AN EXAMINATION OF THE EVIDENCE-BASED LITERACY RESEARCH IN DEAF EDUCATION

THE ABILITY TO READ AND WRITE for a variety of purposes is essential to success in school and in contemporary society. The purpose of this investigation was to conduct an exhaustive review of the literature and a meta-analysis of literacy research in the field of deaf education. Computer and manual searches of 40 years of peer-reviewed journal articles were conducted. A total of 964 articles related to literacy and deafness were identified and examined; 22 articles met the criteria for inclusion in the review. Results indicate that (a) no two studies examined the same dimension of literacy; (b) there was a paucity of well-designed group studies; (c) there were no systematic replication of studies; (d) there is limited data to establish evidenced-based practices. Consequently, increasing the quantity and improving the quality of research in the field is recommended.

JOHN L. LUCKNER, ANN M. SEBALD, JOHN COONEY, JOHN YOUNG III, AND SHERYL GOODWIN MUIR

LUCKNER IS DIRECTOR OF THE NATIONAL CENTER ON LOW-INCIDENCE DISABILITIES, UNIVERSITY OF NORTHERN COLORADO, GREELEY. SEBALD IS PROGRAM COORDINATOR FOR THE NATIONAL CENTER ON LOW-INCIDENCE DISABILITIES. COONEY IS A PROFESSOR OF EDUCATIONAL PSYCHOLOGY IN THE SCHOOL OF PSYCHOLOGICAL SCIENCES, UNIVERSITY OF NORTHERN COLORADO. YOUNG IS A DOCTORAL CANDIDATE IN THE SCHOOL OF EDUCATIONAL RESEARCH, LEADERSHIP, AND TECHNOLOGY, UNIVERSITY OF NORTHERN COLORADO. MUIR IS A CONSULTANT WITH THE COLORADO DEPARTMENT OF EDUCATION.

Read and Write—or Fail

Literacy skills are essential to success in today's technological society. Everyday examples of these skills include accessing the Internet and sending and receiving e-mail; reading instructional manuals for the workplace, computers, or cars; following directions at work, for travel, or for taking medications; and reading the newspaper or enjoying a magazine or book. Literacy is also the key to functioning effectively in school. For most individuals, reading proficiency begins in early childhood, advances with formal reading instruction in school, and continues to increase as the result of quality educational, social, and recreational experiences throughout one's lifetime (Chall, 1996). Without well-developed literacy skills, students cannot participate fully in classroom learning. They are at much greater risk for school failure and lifelong problems with employment, social adjustment, and personal autonomy (Moats, 2000). Consequently, individuals who struggle to read and write are much more likely than literate people to drop out of school, go to prison, or struggle to find and keep meaningful, satisfying work (Cramer & Ellis, 1996).

Literacy skills are also vital at a national level. Countries that are successful at instilling strong literacy skills in their citizens are in a better position to

meet the economic challenges of operating in a global information-based economy. Simultaneously, citizens with strong literacy skills are better prepared to address today's complex educational, social, economic, and political issues. Finally, a population with strong literacy skills enables a country to better meet the complex social challenges it faces. For example, strong literacy skills are linked to better health outcomes for individuals (Berkman et al., 2004). Simultaneously, a highly literate population will be better able to participate in determining how best to allocate scarce national resources among competing priorities, such as education, health, transportation, the environment, defense, and social programs.

The importance of literacy has been highlighted by the National Reading Panel (NRP), which was convened in 1997 in response to a congressional directive to review the scientific literature and to determine the most effective ways to teach children and youth to read. The NRP issued its report, and a summarizing document titled *Put Reading First: The Research Building Blocks for Teaching Children to Read* was developed and disseminated (National Institute for Literacy, 2001). These findings were then incorporated into the No Child Left Behind Act of 2001 (Pub. L. No. 107-110). NCLB emphasizes the development of literacy as well as school systems' accountability for student outcomes. School personnel are required to demonstrate that all students are reading at or above grade level by the end of the third grade, and that they continue to make adequate yearly progress in subsequent years.

The NRP and NCLB support reading instruction based on "scientifically based research," which is defined as "rigorous, systematic, and objective procedures to obtain valid knowledge, which includes research that is evaluated using experimental or quasi-experimental designs, preferably with random assignment" (Slavin, 2002, p. 15). The problem for administrators, educators, and families who work or live with students who are deaf or hard of hearing is the paucity of scientifically based literacy research available for establishing research-based methods of instruction. Unlike the other areas of special education, which address conditions often referred to as high-incidence disabilities (e.g., learning disabilities), and unlike general education, the field of deaf education does not have a large body of empirically based experimental research to draw upon to establish research-based methods for ensuring that every student with a hearing loss becomes a literate adult. Compounding the challenge of meeting the literacy goals of NCLB are the ongoing difficulties experienced by students who are deaf or hard of hearing in the effort to develop reading skills. National research on students who are deaf or hard of hearing (e.g., Allen, 1986; Center for Assessment and Demographic Studies, 1991; Traxler, 2000) indicates that the average student with a hearing loss graduates from high school with reading comprehension skills at about the fourth-grade level. Approximately 20% of students with hearing loss (some 2,000 annually) leave school with a reading level at or below second grade (Dew, 1999).

Obstacles to Fluency for Readers and Writers With Hearing Loss

It is important to note that there are some students who are deaf or hard of hearing who read at grade level (Erickson, 1987; Geers & Moog, 1989); furthermore, there are some who become successful writers (Cambra, 1994; Schirmer, Bailey, & Fitzgerald, 1999). However, for the majority of students who are deaf or hard of hearing, learning to read and write is a tortuously slow and frustrating process. Research and observation suggest a variety of reasons why students who are deaf or hard of hearing struggle to become fluent readers and writers. Five problems are often cited: obstructed access to the phonological code, limited fluency at the onset of formal schooling, inadequate literacy experiences in early childhood, delayed acquisition of vocabulary, and problems with lower-level skills.

Obstructed Access to the Phonological Code

Hearing children learn to map the spoken language they already know to the printed words on a page. For English, as for most languages, that mapping is based on sound. Once children understand the underlying principles of print-sound mapping, once they "crack the code," they use their knowledge of their spoken language to facilitate the reading process (Goldin-Meadow & Mayberry, 2001). Children who are deaf or hard of hearing do not have easy access to the phonological code. Additionally, natural sign languages such as American Sign Language (ASL) have their own vocabularies, morphologies, and syntaxes, which do not parallel those of spoken or printed English (Marschark & Harris, 1996).

Limited Fluency at the Onset of Formal Schooling

Many children who are deaf or hard of hearing begin formal schooling with little fluency in either a spoken or a signed language, or an awareness of print and literacy concepts (Marschark & Harris, 1996). Reading and writing are considered secondary forms of expression, highly dependent on a pri-

mary language system such as speech or sign as a foundation for development. Unlike their hearing peers, who learn to read and write in a language they already know, many students who are deaf or hard of hearing learn to read and write while simultaneously learning their first language.

Inadequate Literacy Experiences in Early Childhood

Children who have stimulating literacy experiences from birth onward have an edge when it comes to building vocabulary, understanding the goals of reading, and developing an awareness of print and literacy concepts (Lyon, 2001). In comparison to their hearing peers, children who are deaf or hard of hearing do not have books read to them as often (Paul, 1998), an activity that has been determined to be an essential component in literacy development (Adams, 1991). In many cases, children who are deaf or hard of hearing do not have books read to them because the adults in their lives do not feel comfortable signing, have a limited sign vocabulary, experience difficulty finding a comfortable way to seat the child and hold the book to accomplish satisfactory visual contact, or do not receive positive feedback from the child (Paul, 1998; Stewart & Kluwin, 2001).

Delayed Acquisition of Vocabulary

Vocabulary is critical to reading comprehension. The larger the reader's vocabulary, the easier it is to make sense of the text (Baumann & Kame'enui, 1991). Research suggests that students who are deaf or hard of hearing experience delays in building their level of vocabulary knowledge, have smaller lexicons, acquire new words at slower rates, and have a narrower range of contexts that result in word learning (Lederberg & Spencer, 2001). Thus, a vicious circle is created: Impoverished vocabularies limit reading comprehension, and poor reading strategies and skills limit students' ability to acquire adequate vocabulary knowledge from context (deVilliers & Pomerantz, 1992).

Problems With Lower-Level Skills

To be effective readers, individuals need to be active, self-regulated, and armed with a variety of strategies to help them understand what they are reading (Snow, 2002). Regrettably, many students who are deaf or hard of hearing continue to struggle with lower-level skills, such as word recognition, syntactic parsing, and vocabulary comprehension. As a result, they do not develop the independent reading strategies they need to understand many narrative or expository texts, such as self-questioning, activating prior knowledge, summarizing the main idea, constructing representational images, predicting what text will follow, drawing inferences, monitoring for misunderstanding, and re-reading difficult passages of text (Andrews & Mason, 1991; Strassman, 1992).

Meta-Analysis: Meeting the Need for "Scientifically Based Research"

In today's service- and knowledge-driven economy, in which high levels of literacy and numeracy are required of almost everyone to achieve a good standard of living, there is a demand for rigorous, sustained scientific research in education (National Research Council, 2002). Simultaneously, as previously noted, NCLB and many federal grant programs call on educators to use "scientifically based research" to guide their decisions about which teaching approaches to use. "Scientifically based research" includes experimental control (or comparison) groups, replication of results through multiple studies, an ability to generalize results, rigorous standards (especially by means of peer review), and the convergence of results between studies (National Center for Education Evaluation and Regional Assistance, 2003). Where strong "scientifically based research" does not exist, it has been suggested that researchers produce syntheses of research summarizing the evidence pertaining to the effectiveness of educational interventions and approaches (Valentine & Cooper, 2004). A common method for integrating a body of literature is meta-analysis. For example, the NRP suggested, "First, where possible, there should be meta-analyses of existing experimental or quasi-experimental research in topic areas not addressed by the NRP" (National Institute of Child Health and Human Development, 2000, p. 19).

Meta-analysis is a statistical procedure used to identify trends in the statistical results of a set of existing studies concerning the same research problem (Glass, 1976; Rosenthal, 1978). Through such a procedure, effects, which are difficult or impossible to discern in the original studies when sample sizes are too small, can be made visible, as the meta-analysis is equivalent to a single study with the combined size of all original studies.

Meta-analytic reviews go beyond narrative reviews in the sense that they are systematic and explicit, and employ quantitative methods of analysis (Rosnow & Rosenthal, 1996). Because of these features, meta-analytic reviews are considered to provide more thorough, comprehensive, and precise summative evaluations that entail greater objectivity than narrative reviews. Moreover, meta-analysis is consistent with American Psychological Association (2001) guidelines that call for the use of effect sizes,

which allow for an evaluation of the practical significance of differences. Consequently, the purpose of the research for the present study was to conduct an exhaustive review of the literature and a meta-analysis of literacy research in the field of deaf education.

Method

General Study Search Process

We used a three-step literature search strategy to identify pertinent studies. First, computer searches in ERIC, PsychINFO, the William S. Gray database, and the Kraus Curriculum database were conducted. The search terms were *deaf*, *deafness*, *hard of hearing*, *hearing impaired*, *literacy*, *reading*, and *writing*. Specifically, the terms *deaf*, *deafness*, *hard of hearing*, and *hearing impaired* were each individually cross-referenced with *literacy*, *reading*, and *writing*. Second, the reference list from every identified study was reviewed. Third, manual searches for articles related to literacy and hearing loss in all issues of the *American Annals of the Deaf*, *Volta Review*, and *Journal of Deaf Studies and Deaf Education* between 1963 and 2003 were conducted.

Specific Study Inclusion Criteria

For the purposes of the present study, *literacy* was defined as the ability to read and write. We relied heavily on materials made available by the What Works Clearinghouse to guide us. Specifically, we used the Study Design and Implementation Assessment Device (Valentine & Cooper, 2004) as a model for the development of our own study team's design and implementation assessment device. One study team member screened each article to identify which were research studies reporting literacy data on students who were deaf or hard of hearing.

Each of the studies included in our analysis had to meet five selection criteria:

1. The study had to have been published in a peer-reviewed journal between 1963 and 2003. Only peer-reviewed studies were considered. Unpublished manuscripts (e.g., dissertations) were excluded.
2. Study participants had to have been identified as students who were deaf or hard of hearing.
3. The study sample had to have consisted of children and youth between ages 3 and 21 years.
4. Studies had to have provided the necessary statistical information for the estimation of effect sizes (e.g., means, standard deviations, group sizes, *F* values, *t* values, *r* values).
5. Studies had to have incorporated a control group.

A total of 964 articles were reviewed. Of these, 516 were excluded because they were position papers, practitioner articles, literature reviews, curriculum development descriptions, or program descriptions. Another 425 were excluded because they were studies that lacked a control group, studies of teachers or families, qualitative studies, or studies that included individuals who were either younger than 3 years or older than 21 years. Three team members reviewed each of the remaining studies to ensure that each included a description of the intervention, a control group, and data related to literacy as a dependent variable, and that each study sample was statistically independent from those in other studies. Because 2 of the studies used the same sample and control group, we were forced to eliminate 1. This process left us with 22 studies to review.

Each study was reviewed and coded according to its outcome domain. In addition, the effect size for each dependent variable was calculated. The effect size is a quantitative expression of the magnitude of difference between the scores of the experimental and control groups. Specifically, it is the difference between two means (e.g., treatment minus control) divided by the pooled standard deviation of the two conditions (Thalheimer & Cook, 2002). While statistical tests of significance tell researchers the probability of the null hypothesis, effect-size measurements tell them the size of the experimental effect and allow them to compare the magnitude of experimental treatments from one experiment to another (Thalheimer & Cook, 2002). Effect sizes have the same meaning across studies, even though studies use different measures and the scores have different score distributions (Glass, 1977). Effect size can be used to review a set of quantitative research studies on a particular problem or it can be used as an aid to interpreting the results of a single study (Wilkinson, 1999).

Generally speaking, the effect size statistic is helpful in judging the practical significance of a research study. An effect size of 1.0 indicates that the treatment group mean was 1 standard deviation higher than the control group mean. Thus, the average participant in the experimental group performed at a level that was higher than that of approximately 84% of all participants in the control group. An effect size of 0 indicates that the treatment and control group means were identical, which indicates that the treatment had no effect. An effect size of 0.2 is considered small; an effect size of 0.5 is moderate; an effect size of 0.8 or greater is large (Cohen, 1992).

In calculating effect size estimates for the present study, we weighted the average scores by sample size according to procedures recommended by

Hedges and Olkin (1985). Weighting was conducted because of the general tendency of treatment effects to be inversely related to sample size. The formula used to determine effect sizes is provided in Appendix A.

Results

Table 1 provides a summary of the reviewed studies. Included are the author(s) of the study and the date of publication, the weighted effect size, the age range and gender composition of the sample (as available), and a research summary. In addition, for the studies with a positive effect size, suggestions for how the results of the study may apply to educational practice are provided. Several studies are listed more than once because multiple assessments (dependent variables) were used to examine the effectiveness of the intervention (independent variable). (In Table 2, the studies are also listed in standard bibliographic format.) Examination of the information provided in Table 1 reveals two important factors:

1. No two studies examined the same dimension of literacy (e.g., reading comprehension, vocabulary, word recognition, writing).
2. No replications of previously conducted studies were undertaken.

Table 1
Summary of the Characteristics of the Reviewed Studies

Study	*Weighted effect size*	*Age range (years, unless otherwise indicated)*	N *(with gender composition where indicated)*[a]	*Research summary*	*Potential applications to educational practice*
Swanson (1982)	3.311	No report	18 (4 females, 14 males)	Naming was used for integration and retrieval of visual information.	Rehearsal
MacGregor & Thomas (1988)	3.152	7.9–13.1	45	Use of a computer-mediated text system that included text passages, an electronic dictionary that provided definitions for unfamiliar words, a sentence with the unfamiliar word used in context, and a game to practice key vocabulary improved vocabulary knowledge.	Explicit vocabulary instruction that includes the definition, a context sentence, and the use of computer games to provide practice with key vocabulary
Anken & Holmes (1977)	1.979	12.11–14.30	10	The use of "adapted classics" improved word meaning.	High-interest literature
MacGregor & Thomas (1988)	1.969	7.9–13.1	45	Use of a computer-mediated text system that included text passages, an electronic dictionary that provided definitions for unfamiliar words, and a game to practice key vocabulary improved vocabulary knowledge.	Explicit vocabulary instruction and the use of computer games to provide practice with key vocabulary
Akamatsu & Armour (1987)	1.829	High school	6	Direct instruction in grammatical principles of American Sign Language and translation to written English improved spontaneous writing skills.	Complementary instruction in sign and translation into written English
Al-Hilawani (2003)	1.767	Third graders	30 (17 females, 13 males)	Use of the key word teaching strategy improved comprehension and vocabulary.	The teacher discusses the story, teaches students to select key words, discuss events, and summarize passages.
Schneiderman (1995)	1.682	11.2–14.0	20	Use of communication games to teach English-language skills within the context of meaningful social interactions improved writing skills.	Social-interactive approach to promoting language development
Al-Hilawani (2003)	1.352	Third graders	30 (17 females, 13 males)	Use of a modified reciprocal teaching approach improved comprehension and vocabulary.	The teacher discusses the story and teaches students to summarize, question, clarify, and predict.

(continued)

Study	Weighted effect size	Age range (years, unless otherwise indicated)	N (with gender composition where indicated)[a]	Research summary	Potential applications to educational practice
Anken & Holmes (1977)	1.135	12.11–14.30	10	Use of "adopted classics" improved paragraph meaning.	High-interest literature
Gillespie & Twardosz (1997)	1.094	4–10	9 (4 females, 5 males)	Evening group storybook reading to children at a residential program had a positive effect on independent reading and interest in books.	Reading stories to students
Boyd & Vader (1972)	1.058	Average = 17.2	20	Watching videos with captions improved comprehension of visual information.	Use of captions
Calvert (1981)	0.987	6.10–8.11	16	Intensified instruction that included a low student/teacher ratio and competency-based instruction improved the ability to recognize correct English syntax.	Intensified and competency-based instruction
Akamatsu & Armour (1987)	0.966	High school	6	Direct instruction in grammatical principles of American Sign Language and translation to written English improved written English grammar.	Complementary instruction in sign and translation into written English
Craig, Carr, & Latham (1964)	0.923	Second graders	20	Use of the natural language approach, which entails the use of phrases, narrative language, and controlled presentation and reinforcement of new vocabulary, improved written language better than analytical grammar approaches (e.g., the Fitzgerald Key) did.	Analytical grammar systems of instruction are less effective than interaction in meaningful situations.
Walker, Munro, & Richards (1998)	0.890	9–18	30 (15 females, 15 males)	Inferential strategy training (e.g., cause-and-effect relationships, predicting outcomes) improved reading comprehension.	Explicit inferential strategy instruction
MacGregor & Thomas (1988)	0.861	7.9–13.1	45	Use of a computer-mediated text system that included text passages, an electronic dictionary that provided definitions for unfamiliar words, and a game to practice key vocabulary improved vocabulary knowledge.	Explicit vocabulary instruction and vocabulary practice
Mander, Wilton, Townsend, & Thomson (1995)	0.743	Average = 7.6	7 (3 females, 4 males)	A word processing program was used to improve spelling accuracy.	Use of a word processing program
Akamatsu & Armour (1987)	0.725	High school	6	The process of having students transcribe 2-to-3-minute videotapes of a person signing a story in English word order, revise their summaries, and respond to questions about the stories increased comprehension.	Multiple exposures to content through sign and written English
Andrews & Mason (1986)	0.693	5–8	23	Reading simple storybooks (7–8 pages) with a picture and 2 or 3 words per page and corresponding manual signs for each word, along with 50 drill cards that had printed words on one side and a corresponding manual sign on the other side, improved pre-reading print knowledge.	Reading to students, discussion of stories, rehearsal of reading words and stories
Dale (1979)	0.628	Average = 10.3	5	The effect of education in a general education setting with intensive support from a trained teacher of the deaf improved word recognition skills.	Support to the general education teacher and supplemental work on conversation skills, reading practice, and daily interaction with the family using home-school notebooks

Study	Weighted effect size	Age range (years, unless otherwise indicated)	N (with gender composition where indicated)[a]	Research summary	Potential applications to educational practice
Calvert (1981)	0.491	6.10–8.11	16	Direct instruction in sight words and key words in stories, instruction in morphologic analysis and use of context clues to figure out word meaning, and intensified reading instruction improved vocabulary.	Direct instruction in sight words, explicit instruction in key words, morphologic instruction, instruction in using context clues, and intensified reading instruction
Walker et al. (1998)	0.453	9–18	30 (15 females, 15 males)	Explicit reading comprehension strategy training (e.g., locating details, story grammar) improved reading comprehension.	Explicit reading comprehension strategy instruction
Calvert (1981)	0.430	6.10–8.11	16	Direct instruction in referent words and phrases in sentences (e.g., pronouns, adverbs, conjunctions), along with an intensified reading program and direct vocabulary instruction, improved the ability to identify correct phrases or words when presented with incomplete sentences.	Direct instruction in referent words and phrases in sentences, and intensified reading instruction
Calvert (1981)	0.388	6.10–8.11	16	Intensified reading instruction improved performance in answering questions about short reading passages.	Intensified reading instruction
Calvert (1981)	0.329	6.10–8.11	16	Intensified reading instruction improved reading comprehension.	Intensified reading instruction
Braden, Shaw, & Grecko (1991)	0.294	7.3–11.6	48	Use of computer-assisted instruction practice activities improved reading.	Use of computers for reading practice activities
Schirmer & Winter (1993)	0.284	10.11–16.00	24 (10 females, 14 males)	Use of thematic organizers had a beneficial effect on comprehension.	Pre-reading activities need to engage students in thinking about the topic and provide direction for applying this knowledge to the actual reading.
Calvert (1981)	0.216	6.10–8.11	16	Intensified reading instruction improved knowledge of syntax.	Intensified reading instruction
Calvert (1981)	0.201	6.10–8.11	16	Intensified reading instruction improved spelling.	Intensified reading instruction
Braden, Booth, Shaw, Leach, & MacDonald (1989)	0.123	Average = 14.5	33	Use of telecommunication conversations improved language skills.	Use of e-mail, chat rooms, and the Internet
Birch & Stuckless (1963)	0.121	Average = 10.3	52 (23 females, 29 males)	Use of programmed language improved understanding of comparative adjectives (e.g., "colder than . . .").	Systematic syntax instruction
Birch & Stuckless (1963)	0.105	Average = 10.3	52 (23 females, 29 males)	Use of programmed language improved understanding of predicate nominatives (e.g., "A dog is an animal").	Systematic syntax instruction
Ensor & Koller (1997)	0.101	Average = 16.9	20 (7 females, 13 males)	Repeated reading of the same passage for 15 minutes for 3 days improved word recognition.	Use of repeated reading
Braden et al. (1989)	0.098	Average = 14.5	33	Use of telecommunication conversations improved reading skills.	Use of e-mail, chat rooms, and the Internet
Ensor & Koller (1997)	0.091	Average = 16.9	20 (7 females, 13 males)	Repeated reading of the same passage for 15 minutes for 3 days improved reading comprehension.	Use of repeated reading

(continued)

Study	Weighted effect size	Age range (years, unless otherwise indicated)	N (with gender composition where indicated)[a]	Research summary	Potential applications to educational practice
Mander et al. (1995)	0.081	Average = 7.6	7 (3 females, 4 males)	Use of a word processing program improved clarity of wording in writing.	Use of word processing program
Schirmer & Winter (1993)	0.052	10.11–16.00	24 (10 females, 14 males)	Students used a textual schema for comprehension processing while reading narrative text.	Use of well-formed stories and novels
Braden et al. (1989)	0.000	Average = 14.5	33	Use of telecommunication conversations had no differential effect on reading.	
Robbins & Hatcher (1981)	0.000	9–12	36 (18 females, 18 males)	Word training had no differential effect on sentence comprehension.	
Wauters, Knoors, Vervloed, & Aarnoutse (2001)	–2.203	Average = 8.4	14	Word recognition ability improved when speech-only training was used, as well as when training included speech paired with sign.	
Birch & Stuckless (1963)	–0.263	Average = 10.3	52 (23 females, 29 males)	Use of programmed language did not positively affect students' ability to develop sentences.	
Mander et al. (1995)	–0.280	Average = 7.6	7 (3 females, 4 males)	Use of a word processing program did not positively affect students' grammar skills.	
Calvert (1981)	–0.288	6.10–8.11	16	Intensified reading instruction did not positively affect students' ability to imitate grammatically correct sentences.	
Birch & Stuckless (1963)	–0.319	Average = 10.3	52 (23 females, 29 males)	Use of programmed language did not positively affect students' ability to use verbs.	
Calvert (1981)	–0.326	6.10–8.11	16	Intensified reading instruction did not positively affect students' grammatical language skills.	
Braverman & Hertzog (1980)	–0.326	8–20	187 (92 females, 95 males)	Caption rate (60, 90, 120 words per minute) did not affect reading comprehension.	
Mander et al. (1995)	–0.359	Average = 7.6	7 (3 females, 4 males)	Use of a word processing program did not positively affect students' accuracy in punctuation use.	
Calvert (1981)	–0.414	6.10–8.11	16	Intensified reading instruction did not positively affect students' ability to use prompted grammatically correct sentences.	
Birch & Stuckless (1963)	–0.526	Average = 10.3	52 (23 females, 29 males)	Use of programmed language did not positively affect students' ability to use predicate adjectives.	
Mander et al. (1995)	–0.574	Average = 7.6	7 (3 females,	Use of a word processing program did not positively affect students' organizational writing skills.	

[a] All samples included both female and male participants.

Table 2
Intervention Studies Reference List

Akamatsu, C. T., & Armour, V. A. (1987). Developing written literacy in deaf children through analyzing sign language. *American Annals of the Deaf, 132*(1), 46–51.

Al-Hilawani, Y. A. (2003). Clinical examination of three methods of teaching reading comprehension to deaf and hard-of-hearing students: From research to classroom applications. *Journal of Deaf Studies and Deaf Education, 8*(2), 146–156.

Andrews, J. F., & Mason, J. M. (1986). How do deaf children learn about pre-reading? *American Annals of the Deaf, 131*(3), 210–217.

Anken, J. R., & Holmes, D. W. (1977). Use of adapted "classics" in a reading program for deaf students. *American Annals of the Deaf, 122*(1), 8–14.

Birch, J. W., & Stuckless, E. R. (1963). Programming instruction in written language for deaf children. *American Annals of the Deaf, 108*(3), 317–336.

Boyd, J., & Vader, E. A. (1972). Captioned television for the deaf. *American Annals of the Deaf, 117*(1), 34–37.

Braden, J., Booth, K., Shaw, S., Leach, J., & MacDonald, B. (1989). The effects of microcomputer telecommunication on hearing-impaired children's literacy and language. *Volta Review, 91*(3), 143–150.

Braden, J. P., Shaw, S. R., & Grecko, L. (1991). An evaluation of a computer-assisted instructional program for elementary hearing-impaired students. *Volta Review, 93*(6), 247–252.

Braverman, B. B., & Hertzog, M. (1980). The effects of caption rate and language level on comprehension of a captioned video presentation. *American Annals of the Deaf, 125*(7), 943–948.

Calvert, D. R. (1981). EPIC (Experimental Project in Instructional Concentration): Report of a study of the influence of intensifying instruction for elementary-school-age deaf children (Central Institute for the Deaf, St. Louis, Missouri). *American Annals of the Deaf, 126*(8), 865–984.

Craig, W. N., Carr, T., & Latham, I. J. (1964). Comparison of two methods of teaching written language to deaf students. *American Annals of the Deaf, 109*(2), 248–256.

Dale, D. (1979). Integration on an individual basis. *Special Education: Forward Trends, 6*(2), 22–24.

Ensor, A. D. I., & Koller, J. R. (1997). The effect of the method of repeated readings on the reading rate and word recognition accuracy of deaf adolescents. *Journal of Deaf Studies and Deaf Education, 2*(2), 61–70.

Gillespie, C. W., & Twardosz, S. (1997). A group storybook-reading intervention with children at a residential school for the deaf. *American Annals of the Deaf, 142*(4), 320–332.

MacGregor, S. K., & Thomas, L. B. (1988). A computer-mediated text system to develop communication skills for hearing-impaired students. *American Annals of the Deaf, 133*(4), 280–284.

Mander, R., Wilton, K. M., Townsend, M. A. R., & Thomson, P. (1995). Personal computers and process writing: A written language intervention for deaf children. *British Journal of Educational Psychology, 65*(4), 441–453.

Robbins, N. L., & Hatcher, C. W. (1981). The effects of syntax on the reading comprehension of hearing-impaired children. *Volta Review, 83*(2), 105–115.

Schirmer, B. R., & Winter, C. R. (1993). Use of cognitive schema by children who are deaf for comprehending narrative text. *Reading Improvement, 30*, 26–34.

Schneiderman, E. (1995). The effectiveness of an interactive instructional context: Principles from the parent-child interaction literature. *American Annals of the Deaf, 140*(1), 8–15.

Swanson, L. (1982). Verbal short-term memory encoding of learning disabled, deaf, and normal readers. *Learning Disability Quarterly, 5*(1), 21–28.

Walker, L., Munro, J., & Richards, F. W. (1998). Teaching inferential reading strategies through pictures. *Volta Review, 100*(2), 105–120.

Wauters, L. N., Knoors, H. E. T., Vervloed, M. P. J., & Aarnoutse, A. J. (2001). Sign facilitation in word recognition. *Journal of Special Education, 35*(1), 31–40.

As such, we were unable to establish distinct categories or apply meta-analytic techniques with any group of studies. Accordingly, our initial syntheses of the research is limited to use of the information presented in Table 1 to identify promising elements of a reading program for students who are deaf or hard of hearing. Results from the studies with large effect sizes suggest the importance of

- rehearsal
- explicit vocabulary instruction and practice with short passages
- high-interest literature
- instruction in the grammatical principles of ASL and how to translate ASL into written English
- teacher discussion of stories, and instruction in reading comprehension strategies
- interaction
- reading to young students
- use of captions
- intensified instruction
- use of word processing
- use of simple stories and word recognition practice with young readers
- use of the general education curriculum
- direct teaching of sight words and teaching of morphological rules

Discussion

The purpose of the present study was to conduct a meta-analysis of research related to literacy and students who are deaf or hard of hearing. We examined the literature published on this topic from 1963 to 2003. A variety of limitations need to be noted. First, despite an exhaustive review of the literature, we were able to locate only 22 studies that met our inclusion criteria. Clearly, there is a need for more

experimental studies in the area of literacy development of students who are deaf or hard of hearing. Second, while every research study was reviewed by three individuals to determine if it met the inclusion criteria, it is possible that a relevant study was excluded. Third, many of the studies included in the review provided insufficient information about the characteristics of the participants. Often, only a general age range was provided, gender breakdown was not supplied, information about degree of hearing loss was omitted, and no information about ethnicity was given. Future researchers should gather and report these important details. Fourth, we used a stringent criterion of quality for our initial review of the literature. As previously noted, we used the recommendations of the What Works Clearinghouse in selecting empirical studies yielding research-based evidence (Valentine & Cooper, 2004). Consequently, we chose to exclude dissertations, professional presentations, and ERIC documents, as well as descriptive and qualitative studies. However, we do not endorse a single research method, but believe, rather, that various research designs are needed for different research questions and purposes. We also believe that in some instances when a group design is appropriate, it may be unacceptable to deny services to control group participants.

Our review of the literature revealed that conducting research on the efficacy of interventions that promote literacy among students who are deaf or hard of hearing presents unique challenges. The low-incidence nature of the population as well as the difficulty posed by random assignment to form treatment and control groups are often-cited problems. However, researchers in the field of deaf education need to think creatively about the use of research designs that lead to the systematic accumulation of knowledge.

Interventions that have anecdotal evidence of effectiveness should be examined by means of alternative research designs (e.g., quasi-experimental designs, single-subject time series designs). Also, studies need to be replicated so that deaf education researchers can strengthen the evidence for drawing causal inferences about interventions.

As a follow-up to the present study, we are in the process of reviewing the other types of literacy research (i.e., studies that did not include a control group) that were not included in this study to summarize the topics and results. We plan to widen our lens using the guidelines for evaluating the quality of evidence suggested for bridging the gap between research and practice for different methodologies (e.g. Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005; Chatterji, 2004; Gersten, et al., 2005; Horner et al., 2005; Thompson, Diamond, McWilliam, P. Snyder, & S. W. Snyder, 2005).

Our review of the literature and the attempted meta-analysis indicate that promoting the literacy skills of students who are deaf or hard of hearing is a highly valued educational objective. Yet our review of 40 years of literature suggests that the field of deaf education does not have what the U.S. Department of Education (2003, pp. 10–11) refers to as "strong evidence of effectiveness" or even "possible evidence of effectiveness" about any specific educational intervention for promoting the literacy development of students who are deaf or hard of hearing. Rather, it appears that most practices have been determined by practitioners and respected professionals in the field. Use of the framework to classify evidence-based practices proposed by Odom and colleagues (2005), which is similar to the system developed by the Oxford Centre for Evidence-Based Medicine (2001), suggests that the majority of the literature in the field of deaf education would be considered Level 4, the lowest level among four proposed levels of evidence:

> Level 1: meta-analysis including well-designed randomized control studies
> Level 2: controlled studies without randomization and quasi-experimental designs
> Level 3: well designed nonexperimental studies (i.e., correlational and case studies)
> Level 4: expert committee reports, consensus conferences, and the experience of respected professionals

Similar findings were reported by Easterbrooks (2005), who reviewed the literature in the area of literacy and deaf education and noted, "Research in the area of literacy, although improving in the last 5 or 10 years, is rife with speculation, pseudo-empirically based for the most part, deferential to a belief system, and characterized by many holes in the knowledge base."

Also, the majority of interventions that are currently used with students who are deaf or hard of hearing (e.g., the language experience approach, bilingual approaches, the writing process, dialogue journals, trade books vs. basal readers, predictable books, teaching sight words, teaching figurative language, the use of story retelling), have a paucity of well-conducted research to support their use. Comparable findings were also reported by Easterbrooks (2005):

> We cannot point to many programs, materials, strategies, or interventions and declare there is experimental

proof of their effectiveness. In addition, many of the practices that are considered sacred cows in deaf education have little or no evidence to support their efficacy.

Given the lack of empirical studies to support practice in the field of deaf education, it may be beneficial to use the information gained from the studies included in Table 1, in combination with the general education literacy research, to develop a model comprehensive literacy program for students who are deaf or hard of hearing. The model, as well as the specific components of the model, could be viewed as working hypotheses that could be researched and revised based on the results of validation studies. As suggested by Levin, O'Donnell, and Kratochwill (2003), the initial hypothesis would be Stage 1 of a 4-stage approach to examining the efficacy of the model and the components. Stage 2 would involve controlled classroom experiments. Stage 3 would entail the integration of the knowledge generated from Stage 2 into the design of randomized classroom trial studies or single-subject studies (Horner et al., 2005). Stage 4 would determine the factors that lead to adoption of the model in educational programs and teacher preparation programs for students who are deaf or hard of hearing (Odom et al., 2005).

While acknowledging that there are professionals (e.g., Garan, 2002; Krashen, 2005) who question the process as well as the results reported by the NRP (National Institute of Child Health and Human Development, 2000), it does provide stimuli for developing a multidimensional model of reading instruction for students who are deaf or hard of hearing (Easterbrooks, 2005; Schirmer & McGough, 2005). Simultaneously, the essential elements of a comprehensive reading program reported by the NRP were also identified in *The National Agenda: Moving Forward on Achieving Educational Equality for Deaf and Hard of Hearing Students* as the "core components" of a reading program for students who are deaf or hard of hearing (*National Agenda,* 2005, p. 22).

The NRP identified five essential areas for effective reading instruction. A combination of the information presented in Table 1 with the recommendations of the NRP suggests that a reading program for students who are deaf or hard of hearing might include the following components:

1. conversation: the use of speech or sign (or both) for informal exchanges of views, ideas or information
2. alphabetic principle: the use of letters and letter combinations to represent phonemes or signs (or both) in a system of writing
3. vocabulary: the words people must know to communicate effectively
4. fluency: the ability to read a text quickly and accurately with ease and expression
5. comprehension: the process of constructing meaning from print
6. writing: communicating through the use of written symbols

Conclusion

At the end of the Agricultural Age, the ability to write your name meant that you were literate. Fifty years later, as society transitioned to the Industrial Age, a sixth-grade education provided the same status. In today's global economy, emerging technologies have set the criteria for literacy much higher:

> In our increasingly technical society it's all about print: instructional manuals for the workplace, for computers, for cars, for putting together children's toys; directions for travel or for work, for taking medications, for making up baby formulas, for safety, for voting, for messages via e-mail, the Internet, pager, and fax. Learning to read opens the door to a better, brighter future. (Shaywitz, 2003, p. 293)

Not long ago, most students who were deaf or hard of hearing were able to graduate from high school and immediately begin earning a paycheck. Most schools for the deaf had vocational education programs that taught skills that matched the available jobs. Examples of these jobs include printing, shoe repair, carpentry, sewing, barbering, welding, and automotive repair. Unfortunately, jobs in manufacturing are diminishing. As a result, employers are seeking workers who are computer literate, as well as skillful in reading, mathematics, and problem solving (Luckner, 2002). Individuals with poor reading skills are at a disadvantage when competing for jobs and are therefore less likely to be employed (Frank, Karst, & Boles, 1989).

The development of literacy skills is regarded as one of the highest priorities in contemporary education. Yet literacy is one of the most complex skills students must master to ensure academic success as well as to function effectively in the workplace and in society. Technology, and the science behind it, permeates all aspects of people's lives, from how they work and communicate to what they shop for and how they pay the bills. The complexity of today's world means that individuals need to have some level of proficiency in reading, mathematics, and science in order to understand and participate fully in the economic and social realms. The crucial factor that promotes or hinders success in today's society is the ability to access, understand, and use different types of

information. The job of educators is to help students develop the attitudes, knowledge, and skills that will enable them to become proficient readers and writers. Improving the quality of research and bridging the gap between research and practice in the field of deaf education is an essential step if educators of the deaf hope to improve educational and career outcomes for individuals who are deaf or hard of hearing. As noted in *The National Agenda: Moving Forward on Achieving Educational Equality for Deaf And Hard Of Hearing Students*, "Research is the foundation upon which quality educational practices for deaf and hard of hearing students is based" (*National Agenda,* 2005, p. 37).

References

Adams, M. J. (1991). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT Press.

Allen, T. (1986). Patterns of academic achievement among hearing impaired students: 1974 and 1983. In A. Schildroth & M. Karchmer (Eds.), *Deaf children in America* (pp. 161–206). San Diego, CA: Little, Brown.

American Psychological Association. (2001). *Publication manual of the American Psychological Association* (5th ed.). Washington, DC: Author.

Andrews, J. F., & Mason, J. M. (1991). Strategy usage among deaf and hearing readers. *Exceptional Children, 57*(6), 536–545.

Baumann, J. F., & Kame'enui, E. J. (1991). Research on vocabulary instruction: Ode to Voltaire. In J. Flood, D. Lapp, & J. R. Squire (Eds.), *Handbook on research on teaching the English language arts* (pp. 604–632). New York: Macmillan.

Berkman, N. D., DeWalt, D. A., Pignone, M. P., Sheridan, S. L., Lohr, K. N., Lux, L., Sutton, S. F., Swinson, T., & Bonito, A. J. (2004). *Literacy and health outcomes* (Summary, Evidence Report/Technology Assessment No. 87). Rockville, MD: Agency for Healthcare Research and Quality.

Brantlinger, E., Jimenez, R., Klingner, J., Pugach, M., & Richardson, V. (2005). Qualitative studies in special education. *Exceptional Children, 71*(2), 195–207.

Cambra, C. (1994). An instructional program approach to improve hearing-impaired adolescents' narratives: A pilot study. *Volta Review, 96*(3), 237–246.

Center for Assessment and Demographic Studies. (1991). *Stanford Achievement Test, eighth edition: Hearing-impaired norms booklet*. Washington, DC: Gallaudet University, Gallaudet Research Institute.

Chall, J. S. (1996). *Stages of reading development* (2nd ed.) Fort Worth, TX: Harcourt, Brace.

Chatterji, M. (2004). Evidence on "what works": An argument for extended-term mixed-method (ETMM) evaluation designs. *Educational Researcher, 33*(9), 3–13.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159.

Cramer, S. C., & Ellis, W. (Eds.). (1996). *Learning disabilities: Lifelong issues*. Baltimore: Brookes.

DeVilliers, P. A., & Pomerantz, S. B. (1992). Hearing impaired students learning new words from written context. *Applied Psycholinguistics, 13*, 409–431.

Dew, D. (Ed.). (1999). *Serving individuals who are low-functioning deaf: Report of the Twenty-Fifth Institute on Rehabilitation Issues*. Washington, DC: George Washington University.

Easterbrooks, S. R. (2005, January). *Review of literacy in literacy development and instruction in students who are deaf and hard of hearing*. Retrieved February 11, 2005, from http://www.deafed.net/DeafedForums/ShowPost.aspx?PostID=1964

Erickson, M. E. (1987). Deaf readers reading beyond the literal. *American Annals of the Deaf, 132*, 291–294.

Frank, K., Karst, R., & Boles, C. (1989). After graduation: The quest for employment by disabled college graduates. *Journal of Applied Rehabilitation Counseling, 20*, 3–7.

Garan, E. M. (2002). *Resisting reading mandates: How to triumph with the truth*. Portsmouth, NH: Heinemann.

Geers, A., & Moog, J. (1989). Factors predictive of the development of literacy in profoundly hearing-impaired adolescents. *Volta Review, 91*(2), 69–86.

Gersten, R., Fuchs, L. S., Compton, D., Coyne, M., Greenwood, C., & Innocenti, M. S. (2005). Quality indicators for group experimental and quasi-experimental research in special education. *Exceptional Children, 71*(2), 149–164.

Glass, G. V. (1976). Primary, secondary, and meta-analysis of research. *Educational Researcher, 5*, 3–8.

Glass, G. V. (1977). Integrating findings: The meta-analysis of research. *Review of Research in Education*, *5*, 351–379.

Glass, G. V., McGraw, G., & Smith, M. (1981). *Meta-analysis in social research*. Beverly Hills, CA: Sage.

Goldin-Meadow, S., & Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research and Practice, 16*(4), 222–229.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. San Diego, CA: Academic Press.

Horner, R. H., Carr, E. G., Halle, J., McGee, G., Odom, S., & Wolery, M. (2005). The use of single-subject research to identify evidence-based practice in special education. *Exceptional Children, 71*(2), 165–179.

Krashen, S. (2005). *Is in-school free reading good for children? Why the National Reading Panel report is (still) wrong.* Retrieved April 22, 2005, from http://www.sdkrashen.com/articles/in-school%20FVR/all.html

Lederberg, A. R., & Spencer, P. E. (2001). Vocabulary development of deaf and hard of hearing children. In M. D. Clark, M. Marschark, & M. Karchmer (Eds.). *Context, cognition, and deafness* (pp. 88–112). Washington, DC: Gallaudet University Press.

Levin, J. R., O'Donnell, A. M., & Kratochwill, T. R. (2003). Educational/psychological intervention research. In W. Reynold & G. Miller (Eds.), *Handbook of psychology: Vol. 7. Educational psychology* (pp. 557–581). Hoboken, NJ: Wiley.

Luckner, J. L. (2002). *Facilitating the transition of students who are deaf or hard of hearing*. Austin, TX: Pro-Ed.

Lyon, R. (2001). *How do children learn to read?* Retrieved September 27, 2004, from www.readingrockets.org/article.php?ID=101

Marschark, M., & Harris, M. (1996). Success and failure in learning to read: The special case (?) of deaf children. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and intervention* (pp. 279–300). Mahwah, NJ: Erlbaum.

Moats, L. C. (2000). *Speech to print: Language essentials for teachers*. Baltimore: Brookes.

The national agenda: Moving forward on achieving educational equality for deaf and hard of hearing students. (2005). Austin, TX: Author.

National Center for Education Evaluation and Regional Assistance. (2003). *Identifying and implementing educational practices supported by rigorous evidence: A user-friendly guide*. Washington, DC: U.S. Department of Education, Institute of Education Sciences.

National Institute for Literacy. (2001). *Put reading first: The research building blocks for teaching children to read*. Retrieved February 15, 2004, from http://www.nifl.gov/partnershipforreading/publications/PFRbooklet

National Institute of Child Health and Human Development. (2000). *Report of the National Reading Panel. Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction* (NIH Publication No. 00-4769). Washington, DC: U.S. Government Printing Office.

National Research Council. (2002). *Scientific research in education*. Washington, DC: National Academy Press.

No Child Left Behind Act of 2001, Pub. L. No. 107-110, § 1201-1226, 115 Stat. 425 (2001).

Odom, S. L., Brantlinger, E., Gersten, R., Horner, R., Thompson, B., & Harris, K. R. (2005). Research in special education scientific methods and evidence-based practices. *Exceptional Children, 71*(2), 137–148.

Oxford Centre for Evidence-Based Medicine. (2001). *Levels of evidence and grades for recommendations*. Retrieved February 8, 2005, from http://www.cebm.net/levels_of_evidence.asp

Paul, P. V. (1998). *Literacy and deafness*: *The development of reading, writing, and literate thought.* Boston: Allyn & Bacon.

Rosenthal, R. (1978). Combining results of independent studies. *Psychological Bulletin, 85*, 185–197.

Rosnow, R. L., & Rosenthal, R. (1996). Computing contrasts, effect sizes, and counternulls on other people's published data: General procedures for research consumers. *Psychological Methods, 1*, 331–340.

Schirmer, B. R., Bailey, J., & Fitzgerald, S. M. (1999). Using a written assessment rubric for writing development of children who are deaf. *Exceptional Children, 65*(3), 383–397.

Schirmer, B. R., & McGough, S. M. (2005). Teaching reading to children who are deaf: Do the conclusions of the National Reading Panel apply? *Review of Educational Research, 75*(1), 83–117.

Shaywitz, S. (2003). *Overcoming dyslexia: A new and complete science-based program for reading problems at any level*. New York: Knopf.

Slavin, R. E. (2002). Evidence-based education policies: Transforming educational practices and research. *Educational Researcher, 31*(7), 15–21.

Snow, C. E. (2002). *Reading for understanding: Toward a research and development program in reading comprehension*. Arlington, VA: Rand.

Stewart, D. A., & Kluwin, T. N. (2001). *Teaching deaf and hard of hearing students: Content, strategies, and curriculum*. Boston: Allyn & Bacon.

Strassman, B. K. (1992). Deaf adolescents' metacognitive knowledge about school-related reading. *American Annals of the Deaf, 137*(4), 326–330.

Thalheimer, W., & Cook, S. (2002). *How to calculate effect sizes from published research articles: A simplified methodology*. Retrieved January 9, 2005, from http://work-learning.com/effect_sizes.htm

Thompson, B., Diamond, K. E., McWilliam, R., Snyder, P., & Snyder, S. W. (2004). Evaluating the quality of evidence from correlational research for evidence-based practice. *Exceptional Children, 71*(2), 181–194.

Traxler, C. B. (2000). The Stanford Achievement Test, ninth edition: National norming and performance standards for deaf and hard-of-hearing students. *Journal of Deaf Studies and Deaf Education, 5*(4), 337–348.

U.S. Department of Education. (2003). *Identifying and implementing educational practices supported by rigorous evidence: A user-friendly guide*. Washington, DC: Institute of Education Sciences.

Valentine, J. C., & Cooper, H. (2004). *What Works Clearinghouse study design and implementation assessment device* (Version 1.1). Washington, DC: U.S. Department of Education.

Wilkinson, L. (1999). Statistical methods in psychology journals: Guidelines and explanations (Task Force on Statistical Inference). *American Psychologist*, *54*(8), 594–604.

Appendix A

Formula Used to Determine Effect Sizes

$$d = \frac{\bar{x}_{\exp} - \bar{x}_{control}}{S_{pooled}}$$

where

$$S_{pooled} = \sqrt{\frac{(n_{\exp} - 1)s^2_{\exp} + (n_{control} - 1)s^2_{control}}{(n_{\exp} - 1) + (n_{control} - 1)}}$$

and where

$\bar{x}_{\exp}$ represents the mean for the experimental group

$\bar{x}_{control}$ represents the mean for the control group

S_{pool} represents the pooled standard deviation between the two groups

The pooled standard deviation is used rather than each group's standard deviation in the calculation because it provides a better estimate of effect size (i.e., an unbiased estimate).

GAIN SCORE (Glass, McGraw, & Smith, 1981)

$$d = \left[\frac{\bar{x}_{\exp-post} - \bar{x}_{\exp-pre}}{S_{\exp-pooled}}\right] - \left[\frac{\bar{x}_{con-post} - \bar{x}_{con-pre}}{S_{con-pooled}}\right]$$

where

$\bar{x}_{\exp-post}$ represents the post-mean for the experimental group (i.e., mean score after the intervention occurred)

$\bar{x}_{\exp-pre}$ represents the pre-mean for the experimental group (i.e., mean score prior to the intervention occurring)

$\bar{x}_{con-post}$ represents the post-mean for the control group (i.e., mean score after the intervention occurred)

$\bar{x}_{\exp-post}$ represents the pre-mean for the control group (i.e., mean score prior to the intervention occurring)

$S_{\exp-pool}$ & $S_{con-pool}$ represent the pooled standard deviations between the pre- and post-measures for each group (i.e., experimental and control); e.g., $S_{\exp-pool}$ is calculated by pooling the $S_{\exp-pre}$ and the $S_{\exp-post}$

UNBIASED EFFECT SIZE, d' (i.e., d-prime)

$$d' = d\left(1 - \left[\frac{3}{4N - 9}\right]\right)$$

where

$$d' \xrightarrow{d} d \text{ for large } N$$

This means that d' approaches d in distribution as the sample size gets larger, which would indicate an unbiased estimation of d. This is done because d is an unknown parameter.