Literacy and Linguistic Development in Bilingual Deaf Children: Implications of the "and" for Phonological Processing

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CUMULATING EVIDENCE suggests that the establishment of high-quality phonological representations is the *cognitive precursor* that facilitates the acquisition of language (spoken, signed, and written). The authors present two studies that contrast the nature of bilingual profoundly deaf children's phonological representations derived from a spoken language and from a signed language using the framework of "functional equivalence" as outlined in McQuarrie and Parilla (2009). The authors argue further that a signed-language phonological system is suited in establishing the "functional" representational base that will support reading acquisition for bilingual deaf learners. They highlight rapidly developing empirical research on dual-language interactions between signed language and written language is highlighted, and discuss the need to take such data into account in any discussion of fundamental skills necessary to support reading achievement in bilingual profoundly deaf learners.

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Research is widely available outlining the factors that contribute to successful language and literacy acquisition in hearing populations, both monolingual and bilingual (see reviews in Ehri, 2005, and Grabe, 2009, respectively). Most current theories of first- and second-language reading development derive from studies on spoken languages that stress the importance of spoken-language proficiency in general, and phonological skills in particular, to learning to read. Similarly, much of the research with deaf populations has accepted the importance of spoken-language skills and aimed at verifying the existence of some quantitative difference between deaf and hearing readers. The dominant hypothesis in the field, the qualitative similarity hypothesis (QSH; see Paul, Wang, & Williams, 2013), posits that whether they learn English as a first or second language, d/Deaf and hard of hearing individuals proceed through stages, produce errors, and use strategies that are similar to those observed in individuals with typical hearing, although the rate of acquisition is quantitatively delayed (Paul & Lee, 2010). The assumption here is that the same fundamental spoken-language skills in the language to be read underlie reading acquisition for all learners.

Research evidence in support of the QSH has been mixed, and debates in the field over what constitutes the fundamental skills that are necessary for d/Deaf and hard of hearing individuals to learn to read are lively (see, e.g., Paul, Wang, Trezek, & Luckner, 2009, for one perspective, and Allen et al., 2009, for another). In particular, the issue of the necessity of spoken-language phonological awareness has been—and continues to be—hotly debated, and resides at the heart of theoretical controversy about deaf children's reading development. We have been asked to address this question in the present article: Is the reading process qualitatively similar, qualitatively different, or both for deaf learners? In response, we suggest that there is no simple answer—and certainly no single answer—given the extreme heterogeneity and the wide array of factors that affect language and literacy learning within the deaf population as a whole. To date, though, hypotheses considering this variability and exploring factors that promote or impede success in learning to read for specific subgroups of deaf learners have yet to receive much attention. A statement by the British physicist Sir Arthur Eddington (1928) reflects what may be at the heart of this neglect: "We often think that when we have completed our study of one, we know all about two, because 'two' is 'one and one.' We forget that we have still to make a study of '*and*' " (pp. 103–104).

In acknowledging Eddington's reminder of the "and," and in considering the question posed to us, we deliberately focus our discussion on bilingual deaf learners—and children who are learning a signed language, for example, American Sign Language (ASL), and concurrently a spoken and written language (e.g., English), and we limit our examination to a very specific subgroup: bilingual profoundly deaf children. Throughout the present article the term *deaf children* refers to those children with a congenital or early acquired severe to profound hearing loss that precludes auditory perception of conversational speech. For these children, irrespective of primary language, access to the "continuous phoneme stream" of a spoken language or a signed language is mediated through visual perception.

In what follows, we argue that visual perception of spoken and signed languages has consequences for how words are represented in the mental lexicon. In identifying these consequences, we present two studies that contrast the nature of deaf children's representations derived from a spoken language and from a signed language using the framework of "functional equivalence" we originally outlined in 2009 (McQuarrie & Parrila, 2009). Here, functional equivalence refers to the extent to which visual perception of either language conveys phonological information at the necessary level of precision to establish segmental structure in the representations of words in the mental lexicon. "Segmental structure" refers to the extent to which a word form can be broken into smaller parts, and is determined by the amount of phonological information that is specified in the word representation (Werker & Yeung, 2005; see also review in Clark, 1993). In light of increasing evidence underscoring the significant role the phonological specification of words plays in both vocabulary development (e.g., Jusczyk, 1996; Metsala & Walley, 1998; Werker & Yeung, 2005) and reading acquisition (see, e.g., reviews in Goswami, 2000; Mody, 2003; Swan & Goswami, 1997), critical importance accrues to the question of what phonological system (spoken or signed) is optimally suited to establishing segmental high-quality word representations in bilingual deaf learners.

Phonological-Lexical Relationships: Cognitive Precursors of Language and Reading

Phonological processing is essential to the comprehension and perception of all language forms (Jusczyk, Hohne, & Mandel, 1995). Simply, "to acquire the native language, a child must do two things: learn the words of the language and extract the relevant phonological characteristics of those words" (Storkel & Morrisette, 2002, p. 22). Deaf children learning a signed language as a first language early in development and hearing children learning a spoken language as a native language are similarly advantaged in their early access to redundant phonological patterns in their language environment. This early exposure to redundant phonological patterning establishes the language-specific phonological representations that set the course for achieving typical language acquisition milestones (see reviews in Pettito, 2000, 2009, for deaf signing children, and Werker & Curtin, 2005, for hearing speaking children). In outlining how exposure to phonological patterning establishes segmental phonological representation, Metsala (1999) and Metsala and Walley (1998) advanced the hypothesis that as young word learners encounter increasing numbers of words with similar phonological and articulatory patterns, a restructuring or reorganization of how words are stored in the brain is required. That is, instead of being stored as wholes (holistic phonological units), words begin to be segmented (i.e., represented in fuller phonological detail). This allows for more efficient storage of words in memory and better access to phonological units smaller than words (cf. Fowler, 1991).

For all children, the advantage of acquiring a rich, phonologically specified lexicon in any language is "an increase in quantity of words represented (vocabulary) and an increase in the quality of representation of those words" (Perfetti, 2013, p. 35). Here, quality is characterized by fully phonologically specified (segmental) representations. There is now a substantial and growing body of evidence indicating that the establishment of phonologically segmented word representations is the *cognitive precursor* that facilitates acquisition and efficient storage of words, access to them, and their retrieval from memory, and provides the foundation for the acquisition of additional grammatical properties of the language (see reviews in Mayor & Plunkett, 2014; Werker & Curtin, 2005). Important to our discussion of reading acquisition, it is this achievement—establishing segmental structure—that underpins hearing children's insight into how spoken words are structured and composed of individual sounds and combinations of sounds, that is, their *phonological awareness.*

The relationship between spoken-language phonological awareness and both successful and problematic reading acquisition has been extensively documented (see, e.g., Adams, 1990, for a review of earlier studies). While it is widely accepted that phonological deficits are a significant contributor to reading acquisition problems (see, e.g., Vellutino, Fletcher, Snowling, & Scanlon, 2004), the underlying cause of these problems in the hearing population remains unclear (see, e.g., Ramus & Szenkovits, 2008). Most researchers believe that poor performance on phonological awareness tasks reflects difficulty with analysis of a word's sound structure, particularly at the phoneme level, which in turn reflects word representations that are not fully phonologically specified and are therefore difficult to segment (e.g., Brady, 1997; Griffiths & Snowling, 2002; Perfetti, 2013; Vellutino et al., 2004). An alternative hypothesis of phonological deficit in reading disability argues that for most hearing individuals the underlying phonological representations are intact, but access to those phonological representations is challenged under high-demand conditions involving storage in short-term memory, speeded retrieval, and conscious awareness of sounds (e.g., Boest et al., 2013; Ramus & Ahissar, 2012; Ramus & Szenkovits, 2008). Whether the phonological deficit lies in the nature of the representations themselves or in the access to the representations (or in both), it is known that for hearing readers, at least, both high-quality representations and access to these representations are important for effective reading acquisition; problems with either can cause significant language and reading problems (see reviews in Ramus & Ahissar, 2012; Ramus, Marshall, Rosen, & van der Lely, 2013).

While the identity of the source of the phonological deficit in hearing individuals is ambiguous, the locus of the phonological deficit underlying poor phonological awareness in the deaf and hard of hearing population is obvious: To varying extents, depending on degree of residual hearing, deficits in auditory perception impair the acquisition of certain phonological categories of spoken language (i.e., attenuates the ability to extract those "relevant phonological characteristics of words" referred to by Storkel and Morrisette, 2002, p. 22) and result in degraded spoken-language phonological representations. However, despite these differences in the origin of phonological deficits between deaf and hearing individuals, it is widely assumed that the specific profiles of phonological deficits of deaf and hearing individuals are similar—the differences being ones of degree, with the phonological deficit in deaf individuals being more severe. A problem with this assumption is that the quality of underlying phonological representations among deaf and hard of hearing individuals may be heavily influenced by the extent to which visual perception alone or visual perception along with varying degrees of residual hearing supports development of accurate segmental representations of words in long-term memory. Given that the sensory information sources that contribute to the development of phonological representations are altered for deaf learners, it is plausible that the nature of phonological deficits may differ significantly, and not only between hearing and deaf readers, but also between subgroups of deaf readers. Different predictions about the underlying skills needed to support language and reading acquisition would result if this were the case. We explore the quality of profoundly deaf learners' spoken-word representations next.

Examination of Functional Equivalence in Spoken-Word Representations

An implicit assumption underlying the QSH, and mainstream educational methods in deaf education, is that profoundly deaf children have awareness of the phonological structure of spoken language; in other words, they have segmental phonological representations. This assumption is premised on the hypothesis that the phonological information derived through visual and tactile perception of speech, through observable lip-patterns and articulatory/motor speech patterns, establishes spoken-language phonological representations that are "functional" in supporting further lexical acquisition and reading acquisition in deaf learners (see review in Perfetti & Sandak, 2000). Surprisingly, however, very little research has been done to test this assumption in terms of the quality of profoundly deaf children's underlying representations of speech. As a result, there is only a limited understanding of the extent to which speech perception *in the absence of audition* results in similarities *or* differences in the way that spoken-language phonological patterns are represented or processed between profoundly deaf and hearing individuals.

Previously, we investigated the extent to which visual perception of spoken language supports the acquisition of segmental phonological representations in prelingual, severely to profoundly deaf bilingual children ages 6–18 years (McQuarrie & Parrila, 2009). We will not review that work in depth here (see McQuarrie & Parrila, 2009, for full details), but will provide a summary of the study to highlight the questions raised by the results for the QSH. In brief, we used a novel phonological similarity judgment task designed to measure deaf children's awareness of segmental phonological structure across three phonological levels of representation: syllable, rhyme, and phoneme. Across all three levels of the task, we systematically manipulated the phonological (sound), visual-tactile (lip-read/motoric pattern) and visual-orthographic (spelling) similarity between sets of words to better index the quality of the phonological representations and the sources of knowledge used to establish them.

Across the three phonological levels we assessed, word sets were graded in difficulty, as examples from the rhyme task illustrate: On the first level of the task, the distracters had no orthographic, phonological, or visual-tactile overlap with the cue (e.g., *cry*—pie, bed, dog). At this level of the task, an accurate response did not necessarily involve conscious representations of the rhyming and nonrhyming units. That is, the target word *pie* differed enough from the other two distractor words in global visual-articulatory shape that a correct rime match could be made without attention to the rhyme unit itself. On the second word set, one distractor shared visual-tactile characteristics with the cue word (e.g., *kite*—night, gun, two); on the third word set, the visual-orthographic pattern between the cue and one distractor overlapped (e.g., *root*—suit, foot, cave). The final word set provided the critical contrast condition in which both visual-orthographic and visual-tactile similarities between cue and distractors were manipulated (e.g., *sour*—flower, soup, zero). Here the cue word (*sour*) and the phonological target (*flower*) have similar phonology and different orthography; one distractor (*soup*) has a similar orthographic pattern with the cue but different phonology, and the other distractor (*zero*) has a lip-read/tactile-motoric pattern similar to that of the cue word but different phonology. (It is helpful to articulate the words silently to fully appreciate the visual-tactile similarity between *sour* and *zero*, or between *kite* and *gun,* to take another example.) Importantly, in this final condition, judgments of phonological similarity directly tap the quality of phonological representations—good performance on this level of the task would provide evidence of segmental phonological representations observed in hearing children (who have no difficulty completing the task).

We predicted that if the sensory information derived from visual perception of speech established segmental representational structure for profoundly deaf learners, as is assumed in the QSH, we should observe (a) segmental organization of phonological representations following the developmental trajectory observed with hearing children (i.e., shifting from larger syllable-like units to smaller phoneme units); (b) equally accurate performance across all task conditions (i.e., using visual-tactile and visual-orthographic distractors should have no noticeable effect); and (c) improved performance across all levels of the task as a function of increasing age and/or reading ability.

Our results did not support these predictions. Rather, insensitivity to spoken-language phonological structure was evidenced at all phonological levels—syllable, rhyme, and phoneme—with deaf students scoring below chance on each critical contrast set. Importantly, neither age nor reading ability contributed to the refinement of spoken-language phonological representations, a finding that is contrary to what is observed in typically developing hearing children (Goswami, 2002). The point of interest here is that if phonological development were proceeding in a qualitatively similar (though delayed) manner to that of hearing children, one would expect to see age and reading ability having a reciprocal effect on spoken-language phonological representations. That is, with increasing age and reading skill, deaf children's spoken-language phonological representations should contain increasingly more accurate and more detailed phonological information resulting in the typical developmental shift from more holistic to more segmental structure. This was not the case. Our results showed that older students did not differ from younger students and skilled readers did not differ from less skilled readers in their ability to exploit relevant phonological contrasts at any level of representation that was tapped in the phonological similarity judgment task (syllable to phoneme).

More tellingly, an examination of response choices indicated that in both low-demand and high-demand conditions, participants made "phonological" similarity judgments on the basis of visual-tactile or visual-orthographic similarity between words (which historically, we argued, has wrongly been interpreted as evidence of "phonological awareness"). One direct implication of our data is that better attention is needed to the design of stimuli used in measures assessing phonological awareness in deaf learners. Failure to control for sensitivity to visual-tactile characteristics in a word (i.e., lip-read and articulatory-motoric patterns) could not just influence but even bias results. For example, it is typically assumed that a hearing child's successful performance on a phonological awareness task reflects the ability to use the phonological units manipulated in the task. However, it is not possible to rule out the option that a deaf learner's explicit attention to spoken-language phonology may not in fact refer to the phonological units manipulated in the task but may instead be focused solely on the global shape (nonphonemic characteristics) of the word. If that were the case, successful performance clearly would not reflect the same assumed ability to use manipulated units as it does with hearing children—and, importantly, that is the very ability that appears critical in supporting written word learning.

Swan and Goswami (1997) advanced the hypothesis that "if the underlying representations of words are of poor quality (degraded, imprecisely specified), then their lexical structures will not be segmentally organized and available for inspection at any phonological level" (p. 22). Thus, it is suggested that poor performance on phonological awareness tasks may not reflect a lack of phonological analysis skills per se, but, rather, that retrieval strategies that are premised on segmental representational structure are not available because the structure itself has not been developed to support such analysis (e.g., Goswami, 2000; Morais, 2003; Swan & Goswami, 1997). In line with this hypothesis, our data suggest that the reduced input specificity of seen (speech-read) as compared to heard speech has long-term cognitive consequences in the representation of phonological structure (i.e., holistic vs. segmental) for deaf learners. Critically, our results indicate that to the extent that word representations are segmented at all, the sources of information used to establish representational structure are different—fundamentally and qualitatively. As we have reviewed thus far, cumulating research over several decades has now made it clear that sensitivity to and knowledge of the phonemic characteristics of words is essential to the construction of high-quality spoken-word and written-word representations.

For any language learner (hearing or deaf), deficits in segmental language skills can be expected to constrain acquisition of both spoken language and reading vocabulary. Consequences include difficulty establishing spoken words in memory, restricted vocabulary acquisition, and inefficient and effortful processing of spoken and written words. Deficits in segmental language skills might thus offer an explanation for the extensive vocabulary deficits consistently reported in the literature among monolingual deaf children (see review in Luckner & Cooke, 2010) and late-exposed signing children (see Lederberg & Spencer 2009; Lederberg, Schick, & Spencer, 2013).

It is important to highlight that while the deaf children in our study showed no evidence of possessing phonemically structured spoken-language phonological representations, many were reading at age-appropriate levels. This finding clearly indicates that reading achievement is possible in the absence of spoken-language phonological awareness and suggests that there are skills other than spoken-language phonological abilities that support the reading achievement of bilingual deaf individuals. Importantly, as bilingual learners, the deaf children we studied did have complete access to the phonological patterning of a natural signed language (in our case, ASL). As outlined above, phonological patterning is a structural building block of both spoken language and signed language. However, the potential role of a visual (signed) phonological system in establishing segmental representations that can support reading acquisition of a different language has been little studied. In what follows, we first provide a brief description of what it means to say that signed language has "phonology." We then extend our question about functional equivalence by examining the extent to which visual perception of signed language supports the acquisition of segmental phonological representations.

What Is Signed-Language Phonology?

Signed languages and spoken languages are perceived via different sensory channels (vision and audition), and produced by a different set of articulators (hands/face and vocal tract, respectively). On a surface level, it would be easy to conclude that such marked differences in perception and expression creates qualitative differences between the languages both at the representational level and in the cognitive processes operating on those representations. Research evidence, however, does not support this conclusion. In fact, linguistic analyses of signed languages show that signed languages exhibit formal organization at the same levels found in spoken languages. This includes a phonological (sublexical) level of structuring internal to the sign (analogous to consonants and vowels) and a level that specifies the precise ways that sublexical units (phonemes) combine to form signs, and signs combine to form sentences (these levels being analogous to the morphological and syntactic levels in spoken languages); see Emmorey (2002) for a review.

At the phonological level, classic descriptions of signed-language phonology recognize three major sublexical phonological units as the primary building blocks of a sign: Handshape (H) refers to the configuration of the hand in formation of a sign; movement (M) describes the path or how the hand moves (e.g., arc, circle, straight) in the sign space; location (L) tags the place of articulation or where the sign is located in space in reference to the body (see Stokoe, 1960, 1978). Some models also take palm orientation and nonmanuals (i.e., the facial expressions and mouthing that often accompany signs) into consideration. (For an overview of sign phonological models, see Sandler & Lillo-Martin, 2006.) In short, a sign is characterized by the co-occurrence of a particular shape of the hand(s) articulated in a particular place with a particular movement (Sandler, 1989). As in spoken languages, meaningless phonological units in sign (handshape, movement, location) combine in rule-ordered ways to form new signs that are contrastive in meaning. In this way, signed languages exhibit minimal pairs (a minimal change that differentiates meaning) similar in function to those seen in spoken languages. For example, changing a single phoneme in a spoken word, as in the /p/ in the word [pie], to the phoneme /t/, creates a new word meaning [tie]. Changing a single phonological parameter in a sign changes the meaning of the sign; changing the location of the ASL sign FATHER from the forehead to the chin changes the meaning of the sign to MOTHER. Both signs share the same handshape and the same movement; a place of articulation/location change provides the phonological contrast that distinguishes minimally between these two signs. As highlighted by Hall, Ferreira, and Mayberry (2012), despite structural differences in surface form, sign language phonology, like spoken-language phonology, plays an organizing role in language representation and processing, supporting lexical access, memory storage, and sign production (see also MacSweeney, Capek, Campbell, & Woll, 2009).

Examination of Functional Equivalence in Sign Language Representation

Recent advances in knowledge of the linguistic structures of signed languages (see, e.g., Boudreault & Mayberry, 2006; Brentari, 2006; Corina & Hildebrandt, 2002; Dye & Shih, 2006; Emmorey, McCullough, & Brentari, 2003; Grosvald, Lachaud, & Corina, 2012; Mann, Marshall, Mason, & Morgan, 2010; Novogrodsky, Fish, & Hoffmeister, 2014) have facilitated more detailed understanding of sign recognition and production and the cognitive capacities that support this process. However, very few studies have directly addressed the processes involved in phonological-lexical acquisition in signed-language recognition (see review in Corina & Knapp, 2006). As a result, a comprehensive description remains to be made of how signs are added to the mental lexicon, how the phonological patterns of those signs are represented in the lexicon to support word learning, and how signed phonological representations may change over time (Corina, Lawyer, & Cates, 2012).

In beginning to explore these questions with school-aged children, McQuarrie and Abbott (2013) investigated the extent to which sign representations had phonologically segmented structure in the same group of bilingual, profoundly deaf children reported on above (see McQuarrie & Parrila, 2009). In addition to addressing their question concerning the quality of the phonological representations that were established, a goal of this study was to determine what role signed-language phonological awareness (i.e., ASL-PA) might play in explaining the reading abilities of these students. Again, we will not review that work in depth here (see McQuarrie & Abbott, 2013, for full details), but will provide a brief description of the ASL phonological awareness task and a summary of the findings.

McQuarrie and Abbott (2013) used a novel sign-language phonological similarity task that required participants to indicate which of three pictured objects was most phonologically similar to a pictured object cue. Pictured objects were used instead of dynamic video sign presentation of words, because to label the pictures and then make analyses of phonological similarity it is necessary to activate phonological representations stored in long-term memory and to perform operations on these representations to solve the task. Pairs of phonologically related signs (a cue and a phonological target) were systematically manipulated based on the number of sign parameters shared between the pairs. In the first condition, signs shared phonological similarity along all three parameters (H + M + L). For example, in ASL the signs NAME and CHAIR are minimal pairs—the point of contrast is provided by a change in palm orientation. In the second condition, signs shared phonological similarity in two parameters (H + M or H + L or L + M) and differed in the third parameter; for example, EAGLE – GLASS share the same handshape and movement, differing only in location. In the final condition, signs shared phonological similarity in a single parameter (H, M, or L) and differed in the other two parameters; for example, GRASS – LION share the same handshape but differ in both location and movement. Successful performance on the ASL-PA task requires the ability to discriminate phonological contrasts within and between signs to make an accurate phonological similarity judgment. Accurate performance thus provides an indication of the extent of segmental organization, or phonological information, contained in the underlying representation of signs in the mental lexicon. If signed-language phonological awareness follows a similar developmental trajectory to that of spoken-language phonological awareness (i.e., shifting from holistic to segmental representational structure), one should see improved performance in the ability to segment sign forms as a function of increasing age (as a proxy for language experience).

Results indicated that bilingual deaf students are indeed sensitive to signed-language phonological structure and are able to accurately discriminate fine-grained phonological contrasts between signs that share one, two, or three sign parameters. Of note, discrimination accuracy was differentially affected by individual parameters. For example, on the single-parameter sets, similarity judgments based on discrimination of shared movement alone was significantly more difficult than handshape and location similarity judgments. Similarly, across all combined parameter sets of the task, handshape and location patterned together, suggesting that these two parameters were relatively distinctive. McQuarrie and Abbott (2013) interpreted these results as being in line with models of signed-language phonology that posit that handshape and location parameters, like consonants in spoken languages, carry more potential for lexical contrast. Movement, however, may be analyzed as more vowel-like, and, like vowels in spoken languages, may not carry as much contrastive power (see Brentari, 2002). Evidence that individual parameters contribute differentially to the salience of phonological contrasts in sign suggests that, like the construct of spoken-language phonological awareness (see review in Goswami, 2000), the construct and underlying components of signed-language phonological awareness are multifaceted. (See, e.g., Mann et al., 2010, for a discussion of phonetic complexity.)

One finding of significance from the study by McQuarrie and Abbott (2013) was that the ability to segment sign forms improved with age. Older participants did better on the task than younger participants. Although there was a surprising lack of variability in age of exposure (AoE) to ASL (i.e., birth to age 5 years) for participants in the study, it is known that native-like phonological development is particularly vulnerable to any delay in early exposure to robust phonological patterning (see, e.g., MacSweeney, Waters, Brammer, Woll, & Goswami, 2008; see review in Mayberry, 2007). Thus, AoE may offer a partial explanation for differences in performance on the ASL-PA task. Still, the fact that a reciprocal relationship between age and improved discrimination accuracy was observed clearly establishes that the deaf children's signed-language phonological representations did contain increasingly more accurate and more detailed phonological information as the children matured as language users. This demonstrates that the emergence of signed-language phonological awareness follows a similar developmental trajectory in the shift from more holistic to more segmental representations to that seen in the emergence of spoken-language phonological awareness.

In addition, McQuarrie and Abbott (2013) found significant positive correlations between the students' signed-language phonological awareness and English reading skills; deaf students with higher ASL-PA scores had stronger reading skills, as reflected in their word recognition and reading comprehension scores (correlations of .47 and .48 respectively). Evidence of significant relationships between children's English reading skills and signed-language phonological awareness skills is consistent with previous evidence of strong associations between English reading abilities and deaf bilingual individuals' signed-language skills at the level of syntax, grammar, and discourse (see review in Chamberlain, Morford, & Mayberry, 2000), and extends those findings to the phonological level of language. Of note, in a recent meta-analysis, Mayberry, del Giudice, and Lieberman (2011) reported that spoken-language phonological skills explained 11% of the variance in reading achievement among deaf learners across the studies reviewed for the meta-analysis. In the study by McQuarrie and Abbott, signed-language phonological awareness accounted for 23% of the variance in both word reading and reading comprehension. These results support the argument that a strong phonological foundation in a signed language may facilitate the acquisition of reading for bilingual (sign-text) deaf students. Lending support to this hypothesis, evidence from studies of young school-aged bilingual hearing children reading in their new language suggests that, irrespective of the language in which early literacy instruction occurs, if children can establish the basic concepts and skills of phonological awareness in any language, then reading in their new language will be facilitated (see Bialystok, 2007). Therefore, it may be the case that McQuarrie and Abbott's findings reflect similar cross-language transfer of phonological awareness skills between a signed language and the written second language.

While the linguistic study of signed languages is a relatively young field, the evidence available to date suggests that signed-language phonology, like spoken-language phonology, is well suited to the task of establishing segmental representational structure, or what Goswami (2002) refers to as the "cognitive precursor skills" of reading. The implications of this research for reading acquisition and development in bilingual deaf children is discussed below.

Learning to Read With Languages: Educational Implications of the "and"

As Grabe (2009) has observed, "Reading in a second language is an ability that combines L2 and L1 reading resources into a dual-language processing system" (p. 129). Previous evidence of strong associations between deaf bilinguals' signed-language skills and English reading abilities (see review in Chamberlain et al., 2000) are extended by current investigations of signed language–written language pairings across languages. These include, for example, ASL-English (e.g., Chamberlain & Mayberry, 2008; Piñar, Dussias, & Morford, 2011), Dutch Sign Language–Dutch (e.g., Ormel, Hermans, Knoors, & Verhoeven, 2012), German Sign Language–German (e.g., Kubuş, Villwock, Morford, & Rathmann, 2014), and Israeli Sign Language–Hebrew (e.g., Miller, 2002). Data patterns reported across these studies demonstrate that increases in signed-language proficiency are positively associated with reading and academic achievement and provide clear indications of associative relations between deaf bilinguals' languages.

A very recent advance in the field is evidence that deaf bilinguals activate ASL phonological representations during processing of written-English words (see, e.g., Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011). Evidence of cross-language sign phonology–text activation has also been reported in Dutch bilingual school-aged children (Ormel et al., 2012) and in German bilingual deaf adult readers (Kubuş et al., 2014). These findings provide the first evidence of signed-language phonological activation during reading. Evidence that written-language orthographic forms activate signed-language phonological forms demonstrates that cross-language interactions occur across modality, and, importantly, that cross-language activation is not restricted to languages that share phonological form similarities, as previously asserted (e.g., Mayer & Wells, 1996).

Understanding of the role of signed-language phonology in supporting young deaf bilingual readers in the early stages of reading is only just emerging. Evidence that bilingual deaf adult skilled readers activate signed-language phonology in response to print raises new questions about the developmental trajectory and role of signed-language phonology in beginning reading and skilled reading. That is, do very young beginning deaf readers demonstrate nonselective access to their dual languages, as seen in older and skilled deaf readers, or does activation of both languages only occur once some threshold level of proficiency in both languages is achieved? Research exploring these questions will contribute to a more nuanced understanding of how dual languages interact to support reading comprehension for bilingual deaf readers.

We have argued that despite the lack of structural similarity between signed-word forms and spoken-word forms, there is compelling evidence of functional equivalence in the organizational principles that lend shape and structure to the lexicons. However, we suggest that differences in the underlying internal structure of phonological representations (signed or spoken) will dictate how the cognitive problem-solving task of mapping orthography to phonology is accomplished. This may entail fundamentally different mapping units and strategies that are maximally effective for different learners. For the typically developing monolingual hearing child, whose lexicon is richly patterned on spoken-language phonological information and who is learning to read an alphabetic script, the most effective unit of mapping is the phoneme. Ehri (2014) has suggested that hearing children are predisposed to take advantage of grapheme-phoneme connections. Perfetti (2013) has clarified this suggestion of predisposition, writing that "taking advantage of these connections is to use essential computational knowledge rather than reflective knowledge" (p. 39). For the typically developing bilingual deaf child whose lexicon is richly patterned on signed-language phonological information, the most effective unit of mapping between signed-language phonology and orthography is yet to be fully resolved. That is, the determination of whether signed-language phonology contributes directly to establishment of a "bonded" name code (i.e., orthography-sign phonology mapping at some level) and/or if it contributes indirectly (i.e., the cognitive skills of segmentation learned through sign acquisition enable the use of such skill in orthographic segmentation) awaits future research. It is plausible to suggest that since bilingual (sign-text) deaf learners of English (or another L2) are already familiar with one phonological system, that of their native sign language, this may provide a gateway to increasing understanding of a new phonological system.

Crucially, in connection with written-word recognition for all learners, Perfetti (2013) has said that "the main point for acquisition is that quality of word representation is the critical development, not such things as 'access strategies,' 'rules,' 'analogies,' etc.; for measurement, the implication is that spelling facility is the measure of quality" (p. 37). A signed-language phonological system appears optimally suited to establishing the connections that build these quality written-word representations in bilingual deaf learners. Perhaps, then, bilingual deaf individuals are equally predisposed to take advantage of these connections using essential computational phonological knowledge derived from a signed language.

As Grabe (2009) has observed, "L2 reading is not just someone learning to read in another language; rather, L2 reading is a case of learning to read with languages" (p. 129). The development of a robust internal organizational framework based on visual (rather than auditory) phonological patterns may provide a scaffold for bilingual deaf learners in getting access to text-based literacy skills. Learning about the text part of the sign-text equation and developing an understanding of how the writing system works is an achievement that is cultivated through instruction. A developmental and strength-based instructional approach requires making the underlying relationships between signed language and written language explicit. For bilingual deaf readers, this begins with acknowledgment of the dual language resources the child brings to the task of learning to read and sequencing learning in a hierarchy that moves from the known (in the first language) to the new (in the second; see, e.g., Andrews & Rusher, 2010; Hoffmeister & Caldwell-Harris, 2014; Kuntze, Golos, & Enns, 2014).

Demonstration that bilingual deaf signers can develop the ability to read English without the ability to use spoken-language phonology and can develop the ability to write English without the ability to speak it may reflect exposure to written input from the early stages of the learning process; it may also indicate that written input in instructional form constitutes a large part of their overall L2 input. One class of hypotheses posit that visual language skills (signed language) may promote competencies and reliance on visual orthographic word forms (see, e.g., Barca, Pezzulo, Castrataro, Rinaldi, & Caselli, 2013; Kuntze, 2004). Evidence supporting this claim comes from eye-tracking studies of skilled and less skilled bilingual deaf adult readers (e.g., Bélanger & Rayner, 2013; Bélanger, Mayberry, & Rayner, 2013), from studies of the orthographic segmentation strategies that skilled bilingual deaf readers use to read printed words (e.g., Emmorey & Petrich, 2012), from research focused on bilingual deaf adults' and children's use of fingerspelling in both reading and spelling (e.g., Emmorey & Petrich, 2012; Haptonstall-Nykaza & Schick, 2007), and from analyses of morphology and spelling development in bilingual deaf children (e.g., Breadmore, Olson, & Krott, 2012). Across all of these studies, skilled readers, both deaf and hearing, were highly efficient at processing text orthographically. Less skilled hearing readers, but not less skilled deaf readers, relied on spoken-language phonological mediation to support orthographic processing. Evidence that both skilled and less skilled adult deaf readers rely on orthographic knowledge in spelling and reading suggests that reliance on orthography may be equally weighted in developing and skilled reading. The results of these studies point to a qualitatively different approach to processing of text between hearing (speech-text) readers and deaf bilingual (sign-text) readers. Taken together, the weight of evidence suggests that while both deaf and hearing readers are able to abstract the principles of English orthography, bilingual deaf readers and spellers appear to use orthography effectively without spoken-language phonological mediation (see also Bélanger, Baum & Mayberry, 2011; review in Mayberry et al., 2011), whereas hearing readers combine orthography and spoken-language phonology to guide reading and spelling.

Conclusion

Dickinson, Golinkoff, and Hirsh-Pasek (2010) have written that "language is unique among precursor abilities in its pervasiveness for both early and later reading competencies" (p. 308), and highlight the fact that becoming a competent reader who understands text requires age-appropriate language skills. In recent years, unequivocal evidence has surfaced documenting the long-term and profound cognitive and linguistic consequences that delayed or restricted access to a *first* language's explicit phonological patterns (spoken or signed) has on lexical acquisition and the resulting organization of the lexicon in deaf learners (see Corina, Lawyer, Hauser, & Hirshorn, 2013; Emmorey, 2007; Jasińska & Petitto, 2013; MacSweeney et al., 2008; Mayberry & Eichen, 1991; Nittouer & Burton, 2005). This research emphasizes the critical role of timing in language development—with delayed or altered phonological acquisition predicting an "atypical" structure of phonological representations—and highlights how language modality and age of language exposure together shape the language representations, and the processing of those representations, in deaf individuals (see review in Mayberry, Marschark, & Spencer, 2010).

In the present article, we have suggested that a profitable approach to identifying factors that support or impede reading development in the deaf and hard of hearing populations is to examine these factors in reference to particular subgroups of deaf learners, if it is to be clearly delineated for whom, under what conditions, and in what contexts the reading process might be qualitatively similar to or qualitatively different from that of hearing readers. To that end, we have emphasized the intimate and critical link between phonological acquisition (signed or spoken) and lexical learning, and have highlighted the need for increased consideration of the ways in which *prerequisite* language foundations (i.e., cognitive precursor skills) are established if bilingual and monolingual deaf children's literacy and literate thinking processes are to be better supported. We have pointed to the available evidence indicating that signed-language phonology meets the test of representational equivalence (segmental organization of the lexicon) and functional equivalence in the development of that lexicon, supporting efficient phonological processing. This evidence leads us to support a qualitatively different hypothesis in reading processes for bilingual deaf readers—one centered on the relationships among signed-language phonology, lexical restructuring, and written-language literacy acquisition. Such a proposal does not deny that there are fundamental skills underlying reading that all learners must master; it simply recontextualizes what those skills represent and how they might be optimally mastered by bilingual deaf learners. While skilled bilingual deaf readers do indeed "crack the orthographic code" (Grainger, 2008), they do not do so in exactly the same way as hearing readers. The recently emergent and rapidly developing empirical research on dual language activation suggests that orthographic processing does connect with sign language phonological processing during the process of visual written-word recognition. We suggest that continued concerns about whether signed-language forms can directly map to orthography are unproductive (and are the wrong level of analysis), as such concerns obscure questions of greater interest related to how dual languages interact in the mental lexicon of bilingual deaf readers. Consistent with many of the earlier discoveries reported in the L2 (speech-text) literature, emerging discoveries reported in the bilingual (sign-text) literature provide solid evidence that the issue is no longer *if* signed-language skills transfer, but *what*, *when*, and *how* they transfer in the course of reading development. Longitudinal studies are needed to address these questions.

The research reviewed in the present article supports the view that bilingual deaf children and adults are a unique population. Observations of young signing children as they are coming to print allow researches and teachers an exclusive opportunity to learn how this group of learners "redefines the possible" using visual sign language phonology to support reading acquisition. Models, theories, and intervention procedures developed for monolingual and bilingual hearing children cannot be assumed to be fully representative or to be maximally beneficial to bilingual deaf children. Instead, models, assessments, and intervention programs should be derived from the deaf signing population itself and tested for effectiveness with this population (Kuntze et al., 2014; Mounty, Pucci, & Harmon, 2013). While research in the area of signed-language phonology and reading is in its infancy in comparison to that on spoken-language phonology and reading, exciting insights into the enabling relations between signed-language phonological knowledge and reading competence are emerging. Increased understanding of the degree to which sign language phonological processing skills influence the time course of reading development for bilingual deaf readers provides a promising and exciting direction for future research.

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