Reading Optimally Builds on Spoken Language: Implications for Deaf Readers

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Reading is not merely “language by eye.” Rather, it builds fundamentally on primary language processes. For hearing readers, this means that spoken language processes, including phonological processes, are critical to high achievement in reading. We examine the implications of this fact for deaf readers by considering the relationship between language and reading and by reviewing the research on the use of phonology by deaf readers. The research, although mixed in its results, suggests that the use of phonology is associated with higher levels of reading skill among deaf readers. We examine related questions, including the additional semantic and visual strategies available to deaf readers, how some deaf readers gain access to the spoken structure of language, and implications for how to improve reading achievement.

Voltaire, in a 1761 letter to Lord Chesterfield, observed that “the consolation of deaf people is to read, and sometimes to scribble” (Voltaire, 1972). This consolation, however, is gained only through efforts that exceed those required for hearing readers (a fact perhaps not appreciated by Voltaire, who suffered only age-related hearing loss, not life-long deafness). In this essay, we examine why deaf individuals must make exceptional efforts to attain literacy.

To some extent, we may belabor the obvious. Achieving high levels of literacy is difficult because deaf readers have limited access to spoken language. However, we think it is worthwhile to consider this proposition in more detail, establishing as clearly as we can the research foundations on which it rests and drawing out some of its implications for literacy instruction.

We begin by giving an abbreviated account of the logical and empirical foundations that support the proposition expressed in the title of our essay: reading builds optimally on spoken language. We then review some of the research that examines how reading works in deaf populations. Finally, we suggest some implications for literacy education, especially in the context of second language acquisition.

Reading Is Not a Parallel Language System

If language were a matter of choosing among a menu of transmission channels, things would be simpler for all readers, not only deaf readers. Linguistic messages by eye would be as effectively transmitted and received as messages by ear. But they are not. And this point needs some elaboration.

First, it must be made absolutely clear that the effectiveness of the visual channel is not at issue. Humans have highly specialized visual perception systems that allow the rapid transmission of information about objects in the world. Trees, moving cars, and human faces—the last especially significant for human communication—are all easily perceived to great advantage without any special instruction. But the construction of linguistic messages has some properties that do not particularly fit well with the visual channel. The most important of these properties concerns the nature of

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messages that are *linguistic,* as opposed to those that are merely semiotic signs. Because signs are interpretable, they suggest messages, as when the sight of falling snow is viewed as a "message" that travel will become difficult, and one must allow extra driving time. However, there is little but confusion that comes from thinking of such natural sign events as real messages. Closer to the idea of message is the sign created intentionally and viewed in such a way as to recover that intention. When an announcement board at a ski resort shows a drawing of a cloud with white chalk marks underneath, the viewer—with sufficient knowledge—will recover the intended message predicting snowfall. So it is not that messages cannot be communicated through nonlinguistic means. Rather, those human messages that have "linguistic" properties are most effectively transmitted by language, not by sign. What Hockett (1960) called the "design features" of language sharply separate language from mere communication.

The fundamental property of language that matches the properties of human messages is its productivity—the achievement of infinite variety in messages (semantics) by finite means from the structure of language (phonology and grammar). The phonological structure of a language provides the means to recombine meaningless sounds into basic meaning-related symbols (words and morphemes). The grammatical structure (its syntax and morphology) provides the means to recombine basic meaning-related symbols to create real messages. Systems that include structure at both levels—meaningless elements to meaningful symbols, meaningful symbols to meaningful messages—are required to provide the full range of potential human messages. To be clear about the phonology level, it can, in principle, be replaced by some functionally equivalent system. This functional equivalence is accomplished in true sign languages, such as American Sign Language (ASL), which replace a speech system with a productive gesture system.

It is critical to take note of the distinction between ASL as a visually based linguistic *system* and the reading of printed language as a visual *process.* The virtues of an effective human visual capacity transfer to sign language. They do not transfer as well to a visual process that must decode from print a spoken language. Thus, ASL is an effective language system; but visual reading of a spoken language is an incomplete language process. It must be completed by a process that refers to the writing system and the language system on which it is based. In this critical sense, then, reading is not a parallel language system. It is a process dependent on the language that provides the basis of the writing system.

Learning to Read Depends on Learning a Writing System and the Language Encoded by That System

What children learn to read is a writing system. And writing systems—all of them—encode spoken languages This is true not only for the alphabetic systems, such as English and Korean, but for the so-called logographic system of Chinese. It is worth examining briefly the case of Chinese, because it appears to offer the possibility of directly obtaining messages without using language. This impression is based on some ideas about Chinese that are partly true historically but false in the modern system (that characters are picture-like symbols of referents) and others that are partly correct but misleading (that the characters map onto meaning only and not pronunciation).

The mistaken belief that Chinese is pictographic may be no longer very widespread, but it is worthwhile to dispel it clearly. Only a small fraction (probably less than 1%) of modern Chinese characters bear a pictorial resemblance to their referent (DeFrancis, 1989). The characters, over time, not only became more abstract, but even from early times (at least the second century) developed phonetic components as well as semantic components. In modern usage, the majority of characters are compounds that include a phonetic component that potentially provides some pronunciation information, although probably not more than half provide valid information (see Perfetti & Tan, 1999). Chinese writing is connected to spoken Chinese languages. It is not a mapping of symbols to referents, not even a highly abstract one.

The question of whether Chinese is read as a visual-to-meaning system is a different one, of course. The Chinese writing system does allow in principle a direct connection of form to meaning. Indeed, all writing systems can allow this direct mapping, and Chinese is an especially good candidate for a system in which this direct form-to-meaning mapping is used to the exclusion of phonology. Although it is not pictographic, it is partly morphemic; its characters can be said to map the morphemes of the language. However, recent research indicates that despite the potential for a process that picks out only meaning units in reading (bypassing phonology), Chinese reading does not work this way. Chinese readers appear to use phonology (for example, the spoken name of a character) as part of word reading, even in tasks in which meaning is the goal. Tan and Perfetti (1998), reviewing the evidence from different paradigms, concluded that phonology plays a strong role in Chinese word reading.

If phonology is important in reading Chinese, then surely it is important in alphabetic systems, which, by design, build graphic-phonological mappings into writing system at the subword level. Indeed, despite a long history of controversy about the role of "phonological mediation" in reading English words, the evidence has converged on the conclusion that reading English words involves, for the skilled reader, an automatic activation of both sublexical (e.g., phonemes) and lexical level phonology. The issues that remain in this area are about the details of word identification and the kinds of computational models that can account for human word reading data; but consensus assumes that phonology is part of most ordinary word reading (Frost, 1998). Phonology is so pervasive a part of word reading across all writing systems that it is plausible to hypothesize a Universal Phonological Principle (UPP), by which reading routinely includes activation of spoken language units in all writing systems (Perfetti, Zhang, & Berent, 1992). According to the UPP, phonological processes in reading are natural products of language-based human cognition. As a writing system is learned, the reader's phonological processes—indeed, all linguistic processes—naturally accommodate the properties of the learned system. In effect, reading builds on an existing linguistic system, and all readers use phonological processes, if they are able. Speech is ontogenetically prior to print. All children learn a native language; not all children learn to read. Such considerations compel the conclusion that speech processes are privileged as a child begins to learn to read. Furthermore, skilled reading continues to make use of phonological information well beyond the time at which one might suppose it could be discarded.

Learning to Read English

The research on how children learn to read is now clear on several points. Critical for present purposes is the conclusion that phonological knowledge drives acquisition in at least two ways. Awareness of phonemes as meaningless abstractions from the speech stream is important in enabling children to learn to read. And phonological decoding strategies are important in making progress in word identification. The evidence for these conclusions is too extensive to be reviewed here, so we will merely stipulate the existence of sufficient evidence to warrant these fairly conservative conclusions: Children who are successful in learning to read English learn that in the English writing system letters (actually graphemes) correspond to speech sounds, and they use this knowledge in actual reading. Even during the first grade, children who later turn out to be more successful readers are those whose reading errors reflect attention to phonology. Furthermore, the development of skill in reading is closely linked to the child's acquisition of phonemic awareness, a sensitivity to the meaningless segments (phonemes) that are the abstract building blocks of the phonological system. The National Research Council Report (1998) on the Prevention of Reading Difficulties in Young Children reviews much of the evidence on the linkage between learning to read and phonological awareness.

There is more to reading than this phonological component, of course. And the other parts—the role of actual reading experience, the attainment of automaticity in reading, and strategies for comprehension—are very important in considering reading by deaf persons as well. For now, we assert this conclusion about the important role of phonology in learning to read English so that we can explore its relevance for deaf readers.

When Deaf Readers Read English

The crux of the matter is this: How does one learn to read in a language one does not know well? This problem encompasses deaf readers for whom ASL or some other sign language is their first or primary language and deaf readers who, regardless of their ASL status, have not acquired skill in a spoken language (such as English).

If phonology—the structure of speech sounds in a spoken language—is a fundamental level of language structure onto which reading is scaffolded, which is the conclusion that follows from the evidence summarized above, then a child who lacks phonology faces an immediate obstacle in learning to read. There are two general questions to pose in examining this obstacle. First, if phonology is important in reading generally, then it might be important in reading by deaf readers. The question then is whether successful deaf readers gain their success partly through the use of a functional phonology, even if it is not the full-blown phonological system available to hearing readers. The second question, given an affirmative answer to the first question, asks what implications follow for deaf literacy.

We address first the question of whether phonology might be functional for successful deaf readers.

Can Deaf Readers Use Phonology?

To address this question, we summarize what we see in the research literature. Our review, which benefits from earlier excellent reviews by Marschark and Harris (1996) and Alegria (1998), is selective, targeted on experimental evidence that addresses the issue directly. In fact, even the best evidence turns out to be inconsistent on the central question of the use of phonology, and we attempt to sort out the inconsistencies where we can.

Evidence Against the Use of Phonology

Much of the evidence that argues against the use of phonology by deaf individuals comes from research on spelling. In hearing readers, the evidence is that spelling is accomplished not merely visually but by reference to phonology. There is a reciprocal relationship between reading and spelling: Whereas reading converts orthography to phonology, spelling converts phonology to spelling. (See Perfetti, 1997, for a discussion of the spelling-reading relationship). Thus, studies of spelling may reveal deaf readers' use of phonology just as studies of hearing readers do.

Spelling. If deaf readers use phonology in spelling, then one might expect that spelling errors, when they are made, expose phonological process. Errors should preserve parts of the word's phonology rather than its visual appearance. However, the separation of visual form and phonological form is very difficult in an alphabetic writing system. If the word *blue* is misspelled as *bleu*, one might suppose that is a simple visual error of reversing two letters. However, such an error could equally well reflect difficulty in representing the letters that spell the /U/ sound in *blue.* This problem of classifying spelling errors as if they either do or do not reflect phonology is nearly intractable in the absence of independent knowledge of how the speller represents (spells) the sounds. The exception to this dilemma comes when the spelling reflects illegal spelling sequences that can be traced to phonological sources, as when squirrel is spelled SKWRL. But such examples can provide evidence only for phonology, not against it. There is another problem to consider in the classification of spelling errors. Spelling reflects letter sequencing, an ordering task executed manually and with letter-by-letter feedback. In other words, there is a coordination dimension of spelling, not just phonological and visual dimensions. An error that is classified as "nonphonological" (*buel* for *blue*) may appear nonphonological in its surface form. But the error could result from a sequencing error or a subsequent failure of a verification process, with phonology already having been involved in the initial stages of spelling.

Given this problem, what do we make of the studies on deaf readers' spelling? One recent study by Aaron, Keetay, Boyd, Palmatier, and Wacks (1998) was interpreted to show nonphonological spelling in deaf children. In one task, in which participants spelled words in sentence contexts, deaf children's overall spelling accuracy was actually better than that of an age-matched hearing control group; however, an error analysis revealed that the two groups made very different kinds of errors. The deaf children produced fewer phonologically acceptable misspellings than did the hearing children; for example, *bloo* for the target word *blue* was considered phonologically acceptable whereas *buel* was not (a problematic classification, as indicated above).

In another version of this task, the sentence contained target words with one or more "silent" letters (e.g., the *w* in *snow*). The authors assumed that spelling errors that omitted silent letters reflected a use of phonology. Again, the deaf individuals' overall accuracy was comparable to that of the hearing individuals. However, the error analysis indicated that the deaf participants were less likely than the hearing participants to omit silent letters from the target words: deaf students omitted only 38% of the silent letters whereas the hearing groups omitted between 75% and 81%. These two findings—that deaf students failed to make phonologically acceptable spelling errors, and that they tended not to omit silent letters—were taken as evidence that the deaf students did not use phonological cues in spelling to the same extent that the hearing children did. Both findings replicated earlier conclusions based on different methods (e.g., Bellugi, Taeng, Klima, & Fok, 1989; Corcoran, 1966; Dodd, 1980).

A particularly interesting comparison comes from a study by Fok and Bellugi (1986), who analyzed the "spelling" errors made by Chinese deaf and Chinese hearing children. Chinese spelling is interesting because it more successfully evades the confound of how words look with how they sound (although not completely). Although in Chinese spelling, the construction of a character is possible without reference to phonology, Fok and Bellugi found that the spelling of hearing children reflected use of phonology. The errors of the Chinese hearing children in their study tended to be substitutions of one character for another having a similar pronunciation but no visual similarity (errors of homophony). Such results are consistent with studies of adult reading in Chinese, which find that errors in written recall tend to be homophones (Zhang and Perfetti, 1993). In contrast to the hearing participants, however, Fok and Bellugi's deaf participants made few homophone errors. Rather, the errors of Chinese deaf individuals tended to be visually similar character substitutions, or "invented" characters (nonexisting Chinese characters).

Lexical decision. One needs evidence on the phonology issue directly from reading tasks as well as from spelling. Even without the use of phonology in spelling, one possibly would see it in reading. One reading task that has been studied in both hearing and deaf readers is lexical decision. In this task, a subject is presented, one at a time, with a series of printed letter strings and asked whether each string is or is not a word. The general logic of the lexical decision task has been that only a minimal contact with the mental representation of the word is necessary for a positive decision. The individual does not have to consider the meaning of the word. By manipulating properties of the words and nonwords, lexical decision tasks aim to expose the orthographic, phonological, and semantic influences in "lexical access," the process by which a reader accesses the information stored with the mental representation of the word.

One relevant result in lexical decision research with hearing readers is that individuals make lexical decisions faster for regularly spelled than for irregularly spelled words, at least for low-frequency words. A regular spelling is one in which the letters of the word map onto their "regular" or most common pronunciation (e.g., *mint*). An irregular spelling is one in which one or more of the letters map onto irregular or less common pronunciation (e.g., *pint*). Regularity effects have traditionally been taken to demonstrate the role of letter-to-phoneme connections in reading, in effect, evidence that subword phonology (letters and phonemes, rather than whole words) is functional in word identification.

And what of deaf readers making lexical decisions? Waters and Doehring (1990) found that unlike hearing persons, deaf individuals showed no regularity effect. Similarly, Beech and Harris (1997) found that the lexical decisions of their deaf participants were less likely than those of hearing participants to show effects of regularity in reading words; they were also less affected by whether nonwords were pseudohomophones—nonwords with the same pronunciations as real words (e.g., *baik)*—or nonhomophones (e.g., *boik).* These findings were interpreted as suggesting that the deaf individuals relied primarily on whole word (lexical) representations for reading, rather than an "assembled phonology."

Although the data from these lexical decision studies seem to converge with the spelling studies in finding no phonology, there are some cautions to note. One is that it is impossible to draw conclusions about the presence or absence of phonology from a failure to find a difference, which is what the logic of comparing regular and irregular words requires in this case. A failure to find an effect can arise from a number of sources within the performance of the specific task. A second point is that lexical decision tasks do not always expose the role of phonology, for a number of reasons, even with hearing participants. The task includes a stage of "verification" following the activation of the word representation by the letter string. This verification stage can make it more difficult to observe effects that are at the word activation (lexical access) stage, including phonological effects.

More generally, Berent and Perfetti (1995) discuss a number of task factors that influence whether a given reading task is likely to expose phonology. Their most important conclusion is that, in any reading task, regularity effects are indeed evidence of phonology, but findings of no regularity effects are not evidence against phonology. Moreover, some tasks are more sensitive to phonology than others. Brief exposure paradigms that limit the exposure of a word (and thus limit the probability of its being identified) can detect sublexical (letters and phonemes) constituents activated during word identification, thus providing evidence for phonology.

Counterevidence

In contrast to the spelling and lexical decisions studies reviewed above, some studies indicate that deaf persons can and do use phonology in ways similar to those hearing persons use. We review three loosely defined classes of this evidence: measures of phonological development, tasks that probably require the use of phonology, and tasks that need not require the use of phonology.

Phonological development. First, Campbell, Burden, and Wright (1992) pointed out that deaf children who are raised in an oral communication environment show severely *delayed*, though not necessarily *abnormal*, patterns of phonological development. For example, when learning to speak, deaf children made mistakes in their first utterances that were similar to those made by hearing children. For example, both hearing and deaf children simplify and omit "difficult" consonants in clusters. (See Dodd, 1987, for a review of corroborating evidence.) Similar results have been obtained in an analysis of the phonological abilities of Cantonese-speaking children with hearing loss (Dodd & So, 1994). Because the phonological structure of Cantonese, which includes tones, is quite different from that of English, finding similarity between hearing and deaf children in phonological development is especially interesting.

Intentional use of phonology. In asking whether deaf readers use phonology, it is helpful to distinguish between automatic use and intentional use. In hearing adult readers, the conclusions about phonology are about an automatic phonology that accompanies reading. It is of interest to know whether deaf readers can use phonology under some conditions even if they do not use it routinely.

Indeed, evidence from several laboratories indicates that deaf readers can use phonological information when the task requires it, as in rhyme judgments (e.g., Campbell & Wright, 1988; Hanson & Fowler, 1987; Waters & Doehring, 1990). For example, Hanson and Fowler (1987) presented participants with two pairs of (written) words and asked them to judge which pair rhymed. The materials were designed such that participants could not rely on orthographic similarity when making their judgments: All pairs of words were orthographically similar; half were also phonologically similar (e.g., SAVE-WAVE), and half were phonologically dissimilar (HAVE-CAVE). While the deaf participants were less accurate than the hearing participants (64.1% and 99.6%, respectively), they did perform significantly better than chance. Hanson and McGarr (1989) report converging evidence.

One direct window on phonology comes from naming tasks, in which participants read aloud as quickly as possible a word or nonword. By definition, performance relies on phonological output. Additionally, the naming of pseudowords (pronounceable nonwords) requires the assembly of phonology from letters, because there is no actual word pronunciation to "look up." Thus, it is of interest that Leybaert (1993) found that deaf readers could accurately read pseudowords aloud in a naming task, clearly implicating an ability to assemble phonology from letters. Also, like the hearing control individuals, the deaf individuals showed word length, frequency, and lexicality effects (faster naming for real words than for pseudowords).

They also showed faster naming to pseudohomophones (e.g., *bloo*) than to other nonwords, just as hearing individuals do. These data indicate that the deaf participants were capable of mapping orthography onto phonology in ways comparable to those of hearing participants.

Incidental use of phonology. A third category of evidence that suggests a functional phonology in deaf readers comes from tasks in which phonology is not required for performance of the task. In some cases, the evidence for phonology comes from a task in which its use is actually detrimental to the demands of the task.

In hearing persons, studies of short-term memory have shown that the recall of visually presented language is sensitive to the phonological structure. This implies, in the case of printed words, that the phonological information of a word is part of its memory representation, either as a direct part of reading or as a means to maintain the word in memory. A classic result from Conrad (1964) demonstrated memory confusions when adult hearing persons simply had to write down short lists of visually presented letters. Thus, a misrecall of the letter "F" was more likely to result in its phonologically similar "S" than its visually similar partner "E." The discovery that memory for visually presented language relied on its phonological more than its visual information has been very important in establishing a phonological component of working memory systems (Baddeley & Hitch, 1974) that functions during ordinary reading (Baddeley and Lewis, 1981; Perfetti and McCutchen, 1982). Indeed, the recall of visually presented words and sentences is more difficult for readers when the words rhyme than when they do not, suggesting that phonologically similar material interferes with attempts to maintain words in memory. Furthermore, this phonological confusion effect is sometimes more prevalent among skilled readers than less skilled readers (Mann, Liberman, & Shankweiler, 1980), consistent with the assumption that less skilled readers have less effective phonological processing.

Thus, the question of whether deaf readers also show phonological confusions in memory takes on some importance. Indeed, the evidence suggests that some deaf individuals are sensitive to rhyme, performing better when recalling lists of nonrhyming words than rhyming words (e.g., Engle, Cantor, & Turner, 1989; Hanson, 1982; Hanson & Lichtenstein, 1990). This sensitivity to rhyme was also discovered by Hanson and Fowler (1987) in a lexical decision task, in which participants were presented with pairs of words that were either orthographically similar and rhyming (e.g., *beach, teach*) or orthographically similar and nonrhyming (e.g., *couch–touch*). Both hearing and deaf participants were faster to make lexical decisions for rhyming than for nonrhyming pairs. Because of the control for spelling, this result requires the inference that phonological information was accessed and used in this simple reading task.

Rhyming effects involve the vowel system. Phonological effects, however, are found also in consonants. Skilled adult readers in silent reading tasks show interference when reading "tongue twisters" (McCutchen and Perfetti, 1982). Hanson, Goodell, and Perfetti (1991) found evidence that deaf readers, like hearing readers, showed the tongue-twister effect in a task that required participants to make semantic acceptability judgments. They found that both hearing and deaf participants were more likely to make acceptability errors when judging tongue-twister sentences than control sentences (i.e., a tongue-twister interference effect). Their experiment included a memory load manipulation that showed that the source of the phonological interference effect was in the memory system rather than resulting from visual confusions. Participants, prior to reading the sentence, had to read a string of digits and then recall them after reading the sentence. When the names of the digits began with the same consonants (/t/: 12, 20, 10, etc.) as the words in the tongue-twister sentences (e.g., Tom and Tim talked together), both hearing and deaf participants made more errors than when the digits to be remembered were phonetically different from the words in the sentences. This result suggests the effects are truly phonological.

In other reading tasks, phonological interference is manipulated specifically at the level of the single word. For example, in the Stroop task, interference occurs when individuals are asked to name the color of the ink in which a color word is written (e.g., to say *green* when one sees the word RED written in green ink). Individuals are slower and less accurate in this interference condition than they are in several different control conditions. Explanations for the basic Stroop interference effect have been the focus of considerable research, but the various possibilities are generally consistent with the idea of competition between the target name (the color) and the printed word. One specific possibility is that the phonological form of the word is activated automatically even when the participant should try to ignore it. Its activation then yields a phonological output (e.g., the name "red") to compete in the color domain with the name "green." Interestingly, this interference effect is attenuated when the participant makes a manual response (pressing a key corresponding to the target color) instead of a spoken response (e.g., Majeres, 1974). This suggests that part of the interference resides in the phonological output process in addition to interference at the level of automatic lexical activation.

With the strong Stroop effects in hearing readers and the role of phonology in these effects, it is of interest to learn whether deaf individuals show the same degree of interference. Leybaert, Alegria, and Fonk (1983) compared the performance of hearing and deaf groups on both a manual and a naming Stroop color-word task. They found that the interference in the manual response condition was comparable for the two groups, but that deaf and hearing performance in the naming task was equivalent only for a subset of the deaf participants. Those with relatively good speech intelligibility showed an effect comparable to that of hearing participants, whereas those with lower speech intelligibility did not. Leybaert et al. concluded that this pattern of results suggests that some (but not all) deaf readers automatically activate phonological representations when presented with printed word stimuli. Also implicating phonology for the deaf readers is the fact that, like the hearing readers, they showed Stroop interference when the letter strings were pseudohomophones of color words (e.g., BLOO). The differences in the extent to which this paradigm exposes phonological processes as a function of the reader's speech intelligibility is especially interesting. We will return to the speech intelligibility issue in a subsequent section.

Counterevidence from Spelling

Our first look at spelling reviewed studies that were interpreted as indicating that deaf readers spelled without phonology. We now turn to some data from the analysis of spelling performance that counters that conclusion, that is, research suggesting that some deaf readers use phonology when they spell words. Leybaert and Alegria (1995) examined the spelling patterns of deaf and hearing children for French words with spellings that were either phonologically transparent or phonologically opaque. This contrast does not have to do with "regularity" in the usual sense of whether the spelling-sound correspondences are predictable. Rather, it concerns the number of possible spellings associated with a given sound. For example, *bleu* is phonologically transparent, whereas *train* is opaque. The difference is in the spelling possibilities for the vowel portions of the two words. Whereas the vowel sound in *bleu* is usually spelled *eu,* the French vowel sound in *train* is spelled in many ways: *ain, ein, in, yn.* For both groups, accuracy was better for the phonologically derivable spellings than for the opaque spellings. Although the effect was attenuated in the deaf readers, the data clearly imply that both groups had access to phonological information when they spelled the words.

Hanson, Shankweiler, and Fischer (1983) examined the effects of spelling-phonology regularity and found the same pattern, a regularity effect for both hearing and deaf individuals. Campbell et al. (1992) also found deaf individuals to be sensitive to spelling regularity. Like the hearing participants, deaf participants in their study were most accurate when spelling regular words, were less accurate for exception words, and were the least accurate for "strange" words (words with idiosyncratic spellings such as *choir* and *eye*). Notably, all of the errors made by deaf readers were highly "alphabetic," close approximations to the spoken words (e.g., SKWRL for *squirrel,* IORN for *iron,* and SPONCH for *sponge*).[1]

The evidence reviewed in this section indicates that some deaf readers tend to show close to normal patterns of phonological development. Additionally, these studies indicate that deaf individuals accessed phonological information in both tasks that seem to demand the access of such information, and those for which such processing is not necessary and sometimes detrimental for successful completion the task. Finally, we have seen that spelling, which in earlier research provided evidence against the use of phonology by deaf individuals, can also produce evidence supporting a role for phonology. We must conclude that there are many deaf readers who have access to spoken language phonology, even if many others do not. And we must conclude that some literacy tasks expose more phonology than others do.

If we take as correct the conclusion that many deaf readers do not use phonology, we need to take the next step toward understanding what cognitive and language systems support their reading.

The Backup Systems: What Can Be Used Instead of Phonology?

Even if the weight of the evidence is that many deaf readers use phonology in reading, it is equally important that many appear not to or perhaps to use it very ineffectively. Furthermore, the studies that demonstrate a use of phonology by deaf subjects often suggest less usage than that observed for hearing subjects. For successful reading to occur in such cases, we would expect some other component of the cognitive or linguistic systems to take on special importance. Several such alternatives have been suggested, including increased use of visual information, increased use of contextual information, and the use of sign-based recoding. We briefly consider each of these in turn.

Visual Information

One way to compensate for reduced access to phonology is to require more of the visual system. Consideration of this possibility requires us to revisit some of the data reviewed in the previous sections. Recall that whereas hearing individuals tend to produce phonologically acceptable spelling errors, deaf individuals tend to make visual or transpositional errors (e.g., *dook* for *book*, and *ture* for *true*, respectively [Aaron et al., 1998]). Even in those studies taken as evidence that deaf people *do* make use of phonological information when they spell (e.g., Hanson et al., 1983; Leybaert & Alegria, 1995), the deaf individuals still tended to make far fewer phonologically acceptable misspellings than did the hearing individuals.

Our criticisms of exclusive spelling-error categorization remain relevant here. Successful spelling and errors in spelling depend on the coordination of several sources of information, and judgments that an error reflects little or no phonology assess the *product* of spelling, not the *process*. Nevertheless, we think that there is enough in the data across several studies to conclude that many errors have a strong visual basis. One might suggest, then, that visually based errors reflect reliance on visual processing. This is a tenuous causal chain, however, at both links: the classification of spelling products and the interpretation of "visual" errors.[2] But it is plausible: Deaf readers place a high premium on encoding words visually. Sometimes this works, and sometimes it doesn't—just as a reliance on phonology sometimes works or sometimes doesn't.

Further evidence for a visual compensation comes from two studies that have produced evidence that deaf readers have access to phonology (Hanson & Fowler, 1987; Hanson & McGarr, 1989). Hanson and Fowler found that hearing participants, when presented with orthographically similar but phonologically dissimilar word pairs (e.g., *couch-touch*), actually showed significant *interference* on a lexical decision. Their deaf participants, however, showed substantially less interference in this condition. Additionally, when Hanson and Fowler's (1987) rhyme judgment task allowed reliance on spelling information (as in judging *team-beam*, compared with *lean-teen*) deaf individuals relied on such information to a much larger extent than did the hearing individuals. A similar pattern was found in Hanson and McGarr (1989). In this study, deaf individuals were presented with a series of printed words and were asked to generate a (written) rhyme for each. Only 52% of the responses correctly rhymed with the target words. Of those correct responses, 70% were orthographically similar to the target words (e.g., *blue-true*, as opposed to *blue-shoe*). The authors point out that such orthographically related rhymes can be supported by spelling as well as phonology, and so may reflect a reliance on visual information. However, in the absence of data from hearing individuals on this set of words, it is unclear whether 70% is particularly high. It is known that hearing persons' rhyme processes are also affected by spelling (Seidenberg and Tannenhaus, 1979).

A conclusion favoring increased reliance on visual processing of letters comes more indirectly from the study by Aaron et al. (1998), which found that deaf persons tended not to make phonological errors in spelling. However, Aaron et al. also report that deaf persons performed comparably to a group of hearing persons on a task that required them to reproduce pronounceable and nonpronounceable pseudowords from memory. The logic was that whereas the spelling of pronounceable nonwords (e.g., *doof*) could be encoded by either orthographic features (e.g., redundant patterns of letters) or rote-visual memory, the nonpronounceable (e.g., *plta*) could be encoded only on the basis of rote visual memory. Thus, equivalent performance on the two types of stimuli by deaf individuals would be taken as evidence that they relied only on rote visual memory. However, both groups accurately recalled more pronounceable than nonpronounceable nonwords. But rather than conclude that the deaf participants had some access to phonology, Aaron et al. concluded just the opposite, on the grounds that the deaf individuals had already demonstrated their nonuse of phonology in the other experimental tasks.

Contextual Information

Context is important in reading. The text being read and the knowledge the reader gains combine to give critical information for comprehension and interpretation. Research on hearing readers, however, points to differences in how that context is used. Skilled readers, in most situations, use context to build rich representations of the semantic content of a text. However, because their word identification processes are rapid and accurate, probably automatic, there is little opportunity for context to affect the basic process of identification. As a word is identified, context serves to help one verify the identity of the word, to select the appropriate meaning of the word, and to place this meaning in the mental model of the text content that the reader has been building. Less skilled readers, on the other hand, more often rely on context to aid in the identification of the words in a text (Perfetti, Goldman, & Hogaboam, 1979; Stanovich & West, 1981). The general finding is that the differences between skilled and less skilled readers in the speed and accuracy of word identification increases as context becomes less helpful—when the word is presented in isolation and when the context is not supportive. This finding has been interpreted as suggesting that less skilled readers have learned to compensate for their poor word identification skills by relying on contextual information.

It seems reasonable to suggest that deaf readers are capable of compensating in a similar manner. Some evidence supports such a notion. Using a paradigm analogous to that used in the Perfetti et al. (1979) study, Fischler (1985) conducted an experiment investigating the degree to which deaf college students were influenced by sentence context in comparison to hearing college students. In the critical conditions, students were required to make lexical decisions to words that were preceded by a range of sentence context condition: congruous (thus supportive), incongruent, unlikely but acceptable sentence context, and no context. Both groups responded more quickly when target words were preceded by congruous sentence contexts than when they were preceded by unlikely but acceptable contexts. Also, both groups were slower to respond in the incongruous condition than in the unlikely condition. Interestingly, these congruency effects were more robust for the deaf students. Like less skilled hearing readers, deaf readers may rely heavily on the semantic information gained from context to identify the word.

Recoding

The evidence that hearing readers automatically convert printed words into phonological forms has grown substantially (Berent & Perfetti, 1995; Lukatela & Turvey, 1998; van Orden, Pennington & Stone, 1990). (See Frost, 1998, for a review.) Historically, this conversion process has often been referred to as "recoding." Although such a term, because it implies intention and effort, might best reserved for beginning readers, we will adopt it here, because it may apply well to deaf readers. Whether automatic "phonological activation" or "recoding," the process of print-to-phonology conversion supports word identification and produces a representation helpful for memory and comprehension.

For deaf readers, the question is the functioning of recoding possibilities other than spoken language phonology. Treiman and Hirsh-Pasek (1983) investigated whether deaf readers used a recoding strategy based on both speech and nonspeech motor systems. They used a suppression paradigm in which motor movements of various kinds were restricted during reading to observe the effect of suppression of various movements on reading. The recoding motor systems included articulation, fingerspelling, sign-based recoding, or no recoding at all. Based on the criteria of whether deaf students were allowed to use the motor system in question during reading, the researchers found that most deaf participants in their study showed no effects of suppressing articulation or fingerspelling, but some showed an effect when full hand suppression (relevant for ASL) was required. The conclusion was that some deaf readers had a sign-recoding strategy in reading. As for hearing readers, the reading comprehension of deaf readers may benefit from recoding text into another form. Phonological recoding may be considered to recruit a form of speech motor articulation support; ASL recoding can be considered to recruit a form of manual motor support. In both cases, the link between the motor system and the language system is the critical feature.

It is interesting, however, that the deaf individuals in the Treiman and Hirsh-Pasek study who showed no evidence of sign-based recoding were better readers than those that did recode. It is possible that, among deaf readers, the most skilled readers do not need to do sign recoding because they have access to other support for reading, including implicit phonology. Such phonology may not be detectable in the "suppression" paradigm used by Treiman and Pasek (1983) because the relevant phonology is difficult to suppress. It is detectable in other paradigms that expose automatic and rapid phonology, including some paradigms reviewed above. The suppression manipulation affects explicit speech motor movements, but does not necessarily affect the neuromotor structures that underlie phonological representations (Perfetti and McCutchen, 1982).

These results suggest that deaf readers do have access to a sign-based recoding strategy. Such a strategy could be an important source of support to compensate for limited access to English phonology and may be used primarily by deaf readers with very limited access. Such recoding may help represent and reinforce semantic information.

In summary, like less skilled hearing readers, deaf readers develop a range of compensating reading strategies. The degree of similarity between the strategic processing of these two groups is striking. Both deaf and less skilled hearing readers have learned to rely more on visual (orthographic) and contextual (semantic) information than phonological information.

How Do Deaf Readers Acquire Phonology?

The evidence suggests that at least some deaf readers have access to phonology. The question becomes how they have gained such access. A key part of the answer is that access to phonology can be obtained by means other than hearing speech.

Lip-reading

One possibility is that some phonology can be acquired via lip-reading. Seeing speech produced is not strictly necessary for the ordinary auditory perception of speech. Hearing people can understand radio broadcasts, and blind children can acquire normal language processing abilities. However, several lines of research indicate that speech comprehension may be influenced in important ways by vision; specifically, some evidence indicates that lip-reading improves speech understanding in both hearing and deaf people.

The McGurk effect (McGurk & McDonald, 1976) exemplifies such a claim. In this effect, there is a mismatch between the auditory and visual stimuli presented to the participant in a phoneme perception task. Significantly, the phoneme actually perceived by the subject is a product (or compound) of both the visual and auditory information. For example, McGurk and McDonald found that when they showed participants a face pronouncing the syllable /gah/, simultaneous with an auditorily presented /bah/, subjects perceived /dah/. In such a case, the perception of the speech appears to take into account the perceiver's view of the articulators as well as the auditory experience, with neither form of information sufficient in the presence of a conflicting signal. McGurk effects also have been found in very young children (e.g., Massaro, 1987). Even 10–16-week-old infants prefer (measured by gaze duration) faces in which sound and lip movements are synchronized than when they are out of synchrony (Dodd, 1979).

For our purposes, the most important implication of the McGurk effect is that visual lip-reading information can influence speech perception. In theories that place gesture information at the heart of speech perception, the connection between articulation and perception is a fundamental property of the human language system (Liberman and Mattingly, 1985; Fowler 1984). However, even without placing gesture at the center of speech perception, articulation and perception clearly can be connected in important ways. And this has an implication for the development of nonauditory connections to phonology.

In exploring nonauditory connections to phonology, one might usefully consider blind persons. The language development of blind children is at risk from two sources, one linguistic and one cognitive. The cognitive risk comes from reduced input from the world of objects that become associated with spoken words. The linguistic source, which is what concerns us here, is that blind children cannot see how speech sounds are made. Does the inability to see speech being produced affect the phonological representations of the blind? The answer seems to be a qualified "yes." Some studies have shown a higher number of articulatory disorders in blind children when they learn to speak (see Mills, 1987, for a review).

More precisely, blind children have been observed to show the following: a muting of the characteristics that distinguish one sound from another, less lip movement in the generation of certain sounds, and general developmental "delay" in speech production. Mills found that, whereas sighted children tend to learn phonemes with a visible place of articulation (such as the bilabials /b/, /p/, and /m/) more quickly than those whose place of articulation is less visible (e.g., /k g h/), blind children tend to be slower to acquire the highly visible phonemes. Moreover, when the blind children made errors, they tended to substitute phonemes that did not share a place of articulation, for example, substituting phonemes produced in the back of the mouth (velars) for phonemes produced by the lips (bilabials). This pattern is not normally seen in hearing children.

Thus, it appears that information about the movement and shape of the lips in speech production can directly affect the development of a phonological representation, even in people with perfectly intact auditory systems. For deaf persons, who view speech that they cannot hear and may learn to interpret the speech they see, these visual processes may contribute to the development of some partial representation of articulatory phonology (see Summerfield, 1987).

Cued Speech and Related Systems

Although lip-reading is certainly an important contributor to the development of phonological representations in deaf persons, some have argued that lip-reading is not sufficient for the development of a complete phonological representation (Alegria, 1998; Alegria, Leybaert, Charlier, & Hage, 1992; Leybaert, 1998). Lip-reading can provide some phonological information, but the visual information underspecifies the phonology. Any given lip movement can potentially map onto more than one phoneme. Alegria and Leybaert and others have argued that techniques that disambiguate lip-reading may provide "referential clarity," specifying which particular sound is to be associated with the visual information. Alegria and Leybaert focus on a system called Cued Speech (CS). Because the CS system embodies the general principles of such a system, we use it to illustrate the potential role of such systems in general.

Essentially, CS works as follows: The speaker employs hand signals, made adjacent to the mouth, which disambiguate both consonants and vowels. Thus, when a speaker makes a hand "cue" while pronouncing a syllable, he presents his viewer with unambiguous phonological information about the syllable. Several studies have found that deaf people trained in CS improved in their ability to correctly identify spoken words, thereby effectively reducing the ambiguity of lip-read information (Alegria, 1998; Nicholls & Ling, 1982). These CS-trained individuals (particularly those trained at a young age) also tended to show marked sensitivity to rhyme and spoken word-length in recall tasks, and their performance was more like that of hearing persons in a task of rhyme judgment. Importantly, the patterns for the children exposed to CS at a young age at home differed from those of children who had received classic oral training plus CS at school. In rhyme judgment, for example, the school-trained group tended to rely on orthographic and lip-read information, whereas the early exposure group tended to perform almost identically to the hearing controls (see Alegria, 1998, for a review of these data).

CS and systems like it seem promising. The data indicate that subjects trained to process speech with CS at a young age seem to develop phonological representations that delineate contrasts not visible in lip movements. It seems that CS has the potential to allow for the construction of a more complete, *motor* representation of speech-based phonology (see Alegria, 1998, for discussion). If so, then CS could become a useful tool in reading instruction for deaf students; it is feasible that deaf children could be taught to decode texts (mapping orthography to this motor-based phonology) in much the same way that many hearing students are taught to read.[3]

Articulatory Feedback

Another possible route to knowledge about phonology is feedback from one's own articulation. Marschark and Harris (1996) argued that the feedback route might be available to deaf children, allowing them to notice their articulation and to represent it as a speech-motor pattern. They supported this claim with correlational data demonstrating that reading ability was correlated with articulation ability in deaf subjects (e.g., Hanson, 1986; Reynolds, 1986). This hypothesis reflects a sound principle of learning based on a motor feedback loop, and thus is quite plausible. How this loop would work in detail is less clear.[4]

Other Avenues to Phonology

Other routes to acquiring some phonological knowledge have been suggested. Fingerspelling, for example, can provide a motor support system that, although certainly not analogous to phonology, can reinforce spelling representations that can provide a coding system. Learning to write can also reinforce spelling and also link it to phonology. Leybaert, Content, and Alegria (1989) and Campbell et al. (1992) have argued that the phonological knowledge acquired by deaf populations is the product of a combination of fingerspelling, exposure to writing, lip-reading, and articulation, rather than from just one of these. This may be a case in which "more is better." Because deaf people do not have access to the primary pathway by which hearing people develop representations of phonology (namely, audition), multiple routes to a functional phonology are probably helpful.

Phonology and Deafness: A Reconsideration

In this section, we revisit the question of whether deaf readers have access to phonology. Our review suggested an equivocal conclusion. Some studies show that deaf readers have fairly well-developed phonological representations. Other studies seem to demonstrate just the opposite.

To some extent, paradigms and the inferential logic they reflect may be responsible. Some tasks are designed to expose automatic phonological activation during word reading (e.g., Stroop). Others require an inference path through the manipulation of the materials—effects of regularity vs. irregularity, for example. Studies that depend on showing reading or spelling regularity effects, however, are weak tests of phonology. They can expose phonology only if they produce differences. If they do not produce differences, there is no conclusion to be drawn. Even irregular words involve phonology (Berent and Perfetti, 1995). Similarly, manipulations that depend on suppression of vocalization cannot detect phonology unless they produce a positive result, a difference between a control condition and a suppression condition. A negative result has many possible explanations. And spelling, as we have emphasized, is not always a clear window on phonology. Some of the contradictory results could be understood as differences that arise because of different experimental tasks.

However, not all the contradictions can be dismissed this way. Some studies of the same type have yielded contradictory results. Both Aaron et al. (1998) and Hanson et al. (1983) used spelling errors as the evidence for phonology, but they reached different conclusions. Although spelling classification itself is too flawed to deliver conclusions against phonology, we suspect there is a more important reason underlying different conclusions that applies to all tasks, not just spelling: Of the many causes for different findings from the same task, one highly general cause is the participants themselves, especially their skill in components of the task being studied. The participants in different studies are often quite different along several important dimensions: age, reading skill and education level, speech intelligibility, and language experience. It is possible that evidence exposing access to phonology has been obtained from persons who are more skilled in reading and possess higher levels of speech functioning, a possibility pertinent to other studies not finding such evidence.

Age, Reading Skill, and Education Level

Some studies have demonstrated significant differences in the use of phonology among deaf individuals based on age, reading skill, and education level. Leybaert and Alegria (1995) examined developmental trends in word processing and spelling in deaf children; comparing "young" (mean age: 10.9 years, range: 8.7 to 13.4) with "older" (mean age: 13.3, range: 10.4–16.8) deaf children. They found that the older children benefited more from grapheme-phoneme regularities, making fewer spelling errors on regular words and a larger proportion of phonologically accurate spelling errors. Additionally, they found that both deaf and hearing young readers were more likely to rely solely on phonological information for spelling than did older subjects from both groups, who tended to use both phonological and morphemic information. Notice this result does not mean that older readers had reduced access to phonology; rather, they had additional access to morphology.

Indeed, age and skill may generally be associated with greater access to phonology, not less. The studies by Hanson and colleagues, which tended to find evidence for access to phonology in a number of different tasks, were carried out with deaf college students. Besides being older, these students have obtained a higher degree of reading proficiency than most deaf people their age. The differences seen across studies may well reflect the differences between younger and less skilled subjects and older and more skilled subjects. Of these two factors, age and reading skill, the level of skill is probably the more important predictor of phonological functioning. Campbell et al. (1992) found a group of deaf 16–18-year-olds tended to spell less like chronological age controls and more like younger reading age controls.

The relationship between reading skill and phonological processing among deaf people needs to be better understood. Phonological sensitivity likely increases reading skill. In addition, a highly motivated learner with some rudimentary access to phonology, who can accomplish some reading by primarily visual means, might then use reading to begin to recruit new phonological sensitivities. Studies of hearing readers have found a reciprocal relationship between the development of reading proficiency and of phonemic awareness (Perfetti, Beck, Bell, & Hughes, 1987). Phonemic awareness predicts early reading success, which, in turn, predicts more advanced phonemic awareness. Furthermore, hearing adult illiterates tend to have rather poor phonological awareness (e.g., Morais, Bertelson, Cary, & Alegria, 1986). A similar relationship may exist in deaf readers. Experience with reading English could lead to richer representations of phoneme-grapheme correspondences and phonological representations more generally. As Leybaert and Allegria (1995) suggested, print exposure could be even more important for deaf than for hearing readers, serving to enhance the underspecified phonological representations that they have derived through lip-reading.

Speech Intelligibility

Several studies point to speech intelligibility as a factor in access to phonology. In Hanson's studies, participants were not only older, better readers; they also tended to perform better on measures of speech intelligibility and lip-reading. These speech skills are strong candidates for helping to establish phonological representations. If so, they may enable a degree of reciprocity between reading ability and phonological knowledge.

In support of this idea, several studies have found that the success of deaf readers who use phonology is predicted by the intelligibility of their speech. Leybaert and Alegria (1995) found that profoundly deaf persons with intelligible speech produced very different spelling patterns from those with unintelligible speech. Moreover, there was an interaction between speech intelligibility and age such that evidence for phonology in spelling increased with age among subjects with intelligible speech, but not for subjects with unintelligible speech. Additionally, Hanson (1986) found that among a group of deaf college students, those that were rated as having good speech intelligibility were more sensitive to spelling-to-sound regularity than were students with poorer speech intelligibility. Leybaert et al. (1983) found that deaf participants with poorer speech intelligibility showed smaller Stroop interference effects than both deaf participants with good intelligibility and hearing participants.

The link between intelligibility and phonological knowledge should be delineated more clearly. However, intelligibility in production is likely a reflection of basic phonological knowledge coded in articulation, rather than some incidental by-product of experience. Leybaert and Alegria (1995) suggested that the quality of a deaf person's speech output may be commensurate with his or her mental model of speech, such that intelligible deaf people have more accurate representations of phonology.

Language Experience

Deaf people also have different language experiences, and this too should affect later access to phonology and reading ability. The early language experience of deaf children born to deaf parents tends to be very different from that of deaf children born to hearing parents. (See Marschark & Harris, 1996, for a thorough review of this literature.) First, deaf children with deaf parents tend to have a more enriched early language environment, because their parents effectively communicate with them from an early age. Hearing parents of deaf children tend not to share effective linguistic communication at first, and this may lead to delayed language development for these children. Thus, in development of a primary language, deaf children of deaf parents may have an early advantage. Other things equal, language development provides a foundation for reading development. Indeed, deaf children of deaf parents tend to read better than do deaf children of hearing parents.

There is another side to this language question, however. The language to be read is a spoken language such as English, rather than ASL. The gain of having a strong ASL primary system may be partly offset by having little or no knowledge of English, including not only its phonology, but its morphology and syntax as well. In effect, learning to read can become a dual task: learning to read and learning English or some other second language at the same time. Marschark and Harris (1996) summarized this problem clearly:

> There is no more reason to believe that ASL or BSL as a first language will facilitate reading of English than reading of Chinese. Although we acknowledge that early exposure to a regular, conventionalized language is essential for normal reading development, it is important to be cognizant of the fact that the transition from signing to reading is different and more difficult than the transition from a spoken language to reading that same language in printed form. (p. 282)

Why then do deaf children of deaf parents tend to become better readers than those who have hearing parents? In part, the answer may be that acquiring any language well, even if it is not the target literacy language, is better than acquiring no language at all, or only a pale version of the target literacy language. But it is also possible that any advantage to an initial grounding in ASL concerns not the cognitive and linguistic foundations of reading, but the cultural and motivational foundations of educational achievement. There appears to be much more to learn in sorting out the various possibilities. But one important observation suggests the direction of the answer. Marschark and Harris pointed out that early exposure to sign language can benefit children learning English as a second language. However, they also observed that deaf children with one deaf parent and one hearing parent actually tend to do better than children with two deaf parents. This could imply that such a child benefits both from early acquisition of a primary language (ASL) and from acquisition of at least some spoken language.

Summary

We have focused on three general factors that may influence the degree to which deaf readers establish phonological representations of spoken languages. Although these factors are separable, they may combine in complex ways. As in hearing populations, various reciprocal relationships are at play when building complex skills such as language, phonology, and literacy; the three factors that we have discussed probably interact with and build upon each other. For example, children who have intelligible speech have probably had lots of exposure to English and are probably more skilled readers.

Conclusions

On average, literacy levels for deaf people are dramatically lower than they are for hearing people (Allen, 1986). It is obvious that deaf individuals have a unique set of obstacles to overcome when learning to read. We have focused on the role that knowledge about spoken language plays in literacy, neglecting many other variables that may matter greatly for laying a foundation for literacy. Parent expectations, socialization experience, motivation, pedagogical methods, and learning environment can all be expected to be important for literacy achievement. And they may be important both directly and in influencing the acquisition of the language foundations, including spoken language phonology, on which literacy is erected.

We must conclude that reading optimally builds on a spoken language foundation, at least so long as the language of literacy is a spoken language. A reading system based on sign is theoretically possible, but practical considerations have inhibited significant development of this alternative. The research that establishes the spoken language basis of reading achievement in hearing populations is clear. It is no longer possible to suppose that reading is a matter of merely attaching meaning to print without reference to the language system on which the writing system is based. Writing systems have evolved to encode spoken language, and even the one major system that has appeared to be an exception, Chinese, turns out to be a more complex case, based generally on spoken language morphology and phonology.

The case for a privileged status for spoken language foundations for reading has three components: (1) Writing systems have evolved to encode spoken language; (2) hearing children who are successful in learning to read do so by learning to connect spoken language to print; (3) hearing adults (well beyond the age at which speech support for reading should be strictly necessary) continue to demonstrate that implicit speech components are activated as part of reading words. This appears to be true across all writing systems. These three empirical pillars support the conclusion that speech processes are foundational in skilled reading. Again, we emphasize a qualifying condition here: This conclusion must follow for a writing system that is based on spoken language. The universality of speech-based writing systems means these systems have been selected over time for their speech-based properties from among the range of possible systems (Defrancis, 1989; Gelb, 1952). Systems based on pictorial symbols became extinct or were supplemented (in the case of Chinese) by speech-based information. The value of the evolved speech-based systems was their productivity in representing the infinite variety of messages that natural languages allow.

Knowledge about spoken language encompasses more than phonological information: Knowledge of morphology, semantics, and syntax is acquired as part of one's basic competence in a primary language, including ASL. A focus on phonology is warranted because of its centrality in alphabetic writing systems and because of the specific obstacle it presents to deaf readers. The low literacy levels among deaf populations must be partly traceable to the fundamental discrepancy between their incomplete spoken language system and the demands of reading a speech-based system. The morphology and syntax of English, however, present additional obstacles for a deaf learner trying to master written English as a second language.

Against this background establishing the centrality of speech-based reading processes, we have reviewed some research that has examined the functioning of spoken language phonology among deaf people. The evidence presents some contradictions on the surface. However, the conclusion must be that many deaf individuals are able to gain access to phonology and to use it in reading. The evidence suggests that, apart from differences in tasks and the logic of experimental inference that can produce differing conclusions, the central factor involved in producing different results is the background of the deaf individuals in the research.

Deaf persons use phonological information in reading to the extent they have gained proficiency in reading, speech intelligibility, and lip-reading. In short, higher levels of achievements in reading may be linked to access to phonology.

We also reviewed some of the visual and semantic support that deaf readers can use. Even those who achieve some level of phonological functioning are able to use context to support their reading. These compensating procedures allow some success in reading, even if they do not completely make up phonology.

We have not entered a debate about what kinds of language experience are optimal for the deaf child. Success in reading is influenced by two factors that lead in different directions on this question. One is that phonology is important in reading any current writing system, and that is what deaf children do. They read a spoken language, not sign. The second factor is the importance of achieving mastery of a primary language, and for this early learning of ASL is important.

These two factors seem to tug in different directions, one emphasizing maximum early exposure to spoken language and the other emphasizing maximum early exposure to sign. The practical issue involves many questions beyond reading achievement. But we are addressing reading achievement, and it seems reasonably clear that optimal language environments will include both primary language acquisition and functional exposure to speech—where "functional" means real opportunities to observe and somehow use elements of speech. For the question of reading achievement, our conclusion is that the deaf child needs both the foundation of a full sign language system and the foundation of a partial spoken language system.

Notes

1. We note again the difficulty of using some spelling errors as unambiguous indicators. SKWRL for *squirrel* is an error one can attribute to phonology with some confidence; there is no word in English beginning with the letter string SKW, let alone SKWR, so there is no obvious basis for a visual error; a phonological source—the /k/, /w/, and /r/ phonemes mapping onto the letters k, w, and r—is compelling. On the other hand, IORN for *iron* is less certain. The misplaced O could reflect the presence of the two-vowel sequence that is actually spoken in *iron*, a phonological error. or could be a visual confusion that misorders the second and third letters.

2. Inferring that a "visual" error means a greater reliance on visual processing is a non sequitor. It might reflect just the opposite or a range of possibilities in between. For example, an error classified as visual may arise from not attending enough to the exact letters and their order in a word. In effect, visual errors would be the residue of processing from a system that is not very good at phonology and not very good at visual processing either.

3. Of course, a deaf student learning to read English must learn more than simply how to map orthography onto phonology; the task requires learning English as a second language. Our point here is only that the use of CS could facilitate the process by building a phonological representation of reading. We return to the issue of other challenges that face deaf students learning English as a second language in our conclusion.

4. Luria (1976) argued that some of the articulatory deficits of conduction aphasics may be associated with a kinesthesic apraxia for the movements in language production (i.e., an inability to determine the positions of the mouth, lips, and tongue for the production of speech). Lacking this somatosensory feedback, the patients often misarticulate certain language sounds. This may suggest that the presence of such feedback works to improve phonological representations.

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