). *Findings from the Teaching for Excellence in Science and Literacy Achievement (TESLA) workshop participant survey, August 2007*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Jones, C.D., & Chapman, H.J. (2007). *McDougal Littell Literature: Evidence-based study interim report*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A. (2007). *Bureau of Indian Education (BIE) Reading First Summative Evaluation Report: 2004-2005 through 2006-*2007 (also individual reports for 42 Cohorts 1, 2, and 3 BIE Reading First and BIE READS! subgrant schools). Logan, UT: EndVision Research & Evaluation.

Sanborn, W., & **Callow-Heusser**, C.A. (2007). *Utah behavior initiative: Success case method evaluation method*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Sanborn, W. (2007). *Oberkotter Foundation's First Year Professionals Program evaluation report*: Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Chapman, H.J., Dorward, J., Lehman, S., & Bates, S. (2007). *Final report of project activities, findings, project training/development, and outreach activities for the NSF MSP evaluation capacity building RETA project*. Logan, UT: Utah State University.

Enno, A., Sanborn, W., & **Callow-Heusser**, C.A. (2006). *Utah State improvement grant evaluation: 2005-2006 behavior initiative evaluation report.* Logan, UT: EndVision Research & Evaluation.

Enno, A., Sanborn, W., & **Callow-Heusser**, C.A. (2006). *Utah State improvement grant evaluation: 2005-2006 new teacher survey report*. Logan, UT: EndVision Research & Evaluation.

Enno, A., Sanborn, W., & **Callow-Heusser**, C.A. (2006). *Utah State improvement grant evaluation: 2005-2006 special education teacher exit report*. Logan, UT: EndVision Research & Evaluation.

Enno, A., Sanborn, W., & **Callow-Heusser**, C.A. (2006). *Utah State improvement grant evaluation: 2005-2006 JumpStart evaluation report*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Chapman, H.J., Dorward, J., Lehman, S., & Bates, S. (2006). *Annual report of project activities, findings, project training/development, and outreach activities for the NSF MSP evaluation capacity building RETA project*. Logan, UT: Utah State University.

Callow-Heusser, C.A. & Allred, D. M. (2005). *Bureau of Indian Affairs (BIA) Reading First summative evaluation report: 2004-2005 school year external evaluation* (also individual reports for 24 BIA Reading First subgrant schools). Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Allred, D., Robertson, D. J., Borman, G., & Dowling, M. (2005). *McDougal Littell Evidence-Based Small Scale Study Final Report: 7th Grade Life Science*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Allred, D., Robertson, D. J., & Sanborn, W. (2005). *McDougal Littell Evidence-Based Small Scale Study Final Report: Middle School Math.* Logan, Utah: EndVision Research & Evaluation.

Callow-Heusser, C.A., Allred, D., Robertson, D. J., & Sanborn, W. (2005). *McDougal Littell Evidence-Based Small Scale Study Final Report: 9th Grade Algebra I*. Logan, Utah: EndVision Research & Evaluation.

Callow-Heusser, C.A., & Robertson, D.J. (2005). *UNM's Project LINK Finance Implementation: Report of Evaluation Findings*. Logan, UT: EndVision Research & Evaluation.

Callow-Heusser, C.A., Worthen, B., Dorward, J., Lehman, S., & Julnes, G. (2005). *Annual report of project activities, findings, project training/development, and outreach activities for the NSF MSP evaluation capacity building RETA project*. Logan, UT: Utah State University.

Callow-Heusser, C.A., Worthen, B., Dorward, J., Lehman, S., Julnes, G., & de Lancer-Julnes, P. (2004). *Annual report of project activities, findings, project training/development, and outreach activities for the NSF MSP evaluation capacity building RETA project*. Logan, UT: Utah State University.

Roggman, L. A., Boyce, L. K., Cook, G. A., **Callow-Heusser**, C. A., & Hart, A. D. (2002). *Nurturing children and their families: Impacts of Bear River Early Head Start*. Final report of the local research partnership for Early Head Start, May 1, 1996, through April 30, 2002. Logan, UT: Utah State University. [one of 17 Early Head Start research sites that were part of the national study conducted by Mathematica Policy Research, including randomized assignment of families and their infants to treatment or control groups, participants included 203 families in Utah from 1996-2002.]

Dorward, J., Reinke, D., & **Elwell**, C.C. (2001). *Formative evaluation of instructional architect project*. Logan, UT: Utah State University.

Wareham, K. & **Elwell**, C.C. (2001). *Final evaluation report: Utah State University's integrated science program 2000*. Logan, UT: Utah State University.

Robertson, D.J., & **Elwell**, C.C. (2000, January). *Evaluation report: Educational Technology Masters of Education degree program*. Logan, UT: Utah State University, Department of Instructional Technology.

Sweeney, J., Van Mondfrans, A., Puhlmann, N., & **Elwell**, C.C. (1999). *Report of a cluster evaluation team visit to Washington State University/University of Idaho Partnership 2020 project.* Logan, UT: Western Institute for Research and Evaluation (WIRE).

Elwell, C.C. (1999). *Final evaluation report: Utah State University's integrated science program 1998*. Logan, UT: Utah State University.

Elwell, C.C., & Thorkildsen, R. (1998). *Evaluation of Utah State University's middle level science education inservice initiative, Summer 1997*. Logan, UT: Utah State University.

Puhlmann, N., **Elwell**, C.C., Jones, S., & Moulding, L. (1998). *Edith Bowen Laboratory School arts program: Year 1 evaluation results from interviews, focus groups, and surveys*. Logan, UT: Utah State University.

Roggman, L.A., **Elwell**, C.C., & Jump, V.K. (1997). *Continuous program improvement report: Year 1*. Logan, UT: Utah State University, Early Head Start Research Partnership.

Eastmond, J.N., Anderson, T., Cluff, L., Cutler, C., **Elwell**, C.C., Kelley, R., Peterson, M., Reiser, R., Walden, B., Walser, T., & Wright, R. (1995). *An educational needs assessment for the department of instructional technology*. Logan, UT: Utah State University.

Elwell, C.C. (1996). *HP Personal Trainer: Instructional multimedia training on CD-ROM for HP's 5Si MX printer.* Unpublished master's thesis, Utah State University, Logan, UT.

Hofmeister, A., **Elwell**, C.C., & Allred, D.M. (1995). *Final report: Research and development on adapting desktop digital video technologies to meet the instructional needs of persons with hearing impairments* (National Institute for Disability and Rehabilitation Research Grant No. H133G10186). Logan, UT: Utah State University. [Randomized assignment to treatment groups repeated measures design]

Eastmond, J.N., & **Elwell**, C.C. (1993). *Evaluation report 1: Distance education French program*. Logan, UT: Utah State University. (ERIC Document Reproduction Service ED 375 661)

Eastmond, J.N., & **Elwell**, C.C. (1994). *The evaluation of interactive videodiscs for language learning: Three journeys*. Logan, UT: Utah State University. (ERIC Document Reproduction Service ED 377 702)

CONFERENCES AND WORKSHOPS PLANNED AND DIRECTED

January 26-28, 2010, San Diego, CA. *Bureau of Indian Education Leadership Institute, School-Level Use of Data to Drive Change in School Systems*. Approximately 280 education line officers, principals, reading and math coaches.

October 6-8, 2009, Phoenix, AZ. *Bureau of Indian Education Leadership Institute, Coaching Teachers Who Use Direct Instruction Programs*. Approximately 150 reading and math coaches.

June 23-26, 2009, Phoenix, AZ. *Bureau of Indian Education Summer Institute, Making a Difference with Direct and Explicit Instruction*. Approximately 240 reading and math coaches and teachers.

June 17-19, 2008, Houston, TX. *Bureau of Indian Education Math Now Summer Institute*. Approximately 300 education line officers, principals, coaches, and teachers.

October 2-3, 2006, Minneapolis, MN. *Think Tank on Evaluation Capacity Building*. Funded by the National Science Foundation (NSF). Approximately 65 NSF principal investigators and leaders from foundations.

October 4-5, 2006, Minneapolis, MN. *MSP Evaluation Summit II: Evidence-Based Findings from the Mathematics and Science Partnerships (MSP)*. Funded by the National Science Foundation (NSF) and sponsored jointly by the Utah State University Evaluation Capacity Building Grant and the University of Wisconsin-Madison Adding Value to the MSPs Grant. Approximately 200 NSF project officers, principal investigators and key personnel from NSF-funded MSPs.

September 14-16, 2005, Minneapolis, MN. *Evaluation Summit: Evidence-Based Findings from the Mathematics Science Partnerships (MSP)*. Funded by the National Science Foundation (NSF) and sponsored jointly by the Utah State University Evaluation Capacity Building Grant and the University of Wisconsin-Madison Adding Value to the MSPs Grant. Approximately 200 NSF project officers, principal investigators and key personnel from NSF-funded MSPs.

October 21-22, 2004, Washington, DC. *Evidence: An Essential Tool*. Funded by the National Science Foundation (NSF). Approximately 300 NSF grant officers, principal investigators and key personnel from NSF-funded Mathematics-Science Partnership Projects.

October 17-18, 2003, Baltimore, MD. *Building Evaluation Capacity: Helping YOU Determine if Your MSP is "Working*." Funded by the National Science Foundation (NSF). Approximately 175 NSF grant officers, principal investigators and key personnel from NSF-funded Mathematics-Science Partnership Projects.

KEYNOTE ADDRESSES

Callow-Heusser, C.A. (2010, January). *Data use: Short cycle. Using data to improve instruction and intervention.* Keynote address presented at the Bureau of Indian Education Leadership Institute, San Diego, CA.

Callow-Heusser, C.A. (2009, October). *Math counts: Providing direct and explicit instruction in math.* Keynote address presented at the Bureau of Indian Education Leadership Institute, Phoenix, AZ.

Callow-Heusser, C.A. (2009, June). *K-8 mathematics: Standards and assessment*. Keynote address presented at the Bureau of Indian Education Summer Institute, Phoenix, AZ.

Callow-Heusser, C.A. (2008, June). *Using data to increase academic success and provide systematic and explicit math instruction to struggling learners*. Keynote address presented at the Bureau of Indian Education Math Now Summer Institute, Dallas, TX.

Callow-Heusser, C.A. (2006, October). *Using evidence to guide decision-making in MSP projects*. Keynote address presented at the MSP Evaluation Summit II: Evidence-Based Findings from the Mathematics and Science Partnerships, Minneapolis, MN.

Callow-Heusser, C.A. (2005, January). *Using evidence in the Mathematics-Science Partnerships*. Keynote address presented at the National Science Foundation Mathematics-Science Foundation Learning Network Conference, Washington, DC.

Callow-Heusser, C.A. (2004, October). *Evidence: An essential tool*. Keynote address presented at the National Science Foundation Mathematics-Science Partnership Meeting sponsored by the Evaluation Capacity Building Project at Utah State University, Washington, DC.

INVITED WORKSHOPS (not including workshops conducted at individual schools)

Callow-Heusser, C.A. (2010, October). *DIBELS and data use: Using data to drive instruction in BIE READS! schools*. Workshop presented at the Bureau of Indian Education (BIE) Leadership Institute, Phoenix, AZ.

Callow-Heusser, C.A., Howe, K., Carnine, L., & McKnight, C. (2010, January). *School-level use of data to drive change in school systems*. Workshop presented at the BIE Leadership Institute, San Diego, CA.

Callow-Heusser, C.A., McKnight, C., & Carnine, L. (2009, October). *Coaching teachers who use direct instruction programs in reading and math*. Workshop presented at the BIE Leadership Institute, Phoenix, AZ.

Callow-Heusser, C.A., Carnine, L., & Brumbley, S. (2009, June). *Making a difference with direct and explicit instruction in math and reading*. Workshop presented at the BIE Summer Institute, Phoenix, AZ.

Callow-Heusser, C.A., Gersten, R., Shinn, M.R., & Stein, M. (2008, June). *BIE Math Now: Using data to drive instruction and intervention*. Workshops presented at the BIE Math Now Summer Institute, Houston, TX.

Callow-Heusser, C.A. & Chandler, A. (2008, June). *DIBELS reading assessments: Using technology in BIE Reading First schools*. Workshop presented at the Access Native America meeting in Lawrence, KS.

Callow-Heusser, C.A. (2008, March). *BIE Reading First "State of the State" data summit*. Workshop presented at the Bureau of Indian Education's Reading First and BIE READS! Leadership Institute, San Diego, CA.

Callow-Heusser, C.A., Barnes, T.P., Callow, P.M., & Callow, R.S. (2007, November). *Dynamic Indicators of Basic Early Literacy Skills (DIBELS): Administration and data use*. Workshop presented at the Bureau of Indian Education's BIE READS! Reading Institute, Albuquerque, NM.

Callow-Heusser, C.A., & Barnes, T.P. (2007, August). *Administering the DIBELS assessments and using data to plan instruction and intervention*. Workshop presented at the Bureau of Indian Education's Reading First Summer Institute, Phoenix, AZ.

Callow-Heusser, C.A. (2007, April). *BIE Reading First data summit*. Workshop presented at the Bureau of Indian Education's Leadership Summit, Albuquerque, NM.

Callow-Heusser, C.A., Allred, D., Barnes, T.P., Krebs, S., Chandler, A., Leonard, A.J., Mielcarek, S., & Whitehorse, B. (2006, June). *Administering the DIBELS assessments and using progress data to plan instruction*. Workshop presented at the Bureau of Indian Education's Reading First Summer Institute, Phoenix, AZ.

Callow-Heusser, C.A. (2005, December). *Using assessment data to prevent reading difficulties*. Workshop presented at the Bureau of Indian Education's Reading First Grantwriting Workshop, Albuquerque, NM.

Callow-Heusser, C.A. (2005, January). *Using evidence in the NSF Math-Science Partnerships: The Design-Implementation-Outcomes (DIO) cycle of evidence*. Workshop presented at the National Science Foundation's Math and Science Partnership Learning Network Conference, Washington, DC.

Callow-Heusser, C.A., & Schneider, S.H. (2004, January). *Developing logic models for MSP projects*. Workshop presented at the National Science Foundation's Math and Science Partnership Learning Network Conference, Washington, DC.

Callow-Heusser, C.A., & Engle, M. (2003, October). *MSP partnerships: Defining and measuring partnerships and collaborations*. Workshop presented at the National Science Foundation's workshop, Building Evaluation Capacity: Helping YOU Determine if Your MSP is "Working", Baltimore, MD.

Althouse, R. B., & **Elwell**, C. C. (1988, February). *Knowledge engineering with expert systems: Concepts, shells, applications, and programming*. Workshop conducted at Retool `88, Council for Exceptional Children, Logan, UT.

REFEREED PRESENTATIONS (presented at nationally recognized conferences, not including invited technical assistance workshops and presentations at NSF meetings, BIE Leadership Institutes, or BIE Reading First, BIE READS! and BIE Math Counts schools)

Boben, M., **Callow-Heusser**, C.A., Gummer, E., Meyer, S., Sutton, J., Wareham, K.L., Wong, K. (2009, November). *Evaluating U.S. Department of Education and National Science Foundation programs for improving mathematics and science education - Rigor, relevance, context, and challenges*. Panel presentation at the annual conference of the American Evaluation Association, Orlando, FL.

Callow-Heusser, C.A. (2009, November). *Painting a picture worth 1000 words: Using Microsoft Excel or R Statistical Software with Adobe Photoshop Elements to create graphs and charts with powerful messages*. Paper presented at the annual conference of the American Evaluation Association, Orlando, FL.

Callow-Heusser, C.A., & Wareham, K.L. (2009, November). *Balancing the call for evidence-based research designs with formative evaluation to improve implementation of inquiry-based science teaching*. Paper presented at the annual conference of the American Evaluation Association, Orlando, FL.

Callow-Heusser, C.A. (2009, April). *Bureau of Indian Education's Reading First: Regression discontinuity analyses based on DIBELS and SAT-10 outcomes*. Paper presented at the annual conference of the American Educational Research Association, San Diego, CA.

Callow-Heusser, C.A. (2008, November). *Developing classroom and school-level measures of implementation fidelity for Reading First programs*. Paper presented at the annual conference of the American Evaluation Association, Denver, CO.

Callow-Heusser, C.A., & Chapman, H.J. (2008, November). *Providing intervention to struggling readers in Bureau of Indian Education Reading First schools: Does the data show it's making a difference using a regression discontinuity design?* Poster presented at the annual conference of the American Evaluation Association, Denver, CO.

Callow-Heusser, C.A., & Barbero, L.B. (2008, October). *The impact of Reading First on Bureau of Indian Education schools*. Paper presented at the annual conference of the National Indian Education Association, Seattle, WA.

Sutton, J., Bendada, A., Gummer, E., **Callow-Heusser**, C.A., & Meyer, S. (2008, March). *Mathematics and Science Partnership evaluation issues and challenges*. Paper presented at the annual conference research presession of the National Council of Teachers of Mathematics, Salt Lake City, UT.

Chapman, H.J., & **Callow-Heusser**, C.A. (2007, November). *Increasing the value of items on a measure: A practitioner's guide to item response theory analysis*. Demonstration session presented at the annual conference of the American Evaluation Association Conference, Baltimore, MD.

Callow-Heusser, C.A., Sanborn, W., & Chapman, H.J. (2007, November). *Evaluating organizational learning in education: Modifying and validating an instrument with empirical evidence from health settings*. Presentation given at the annual conference of the American Evaluation Association, Baltimore, MD.

Callow-Heusser, C.A., & Chapman, H.J. (2007, November). *Validating an organizational change survey: Reading First in Bureau of Indian Education (BIE) schools*. Paper presented at the annual conference of the American Evaluation Association, Baltimore, MD.

Barbero, L., **Callow-Heusser**, C.A., Chandler, A., Mielcarek, S., & Hope, E. (2007, October). *Reading First:A Bureau of Indian Education success story*. Paper presented at the annual conference of the National Indian Education Association, Waikiki, HA.

Callow-Heusser, C.A., & Sanborn, W. (2006, November). *Evaluation processes and findings of the Bureau of Indian Education Reading First Program after two years*. Poster presented at the annual conference of the American Evaluation Association, Portland, OR.

Callow-Heusser, C.A., Sanborn, W., & Chandler, A. (2006, November). *Changing systems through use of data and evaluation findings: The Bureau of Indian Education's Reading First Program results in high levels of student success in reading*. Paper presented at the annual conference of the American Evaluation Association, Portland, OR.

Callow-Heusser, C.A., Sanborn, W., & Veeder, M. A. (2006, June). *Substantial K-3 reading progress in BIA Reading First schools*. Paper presented at the 19th Annual Convention of the American Indian Psychologists and Psychology Graduate Students, Logan, UT.

Callow-Heusser, C.A., Borman, G.D., Robertson, D. R. & Allred, D.M. (2006, April). *Conducting randomized and quasi-experimental studies of the effectiveness of math and science curricula: Process and findings.* Paper presented at the annual conference of the American Educational Research Association, Portland, OR.

Callow-Heusser, C.A., & Allred, D.M. (2005, November). *Conducting a randomized experiment without gathering qualitative data is like a betting on a two-headed horse—You might not be able to explain which one "won by a nose*". Skill building workshop presented at the annual conference of the American Evaluation Association, Toronto, CA.

Torres, R.T., Della-Piana, G.M., **Callow-Heusser**, C.A., & Dorward, J. (2005, November). *Logic model practices and tools: Session I (Subtleties and nuances of evaluation practice using logic models) and Session II (An online logic model tool and the Design-Implementation-Outcomes Cycle of Evidence: Improving evaluation efforts in NSF's Math Science Partnership Program).* Panel and Demonstration Sessions presented at the annual conference of the American Evaluation Association, Toronto, Ontario, Canada.

Dorward, J., Chapman, H.J., & **Callow-Heusser**, C.A. (2005, October). *An online logic model tool and the Design-Implementation-Outcomes cycle of evidence: Improving evaluation efforts in the Math and Science Partnership program*. Paper presented at the annual conference of the American Evaluation Association Annual, Toronto, Ontario, Canada.

Chapman, H. J., **Callow-Heusser**, C.A., & Dorward, J. (2005, September). *Establishing partnerships to provide evaluation technical assistance and promote evidence-based designs*. Paper presented at the National Science Foundation's Mathematics-Science Partnership (MSP) Evaluation Summit: Evidence-Based Findings from the MSPs, Minneapolis, MN.

Callow-Heusser, C.A. (2005, January). *Using evidence in Math-Science Partnerships: The DIO cycle of evidence*. Paper presented at the National Science Foundation's MSP Learning Network Conference, Washington, DC.

Callow-Heusser, C.A., Dorward, J., Webb, N., Blank, R. (2004, November). *If we build it, will they come? Insights from three NSF RETA projects funded to provide evaluation assistance to MSP projects*. Paper presented at the annual conference of the American Evaluation Association, Atlanta, GA.

Callow-Heusser, C.A. (2003, November). *Developing implementation evaluation models to provide assistance to the National Science Foundation's Math Science Partnerships*. Paper presented at the annual conference of the American Evaluation Association, Reno, NV.

Callow-Heusser, C.A., Roggman, L.A., Christiansen, K., & Sharp, O.R. (2003, November). *Hot on the trail: Minimizing participant attrition over time*. Paper presented at the annual conference of the American Evaluation Association, Reno, NV.

Hart, A.D., & **Callow-Heusser**, C.A. (2003, November). *How to scrub your data: Data cleaning and management techniques*. Paper presented at the annual conference of the American Evaluation Association, Reno, NV.

Callow-Heusser, C.A., & Engle, M. (2003, October). *MSP partnerships: Defining and measuring partnerships and collaborations*. Presentation at a National Science Foundation/Utah State University workshop, Building Evaluation Capacity: Helping YOU Determine if Your MSP is "Working", Baltimore, MD.

Callow-Heusser, C.A., Bolland, K., & Morell, J.A. (2002, November). *Digital resources and links to communities of evaluators: Spreading information, tools, and support worldwide*. Paper presented at the annual conference of the American Evaluation Association, Washington, DC.

Callow-Heusser, C.A., Roggman, L.A., & Hart, A.D. (2002, March). *Research as intervention: Does data collection change research families' behavior?* Paper presented at the annual conference of the Southwest Society for Research Human Development, Austin, TX.

Elwell, C.C. (2000, November). *Building evaluation capacity byte by byte: More computer-based and on-line resources for evaluators*. Paper presented at the annual conference of the American Evaluation Association, Waikiki, HA.

Elwell, C.C, Lubke, M.M., & Robertson, D. (2000, November). *On-line data collection, reporting, & data-based decision-making system for safe schools violations*. Paper presented at the annual conference of the American Evaluation Association, Waikiki, HA.

Lubke, M.M., & **Elwell**, C.C. (2000, November). *Using technology to build evaluation capacity in the new millenium*. Paper presented at annual conference of the American Evaluation Association, Waikiki, HA.

Elwell, C.C. (November, 1999). *Take a byte: A growing collection of online resources for evaluators.* Paper presented at the annual conference of the American Evaluation Association, Orlando, FL.

Elwell, C.C., Walser, T.M., & Slocum, T.A. (1999, November). *Evaluation results and challenges from a comprehensive school reform model in Utah*. Paper presented at the annual conference of the American Evaluation Association, Orlando, FL. [Randomized assignment of schools to treatment or comparison groups]

Elwell, C.C., Scriven, M., Trochim, W.M.K., & SenGupta, S. (1998, November). *Take a byte: Electronic mail groups and internet resources for evaluators*. Paper presented at the annual conference of the American Evaluation Association, Chicago, IL.

Elwell, C.C., Walser, T.M., & Slocum, T.A. (1998, November). *Computer-based scoring of written language*. Paper presented at the annual conference of the American Evaluation Association, Chicago, IL.

Walser, T.M., **Elwell**, C.C., & Slocum, T.A. (1998, November). *Comparing standardized and alternative measures of written language*. Paper presented at the annual conference of the American Evaluation Association, Chicago, IL.

Elwell, C.C. (1996, August). *HP's Personal Trainer and the CBT development cycle: It's not all instructional design and programming!* Paper presented at Utah State University's Eighth Annual Summer Instructional Technology Institute, Automating Instructional Design and Instructional Design Support Systems, Logan, UT.

Elwell, C.C. (1996, August). *HP's Personal Trainer: Automating instructional software simulations with the ID2 simulation builder.* Paper presented at Utah State University's Eighth Annual Summer Instructional Technology Institute, Logan, UT.

Eastmond, J.N., & **Elwell**, C.C. (1994, May). *The evaluation of interactive videodiscs for language learning: Three journeys.* Paper presented at the 14th Annual Conference of the Canadian Evaluation Society, Quebec City, Quebec, Canada.

Elwell, C.C. (1994, May). *Evaluating instructional video adaptations: Research and development with desktop digital video technologies.* Paper presented at the 14th annual conference of the Canadian Evaluation Society, Quebec City, Quebec, Canada.

Elwell, C.C., Allred, D.M., & Hofmeister, A. (Producers and Directors). (1994). *Adapting instructional video using digital video technologies to meet the needs of students with hearing impairments* [Videotape]. Presented at the annual meeting of principal investigators, Washington, DC: National Institute for Disability and Rehabilitation Research.

Elwell, C.C. (1993, February). *Captioning instructional video using multimedia computers*. Paper presented at the Florida Adaptive Technology Conference, Tampa, FL.

Elwell, C.C. (1992, October). *Captioning instructional video*. Paper presented at the Technology in the Rockies Conference, International Society for Technology in Education, Denver, CO.

Findlay, P.H., & **Elwell**, C.C. (1992, May). *CD-ROM: A medium for delivering paraprofessional training materials.* Paper presented at the National Conference for Persons with Disabilities, California State University, Northridge, Los Angeles, CA.

Elwell, C.A. (1986, May). *Expert systems: Development and delivery on PCs*. Paper presented at the Sperry Technical Symposium, Brainerd, MN.

SELECTED PRODUCTS

Callow-Heusser, C.A., Robertson, D.J., & Lehman, S. (2006). *Digital evaluation resources for Mathematics Science Partnerships*, http://www.usu.edu/cbec (no longer active). Logan, UT: Utah State University.

Hofmeister, A.M. (2003). *Reading for All Learners Program*. Logan, UT: Utah State University, now at Academic Success for All Learners, Inc. [developed computer software for connected and decodable text passages to control introduction of characters and words, helped field-test materials]

Callow-Heusser, C.A. (2003). *Digital resources for evaluators, version 4*. Logan, UT: Author. [http://www.resources4evaluators.info, no longer updated]

Elwell, C.C. (2001). *Electronic resources for evaluators, version 3*. Logan, UT: Author. [http://www.be-webbed.com/EvalResources.html]

Lubke, M.M., **Elwell**, C.C., Robertson, D., & Paskett, K. (2000). *Incident reporting system for Utah school districts' safe schools violations.* Logan, UT: Utah State University Research Foundation (USURF). [http://www.risep.usu.edu/]

Elwell, C.C. (1999). *Electronic resources for evaluators*. Logan, UT: Author.

Elwell, C.C. (1999). InspecText [Computer program]. Logan, UT: Author.

Elwell, C.C., Walser, T.M., & Slocum, T.A. (1998). *A program to score TOWL-3 spontaneous writing samples* [Computer program]. Logan, UT: Utah State University.

Levine, A., **Elwell**, C.C., & Diehl, R. (1998). *Civil & environmental engineering concepts: Units of expression* [CD-ROM]. Logan, UT: Utah State University.

Hewlett-Packard Co. (1996). *HP Personal Trainer for HP LaserJet 5Si and 5Si MX printers* [CD-ROM]. Boise, ID: Hewlett-Packard Co. [developed computer program shipped with all HP LaserJet 5Si and 5SI MX printers using ID_2 technology with Dr. M. David Merrill]

Elwell, C.C., Hofmeister, A., Allred, D.M., & Bishop, J.M. (1995). *Caption-IT! Digital video captioning tool* [Computer program]. Logan, UT: Utah State University.

Hofmeister, A., Likens, M., **Elwell**, C.C., & Allred, D.M. (1995). *Least restrictive behavioral interventions training: Preliminary and level I strategies, version 1.0* [CD-ROM, videotape]. Salt Lake City, UT: Utah State Office of Education (USOE).

Hofmeister, A., Findlay, P.H., & **Elwell**, C.C. (1994). *Classroom-based instructional resource materials for paraeducators, version 3.0* [CD-ROM]. Logan, UT: Utah State University.

Systems Impact, Inc. (1993). *Tables, graphs, and statistics* [Computer program, videodisc]. Salt Lake City, UT: Systems Impact, Inc. [developed computer graphics and software program]

Thornburg, M., Shuster, T., **Elwell**, C.C. & Hofmeister, A. (1991). *Metacognitive strategies for learning skills* [Computer program]. Logan, UT: Utah State University, Edith Bowen Laboratory School.

Ferrara, J.M., Findlay, P.H., & **Elwell**, C.C. (1990). *LD trainer: An expert system for preservice training in classifying students with learning disabilities* [Computer program]. Logan, UT: Utah State University.

Ferrara, J.M., Baer, R., Likins, M., Althouse, R. B., & **Elwell**, C.C. (1988). *Class.LD: An expert system for classification of students with learning disabilities* [Computer program]. Logan, UT: Utah State University.

Ferrara, J.M., Guirre, S., Althouse, R.B., & **Elwell**, C.C. (1988). *IH trainer: An expert system for preservice training in classifying intellectually handicapped students* [Computer program]. Logan, UT: Utah State University.

Elwell, C.C. (1986). *MCDS: Microcomputer diagnostic support expert system for technical support personnel* [Computer program]. Salt Lake City, UT: Sperry Micro-Products Division.

Elwell, C.C., & Kessler, R.M. (1985). *Spell checker in LISP* [Computer program]. Salt Lake City, UT: University of UT.

SERVICE

2011	Co-Chair, Evaluation Policy Topical Interest Group, American Evaluation Association.
2010-2011	DIBELS technical assistance (email, telephone), Bureau of Indian Education schools (after contract ended).
2008-2010	Books and Bags for American Indian Students, BIE schools in Arizona.

2007, 2009	Leadership Committee, Logan Dance and Social Club, Logan, UT.
2002-2004 1996-1998	Webelos Den Leader, Pack #299, Logan, UT.
1998-2004 1988-1992	Religious Education Youth Director and Teacher, Logan, UT.
1990-2004	Room Parent, Classroom Volunteer, Logan and Cache School Districts.
1988-2002	Member and School Volunteer, Parent Teacher Association (PTA), Logan & Cache School Districts.
1990-2002	Cache Valley District 7 Soccer Coach for years 1990, 1991, 1993, 1994, 1995, 2002.
1998-2002	Boy Scouts Parent Volunteer, Troop #1, Logan, UT.
2000-2002	Cub Scouts Den Leader, Pack #299, Logan, UT.
1993, 1994	Presenter, Expanding Your Horizons in Science and Math, Utah State University, Logan, UT.
1991-1993	Girl Scouts Troop Leader, Logan, UT.
1991, 1992	Chair, Cache Valley Century Bicycle Tour, Logan, UT.
1989-1990	Parent Teacher Association (PTA) Safety Commissioner, Edith Bowen Laboratory School, Logan, UT.
1983-1985	Tutor, Disabled Student Center, University of Utah, Salt Lake City, UT.

CURRENT PROFESSIONAL MEMBERSHIPS

2006-present	Association for Direct Instruction (ADI)
2006-present	National Indian Education Association (NIEA)
2005-present	Society for Research on Educational Effectiveness (SREE)
1997-present	American Educational Research Association (AERA)
1997-present	American Evaluation Association (AEA)