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Words to Meanings

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At the beginning of our long collaboration, Isabelle Liberman and I were concerned with testing explanations of reading problems that were current at the end of the 1960s. At that time, ideas about causation regularly invoked neuropsychological concepts such as poorly established cerebral dominance. Reversals of letters and words were still considered to be the hallmark of dyslexia (Hermann, 1958; Orton, 1925). As for treatment, that was the heyday of motor patterning, balance beams, and eye exercises. Our early work was devoted more to showing what reading disability was not than to explaining what it was (e.g., I. Y. Liberman, Shankweiler, Orlando, Harris, & Bell-Berti, 1971). Of course it is appropriate, in principle, to seek out the biological bases of reading problems. Indeed, that search has enjoyed some recent successes, but from where we stood in the 1960s, the question of mechanism was premature. The basic work of describing the phenotype had not been done.

Absorbed as we were with the task of clearing away explanations of reading difficulties that ignored the phenomena of reading, we only later came to focus on the concept of phonological awareness. This idea emerged when we began to ask ourselves what could be involved in learning the alphabetic principle and why that might be so much harder for a young child than development of the spoken language. Because writing transcribes language, it seemed natural to ask how reading builds on the foundations of the child's development of primary language. Some of the groundwork and tools we needed to pursue these questions were at hand. Research on reading was new to Haskins Laboratories at the time, but the environ-

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In 1998, the SSSR gave its award for Outstanding Scientific Contribution to the Study of Reading to Alvin M. Liberman, the late Isabelle Y. Liberman, and Donald Shankweiler. This article is based on Dr. Shankweiler's talk at the awards presentation at the annual meeting of the SSSR in San Diego, April 1998.

ment of the Labs contained the right nutrients for productive ideas to take root, and the concept of phonological awareness evolved in discussions with our colleagues Alvin Liberman and Ignatius Mattingly.

Making the connection between the discrete letters of the written word and the phonologic segments they represent is the core of reading. We proposed that this connection requires an awareness that all words can be decomposed into phonologic segments. But speech is not an acoustic alphabet; successive segments are coproduced in such a way that they overlap. So there cannot be simply a straightforward matching of letters and segments. We knew that the principle of alphabetic writing was considered to be a late discovery of our species. So it made sense that it might also be somewhat difficult for a child to grasp (I. Y. Liberman, 1973; Mattingly, 1972; Shankweiler & Liberman, 1972).

But when we looked for research that would support this hypothesis, we came up with very little. By and large, people had not asked the question whether preschool children can apprehend phonological segments. When we carried out our own studies of the question, we found that, in general, preschool children lack awareness of phonemes, although many have some appreciation of larger phonological structures such as syllables (I. Y. Liberman, Shankweiler, Fischer, & Carter, 1974). So, we then had evidence in hand that at the threshold of beginning reading most children lack awareness of the phonemic segments that are the basis of alphabetic writing. Subsequently, the work of other researchers at Haskins Laboratories and elsewhere yielded direct evidence that training in phonological awareness promotes reading and spelling later on.

By the mid-1980s the importance of phonological awareness for reading was being taken seriously by a sizable group of researchers and practitioners, and by this time it had become apparent that the problems of the poor reader were not limited to achieving awareness. Problem readers also had other difficulties in the phonologic domain (in phonetic perception, naming, and memory) that we and many others have continued to explore.

My purpose is to place phonological awareness in the context of the problems of reading and the other symptoms of reading disability. The need to be both brief and wide ranging forces me to be selective in making reference to the research literature; much of the documentation that a full discussion of these problems would require has had to be omitted. Because Isabelle Liberman is a corecipient of the Research Award of Society for the Scientific Study of Reading (SSSR), it is appropriate to note places where her influence has been especially strong.

ASSERTIONS

The body of this article contains eight assertions about the development of reading and its difficulties (or, more accurately, seven assertions and a promissory note).

1. Emergence of Phonological Awareness Follows a Developmental Pattern

Phonological awareness, to put it in a nutshell, is the ability to make judgments about the phonological structure of spoken words. Ability to distinguish minimal pair words (e.g., *bat/pat*) does not imply phonological awareness. Awareness is not a matter of skill in phonetic discrimination or identification. These abilities go hand in hand with knowing a language, but phonological awareness does not come free with language acquisition.

Segments come in different kinds and sizes. So phonological awareness is not all of a piece. It is a group of related abilities, each with different cognitive requirements and its own developmental course. Children apprehend words, syllables, onsets, and rimes earlier than they apprehend phonemes (Treiman, 1985). Studies of illiterate adults by the Brussels group showed that, in general, even extended experience with the spoken language does not by itself result in ability to isolate phoneme segments (Morais, Cary, Alegria, & Bertelson, 1979). In this connection, Byrne (1996) showed that preliterate children tend initially to assume that letters represent units of meaning (i.e., *morphemes*), not units of phonological form. The tendency to try to connect letters directly to meanings points to another reason that the meaningless segments of words, their *phonemes,* are not particularly salient for children.

As to the importance of maturation versus specific experience, Isabelle and I surmised that each would play a role in the development of awareness. We noted that the beginning school child does not start out at ground zero. Syllable awareness and, as others have shown, rhyme awareness are found in many preschoolers; full phoneme awareness is found in few. We observed a spurt in both syllable and phoneme segmentation abilities after school onset, suggesting the influence of reading instruction on the development of awareness (I. Y. Liberman et al., 1974). Effects of schooling and other age-related factors were partitioned and separately measured by Bentin, Hammer, and Cahan (1991).

The fact that reading instruction may, and often does, include activities that promote phonological awareness does not mean that instruction necessarily has this effect. Indeed, there is clear evidence that children taught by an exclusively whole word method do not infer the alphabetic principle by print exposure alone (Seymour & Elder, 1986). Byrne (1992) found that even controlled print exposure, focusing on minimal contrasts, did not lead most beginning readers to infer the alphabetic principle unless they had been previously made aware of segments and had the correspondences with print explicitly pointed out to them. Children also do not infer the alphabetic principle from training in letter sound correspondences alone, as experiments by Ball and Blachman (1991) showed. For such training to be effective, it needs to be combined with training designed to promote phonemic awareness.

Isabelle and I and our colleagues put our faith in the importance for the would-be reader of becoming aware that words come apart into segments. Regarding phonological awareness to be a prerequisite for literacy, as we did, is not to deny that awareness and literacy are reciprocally related (see Mann & Liberman, 1984). Experience with reading and writing could be expected to augment and refine one's awareness of segments. Some aspects of sublexical structure seem to be chiefly antecedent to reading, and others are more apt to be consequent. We still have much to learn about the path leading from preschool phonological abilities to reading.

In the early years, we assumed that the critical insight leading to awareness was specifically metalinguistic. We assumed that speech-based phonetic representations, which later get hooked up with print, are segmented, part of children's natural endowment for language. We did not think of the underlying representations themselves as plastic, developing entities. Persuaded by the arguments of Michael Studdert-Kennedy (Studdert-Kennedy & Goodell, 1995) and Anne Fowler (1991), I now embrace the hypothesis that the grain of the underlying representations changes during development from relatively coarse at the onset of speech to become more finely segmented and detailed in later childhood. Phonemic organization of word representations is not a given but the result of a developmental process that undergoes reorganization under the pressure of vocabulary growth. If this view is right, then the emergence of phonological awareness is largely constrained by the development of the underlying representations.

Orthographies vary in their phonologic transparency and apparently in their cognitive demands. In this connection, Wimmer complained that research on the problems of learning to read and to spell is "anglo-centric" (Wimmer, 1993; Wimmer & Landerl, 1997). I agree. Our conceptions of phonological awareness and reading have much to gain from cross-language study. This was Isabelle's view. She was an early and forceful advocate of a comparative approach, working with collaborators in several countries to design appropriate research. Studies conducted with children in more than a dozen language communities have borne out the critical role of phonological awareness in learning to read in an alphabetic system.

It is also true, however, that cross-language data strongly suggest that the ease or difficulty of segmental analysis and its use in reading and spelling is not the same across all systems that use an alphabet. Studies on Italian preschoolers, conducted by Cossu, suggest that it is somewhat easier to isolate the phoneme segment in an open-syllable language like Italian, than in a closed-syllable language like English (see Cossu, Shankweiler, Liberman, Tola, & Katz, 1988). In addition, the locus of reading problems may vary across systems. To give just one example, vowels in English are misread twice as frequently as consonants (C. A. Fowler, Liberman, & Shankweiler, 1977). But in German, Italian, and Serbo-Croatian, consonant errors prevail; English is the outlier (Shankweiler, 1994). Observations like these are more than just curiosities; they need to be interpreted. Cross-language comparisons are

important, because only in this way can we hope to learn which of the problems of reading are universal and which ones are specific to particular linguistic environments (Elbro, 1996; I. Y. Liberman, Liberman, Mattingly, & Shankweiler, 1980).

2. Early Instruction Designed to Promote Phonological Awareness and Letter Knowledge Confers an Advantage in Reading and Spelling That Is Measurable Years Later

Success in a variety of reading skills depends on establishing phonological awareness at an early stage. But neither awareness nor letter knowledge is sufficient by itself to instill the alphabetic principle. Children need to be taught about words coming apart into segments and about the letters and letter groups that represent them. Children given explicit instruction in phonemic organization in preschool become better decoders as beginning readers and in some studies show an advantage in reading and spelling skills years later (Bradley & Bryant, 1983; Brady, Fowler, Stone, & Winbury, 1994; Byrne & Fielding-Barnsley, 1995; Lundberg, Frost, & Petersen, 1988).

Several researchers have tried to gauge the size of treatment effects and their duration. There is some cause for concern on both counts, especially with learners whose heredity or environment place them most severely at risk. Torgesen, Wagner, and Rashotte (1997) and Olson, Wise, Ring, and Johnson (1997) maintained that the evidence for lasting effects of training is weak for such populations. This is cause for concern because the hope that impels research on treatment is that training to promote phoneme awareness, delivered in the right way at the right time, inoculates children against reading failure, even those children who are most at risk.

But, realistically, should we have hoped for better than has been achieved in training studies? The remarkable thing is not that the effects are small, but that there are any measurable effects after years have elapsed in ordinary schools in which there was no coordination of the subsequent curriculum with the intervention. Until well-designed programs of intervention are fully coordinated with the efforts of suitably trained teachers, we should not underestimate the importance of short-term gains. As Stanovich (1986) described in his discussion of Matthew effects, small differences in the early school years can result in major skill differences later.

3. Phonologic Analysis of Print (Decoding) Is Necessary for Acquiring Reading Mastery in an Alphabetic System

Phonology is indispensable to reading for the same reason that it is indispensable to spoken language. Its primary function, A. M. Liberman (this issue) reminds us, is to

make productivity possible. By combining and permuting a few dozen consonant and vowel segments, an almost unlimited number of words may be formed. Alphabetic writing captures this advantage for the reader, but only for the reader who grasps the alphabetic principle and knows how to use it.

Decoding is the use of phonological awareness and letter knowledge to make informed guesses about the identity of new words. Novel words cannot be decoded without concomitant awareness of the segmental nature of speech. Teaching beginners to relate letter patterns to phonological patterns requires skill. Isabelle warned against teaching practices that could mislead the learner to wrongly suppose that words consist of strings of sounds. That mistake leads to the further error that individual letters represent discrete pronounceable units. These misapprehensions frustrate a child's attempts to decode because, invariably, they lead her or him to a nonword instead of to a word. So, in the three-letter word *bag,* thinking that *b* says *buh, a* says *ae,* and *g* says *guh* leads not to the word *bag* but to *buh–ae–guh,* a three-syllable nonword (I. Y. Liberman, 1971).

But possession of decoding skill alone does not make someone a skilled reader. Share (1995) noted that decoding skill only provides opportunities for self-teaching. Other factors, such as amount of print exposure and memory, influence the outcome as well. Sophisticated procedures for word recognition cannot be taught, but the rudimentary word attack skills the beginner needs to bootstrap into lexicalized reading can be taught directly and should be.

It is possible to read an alphabetic orthography at a coarser grain than phonemically. Some beginning readers, for example, treat printed words as logograms. Logographic reading does not require using or understanding the alphabetic principle. But that way of reading offers no way to attack new words, and consequently the burden on memory becomes insupportable when the reading vocabulary expands beyond a certain point (Gough & Hillinger, 1980). For skilled readers, skill in decoding is nearly autonomous; words can be read nearly as well in list form as in the context of connected text (Nicholson, 1991).

The best test of the ability to recognize novel words is reading phonotactically legal nonwords. Analyses conducted by Gough and Walsh (1991) suggest that exception word skill is dependent on prior establishment of skill in decoding. Children who are better decoders are better able to learn new exception words. They are also better comprehenders of what they read. Nonword reading correlated with comprehension at .8 in the Yale–Haskins studies of children 7 to 9 years of age (Shankweiler et al., 1995; Shankweiler et al., 1999), and this agrees with other results in the literature (e.g., Hoover & Gough, 1990). Longitudinal studies by Freebody and Byrne (1988) found that children who failed to establish good decoding skills at the beginning had a poorer prognosis for reading comprehension in later grades.

4. Phonological Awareness Is Largely Absent in Dyslexic Children and Adults, and Nonword Decoding Skills Are Correspondingly Weak

Dyslexic adults are remarkably like dyslexic children. Problems with phonological awareness plague dyslexic individuals at all age levels. This was the conclusion that Isabelle reached in the mid-1980s based on exploratory work undertaken with Rubin, Duques, and Carlisle (I. Y. Liberman, Rubin, Duques, & Carlisle, 1985). More recently, Bruck's (1992) reading-age match comparisons indicated that the stability of adult dyslexics' problems with awareness may not be entirely a matter of limited reading experience. Adult college-educated dyslexics actually performed at a lower level than unimpaired children in the 6th year of elementary school (see also A. Fowler & Scarborough, 1993).

Twin studies have confirmed that children from affected families have a heightened risk of developing reading problems. The Colorado Twin Studies conducted by DeFries, Olson, Pennington, and their colleagues have yielded specific evidence that weakness in phonological analysis and its products (including nonword decoding and word-specific knowledge of spellings) is the strongly heritable element in dyslexia (Olson, 1994).

It has often been claimed that long-term poor readers are incapable of profiting from instruction that is phonologically analytic and that they can only be taught by a global sight–word method. This is a belief that Isabelle battled during her whole career (see I. Y. Liberman & Mann, 1981). She would be pleased to know about recent studies designed to evaluate success in teaching basic phonological skills to children who were ill prepared for reading or had failed with other teaching methods (Foorman, Francis, Fletcher, Winikates, & Mehta, in press; Tunmer & Chapman, 1997; Vellutino, Scanlon, & Sipay, 1997). Children who carry heavy risk factors may require a more intensive level of instruction than unselected children. In this regard, it is most important to appreciate that genetically influenced does not mean unmodifiable (Wise, Olson, Ring, & Johnson, 1998). Educating the public on this point could go a long way toward overcoming the hostility of some parents and educators to biologically based approaches to reading disability.

5. Deficient Phonological Awareness Is One of a Group of Symptoms That Stems From a Weakness of the Phonological Component of Language

What do we mean by a "phonological weakness," and how is it expressed by the poor reader? The notion of plastic and variable phonological representations may

be germane. The proposal is that children may vary in the grain of their phonological representations. Some may store words at a course grain corresponding to loosely organized gestural complexes. Others may store them at a finer grain as combinations of phoneme segments. Phoneme-level representation is arguably the organizing principle of the mature lexicon because only in that way could productivity be assured. In children with coarse-grained representations, development of full phoneme awareness could be blocked, and correspondingly, the alphabetic principle would be opaque to those children.

From this perspective we could surely expect that dyslexic persons would be at a disadvantage in other behaviors that depend on phonological representations, and they are. They usually score poorer than normal on tests of short-term memory for verbal materials (Brady, 1991), rapid and accurate naming (Katz, 1986; Wolf, 1991), perception of speech in noise (Brady, Shankweiler, & Mann, 1983), and the degree to which perception of phonologic segments is categorical (Godfrey, Syrdal-Laskey, Millay, & Knox, 1981).

The Yale–Haskins study (B. A. Shaywitz et al., 1991) was undertaken some years ago to better define the phenotype or phenotypes of reading disability, based on a diverse sample of school children with learning problems. We asked whether the cognitive profile of reading disability is distinguishable from that of other learning difficulties, such as arithmetic disability and attention deficit disorder. The answer was clearly *yes*. Children with a specific reading deficit were distinguished from those with a specific deficit in arithmetic by their profile on phonological measures, most of all on phonological awareness (Shankweiler et al., 1995). For arithmetic, unlike reading, there is perhaps no single key that unlocks the possibility of skill development.

The phonologic deficit hypothesis draws support from biogenetic data. One example, to which I referred, is that genetic variation related to dyslexia and reading differences is greatest on tasks that require phonological analysis, such as nonword reading and phoneme segmentation. In collaboration with colleagues at Yale Medical School, our research group was excited to report recently that a similar degree of specificity emerges in patterns of brain activation during reading-related activities. It was shown that differences between dyslexics and nonimpaired readers, both in performance on the critical tasks and in the corresponding brain activations from functional magnetic imaging, are maximal when the experimental task engages phonologic analysis and assembly (S. E. Shaywitz et al., 1998).

6. The Cognitive Profile That Characterizes Poor Readers Is Largely Independent of IQ

The idea that specific reading disability should be defined on the basis of a discrepancy between achievement and expectation based on IQ has been a methodological

canon and is entrenched in federal law. The belief was that only through such a procedure could we isolate a group of poor readers sufficiently homogeneous to enable us to reach definite conclusions about the characteristics and prognosis of reading disability. I formerly shared this belief. Len Katz and I used to argue about it. The data eventually showed that Len was right. He can take some satisfaction from recent findings that now make this practice indefensible. The results of two large-scale studies, one by Stanovich and Siegel (1994) and the other by the group centered at Yale and Haskins Labs (Fletcher et al., 1994), reached the same conclusion: A similar cognitive profile was obtained for IQ-discrepant poor readers and for children who were equally poor at reading but with lower IQs so that they did not meet the discrepancy criterion. Reading disability marked by phonological deficits occurs at both high and low IQ.

Discarding the pernicious IQ-discrepancy definition is a large step toward changing the target of our efforts from fixing things after they are broken to preventing reading failure by preschool intervention. The eclipse of the discrepancy definition does not mean, of course, that all attempts to make groupings among poor readers are necessarily invalid or that IQ measures have no legitimate uses in reading research, and it does not vitiate the concept of dyslexia. We still need a more complete theory to explain why dyslexia is more than an end point on a continuum. The phonological deficit hypothesis is a good beginning. We know that both biogenetic and environmental causes contribute to a phonological deficit. A task for the future is disentangling their intertwined effects.

7. Phonological Codes Are Computed Very Early in the Process of Word Recognition: A Challenge to Dual-Route Theory

Path-breaking experiments, carried out by Berent and Perfetti (1995) and by Lukatela and his associates (see Carello, Turvey, & Lukatela, 1992), using brief visual masking, demonstrated involvement of phonology at a very early stage in word recognition. These studies mount an effective challenge to dual-route theory—the idea that there are instantiated in readers two independent routes from the written word to the lexicon: a putatively faster visual–semantic route and a slower, backup phonologically analytic route (visual–phonologic–semantic). This view of the functional architecture for reading has dominated research on word recognition by the experienced reader for at least 20 years.

Dual-route theory has served a useful function in directing the attention of researchers to the key question of how lexical access is achieved in reading (see Frost, 1998, for a balanced discussion of the evidence). However, the theory is beset by difficulties that have never been satisfactorily resolved. One difficulty, pointed out by Ehri (1992), is that the theory holds up one standard for the beginner (development

of the phonologic route) and a different and seemingly incompatible standard for the practiced, skilled reader (attainment of fluency based on the development of an autonomous visual lexicon). But if word recognition is mandatorily a phonologically analytic process, then the skill of the mature reader is no longer at odds with the skill of the learner. Moreover, because most of the language apparatus is already in place before a person learns to read, it would seem beneficial for the reading process to develop so as to take full advantage of preexisting speech processes. If so, readers would need to tap into the language representations as early as possible in the process of word identification (Shankweiler & Liberman, 1976).

8. Coming to Grips With the Parts of the Reading Process That Lie Beyond the Word

Everybody seems to agree that we should be studying comprehension, but how? The first step is to restate the key fact on which the further understanding of reading problems is built: Difficulty in identifying the individual words of the text is the common denominator in reading disability (Shankweiler, 1989). But the relation between reading the words and comprehending the text is more complex than it might seem. There is more to decoding than accuracy alone. Decoding speed is critical. Slow decoding reduces the reader's ability to read with understanding. Perfetti and his colleagues explained why: Higher level processes have to compete with word decoding for the same time-limited resources (Perfetti & Hogaboam, 1975).

Chief among these resources is memory. Common sense dictates that some kind of temporary memory is important for apprehending linguistic messages conveyed by sequences of words. Consider the memory system that allows us to integrate what comes later with what came earlier when we are processing language. This form of memory has limited capacity and is highly temporary unless maintained by rehearsal. The more automatic word decoding has become, the more efficiently this memory can be employed.

Verbal working-memory deficits could undermine reading at several places, ranging from detecting orthographic patterns to building tree structures and assigning semantic roles. Poor phonological awareness, in contrast, may impair word-level processes specifically. It is observed that ordinary span measures, like digit span or word span, are not strongly related to reading comprehension, at least in experienced adult readers (Daneman & Carpenter, 1980). The memory that is needed for coping with continuous material must encompass both storage and control functions (Baddeley, 1986; Carpenter & Just, 1988). Phonological representations are the common coin of this working memory because these are at the interface between signal and linguistic message (Shankweiler & Crain, 1986).

There are good grounds for believing that the human sentence parser is highly memory conserving. For example, some people with severely curtailed immediate memory spans can nevertheless understand many sentences well. A good theory of

working memory would predict relative memory costs associated with different kinds of sentences and different levels of reading skill (Crain, Shankweiler, Macaruso, & Bar-Shalom, 1990). Crain, Ni, and I have made a start toward the development of such a theory and have tested some of its predictions (Ni, Crain, & Shankweiler, 1996).

One requirement for success in studying comprehension problems is a satisfactory way to assess differences in working memory; the other ingredient for success is a way to track sentence processing while it is going on. Conventional tests of comprehension assess the outcome of the processes of comprehension, not the processes themselves. Few online techniques to study sentence and text processing are available. Eye-movement tracking is one technique that holds promise in the study of individual differences and dyslexia (Rayner, 1985).

Using an eye tracker, we have begun to learn how grammatical complexities and semantic complexities are dealt with by people with marked limitations in working memory. If decoding consumes too much working memory, then there is not enough of this limited resource for integrative processes. But which integrative processes are adversely affected? A possibility we have proposed is that resolving sentence ambiguities that require retrieving a particular item of world knowledge is more memory-consuming than is the case for ambiguities that can be resolved by syntactic means. Eye-movement records we have obtained with college students, grouped by high and low working memory, support this expectation (see Crain, Ni, Shankweiler, Conway, & Braze, 1996). Because of their working-memory limitations, we expect that dyslexics will experience marked difficulties with sentences of the first kind.

Having speedily traversed the ground from words to meanings, I have taken stock of what I think we have learned about the role of phonological processes in reading acquisition and reading difficulties. I am confident that Isabelle would have felt gratified by the advances in the science of reading along so many of the lines she herself cultivated and encouraged and that she would also feel gratified by the quickening pace of phonologically directed research on intervention to prevent the occurrence of reading problems. As a result of the advances I have identified, there is now a scientific basis for evaluating claims regarding treatment, prevention, and design of instruction, but I suspect Isabelle would also be worried by the turn of events in some instances. It would worry her as it worries me, that in becoming a buzzword, phonological awareness stands in danger in some quarters of being trivialized and dismissed as just another passing fad.

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