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THEORY/REVIEW MANUSCRIPT

Cued Speech and the Development of Reading in English: Examining the Evidence

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Abstract

Even though Cued Speech has been a communication option for 50 years, it has not been widely adopted among users of English or in the country where it was created (i.e., the United States). This situation has led scholars and practitioners in the field of deafness to question whether the original intent of creating this system has been realized and if there is an adequate research base to support the use of Cued Speech in developing English reading abilities. The purpose of this review was to examine the available research to determine whether there is evidence available to address the persistent questions about Cued Speech and English. Information from four areas of literature was reviewed and summarized, with converging findings from the available data sources revealing support for the role Cued Speech plays in developing reading abilities in English. Limitations of the current literature base and directions for future research are explored.

Cued Speech and the Development of Reading in English: Examining the Evidence

Twenty sixteen marked the 50th anniversary of the development of Cued Speech by Dr. R. Orin Cornett, the former Vice President for Long Range Planning at Gallaudet University. Cornett's self-proclaimed obsession "with concern about the fact that prelingually deaf children are, as a rule, very poor readers" (Cornett, 1967, p. 1) guided the creation of this communication system. He believed that insufficient access to phonology led to the challenges deaf[1] students historically experienced with the written form of English, suggesting that the communication systems of the time were unable to adequately represent this critical aspect of the English language for some deaf students (Shull & Crain, 2010).

During the mid 1960s when Cued Speech was developed, the majority of deaf students in the United States were being educated using an oral communication approach. However, there were also an increasing numbers of deaf educators at that time who were strongly advocating for the use of manual communication, including fingerspelling and the use of signs, to support the development of language. Recognizing the divergent perspectives of the individuals supporting these two approaches, Cornett sought to create a system that would adhere to the basic principles underlying each and to develop a communication method that proponents of each philosophy could embrace (Cornett, 1967).

Drawing from the principles of the oral communication method, Cornett recognized that a newly developed system would need to include visible information on the mouth (e.g., speechreading) as a primary component. Further highlighting the importance of speechreading, Cornett emphasized that any manual aspect of the system "would have to be *unintelligible* if used without the information on the lips" (Cornett, 1967, p. 5). In other words, the manual components of the system would be designed to disambiguate phonemes and words that appear visually similar on the mouth, but the gestures alone could not be used to communicate the language. The primary principle drawn from manual communication was to ensure clear communication. To adhere to this requirement, the system would need to facilitate rapid learning and effective communication in the classroom and take into account the need to communicate at distances of approximately 20 feet (Cornett, 1967).

Additional considerations included the ability of the system to represent the phonemes of spoken English, aid in the identification

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of syllables, and to synchronize with a conversational rate of spoken language in order to maintain a natural rhythm of communication. The ability of a deaf child to learn the system by using it with his or her parents was also a goal (Cornett, 1967). Collectively these tenents were used to create the resulting Cued Speech system comprised of three components; the mouth movements associated with speaking the language, eight handshapes or cues to represent the consonants, and four placements near the mouth to represent vowels (Shull & Crain, 2010; see also http://www.cuedspeech.org for cue charts).

Despite Cornett's attempt to offer the field of deaf education a communication "compromise" (Cornett, 1967, p. 3) that could overcome the inherent limitations of the approaches of the time (e.g., ambiguity of speechreading, inability of fingerspelling and signs to represent phonemic information), Cued Speech has not been widely adopted among users of the language for which it was initially developed (i.e., English) or in the country where it was created. In fact, a recent report compiled by the United States Government Accountability Office (2011) indicated that less than 2% of deaf students in the United States use Cued Speech as the primary mode of communication for instruction.

Over the years this situation has led researchers and practitioners in the field of deafness to question whether Cornett's goal of improving the development of reading in English was realized and if there is currently an adequate evidence base to support the use of Cued Speech to improve deaf children's English reading abilities. Marschark and Spencer (2006) captured several of the persistent questions about Cued Speech and its role in the development of reading in English when they stated,

> …there is now abundant evidence that deaf children who receive Cued Speech at home and at school make significant strides in spoken language and print literacy—as long as they are learning French. Even after 40 years, there remains no empirical evidence that Cued Speech has similar benefits for children learning English (C. LaSasso, personal communication, December 16, 2004), despite the strong support for Cued Speech by its advocates in North America. Why not? French and English are similar in having considerable variability at the level of phoneme-to-grapheme translation, but in French, there are no inconsistencies at the level of grapheme-to-phoneme translation (Alegria & Lechat, 2005). Whether this difference could result in Cued Speech being less effective for learners of English than French remains to be determined (such irregularities do affect performance in some tasks; see Alegria & Lechat, 2005). Nevertheless, the fact that the benefits to deaf children's spoken English have not received empirical support in the decades since the creation of Cued Speech (for English) suggest that such evidence is neither easily produced nor of great generality. How can we expect parents and their deaf children to embrace methods alleged to support the development of spoken language when we are unable to demonstrate their utility? (p. 16–17)

In addressing the points regarding the development of spoken language, despite the use of the word *speech* in the title of the communication system, a review of Cornett's early work (Cornett, 1967) as well as publications reflecting on the system years after its development (Cornett, 1985, 1986, 1987, 1994a,b), suggest that spoken language was not necessarily the main intent of the system. While Cornett (1967) did indicate that Cued Speech can "provide the speaking deaf person a means of discovering his own misconceptions about the pronunciation of specific words" (p. 10), the objectives outlined for the system were primarily centered on developing a means of increasing communication between young deaf children and their parents, the majority of whom were hearing individuals who used spoken English to communicate. It was hypothesized that using Cued Speech would increase the clarity of communication between deaf children and their families, which in turn would foster mental and linguistic development, create the ability to think in the phonemic equivalent of spoken English, and provide varying degrees of support to speechreading based on the individual needs of the child (Cornett, 1967). From these descriptions it appears as though the central aim was to develop a system to fully convey and develop English *language* more generally, rather than spoken language specifically.

More than 30 years after Cued Speech was developed, a distinction between the terms *Cued Speech* and *cued language* was offered. Fleetwood and Metzger (1998) suggested that Cued Speech denotes a communication modality, whereas the term cued language refers to a traditionally spoken language that uses the visual system of Cued Speech to convey it (see also Shull & Crain, 2010 for discussion). In relation to reading, cued language can be considered the language of instruction (e.g., English, French) while Cued Speech refers to the modality in which the instruction is delivered. As will be described below, this nuanced difference in terminology influenced the areas of literature reviewed as part of the present examination.

The remaining points offered by Marschark and Spencer (2006) provided the foundation for the present review and the basis for reviewing the four distinct areas of literature described below. The statements regarding the structural differences between French and English, the impact of these differences on the development of reading across languages, and the applicability of findings of studies in cued French to inform understandings of cued English became the primary aim of this inquiry. To address this goal, evidence from recent cross-language studies will be used to demonstrate that the foundational requisites for literacy learning are relatively consistent across alphabetic languages; therefore, the findings of studies conducted in cued French can be used to support of the efficacy of cued English. To contextualize this literature, a discussion of the essential elements required to develop English reading skills will be provided, followed by a summary of findings from cross-language reading investigations and studies examining cued French. Evidence gathered from these two areas of literature relates to cued language as the language of instruction for reading.

When considering Cued Speech as a mode of instructional delivery, and in particular its ability to convey the phonemes of English, the research supporting the use of the See-the-Sound Visual Phonics instructional tool, more commonly known as Visual Phonics (International Communication Learning Institute, 1996), to supplement phonologically based reading instruction for deaf students provides a third area of literature to explore. To address the criticism regarding the lack of empirical evidence for cued English, studies directly examining the impact of Cued Speech on the development of English reading skills will comprise the fourth area of research reviewed.

Arguably, any well-designed research investigation of Cued Speech (e.g., pre-, post-test, qualitative) would add to the relatively scant literature base currently available on this topic. However, given the on-going debates regarding the role of this communication system in the development of reading in English, the choice was made to only consider studies employing the most rigorous study designs. Therefore, when gathering evidence from these four sources of information (i.e., cross-language studies, investigations involving cued French, examinations of Visual Phonics, and explorations of cued English), only studies using group comparison (e.g., experimental, quasi-

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experimental) and single-subject designs were considered. This decision is supported by current standards in the field of special education (Council of Exceptional Children, 2014) as well as the ability to infer causality from investigations employing these designs. As such, the decision to only review studies using these designs assists in minimizing "alternative explanations for both the results of the study and the conclusions that researchers draw" (Odom, Brantlinger, Gersten, Horner, Thompson, & Harris, 2005, p. 141), and thus assures greater confidence in the findings obtained.

In explicating the findings of the studies of cued French, Visual Phonics, and cued English, descriptive statistics (e.g., age and grade equivalents, mean scores) and summaries of results will be used to contextualize the performance across groups of participants within each investigation examined. Following the presentation of research findings, the strengths and limitations of the current literature base will be discussed, and directions for future research explored.

Essential English Reading Skills

Research has consistently documented the differential and relative contributions of English language and phonological processing abilities in the literacy learning process (Adams, 1990; Chall, 1996; McGuinness, 2005; Shanahan, 2006; Snow, Burns, & Griffin, 1998; Snowling & Hulme, 2005; Whitehurst & Lonigan, 1998). In a seminal investigation of this phenomenon, Storch and Whitehurst (2002) examined the relations between code-related skills (e.g., phonological processing) and language-related abilities (e.g., vocabulary, syntactic knowledge) and their influence on reading achievement. In this study, the researchers documented the reading development of more than 600 students over a 6-year period from preschool through 4th grade.

Results of this longitudinal investigation provided support for the theory that specific reading skills make their most important contributions to later achievement at various stages during the developmental process. For example, findings suggested that code-related skills had the strongest influence in the early years when children are learning to "crack the code" (i.e., relate sounds to letters and use this knowledge to decode printed words), whereas the impact of language-related abilities becomes increasingly stronger once phonological skills are solidified and comprehension of more sophisticated texts becomes the goal (Storch & Whitehurst, 2002; see also Lonigan, Burgess, & Anthony, 2000; Wagner, Torgesen, & Rashotte, 1994; Wagner et al., 1997).

The results of this study are further supported by the findings of the National Early Literacy Panel (NELP, 2008), which was based on a meta-analysis of scientific research aimed at determining the specific early literacy skills that predict later conventional literacy outcomes. Results of the NELP's review revealed six skills that were considered independent, longitudinal predictors of later achievement. In other words, these skills were found to have medium to large predictive relations with later literacy outcomes even after controlling for other variables such as socioeconomic status or IQ. The six skills include: (1) phonological awareness, or the ability to recognize and manipulate the sound structures of the language without the aid of print (e.g., rhyme words, identify syllables, blend and segment phonemes); (2) alphabetic knowledge, which involves naming letters and relating sounds (phonemes) to printed letters (graphemes); (3) phonological memory, or the ability to remember spoken information for a short period of time; (4) rapid automatic naming (RAN) of letters or digits presented in a random order, (5) RAN of objects (represented by pictures) or colors that appear in a random order; and (6) writing, including the ability to write individual letters or one's name upon request (NELP, 2008).

In regards to phonological awareness specifically, research indicates that these abilities rapidly develop between the ages of three and five and are relatively secure at the onset of formal reading instruction around the age of six (Gillon, 2004). As they mature as pre-readers, children are able to recognize and manipulate increasingly complex linguistic units, beginning with the more concrete segments of language such as words and syllables, and then moving to those that are considered more abstract such as individual phonemes. While development of these skills tends to follow a hierarchical progression, simultaneous and overlapping acquisition often occurs (see Pufpaff, 2009 for review). Phonological awareness assessment tasks and instructional activities also reflect varying degrees of difficulty in terms of response mode. As such, tasks that involve recognition (e.g., rhyme recognition) are likely to develop before those involving production (e.g., rhyme generation), with phoneme manipulation tasks (e.g., phoneme identification, deletion, substitution) among the most difficult to perform (see Adams, 1990; Burgess, 2006; see also Mayer & Trezek, 2015 for discussion regarding deaf learners).

The role of phonological abilities in the development of reading for deaf individuals has been the topic of recent debate in the field (Allen et al., 2009; Mayer & Trezek, 2014; Paul, Wang, Trezek, & Luckner, 2009; Wang, Trezek, Luckner, & Paul, 2008). However, there is a growing body of empirical evidence to support the contribution of phonological awareness to the development of reading in English for deaf learners (Cupples, Ching, Crowe, Day, & Seeto, 2014; Dillon, deJong, & Pisoni, 2011; Easterbrooks, Lederberg, Miller, Bergeron, & Conner, 2008; Harris & Beech, 1998; Kyle & Harris, 2011; Spencer & Tomblin, 2009).

Cross-language Studies

In the field of deafness, the applicability of evidence from studies conducted in French to those in English has been raised (Marschark & Spencer, 2006). Interestingly in the field of reading, the converse has been the case. In fact, several international researchers have questioned whether English should be considered an "outliner orthography", (Caravolas et al., 2012, p. 678) or an alphabetic language that is significantly different from others due to the inconsistencies in its grapheme-to-phoneme correspondences, and if the research supporting the relationship between the aforementioned longitudinal predictors applies across languages with varying degrees of orthographic depth. Languages where there is a relatively straightforward relationship between the graphemes and phonemes, such as Finnish, Italian, and Greek, are said to be shallow, consistent, or transparent. On the other hand, languages that contain greater irregularity in their grapheme-to-phoneme correspondences, such as English and to a lesser degree French, have been coined deep, inconsistent, or opaque (Caravolas et al., 2012; Vaessen et al., 2010; Ziegler, et al., 2010).

A variety of methods can be used to determine the orthographic depth of a language, with entropy values being the most frequently employed. Entropy values reflect the number of sound pronunciations associated with a given grapheme. For example, if a grapheme is always associated with only one phoneme, the entropy value for that grapheme is 0. Therefore, higher entropy values indicate a greater number of possible pronunciations for a given grapheme and thus greater orthographic

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depth (Vaessen et al., 2010). Despite having different orthographic and phonological structures, all alphabetic languages have word onsets (Ziegler et al., 2010). These onsets, or initial grapheme-to-phoneme mappings, have been found to be a reliable means of comparing languages (Vaessen et al.). As an example, onset entropy values for six different alphabetic languages include Finnish 0.0, Hungarian 0.17, Dutch 0.23, Portuguese 0.42, French 0.46, and English 0.83 (Ziegler et al.).

Several recent cross-language investigations have explored whether the predictors of reading development vary as a result of orthographic depth. In a study conducted by Caravolas et al. (2012), several cognitive skills associated with reading development including cognitive ability, letter knowledge, phoneme awareness, RAN for objects and colors, and verbal memory span were measured in children at the onset of literacy instruction and again 10 months later. A total of 735 children representing 4 different languages including English, Spanish, Czech, and Slovak served as study participants. Findings of this investigation demonstrated that letter knowledge, phoneme awareness, and RAN served as predictors of literacy skills in all four languages across the 10-month study. These findings led the authors to conclude that despite variations in orthographic depth, there was an extremely consistent pattern of reading skill development across the languages studied.

In a second investigation, measures of word reading, phonological decoding (i.e., nonsense word reading), phonological awareness, RAN, phonological short-term memory, nonverbal IQ, and vocabulary were used to evaluate how cognitive components of reading compared across five European languages (Ziegler et al., 2010). A total of 1,265 Dutch, Finnish, French, Hungarian, and Portuguese speaking second grade students participated in this study. Results of this investigation revealed that phonological awareness was an important cognitive component of reading in all languages, but the overall impact was modulated to some degree by the depth of the orthography. This finding suggests that while phonological awareness is important in all languages, it may be a more essential component when learning to read a language with a deep orthography as compared to one that is shallow. Interestingly, the results of this investigation also revealed that the impact of vocabulary was found to be stronger in languages with shallow orthographies than in those that are deep.

The final cross-language study reviewed was designed to determine the contribution of orthographic depth on the predictive ability of four cognitive skills, phonological awareness, RAN, letter-sound processing, and verbal working memory. Using a longitudinal design, the researchers assessed 2,245 Dutch, Hungarian, and Portuguese speaking students over a 4-year period from first through fourth grade (Vaessen et al., 2010). Findings of this investigation revealed similar patterns of developmental trajectories across all three languages. For example, phonological awareness was found to contribute most strongly to beginning reading and then shifted in its relative importance as a function of increased reading experience and expertise. It is interesting to note that these findings are consistent with those obtained by Storch and Whitehurst (2002) in their longitudinal study of reading in English. While the underlying cognitive processes of reading were consistent across languages in this study, differences in patterns of development were associated with differences in the orthographic depth of the language. Therefore, the findings suggest that children learning to read a language with a deep orthography may require additional time to solidify grapheme-to-phoneme relations than children learning to read a language with a shallow orthography (Vaessen et al.).

As Marshark and Spencer (2006) indicated, both English and French have considerable variability in their phoneme-to-grapheme translations, which has been referred to as *feedback* features (i.e., the way in which individual phonemes are encoded in print) and relates to spelling. However, French is more consistent in the grapheme-to-phoneme translations required for reading, or *feedforward* features (i.e., the way in which individual phonemes are decoded from print), when compared to English. Therefore, this situation suggests that while it may be equally challenging to learn to spell in both French and English, French may be easier to learn to read (Ziegler, Jacobs, & Stone, 1996).

In relating the findings from the cross-language studies to cued languages, differences that reside within the orthography of the language will exist whether the language is spoken or cued. As such, methods of reading instruction may need to differ as a function of the orthographic depth of the language, regardless of the mode of delivery. Therefore, results of the cross-language studies lend empirical support for using the findings of studies conducted in cued French to inform understandings of cued English.

Literature Search

To conduct an initial exploration of the literature, the terms *Cued Speech* and *literacy* were entered in several electronic search engines (e.g., EBSCOhost, Google Scholar, ERIC) to identify relevant works. Given the assumption that the body of literature would be relatively small, chapters in edited books were considered in addition to articles published in peer review journals. Furthermore, the year the search was conducted (i.e., 2016) reflects the only limitation imposed in terms of publication date. A review of references cited in the retrieved articles was also conducted in order to uncover additional publications. Studies were included in the present review if they were published in English and used either a group comparison or single-subject design to examine various precursor abilities associated with later literacy achievement (e.g., phonological awareness, phonological short-term memory).

Because rhyme generation tasks requiring participants to write words have historically been used as a means of determining deaf individual's sensitivity to phonological structures (Hanson & McGarr, 1989), studies employing a measure of spelling were also included if the words produced were analyzed relative to their phoneme-to-grapheme relations. As such, these analyses provided data on both phonological processing (i.e., ability to rhyme) and alphabet knowledge (i.e., ability to encode words using knowledge of phoneme-to-grapheme relations). Even though no date limits were imposed, the resulting studies represent relatively recent investigations conducted between 2000 and 2013.

Studies of Cued French

Applying the aforementioned criteria led to the identification of six publications of cued French summarizing the findings of seven studies, five evaluating reading-related skills and two examining spelling. Table 1 provides a summary of information obtained from these studies.

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Table 1. Studies of cued French

Authors/date	Study focus	Number of participants	Age of participants (mean)	Exposure to CS (mean)	Literacy task	Notes
Bouton, Beroncini, Serniclaes, & Colé (2011)	Reading	CS$^+$ $n = 9$ CS$^-$ $n = 9$ RL = 18 CA = 18	CS$^+$ 8;8 CS$^-$ 9;1 RL 7;6 CA 9;1	CS$^+$ prior to the age of 2 years	Phonemic awareness	All deaf participants used CIs
Charlier & Leybaert (2000) Study 1	Reading	*Readers* CS$^+$ $n = 16$ CS$^-$ $n = 18$ Oral $n = 29$ SL$^+$ $n = 12$ SL$^-$ $n = 20$ H $n = 12$ *Non-readers* CS$^+$ $n = 5$ H $n = 10$	*Readers* CS$^+$ 10;1 CS$^-$ 12;7 Oral 13;3 SL$^+$ 10;4 SL$^-$ 10;1 H 8;7 *Non-readers* CS$^+$ 5:6 H 5;10	CS$^+$ from 28 months CS$^-$ from 56 months	Rhyme recognition	H matched by grade
Charlier & Leybaert (2000) Study 2	Reading	CS$^+$ $n = 20$ CS$^-$ $n = 20$ H1 $n = 20$ H2 $n = 20$	CS$^+$11;4 CS$^-$16;10 H1 10;6 H2 10;4	CS$^+$ from 39 months CS$^-$ from 85 months	Rhyme generation	H matched by reading level
Colin, Magnan, Ecalle, & Leybaert (2007)	Reading	CS $n = 21$ H $n = 21$	CS 6;0 H 6;1	From 25 months $n = 7$ From 56 months $n = 7$ From 1st grade $n = 7$	Rhyme decision, rhyme generation, common unit identification, written word recognition	Longitudinal study comparing performance in K and 1st grade
Colin, Leybaert, Ecalle, & Magnan (2013)	Reading	Early CS $n = 6$ Late CS $n = 6$ Beginner CS $n = 6$ H $n = 18$	Age at onset of study in K Early CS 6;3 Late CS 5;10 Beginner CS 6;5 H 6;0	Early CS from 14 months Late CS from 62 months Beginner CS entering 1st	Rhyme decision, rhyme generation, common unit identification, written word recognition, cloze sentence comprehension, spelling, receptive vocabulary	Follow-up to Colin et al. (2007) study after 22 months of reading instruction in 2nd grade
Leybaert (2000)	Spelling	CS-Home $n = 28$ CS-School $n = 28$ H $n = 30$	CS-Home 8;10 CS-School 11;1 H 8;9	CS-Home from 18 months CS-School at school	Write words associated with drawing or sentence context, represent both high- and low-frequency French words	
Leybaert & Lechat (2001)	Spelling	CS-Home Young $n = 20$ CS-School $n = 18$ SL-Home $n = 14$ SL-School $n = 10$ H Young $n = 16$ CS-Home Older $n = 5$ H older $n = 16$	CS-Home Young 8;2 CS-School 10;10 SL-Home 11;1 SL-School 11;7 H Young 8;11 CS-Home Older 11;9 H Older 11;3	CS-Home Young from 24 months CS-School from 49 months CS-Home Older NR	Encode dominant and non-dominant transcriptions of three specific phonemes within high, medium, and low-frequency French words	

Note: Age reported in years; months; CS = Cued Speech; CS$^+$ = exposed to CS at home; CS$^-$ = exposed to CS in school only or no exposure to CS; RL = hearing control matched by reading level; CA = hearing control matched by chronological age; CI = cochlear implant; Oral = orally educated; SL$^+$ = exposed to sign language early in life; H = hearing; K = kindergarten; NR = not reported.

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Investigations of Reading

Three of the studies of reading compared the performance of deaf students from both cueing and non-cueing backgrounds to that of hearing participants. In the first study of this type, a rhyme recognition task measuring participants' ability to judge whether pairs of pictures representing rhyming words was used. Four different types of word pairs were used in this investigation including rhyming pairs ending with similar spellings (R^+O^+), rhyming pairs ending with different spellings (R^+O^-), non-rhyming pairs ending with sounds that appeared similar on the mouth (i.e., a similar speechreading image R^-SR^+), and non-rhyming pairs ending with dissimilar speechreading images R^-SR^- (Charlier & Leybaert, 2000).

Participants were five groups of prelingually deaf children including those who were: (1) exposed to Cued Speech at home from a mean age of 28 months (CS^+, $n = 16$, mean age = 10;1), (2) exposed to Cued Speech only in school from a mean age of 56 months (CS^-, $n = 18$, mean age = 12;7), (3) orally educated students (Oral, $n = 29$, mean age = 13;3), (4) native signers with deaf parents who used sign language to communicate (SL^+, $n = 12$, mean age = 10;4), and (5) students exposed to sign language at a later stage in school (SL^-, $n = 20$; mean age = 10;1). A control group of hearing children (Hearing, $n = 12$, mean age = 8;7) matched to the deaf students by school level (2nd through 5th grade) served as the sixth group of study participants. The inclusion of various groups of deaf children allowed the researchers to examine if language alone (cued or signed) was sufficient for the development of rhyming abilities or if the exposure to the phonological input provided by Cued Speech was necessary to develop these skills. To determine if participants exposed to Cued Speech at home assisted in the development of rhyming abilities independent of their subsequent reading and spelling experiences acquired through instruction, the researchers included CS^+ participants that could be considered relatively secure readers due to their age (mean age 10;1) as well as CS^+ (mean age 5;6) and Hearing (5;10) pre-readers (Charlier & Leybaert, 2000).

Results of this investigation revealed no statistically significant difference between the CS^+ and Hearing readers in their ability to judge rhymes, with mean accuracy scores for the CS^+ participants being relatively similar across the four types of words (R^+O^+ = 97.4%, R^+O^- = 94.9%, R^-SR^+ = 93.8%, R^-SR^- = 100%) when compared to Hearing readers (R^+O^+ = 95.8%, R^+O^- = 97.0%, R^-SR^+ = 97.7%, R^-SR^- = 99.2%). The fact that the CS^- participants' scores on these measures (R^+O^+ = 86.4%, R^+O^- = 73.9%, R^-SR^+ = 68.3%, R^-SR^- = 95.6%) were more similar to those obtained by the Oral (R^+O^+ = 92.2%, R^+O^- = 71.6%, R^-SR^+ = 73.8%, R^-SR^- = 83.5%), SL^+ (R^+O^+ = 89.3%, R^+O^- = 58.2%, R^-SR^+ = 74.7%, R^-SR^- = 96.7%), and SL^- (R^+O^+ = 82.9%, R^+O^- = 66.6%, R^-SR^+ = 58.6%, R^-SR^- = 92.0%) groups, and generally lower than those achieved by the CS^+ and Hearing readers, led the researchers to surmise that early exposure to Cued Speech at home led to the development of rhyming abilities and skill levels commensurate with hearing peers.

Furthermore, the fact that CS^-, Oral, SL^+, and SL^- participants were less able to identify rhymes among the pairs of pictures representing rhyming words with different spellings suggested that they relied more heavily on their knowledge of spelling to identify rhymes than the CS^+ and Hearing participants. This finding was further confirmed by the scores obtained by the CS^+ pre-readers, who actually evidenced higher mean scores on the four word types (R^+O^+ = 100%, R^+O^- = 94.4%, R^-SR^+ = 89.0%, R^-SR^- = 100%) than their Hearing counterparts (R^+O^+ = 91.3%, R^+O^- = 91.0%, R^-SR^+ = 78.6%, R^-SR^- = 94.0%). Even though all groups of deaf participants were less able to accurately identify non-rhyming pairs ending with a similar speechreading image, the percentage of CS^+ participants experiencing difficulty with these pairs was significantly lower than the other groups of deaf participants (37% vs. 69–90%) (Charlier & Leybaert, 2000).

While the authors reported that the students in the hearing control group were matched to the deaf participants based on grade level, the hearing students were at least one year younger than all five groups of deaf readers (Charlier & Leybaert, 2000). Therefore, it may be possible that differences in performance between the CS^+ and Hearing participants may have been noted had the participants been more closely matched in terms of age. However, in relating participants' rhyme abilities to other factors, the researchers only identified a significant correlation between chronological age and rhyming accuracy for deaf students in the Oral and SL^- groups, suggesting that the older participants in these groups possessed better rhyming abilities (Charlier & Leybaert).

The second investigation involved a more difficult phonological awareness task, the ability to generate rhyming words. Two new groups of deaf participants with similar characteristics to those in the first study, CS^+ ($n = 20$, mean age = 11;4, exposed to Cued Speech from a mean age of 39 months) and CS^- ($n = 20$, mean age = 16;10, exposed to Cued Speech from a mean age of 85 months), as well as two groups of Hearing controls matched for reading level ($n = 40$; mean age = 10;6 and 10;4), were recruited for this study. Because the researchers were also interested in gaining information about the sources of information used by participants when generating rhymes, the consistency in rhyme of the target word (e.g., one pronunciation for the spelling pattern vs. two) and the representation of the word (e.g., picture vs. written word) varied (Charlier & Leybaert, 2000). It has been suggested that the ability to generate rhyming words that are orthographically different than the target word provides evidence of dependence on a phonological strategy rather than an orthographic one (Charlier & Leybaert; Hanson & McGarr, 1989).

Findings of this study indicated that while the CS^+ participants were able to produce a high percentage of rhyming words that were orthographically different from the target, their performance did differ from that of the Hearing controls. As a group, the CS^+ participants relied more heavily on spelling consistency when generating rhymes for both pictures and words than their hearing counterparts. However, results also indicated that the CS^+ participants outperformed their CS^- peers in rhyme generation, even after controlling for reading ability. In analyzing the types of rhyming words generated, the two groups of Hearing participants were found to produce a higher percentage of orthographically dissimilar words (m = 52.3% and 51.2%) as compared to orthographically similar words (m = 38.6% and 40.3%), the CS^+ participants generated nearly equal percentages of orthographically dissimilar (m = 41.1%) and similar words (m = 40.9%), and the CS^- students were found to produce a greater percentage of orthographically similar words (m = 32.9%) than orthographically dissimilar words (m = 23.9%) (Charlier & Leybaert, 2000).

An error analysis suggested that the majority of the errors produced by all three groups occurred when the rhyme generated shared the same vowel as the target, both phonetically and orthographically, but not the consonant. While the CS^+ and two groups of Hearing participants produced this type of error nearly equally (4.5%, 4.4%, and 3.5%, respectively), this error pattern was more common among the CS^- participants (11.0%).

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Collectively, the findings of these two studies led the authors to conclude that exposure to Cued Speech at home from an early age resulted in relatively strong rhyme abilities and levels of performance on recognition and generation tasks that had not been previously reported for profoundly deaf students (Charlier & Leybaert, 2000).

The third study measured the reading and reading-related abilities of 18 cochlear implant users, 9 who had used Cued Speech before the age of two (CS^+, mean age = 8;8), and 9 who had never been exposed to Cued Speech (CS^-, mean age = 9;1). Each deaf participant was matched with a hearing child of the same chronological age (CA, mean age = 9;1) and a second with the same reading level (RL, mean age = 7;6). To assess phonemic awareness, a relatively more sophisticated phonological skill than rhyming, participants were shown three pictures and were asked to indicate which two pictures had the same beginning sound. Phonological short-term memory was also assessed and measured by the time in seconds required to repeat both phonetically similar and dissimilar words. Word reading abilities were assessed using irregular word and pseudoword reading tasks (Bouton, Beroncini, Serniclaes, & Colé, 2011).

Results of this study revealed that the CS^+ participants' percentage of correct responses on the phonemic similarity judgment task (m = 99.3%) as well as recall for phonologically similar (m = 62.4%) and dissimilar (m = 60.5%) words was higher than those obtained by the CS^- participants (m = 79.3%, 57.7%, and 55.9%, respectively), particularly for the phonemic similarity judgment task. Interestingly, the CS^+ participants also achieved higher scores on this task than both the CA (m = 93.1%) and RL controls (m = 92.2%). However, differences in the percentage of correct responses was noted on the recall tasks when the performance of the CS^+ participants was compared to the CA controls for both phonologically similar (m = 70.1%) and dissimilar (m = 83.6%) words, but less so when comparing the performance of the CS^+ participants to the RL controls, particularly for phonologically similar words (m = 64.2%, phonologically dissimilar words m = 76.4%).

Despite the differences in performance across groups, findings suggest that all groups appeared to read pseudowords using a sublexical (i.e., phonological) strategy and irregular words through a lexical one. Results of the word span task revealed that both groups of deaf participants recalled phonologically dissimilar words (CS^+ m = 5.1 s, CS^- m = 6.0 s) more quickly than phonologically similar words (CS^+ m = 6.9 s, CS^- m = 8.5 s), regardless of exposure to Cued Speech. However, the ability of the CS^+ participants to recall phonologically similar words was found to be more similar to the CA controls (m = 7.1 s), whereas the results for CS^- participants were more consistent with those obtained for the RL controls (m = 8.9 s) (Bouton et al., 2011).

Two additional studies of reading compared the performance of deaf Cued Speech users to hearing controls using longitudinal designs. In the first study, the researchers were interested in determining whether the phonological skills of deaf pre-readers predicted later phonological and reading skills after 1 year of instruction. The performance of 21 deaf participants (i.e., 7 who received Cued Speech at home from a mean age of 25 months, 7 who received Cued Speech in their school from a mean age of 56 months, and 7 children who were exposed to Cued Speech for the first time at the start of first grade) was compared to hearing readers. At the onset of the study in kindergarten, the mean age of the deaf participants was 6-years-old and the hearing controls 6 years, 1 month. Measures of speech intelligibility, rhyme decision, and rhyme generation were administered in kindergarten, and assessments of rhyme decision, common unit identification, and written word recognition were administered in first grade (Colin, Magnan, Ecalle, & Leybaert, 2007).

Findings indicated that while the deaf participants achieved lower scores on measures of rhyme decision (m = 11.0) and rhyme generation (m = .87) than their hearing peers (m = 12.76 and 1.95, respectively) in kindergarten, and rhyme decision (deaf m = 13.34, hearing m = 16.43), common unit identification (deaf m = 9.28, hearing m = 15.83), and word recognition (deaf m = 16.38, hearing m = 23.81) assessments in first grade, phonological skills were found to predict written word recognition skills in first grade across all groups. For example, greater accuracy in completing the phonological tasks in kindergarten was associated with fewer errors on the written word choice test administered in first grade. Results also suggested that the length of exposure to Cued Speech explained a significant proportion of variance among the deaf participants in first grade, but not in kindergarten. This led the researchers to question whether young deaf children were able to recognize the ability of Cued Speech to provide the phonological information necessary to engage in rhyming, as participants were not observed producing the manual cues when completing these tasks. However, participants did appear to recognize the utility of Cued Speech to detecting common units, perhaps indicating a developmental difference and/or the influence of reading instruction (Colin et al., 2007).

The second investigation represents a follow-up to the first, with the same participants being assessed at the end of second grade or after 22 months of reading instruction. In this study, students exposed to Cued Speech at home before kindergarten (mean age 14 months) were categorized as Early CS (n = 6, mean age in kindergarten = 6;3), those upon entering kindergarten (mean age 62 months) as Late CS (n = 6, mean age in kindergarten = 5;10), and those at the onset of first grade as Beginner CS (n = 6, mean age in kindergarten = 6;5). In addition to the information provided by the assessments in kindergarten and first grade within the initial study (Colin et al., 2007), a cloze sentence comprehension, spelling, and receptive vocabulary test were administered in second grade. As with the previous study, results of the three groups of deaf participants were compared to Hearing controls (n = 18, mean age in kindergarten = 6;0) (Colin, Leybaert, Ecalle, & Magnan, 2013).

The pattern of performance whereby the Early CS participants outperformed the other two groups of deaf participants at the beginning of first grade was also demonstrated at the end of second grade. When compared to the Hearing controls, there was no significant difference in the performance of the Early CS participants on phonological, written word choice, cloze sentence comprehension, or spelling assessments. Mean raw scores obtained by groups for orthographically correct words (OCW), pseudo-homophones (PH), visually similar pseudo-homophones (VSP), pseudo-words (PW), and non-words (NW) on the written word test administered in second grade illustrate participants' performance. For example, the Early CS participants' scores on these tasks (m = 30.33, 4.83, 0.67, 0.17, and 0.00, respectively) were more similar to those obtained by Hearing controls (m = 29.06, 4.93, 1.56, 0.46, and 0.00, respectively) than those of the Late CS (m = 25.00, 6.50, 2.67, 1.17, and 0.67, respectively) and Beginner CS participants (m = 22.83, 7.00, 3.00, 1.83, and 1.33, respectively). The total number of correct responses on the spelling test administered in second grade also documents the similarities between the Early CS participants (m = 38.17) and Hearing controls (m = 38.89) as compared to the Late CS (m = 28.50) and Beginner CS (m = 26.67) participants.

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Investigations of Spelling

The first study of spelling involved two groups of deaf participants, those who were exposed to Cued Speech at home from a mean age of 18 months (CS-Home, *n* = 28, mean age = 8;10) and a second group who were exposed to Cued Speech primarily at school (CS-School, *n* = 28, mean age = 11;1). Similar to several studies of reading, the deaf participants in this investigation were matched with Hearing controls (*n* = 30, mean age = 8;9) based on spelling ability. To assess their spelling abilities as part of the investigation, participants were asked to write words associated with a drawing or sentence context that represented both high- and low-frequency French words. Responses were then marked as correct or incorrect and further analyzed based on five error types including phonological substitutions, context-sensitive errors, nonphonological substitutions, transpositions, and the category of other (Leybaert, 2000).

Of particular relevance to the current examination of the literature, results of this study indicated that phonological substitutions constituted the majority of errors produced by the CS-Home participants for both high- (*m* = 11.8%) and low-frequency (*m* = 15.8%) words, which was consistent with the pattern of performance observed for the Hearing participants (*m* = 14.5% and 23.9%, respectively). On the other hand, the CS-School participants produced fewer phonological substitutions, particularly for high-frequency (*m* = 6.7%) words (low-frequency *m* = 11.9%). The CS-School participants also evidenced a greater percentage of nonphonological substitutions, particularly for low-frequency words (*m* = 10.9%) when compared to the CS-Home (2.6%) and Hearing (1.0%) participants (Leybaert, 2000).

In comparison to the Hearing controls, both groups of deaf participants made a greater number of transposition errors that did not demonstrate adherence with the phonological representation of the target word, with the CS-School group making slightly more errors of this type for both high- (*m* = 0.4) and low-frequency (*m* = 0.5) words than the CS-Home participants (*m* = 0.1 on both word types). When considering errors in the “other” category, the CS-Home group produced a greater percentage of this type of misspelling for both high- and low-frequency words (*m* = 2.2 and 3.4, respectively) as compared to Hearing controls (*m* = 0.5 and 1.2, respectively), but significantly fewer than the CS-School participants, particularly when considering low-frequency words (*m* = 10.3, high-frequency *m* = 3.8). After conducting an in-depth analysis of various aspects of French spelling across participants' responses (e.g., phoneme-to-grapheme dominance, consonant clusters, context-dependent rules, morphological spellings), the author concluded that the majority of spelling errors evidenced by the CS-Home children represented phonologically accurate attempts and that the overall differences between this group and Hearing participants were relatively negligible. This finding is particularly compelling considering how well matched the CS-Home (*m* = 8;10) and Hearing (*m* = 8;9) participants were in terms of age (*m* = 8;10 and 8;9 respectively) and spelling ability (Leybaert, 2000).

The second investigation of spelling focused on the ability of participants to encode both dominant and non-dominant transcriptions of three specific phonemes within high, medium, and low-frequency French words. Responses were considered correct if an accurate transcription of the target grapheme was produced, regardless of how the remainder of the word was spelled. Participants' errors were then characterized as phonologically accurate or inaccurate. Study participants included 67 deaf children that differed in language approach, be that Cued Speech (CS) or sign language (SL), as well as degree of exposure to the language (i.e., early at home or later at school), and 32 hearing controls. The researchers initially matched participants on a measure of word recognition; however, this resulted in the CS-Home and Hearing control groups being two to three years younger than the other three groups of deaf children. Therefore, separate groups for younger and older CS-Home and Hearing participants were created, resulting in the following seven groups: CS-Home Young (*n* = 20, mean age = 8;2, exposed to Cued Speech from 24 months of age) Hearing Young (*n* = 16, mean age = 8;11), CS-School (*n* = 18, mean age = 10;10, exposed to Cued Speech from 49 months of age), SL-Home (*n* = 14, mean age = 11;1), SL-School (*n* = 10, mean age = 11;7), CS-Home Older (*n* = 5, mean age = 11;9), and Hearing Older (*n* = 16, mean age = 11;3) (Leybaert & Lechat, 2001).

In general, the presence of phonologically accurate errors (e.g., use of phonological or inventive spelling such as pepol for people) tend to be appear more often in the spelling of younger learners who are just beginning to make the connection between spoken and written language and have yet to be taught conventional spelling rules. These types of errors are frequently used as evidence of phonological coding (see Mayer, 2007 for discussion). In this investigation, the Hearing Young and CS-Home Young participants produced more phonologically accurate errors (*m* = 8.16 and 6.21, respectively) than the CS-School (*m* = 3.71), SL-Home (*m* = 1.84), and SL-School (*m* = 2.16) subjects. As further evidence that the Hearing Young and CS-Home Young differed from the other deaf participants in this regard, the number of phonologically inaccurate errors produced by the CS-School (*m* = 6.95), SL-Home (*m* = 8.43), and SL-School (*m* = 9.06) exceeded those that were characterized as phonologically accurate. However, this was not the case for the phonologically inaccurate errors produced by the Hearing Young (*m* = 0.63) and CS-Home Young (*m* = 2.49) participants. As to be expected, the Hearing Older and CS-Home Older participants demonstrated fewer phonologically accurate (*m* = 3.50 and 1.93, respectively) and inaccurate (*m* = 0.06 and 1.26, respectively) errors than the younger participants in this study (Leybaert & Lechat, 2001).

Study findings also indicated that Hearing and CS-Home participants were best able to transcribe dominant versus non-dominant graphemes across all three types of words, with the effect of word frequency (i.e., high, medium, low) being more marked for non-dominant than dominant graphemes. As with the previous study of spelling (Leybaert, 2000), these groups of participants were well matched in terms of age (CS-Home Young *m* = 8;2; Hearing Young *m* = 8;11, CS-Home Older *m* = 11;9, Hearing Older *m* = 11;2). For the two groups of SL participants, the effect of dominance based on word frequency was not evident and a similar pattern of performance across dominant and non-dominant graphemes was noted. The CS-School group evidenced mixed performance when compared to the other participants, with an effect of dominance being observed, but the effect of frequency across dominant and non-dominant graphemes being similar (Leybaert & Lechat, 2001). Collective findings of these studies suggest that the spelling abilities of deaf children exposed to Cued Speech evidence the use of phonological coding. This finding is particularly compelling given the considerable variability in the phoneme-to-grapheme translations necessary to spell in French as compared to the grapheme-to-phoneme translations that are required for reading.

Studies of Visual Phonics

While Cued Speech is characterized as a communication system, Visual Phonics is an instructional tool designed to provide

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learners with visual access to individual phonemes of the language and information regarding articulatory features of the phonemes. As such, this multisensory system consists of 46 hand gestures created to mimic elements of the production of phonemes in English and corresponding line-drawn symbols that mirror the hand movements used when representing each phoneme. When used to supplement reading instruction, this tool provides learners with additional visual and kinesthetic information, above and beyond what is gained through audition, speechreading, and producing phonemes verbally or through mouth movements (Wang, Trezek, Luckner, & Paul, 2008). These gestures were also purposefully designed to help learners differentiate phonemes with similar articulatory features (International Communication Learning Institute, 1996).

To contrast the gestures developed for two phonemes articulated in a similar manner (/b/ and /p/), the Visual Phonics gesture for the phoneme /b/ is produced by holding a close 5-hand adjacent to the mouth with the fingers facing the cheek. The gesture is then quickly moved forward and then returned to its original position as the phoneme /b/ is verbally produced or demonstrated with the corresponding mouth movement. The gesture for the phoneme /p/, on the other hand, is produced by holding a closed flat O-shaped hand next to the mouth with the fingers facing away from the body. The hand is then extended slightly forward to an open 5-hand position and then returned to its original location as the phoneme /p/ is produced. The rapid speed used when producing these gestures offers the viewer further information about the manner of production of these phonemes, which are stop sounds. Conversely, continuous phonemes are produced with a more fluid movement. For example, the gesture for the phoneme /m/ uses a flat hand held horizontally next to the mouth with the fingers facing down. As the hand is moved forward, the fingers are waved slightly to indicate the vibration that occurs during the production of this phoneme (Morrison, Trezek, & Paul, 2008; Trezek, Wang, & Paul, 2010).

Given the nature of the Visual Phonics system, which allows for phonological representations at the sublexical and lexical levels, this system is most effective for developing skills that require students to manipulate individual phonemes and/or short strings of phonemes within words. In other words, the tool is inherently too cumbersome to convey the appropriate rate of conversational language required to complete some phonological awareness activities such as producing the entire word in syllable blending (e.g., kin…der…gar…ten = kindergarten) and/or syllable segmentation (e.g., transportation= trans…por…ta…tion) tasks, or manipulating syllables in activities that require students to delete segments of language beyond the level of an individual phoneme (e.g., Say baseball. Now say baseball without base.) (see Mayer & Trezek, 2015 for discussion).

As previously discussed, the term Cued Speech (as compared to cued language) has been used to refer to a modality for instructional delivery (Fleetwood & Metzger, 1998). Using this definition highlights the similarities between Cued Speech and Visual Phonics, as both systems offer a visual means of representing phonemes of a language. Therefore, reading activities that involve teaching phonemic awareness (i.e., manipulating individual phonemes within words without the aid of print), the alphabetic principle (i.e., the relationship between graphemes and phonemes), and phonics (i.e., using knowledge of the alphabetic principle to decode words) can be delivered using either Cued Speech or Visual Phonics. However, because Visual Phonics is limited to sublexical and lexical levels representations only, the primary difference between the two systems is reflected in the ability to use Cued Speech to represent a conversational rate of language. This feature affords the applicability of Cued Speech to a larger range of activities that develop code-related skills such as the phonological awareness activities described above (e.g., blending, segmenting and manipulating syllables) as well as those focused on developing language-related abilities (e.g., vocabulary, syntactic knowledge) and more advanced reading skills (e.g., reading fluency, comprehension) (see LaSasso et al., 2010 and Mayer & Trezek, 2015 for discussions).

Over the past decade, there have been a significant number of intervention studies conducted exploring the efficacy of providing deaf students with instruction in phonemic awareness, the alphabetic principle, and phonics. The vast majority of these investigations have included the Visual Phonics instructional tool as part of the intervention (Beal-Alvarez, Lederberg, & Easterbrooks, 2012; Guardino, Syverud, Joyner, Nicols, & King, 2011; Narr, 2008; Smith & Wang, 2010; Trezek & Hancock, 2013; Trezek & Malmgren, 2005; Trezek & Wang, 2006; Trezek, Wang, Woods, Gampp, & Paul, 2007; Tucci & Easterbrooks, 2015). Of these studies, one employed a group comparison design (Trezek & Malmgren, 2005) and three used single-subject design (Beal-Alverez et al., 2012; Tucci & Easterbrooks, 2015). These articles were located as part of recent investigation conducted by the author that applied the Council of Exceptional Children (2014) standards for evidence-based practices to the body of intervention research in the domain of reading and deafness (Trezek & Wang, 2017). Given the similarities in the criteria used in that review and the present investigation (e.g., studies using group comparison and single-subject designs) as well as the range of publication dates (i.e., between 2000 and 2016), an additional search of the literature was not necessary to identify studies of Visual Phonics. Table 2 provides a summary of information obtained from these studies.

Group Comparison Study

This study was designed to evaluate the efficacy of a phonics treatment package implemented with middle school aged deaf students with varying degrees of hearing loss (i.e., slight to profound). The 23 participants were matched based on their scores on a 45-point curriculum-based measure assessing the grapheme-phoneme relations taught through the treatment package and the ability to apply this knowledge to the reading of words. Participants of each matched pair were then randomly assigned to either the treatment (n = 11, mean age 13;5) or comparison (n = 12, mean age 13;4) group (Trezek & Malmgren, 2005).

The intervention provided to the treatment group members was based on the first 20 lessons of the *Corrective Reading-Decoding A* curriculum (Engelmann, Carnine, & Johnson, 2008), a commercially available remedial reading program designed for students beyond the third grade level who continue to struggle with basic decoding skills. This 65 lesson curriculum focuses on the development of: (1) phonemic awareness abilities (e.g., initial, medial, and final sound identification; phoneme blending), (2) the alphabetic principle (i.e., decoding and encoding grapheme-phoneme relations), and (3) phonics skills (e.g., blending sounds to form words, segmenting sounds to spell words). Visual Phonics was used throughout the implementation to represent phonemes that were explicitly taught within the curriculum (Trezek & Malmgren, 2005).

In addition to Visual Phonics, a computer program developed by the Oregon Center for Applied Sciences (2001) was used to supplement instruction. The computer program included a pictorial glossary of the words taught within the lessons and the Baldi technology (a semi-transparent "talking head" see Massaro, 2006)

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Table 2. Studies of visual phonics

Authors/date	Study focus	Number of participants	Age of participants (mean)	Exposure to VP (mean)	Literacy task	Notes
Beal-Alvarez, Lederberg, & Easterbrooks (2012) Study 1	Reading	N = 1	5;0	At onset of study	Alphabetic principle	Evaluated *Foundations of Literacy* curriculum
Beal-Alvarez, Lederberg, & Easterbrooks (2012) Study 2	Reading	N = 3	P1 4;7 P2 4;7 P3 4;4	At onset of study	Alphabetic principle, phonics	Evaluated *Foundations of Literacy* curriculum
Trezek & Malmgren (2005)	Reading	T *n* = 11 C *n* = 12	T 13;5 C 13;4	At onset of study	Phonemic awareness, alphabetic principle, phonics, pseudoword decoding	Evaluated 20 lessons from the *Corrective Reading Decoding A* remedial reading program
Tucci & Easterbrooks (2015)	Reading	N = 3	P1 4;5 P2 4;10 P3 5;5	At onset of study	Alphabetic principle, phonemic awareness	Evaluated *Foundations of Literacy* curriculum

Note: Mean age of participants reported in years; months; VP = Visual Phonics; P = participant; T = treatment group; C = comparison group.

to support participants' acquisition and/or approximation of the articulatory features of each phoneme taught. Participants in the comparison group received the reading instruction that was in place at the school prior to the onset of the 8-week intervention study (Trezek & Malmgren, 2005).

Findings of this investigation revealed a significant difference between the two groups on the post-test measure, with the treatment group (m = 44) performing significantly better than the comparison group (m = 14.9). In addition to the curriculum-based measure that was used as a pre-, post-intervention assessment, a 30-point generalization probe involving a pseudoword decoding task was also administered at post-test. Findings of the generalization measure mirrored those of the post-test, with the treatment group (m = 29.54) significantly outperforming the comparison group (m = 4.0). Interestingly, while degree of hearing loss was highly correlated with performance for all students at pre-test, this was not the case for the treatment students following the intervention. In fact, the performance of several participants in the treatment group with more significant hearing losses (i.e., severe to profound) exceeded that of the peers with less significant losses (Trezek & Malmgren, 2005).

Of particular relevance to the present review of the literature, in the daily instructional logs documenting observations of participants, the treatment teacher reported that the Baldi technology was rarely needed to reinforce the articulatory features of the sounds after their introduction, and that the Visual Phonics cues alone appeared to provide sufficient support for retaining the information following initial instruction. Overall findings of this investigation lend support for the Visual Phonics instructional tool for differentiating phonemic awareness and phonics instruction for students with varying degrees of hearing loss requiring remedial reading instruction (Trezek & Malmgren, 2005).

Single-Subject Studies

The first publication in this category reported the findings of two investigations examining the use of Visual Phonics to supplement instruction from a researcher-developed early literacy curriculum titled *Foundations of Literacy*. This prekindergarten curriculum, developed specifically for deaf children, targets a variety of early literacy skills including phonological awareness, alphabetic knowledge, and vocabulary through language-rich activities (Lederberg, Miller, Easterbrooks, & Connor, 2011). Students typically receive instruction from this curriculum an hour per day, 4 days per week, over at least a 25-week period (Tucci & Easterbrooks, 2015).

In the first study, a multiple baseline probe across content design was used to evaluate the ability of a 5-year-old child to acquire the grapheme-phoneme correspondences taught in the *Foundations of Literacy* curriculum. Because the child did not use vocalized speech, Visual Phonics was used as the primary means of determining the acquisition of these skills. Findings indicated that given 16-hr of instruction over an 8-week period, the child was able to master the 8 grapheme-phoneme correspondences taught (Beal-Alvarez, Lederberg, & Easterbrooks, 2012).

The second study summarized in this publication employed a similar study design to that of the first and evaluated the acquisition of grapheme-phoneme correspondences among three preschool children (ages 4;4, 4;7 and 4;7 at the onset of the study) with varying degrees of speech perception abilities who were instructed using sign language. In addition to measuring participants' growth in ability to master the correspondences taught, generalization probes were administered and a descriptive analysis of the use of Visual Phonics was conducted. Results of this investigation revealed that skill acquisition was similar across the three children, in that they reached criteria for all grapheme-phoneme correspondences taught and demonstrated skill maintenance up to 20 weeks after initially reaching criteria. The children were also able to generalize skills from the instruction received, as evidenced by their ability to apply knowledge of grapheme-phoneme correspondences to decode words. Together the results of these two investigations led the authors to conclude that the curriculum and the Visual Phonics tool was an effective combination for teaching grapheme-phoneme correspondences to deaf preschoolers with limited speech perception who used sign language for communication (Beal-Alvarez, et al., 2012).

The third single-subject study also examined instructional components of the *Foundations of Literacy* curriculum using a multiple baseline across content (i.e., syllable segmentation, letter-sound correspondence, and initial-sound identification) design. Participants of this study were enrolled

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in a self-contained prekindergarten classroom at a day school for the deaf. The three participants (ages 4;5, 4;10, and 5;5 at the onset of the study), who had varying degrees of functional hearing, were instructed using sign language and Visual Phonics. Given the constraints of the Visual Phonics system discussed above, the instructional tool was only used to supplement the letter-sound correspondence and initial-sound identification (not syllable segmentation) portions of the lessons (Tucci & Easterbrooks, 2015).

Findings of this study revealed that the three participants were able to master all the letter-sound correspondences taught. In regards to initial-sound identification, two of the participants reportedly mastered this skill by the end of the study period, while the third evidenced marked improvements in this area of instruction. The authors noted that the third participant's limited functional hearing most likely contributed to the results achieved in the area of initial-sound identification. Overall findings suggested that Visual Phonics was an effective supplement for teaching letter-sound correspondences and initial-sound identification to students who use sign language; however, participants with more use of residual hearing tended to demonstrate greater gains as compared to those with limited functional hearing (Tucci & Easterbrooks, 2015).

The group comparison and single-subject design studies evaluating the effectiveness of Visual Phonics to supplement reading instruction for deaf learners reveal promising findings for this instructional tool. In fact, the results of a recent investigation that employed the Council of Exceptional Children (CEC, 2014) standards for evaluating evidence-based practices to examine intervention research from the domain of reading and deafness further support this assertion. Using the CEC standards, eight quality indicators are applied to determine the methodological quality of group comparison and single-subject studies. Results of the quality indicators allow researchers to classify practices using five categories: (1) evidence-based practice, (2) potentially evidence-based practice, (3) mixed evidence, (4) insufficient evidence, and (5) negative effects. Findings of this investigation revealed that explicit phonological/phonemic awareness and/or phonics instruction supplemented by Visual Phonics was one of three categories of interventions rated as potentially evidence-based (Trezek & Wang, 2017). Therefore, evidence from this area of the literature provides support for Cued Speech as mode of instructional delivery.

Studies of Cued English

Using the search procedures previously described (see Literature Search section) resulted in the identification of two studies of cued English and reading that used a group comparison design (Crain & LaSasso, 2010; LaSasso, Crain, & Leybaert, 2003). Table 3 provides a summary of information obtained from these investigations. The first study used a group comparison design to evaluate the rhyme generation skills of deaf and hearing participants with similar reading abilities. Of the 20 deaf participants, 10 had been exposed to Cued Speech before the age of 7-years-old (CS, mean age = 19.2), and 10 were students at Gallaudet University from non-Cued Speech backgrounds (NCS, mean age = 21.3). The 10 hearing participants were college students enrolled in a sign language class (Hearing, mean age = 20.1) (LaSasso et al., 2003).

As previously indicated, the ability to generate rhyming words that are orthographically different than the target word provides evidence of dependence on a phonological strategy rather than an orthographic one (Charlier & Leybaert, 2000; Hanson & McGarr, 1989). In this investigation, participants were instructed to write as many words as possible to rhyme with 54 different target words, 31 of which contained consistent orthography-to-phonology (O-P) patterns and the remaining 23 had inconsistent orthography-to-phonology (I-O-P) rhymes. Rhymes generated by participants were evaluated at several levels. First, they were examined to determine if they represented a correctly spelled English word or a phonetically acceptable non-word. Second, responses were classified as rhyming or non-rhyming, and then rhyming words were classified as orthographically similar to the target (e.g., blue-glue, school-cool) or orthographically dissimilar to the target (e.g., blue-few, bear-fare). Finally, errors were described using six categories including vowel, vowel with orthographic similarity, orthographic, some orthography, speech related, or unclassified (LaSasso et al., 2003).

In regards to correct responses to O-P and I-O-P target words, findings revealed a significant difference in the total percentage of correct responses provided by Hearing participants (m = 97.58%) when compared to the NCS participants (m = 81.96%), but the performance of the CS participants (m = 92.43%) did not differ significantly when compared to either the Hearing or NCS group. As was the case in studies of cued French, the responses of both groups of deaf participants appeared to be more highly influenced by spelling than those of the Hearing participants (Charlier & Leybaert, 2000). While both groups of deaf participants were found to more easily produce correct rhymes for the O-P targets (CS m = 95.44%, NCS m = 85.64%) than for the I-O-P ones (CS m = 87.26%, NCS m = 75.64%), results indicated that the frequency of correct orthographically dissimilar responses was higher for the Hearing (m = 62.50%) and CS (m = 56.90%) participants than the NCS (m = 33.70%) group, with the latter group generating the greatest number of orthographically similar rhymes (NCS m = 48.20%, CS m = 35.60%, Hearing m = 34.80%) (LaSasso et al., 2003).

Table 3 Studies of cued English

Authors/date	Study focus	Number of participants	Age of participants (mean)	Exposure to VP (mean)	Literacy task	Notes
Crain & LaSasso (2010)	Reading	CS n = 10 NCS n = 10 H n = 10	CS 19;2 NCS 21.3 H 20.1	Before the age of 7 years	Rhyme generation	CS participants reportedly received instruction via CS from either a certified teacher or transliterator
LaSasso, Crain, & Leybaert (2003)	Reading	CS n = 10 O n = 10 H n = 10	CS 12;4 O 12;6 H NR	NR	Rhyme generation	

Note: Mean age of participants reported in years; months; CS = Cued Speech; NCS = participants not exposed to Cued Speech; H = hearing participants, Oral = orally educated deaf participants; NR = not reported.

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Findings also confirmed the relationship between the deaf participants' reading level and performance on study measures, with better readers generating a greater number of correct responses to I-O-P targets that were orthographically dissimilar. Finally, results of this study revealed that while the CS participants made more rhyming errors (m = 7.6%) than the Hearing participants (m = 2.4%), these two groups evidenced a significantly lower percentage of errors than the NCS participants (m = 18.2%). Given that the overall performance of the CS participants in this study did not differ significantly from that of the Hearing participants led the authors to conclude that the phonological representations acquired through the use of Cued Speech contributed to the phonological and reading abilities evidenced by these individuals (LaSasso et al., 2003).

The second group comparison study used a similar study design to that of the first. In this investigation, the rhyme generation abilities of 10 deaf students from a Cued Speech (CS) background (mean age = 12;4) were compared to 10 age-matched deaf participants from an Oral education background (mean age = 12;6) as well as to 10 Hearing participants. Specific information regarding the age of the Hearing participants was not included; however, all study participants were reportedly between 10- and 14-years-old. As in the first study, responses were classified as words or non-words and judged whether or not they rhymed with the target. Correct responses were then determined to be orthographically similar or dissimilar as compared to the target and errors in incorrect responses were analyzed using the same six classifications (Crain & LaSasso, 2010).

As with the investigation with older students, there was no difference in reading comprehension abilities between the two groups of deaf participants. However, a significant difference was noted when comparing assessments of speech intelligibility and hearing loss, with the Cued Speech participants having significantly lower ratings on the measure of speech intelligibility and more significant degrees of hearing loss. In terms of ability to produce correct orthographically dissimilar responses, the Oral group was found to produce this type of response less frequently (m = 50.7%) than both the Cued Speech (m = 59.5%) and Hearing (m = 69.6%) groups. The Oral group also produced a statistically significantly higher percentage of overall errors (m = 17.4%) when compared to the Cued Speech (m = 8.4%) and Hearing (3.5%) groups. However, when comparing the performance across the three groups, a similar pattern of performance evidenced in the first study of cued English emerged. In the present investigation, a statistical difference between the performance of the Hearing and Oral groups was noted, but not between the Cued Speech participants and either the Oral or Hearing groups (Crain & LaSasso, 2010).

In this investigation, the authors were also interested in further exploring participants' phonological awareness abilities in relation to demographic variables as well as study measures and assessments of reading abilities. Investigating the relationship between phonological awareness and reading ability revealed a significant correlation, with higher levels of phonological awareness being associated with better scores on a standardized measure of reading achievement. When examining the relationship between phonological awareness (operationalized as correct OD rhyming responses) and degree of hearing loss specifically, a correlation was found for participants in the Oral group but not within the Cued Speech group or when the two groups of deaf participants were considered collectively. This was also the case when examining the relationship between phonological awareness and speech intelligibility as well as the association of reading ability (as measured by the Stanford Achievement Test-9) and speech intelligibility. These findings suggest that the phonological and reading abilities of the Oral participants in this study were more closely related to their degree of hearing loss and level of speech intelligibility than the Cued Speech participants (Crain & LaSasso, 2010).

In further examining the differences evidenced by the two groups of deaf participants, the researchers found that the higher scores obtained by the Cued Speech group on the measure of phonological awareness could not be explained by higher scores on the SAT-9 reading comprehension measure. This finding suggested that the Cued Speech participants did not develop phonological awareness abilities through reading experiences alone. In fact, when considering individual performance across all three groups of study participants, higher levels of phonological awareness were associated with higher scores on the measures of reading comprehension (Crain & LaSasso, 2010).

Discussion

The primary purpose of the present review was to examine four distinct areas of literature and summarize the available empirical evidence to support the role of Cued Speech in the development of reading in English. The results of recent cross-language studies reinforced the applicability of findings of studies of cued French to inform understandings of cued English. Findings across studies of both French and English suggest that exposure to Cued Speech contributes to the development of the phonological and reading abilities of deaf learners with varying degrees of hearing loss and ratings of speech intelligibility. The written rhyme generation measure used in several of these investigations provides data to evaluate both the phonological processing abilities and phonics skills of study participants. Results indicate that the phonological processing abilities of study participants appear to develop independent of reading experience and instruction, which has also been demonstrated among hearing readers. In general, findings revealed that participants with greater exposure to Cued Speech tended to outperform their deaf counterparts with less or no exposure to this communication system, although differences in performance relative to hearing peers was demonstrated for some literacy-related tasks. As such, the impact of these differences on the development of conventional literacy skills for users of cued French and cued English offers interesting avenues for future research.

Available studies of both cued French and cued English using group comparison designs were examined and the results revealed positive effects of cued languages on the development of various longitudinal predictors associated with literacy achievement (e.g., phonological awareness, phonemic awareness, alphabet knowledge, phonological memory). Given the low incidence nature of deafness in general, and the number of students using Cued Speech specifically, the researchers should be commended for executing studies employing rigorous designs and involving various comparison groups. Specific strengths in the design of these studies and their subsequent findings were also noted.

For example, in regards to the studies focused on reading and spelling in cued French, all seven (Bouton et al., 2011; Charlier & Leybaert, 2000; Colin et al., 2007, 2013; Leybaert, 2000; Leybaert & Lechat, 2001) included participants who varied in their length of exposure to Cued Speech as well as hearing controls match by age, grade, or reading/spelling level. Two of these studies also included deaf participants who used other communication modalities (i.e., oral, sign language) (Charlier & Leybaert, 2000

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Study 1; Leybaert & Lechat, 2001) and one investigation compared findings across readers and pre-readers (Charlier & Leybaert, 2000 Study 1).

With the exception of one study of conducted by Charlier and Leybaert (2000, Study 1) that included a group of high school aged students (i.e., mean age = 16;10), the remaining six studies of cued French examined the performance of primary and elementary-aged students (age 5;6 to 13;3). Using these groups of Cued Speech participants allowed the researchers to examine the development of phonological skills in primary students in kindergarten through second grade as well as literacy learners through the elementary years. The inclusion of two longitudinal studies of reading (Colin et al., 2007, 2013) provided further information regarding the development and maintenance of skills over time, which was a notable strength within this category of research.

The studies of cued English shared many of the same strengths as those conducted in cued French, in that they included deaf participants who used other communication modalities and hearing controls match by reading level. Furthermore, the investigation conducted by Crain and LaSasso (2010) explored not only participants' phonological abilities, but also the relationship between these abilities and demographic variables (e.g., degree of hearing loss, speech intelligibility) and reading achievement. Examining these associations provided further evidence of the positive impact of Cued Speech on the literacy outcomes for deaf learners.

While the investigation of college-age deaf students may raise questions regarding the influence of other factors (e.g., age, learning experiences) above and beyond Cued Speech, the inclusion of comparison group members of a similar age provides support for the conclusions drawn by the researchers. Furthermore, the similarity in study design, measures used, and results achieved in the two studies of cued English provide additional support for the findings obtained in each. The positive results achieved in the studies of Visual Phonics also serve to bolster the support for providing deaf learners with access to the phonemes of English through a visual modality.

While the primary purpose of the review was to examine the research associated with precursor abilities such as phonological awareness, the inclusion of reading achievement data in several investigations offered some insights into the conventional literacy skills of students exposed to Cued Speech. For example, even though data on the reading achievement levels of hearing participants was not reported, a study conducted by Charlier and Leybaert (2000, Study 1) revealed that participants with greater exposure to Cued Speech did evidence higher reading levels than the other groups of deaf participants (mean reading levels = CS^+ 5.3, CS^- 3.2, Oral 3.4, SL^+ 3.3, SL^- 3.7). It is also important to note that the participants with more experience with Cued Speech were also among the youngest deaf participants included in the investigation (mean age = CS^+ 10;1, CS^- 12;7, Oral 13;3, SL^+ 10;4, SL^- 10;4).

Similarly, a second study revealed that the length of exposure to Cued Speech appeared to impact reading achievement levels, suggesting that participants with greater exposure to Cued Speech scored slightly higher than those participants with less experience with Cued Speech (mean reading age CS^+ = 7;9, CS^- = 7;1). In this case, data was available for hearing participants who were matched with the deaf participants by chronological age (approximately 9-years-old), with these scores suggesting more than a year difference in reading achievement between the deaf and hearing participants (mean age for hearing participant = 9;1) (Bouton et al., 2011). Therefore, while length of exposure to Cued Speech does appear to modulate conventional reading outcomes to some degree, current available data suggests that these deaf Cued Speech users are not attaining achievement levels commensurate with their hearing age peers. Therefore, future studies that directly examine the impact of precursor abilities on the development of conventional literacy skills are needed to more firmly establish the relationship between them. Furthermore, this data can be used to determine if, as a group, deaf students exposed to Cued Speech are evidencing higher levels of literacy achievement than what has historically been reported for deaf learners (Qi & Mitchell, 2012).

While strengths were noted in the studies reviewed, the limitations of the available group comparison and single-subject design investigations of Cued Speech and Visual Phonics were also recognized. First, none of the reviewed studies employed a standardized test to measure participants' abilities in the areas assessed including phonological awareness (e.g., rhyme judgment or generation), phonemic awareness (e.g., initial-sound identification), phonological short-term memory, the alphabetic principle, word reading, pseudoword decoding, or spelling. A second limitation was noted in relation to the lack of measures assessing reading and spelling abilities beyond the word level (e.g., reading comprehension, written expression), as including assessments of this type would serve to illustrate the benefits of using Cued Speech and/or Visual Phonics on conventional literacy skill development. Finally, because the researchers created comparison groups based on various demographic variables (e.g., age, communication system, reading or spelling ability, scores on pre-test measure), this resulted in relatively small groups of participants (e.g., n = 5 to 10) in several studies. Although statistical power can be affected by the reduced sample size in the comparison group, the control of extraneous error variability and minimization of threats to internal validity support the matching strategy employed in these investigations.

Limitations

The limitations of the present review are also acknowledged. While various approaches were used to located potential studies, it is possible that relevant publications were inadvertently excluded. In addition, because the decision was made to limit the review of studies of cued French, Visual Phonics, cued English to those employing group comparison and single-subject designs, the inclusion of investigations using alternative designs (e.g., pre-, post-test) may have resulted in different conclusions being drawn. However, given the methodological rigor of the studies included in the review, this limitation is mitigated to some degree. Finally, because only descriptive statistics (e.g., age and grade equivalents, mean scores) and summaries of study results were used as to contextualize the performance across groups of participants, it is possible that conducting a statistical analysis of findings across studies (e.g., meta-analysis) may also have resulted in different conclusions being drawn.

Conclusion

Results of this inquiry revealed evidence to support the use of the Cued Speech communication system. A total of seven investigations of cued French were available that examined various longitudinal predictors of literacy achievement (e.g., phonological awareness, phonemic awareness, alphabet knowledge, phonological memory). Converging evidence from these investigations suggests that exposure to Cued Speech has a positive influence on

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the development of deaf learners' phonological and phonemic awareness abilities, knowledge of the alphabetic principle, and phonics skills that are associated with later conventional reading and spelling achievement. The similarity in study design, measures (e.g., rhyme generation), and results obtained in studies of both cued French and cued English lends further support for the congruence of findings across languages.

Similarly, the results of the four studies of Visual Phonics provide positive evidence for using a visual, gestural system for developing phonemic awareness abilities, knowledge of the alphabetic principle, and the phonic skills among deaf learners. Given the inherent limitations of the Visual Phonics instructional tool in providing access to phonological information beyond the phoneme level, users of Cued Speech may be advantaged in terms of the range of reading-related skills (e.g., phonological awareness) that can be acquired through the use of this communication system. As such, findings of the investigations of Cued Speech in English revealed support for developing phonological awareness abilities (i.e., rhyme generation) in addition to skills associated with the alphabetic principle and phonics.

Arguably, the evidence to support any method or intervention in deaf education is not easily produced. As an example, a recent review of intervention research conducted in reading and deafness resulted in the identification of a total of 30 studies in 7 categories of intervention over a 15-year period. Of these 30 studies, only 9 used either a group comparison or single-subject design and evaluated the reading-related skills for a total of 176 deaf participants (Trezek & Wang, 2017). Interestingly, the present evaluation found that the total number of studies of Cued Speech that employed group comparison design and were conducted during this same 15-year timeframe was also 9. These investigations collectively involved 337 deaf and 189 hearing participants. Undoubtedly, the methodical rigor of these studies, the inclusion of hearing comparison groups, and the use of longitudinal designs in several studies lends support for the generality of study findings.

While the present examination confirms the existence of empirical evidence to support the role of Cued Speech in the development of reading and English, further research is certainly warranted. Specifically, additional studies examining the use of cued English using group comparison and single-subject designs, particularly those involving elementary-aged students, should be conducted. It is also recommended that these studies consider using standardized measures of phonological abilities such as the *Comprehensive Test of Phonological Processing-Second Edition* (Wagner, Torgensen, Rashotte, & Pearson, 2013) that would allow for the evaluation of a broad array of skills and provide the opportunity to compare findings to a normative sample. Future studies that examine abilities beyond the word level by including standardized assessments of reading fluency, comprehension, and written expression would allow researchers to further examine the impact of Cued Speech on the development of conventional literacy skills among deaf learners.

Additional studies employing longitudinal designs and/or exploring specific literacy interventions would provide a means of further examining the impact of cued English on the development of phonological abilities and the influence of these skills on later reading and spelling achievement. Comparative studies of Cued Speech and Visual Phonics could shed additional light on the similarities and differences between these two systems and evaluate their utility in supporting the development of various phonological and literacy-related abilities among deaf learners. A replication of the cross-language investigations reviewed as part of this examination could also be conducted to provide valuable insights regarding the contribution of phonological abilities to the development of conventional literacy skills across cued French and cued English. Finally, conducting a meta-analysis of results from the investigations of cued French and English included in the present review would allow for the calculation of effect sizes and the ability to compare findings across studies, thus providing further insights regarding the overall treatment effect of Cued Speech.

Note

1. The general term "deaf" is used to refer to any individual identified with a hearing loss, from mild to profound, irrespective of the use of amplification (i.e., individuals with cochlear implants are deaf) and/or membership in the Deaf community.

Conflicts of Interest

No conflicts of interest were reported.

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