Understanding Phonological Processing in Reading

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IN THE PAST DECADE, many professionals working in education, psychology, and speech and language pathology have focused on the study of phonological skills and their relationship to early reading. More recently such research has focussed on the use of Functional Magnetic Resonance Imaging (fMRI) technology to generate information about neurological anatomy and physiology relative to the reading process. The type of processing that affects reading ability is usually referred broadly to auditory processing or often the narrower term-Phonological Processing is used. This paper discusses phonological processing and its role in reading and assists the reader to understand this by explaining phonological processing in the following three ways:

1. Phonological Representation,
2. Three Kinds of Phonological Processing
3. The Model of Phonological Processing.

Introduction to Phonological Processing Abilities

Auditory processing and auditory processing disorders have been of interest to researchers and clinicians in the fields of psychology education, and speech and language for much of the present century. Interest in auditory processing and its disorders has been heightened by evidence that their importance is not limited to comprehending spoken language. They play a critical role in learning to read, write, and spell, particularly for alphabetic writing systems such as English. They also appear to be involved in mathemati cal computations. The past decade has witnessed a profound advancement in the understanding of phonological processing (the kind of auditory processing that is most strongly related to mastery of written language, and is clearly implicated as the most common cause of reading disabilities or dyslexia) Phonological processing refers to the use of phonological information, especially the sound structure of one's oral language, in processing written language (i.e., reading, writing) and oral language (i.e., listening, speaking) (Jorm & Share, 1983; Wagner & Torgesen, 1987). When kindergarten children are given phonological processing tasks, their performance is remarkably predictive of how well they will read several years later. On the basis of a growing number of studies of beginning readers, one may conclude that causal relations seem to exist between the development of phonological processing abilities and the acquisition of word-level reading skills: Some phonological processing abilities exert a substantial causal influence on the subsequent development of word reading skills; conversely, letter knowledge exerts a more modest causal influence on the subsequent development of phonological processing abilities (Ball & Blachman, 1988; Bradley & Bryant, 1985; Ehri, 1987; Lundberg, Frost, & Petersen, 1988; Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgesen, & Rashotte, 1994; Wagner et al., 1997). A deficit in some aspect of phonological processing ability is viewed as a cause of the most common form of reading disability (Bruck, 1990; Bruck &Treiman, 1990; Fe! ton & Wood, 1990; Olson, Wise, Conners, & Rack, 1990; Shankweiler & Liberman, 1989; Stanovich & Siegel, 1994; Torgesen & Wagner, in press). The critical problem for the majority of cases of reading disability is at the level of decoding individual words and components of words (i.e., the ability to decode a word phonetically and pronounce it correctly). Deficits in phonological awareness, phonological memory, and rapid naming are common in children with reading disabilities. These deficits appear to be the root of many of the decoding difficulties faced by individuals with reading disabilities.

Levels of Phonological Representation

The term *phonological* derives from the Greek word phone, which means "voice" or "sound." At its most basic level, a spoken word such as cat is represented by varying waves of acoustic energy (Crowder & Wagner, 1991). This representation can be captured in a spectrogram, which represents amounts of acoustic energy by frequency. Analysis of spectrograms reveals that the separation of words into distinct sounds, or even of sentences into discrete words, is largely a cognitive—perceptual phenomenon rather than a result of features of the acoustic signal itself. Breaks in the presence of acoustic energy do not correspond to breaks between letters or even words for the most part. The acoustic signal that travels from the speaker's voice to the listener's ear is largely continuous, despite the perception of individual words and sounds within words.

At the *phonetic level*, a level that is one step removed from the actual acoustic signal, speech is represented by strings of phones or basic sounds of a language. Phones are the universal set of speech sounds found in languages. Each phone represents a particular combination of articulatory gestures, including the placement of the tongue in the mouth, the position of the lips, whether the mouth is opened or closed, and whether the vocal cords are vibrating. The sounds corresponding to the letter 'p' in the words pit, tip, and spit represent different phones, despite the fact that they are represented by a single letter in written English. To verify that the 'p' in each of the three words is produced by subtle differences in articulatory gestures, hold your hand several inches in front of your mouth while saying each word. You will feel a pronounced burst of air associated with the 'p' in pit, a lesser burst of air associated with the 'p' in tip, and virtually no burst of air associated with the 'p' in spit.

At the *phonological level*, which is one step removed from the phonetic level, related phones (called allophones) are combined into families called phonemes. Phonemes represent differences in speech sounds that signal differences in meaning—they are differences listeners hear when attending to speech in everyday conversation. At this level, the three phones associated with the 'p' in pit, tip, and spit are allophones of the single phoneme "p". The phoneme /p/ is distinguished from the phoneme "k", which signals the fact that the words pit and kit have different meanings. All spoken words in English can be represented with a set of 35 to 45 phonemes depending on which classification system is used (Denes & Pin- son, 1963). At still higher levels, phonemes can be combined into larger units, such as onsets (i.e., the initial consonant or consonant cluster of a syllable), rimes (i.e., the remaining vowel and consonant or consonant cluster), syllables, and words.

Three Kinds of Phonological Processing

Three kinds of phonological processing appear to be especially relevant for mastery of written language:

(i) Phonological Awareness
(ii)Phonological Memory
(iii)Rapid Naming

Phonological Awareness

Phonological awareness refers to an individual's awareness of and access to the sound structure of his or her oral language (Mattingly, 1972). The spoken words of a language represent strings of phonemes that signal differences of meaning. The spoken word cat has three phonemes, each of which happens to correspond to the sound made by the three letters of the printed word CAT. Change the first sound from "k" to "b" and you have the spoken word bat. Of the nearly infinite number of possible strings of

phonemes that might be represented in an oral language, only a relatively small number actually occur, and these occur in multiple words. Children who have some awareness of this structure seem to have an

advantage learning to read the printed forms of a language. This makes sense given that many printed languages attempt to convey pronunciation as well as meaning, and even more so for alphabetic languages such as printed English because letters of the alphabet have a rough correspondence to phonemes.

As children develop, they demonstrate awareness for increasingly smaller phonological units of speech. Initially, their awareness is limited to word-length phonological units, as in recognizing the two parts of the compound word cowboy. Next, they become aware of syllables within words, as in recognizing each syllable of the two-syllable word seven. Eventually, awareness proceeds within the syllable to recognition of onsets and rimes. For example, for the first syllable of the word seven, the onset is the sound of the initial 's' and the rime is the sound of the vowel and remaining consonant 'ev'. Eventually, awareness is demonstrated for individual phonemes within syllables. Awareness occurs for individual phonemes within rimes, as when recognizing the sounds represented by the letters 'e' and 'm' in the word stem. Subsequently, awareness of individual phonemes within consonant clusters occurs, as when recognizing the sounds represented by the letters 's' and 't' in stem.

An important reason for assessing phonological awareness is that clear implications for intervention exist. Many children who are weak in phonological awareness show improved reading performance after being given intervention designed to improve their phonological awareness (Ball & Blachman, 1991; Brady, Fowler, Stone, & Winbury, 1994; Bradley & Bryant, 1985; Cunningham, 1990; Lundberg et a!., 1988; Torgesen, Morgan, & Davis, 1992). In general, reading approaches that feature systematic, explicit instruction in phonological awareness and phonetic decoding skills produce stronger reading growth in children who are weak in phonological awareness compared with reading approaches that do not teach these skills explicitly (I. S. Brown• & Fekon, 1990; Fekon, 1993; Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Hatcher, Hulme, & Ellis, 1994; Lovett, Borden, Lacerenza, Benson, & Brackstone, 1994; Torgesen, Wagner, & Rashotte, 1997; Torgesen et al., in press).

Phonological Memory

Phonological memory refers to coding information phonologically for temporary storage in working or short-term memory. When you attempt to remember a phone number you have looked up, as you make your way to the phone, you are storing the number temporarily in working memory. You probably do so not by storing a visual representation of the sequence of digits (although you may be able to do this if you try), but rather by storing a phonological representation of the sounds of the digit names.

The part of memory most involved in storing, phonological information is called the phonological loop. The phonological loop provides a brief, verbatim storage of auditory information (Baddeley, 1986, 1992; Torgesen, 1996). The phonological loop consists of two parts working together. The first is a phonological store, which can be thought of as a tape recording loop that retains the most recent 2 seconds worth of auditory information that has been recorded. The second is an articulatory control process that provides input to the phonological loop initially and also can refresh information already in the loop so that it can' be stored for longer than 2 seconds.

A deficient phonological memory does not appear to impair either reading or listening to a noticeable extent, providing the words involved are already in the individual's vocabulary. However, phonological memory impairments can constrain the ability to learn new written and spoken vocabulary (Gathercole & Baddeley, 1990; Gathercole, Wil1is, & Baddeley, 1991). Studies of elementary school age children indicate that deficits in phonological memory result in impaired development of written and spoken vocabularies (Gathercole & Baddeley, 1990).

Perhaps the most comprehensive investigation of impaired phonological memory is a series of over 20 experiments that investigated the consequences of poor phonological memories for children with reading disabilities (Torgesen, 1988, 1996; Torgesen & Houck, 1980; Torgesen, Rashotte, & Greenstein, 1988). Early studies demonstrated that the origin of the memory deficit was a specific deficit in phonological coding of familiar verbal materials such as digits and words. Alternative explanations, such as inattention, anxiety, poor use of mnemonic strategies, or poor motivation, were ruled out. The children were not impaired in short-term memory for nonverbal material, longterm memory, or listening comprehension; however, they showed severe impairments in decoding visually presented nonsense syllables. When followed up approximately a decade later, over half of the individuals still had severe memory impairments, and those who did showed almost no improvement in reading skills. Finally, consistent with the studies of Gathercole and Baddeley (1990), individuals with impaired phonological memories as children scored poorly on the Vocabulary subtest of the Wechsler Adult Intelligence Scale a decade later, yet performed adequately on nonverbal performance subtests such as Block Design. This means that intelligence test such as the WISC IV will be less reliable for those students who have significant phonological processing problems.

Phonological coding in working memory may not be all that important for reading common known words, although some controversy exists about this assertion (Crowder & Wagner, 1991). It is clear, however, that phonological coding in working memory is potentially more useful when attempting to decode new words, particularly words that are long enough to decode bit by bit, as a means of storing intermediate sounds.

Rapid Naming

The third kind of phonological processing is rapid naming. Rapid. naming of objects, colors, digits, or letters requires efficient retrieval of phonological information from long-term or permanent memory. When reading, young readers presumably retrieve (a) phoneme associated with letters or letter pairs, (b) pronunciations of common word segments, and (c) pronunciations of whole words. The efficiency with which children are able to retrieve phonological codes associated with individual phonemes, word segments, or entire words should influence the degree to which phonological information is useful in decoding printed words (Baddeley, 1986; Wolf, 1991).

Measures of rapid naming require speed and processing of visual as well as phonological information. Some researchers who study rapid naming suggest that rapid naming tasks assess the operation of a precise timing mechanism that is important for the developing knowledge of common letter patterns in printed words (Bowers & Wolf, 1993; Wolf, 1991). Consequently, individuals who show poor performance on rapid naming tasks are expected to have difficulty reading fluently. Individuals who have double deficits—that is, deficits in both rapid naming and phonological awareness—appear to have greater difficulty learning to read than do individuals with deficits in either rapid naming or phonological awareness alone (Bowers & Wolf, 1993).

The Model of Phonological Processing

The frame of reference described above can be depicted in a model of phonological processing (Wagner & McBride-Chang, 1996; Wagner et al., 1987; Wag ner & Torgesen, 1987; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wag ner et al., 1,994; Wagner et al., 1997). This model is presented in Figure 1

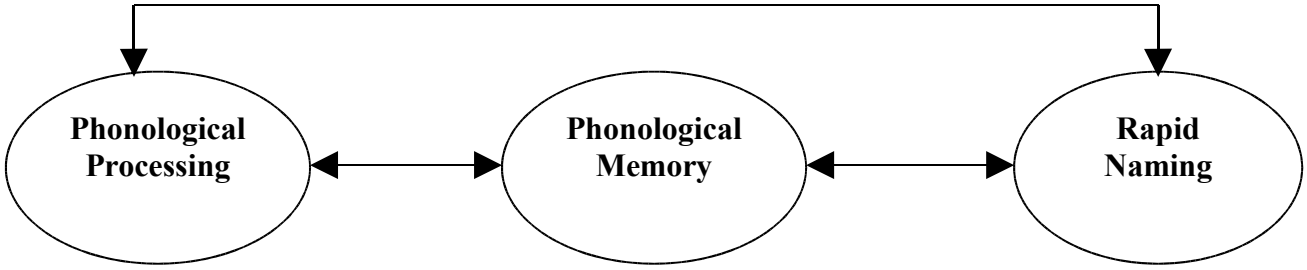

Figure 1.1. The Model of Phonological Processing.

Phonological Awareness, Phonological Memory, and Rapid Naming represent three correlated yet distinct kinds of phonological processing abilities. These abilities are correlated rather than independent. In general, phonological awareness and phonological memory tend to be more highly correlated with one another than with rapid naming. In addition, the three kinds of phonological processing abilities tend to become less correlated with development. For very young children, phonological awareness and phonological memory can be nearly perfectly correlated (Wagner et al., 1987; Wagner et al., 1993)

Interventions

Children with well-developed phonological awareness learn to read more easily than do children with poorly developed phonological awareness. A deficit in phonological awareness is viewed as the hallmark of reading disability or Dyslexia. Poor phonological awareness is associated with poor reading in almost all individuals who struggle in learning to read.

However of the three kinds of phonological processing, phonological awareness appears to be the most responsive to interventions. For individuals with a deficit in phonological awareness who are at or below the initial stage of reading acquisition, intervention designed to promote phonological awareness may prove fruitful. For individuals with a deficit in phonological awareness who are beyond the initial stage of reading acquisition, a more productive way to enhance phonological awareness is likely to be in the context of a reading program that is structured and systematic, and that explicitly points out connections between spoken and written language (e.g., letter— sound correspondences, blending skills).

This paper has, in a brief manner, attempted to assist the reader to conceptualize Phonological Processing relative to reading and therefore, almost by default, help in understanding that phonological processing deficit lies at the heart of early reading failure. This said, the converse is a welcoming thought, in that a proper appreciation and treatment of phonological processing difficulties will enhance reading ability and related literacy skills.