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Learning to Read: What We Know and What We Need to Understand Better

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Abstract

The authors review current knowledge about the cognitive processes underlying the early stages of word reading development. Recent findings in a variety of alphabetic languages converge on the conclusion that there are 3 “cognitive foundations” for learning to read: letter–sound knowledge, phonemic awareness, and rapid automatized naming skills. Deficits in each of these skills appear causally related to problems in learning to read, and deficits in letter–sound knowledge and phonemic awareness appear to be remediable by suitable teaching. The authors argue that this evidence has important practical implications for early education and for the diagnosis and treatment of children with reading difficulties.

Keywords

reading; decoding; dyslexia; intervention; causes

Learning to read is a key objective of early education and difficulties in learning to read can have serious adverse consequences. A proficient reader can decode print efficiently and build a coherent “mental model” of the meaning of a passage. Although being a good reader involves much more than having efficient decoding skills, it is certainly the case that poor decoding will be an obstacle in developing adequate comprehension skills. In this article, we discuss the mechanisms by which children learn to decode print and why children with dyslexia have difficulties in this realm (for a discussion of difficulties specifically affecting the development of reading comprehension, see Hulme & Snowling, 2011). We focus particularly on individual differences in cognitive skills that appear to place constraints on the early phases of learning to read in alphabetic languages (languages where a small number of letters are used to represent the phonemes, or speech sounds, that make up spoken words). Drawing on this evidence, we argue that identifying the proximal causes of reading difficulties is critical for planning educational interventions.

CAUSAL INFLUENCES ON LEARNING TO READ

Levels of Explanation

When considering causal influences on the development of reading, it is important to distinguish different levels of explanation (Hulme & Snowling, 2009; Morton & Frith, 1995). The ultimate causes of individual differences in learning to read are the biological and environmental factors that shape the development of brain systems underlying reading. There is good evidence for genetic influences on how easily children learn to read and causal risk factors for the severe reading problems that are seen in children with dyslexia (e.g., Pennington & Olson, 2005; Plomin & Kovas, 2005).

A range of environmental factors, including the literacy environment in the home, also influence children's reading development. For example, "code-focused" activities by parents with their preschool children (teaching children letter-sound relations and how to recognize printed words) give children a head start in mastering reading (decoding) skills when they enter school (Sénéchal & LeFevre, 2002). Conversely, "meaning-focused" activities (reading stories aloud and discussing them with the child) appear to improve language and reading comprehension skills.

The quality of instruction children receive also influences reading development. Phonically based reading instruction (explicitly teaching children the letter-sound relations and how to use "sounding out" strategies to read unfamiliar words) is more effective than less systematic approaches (National Institute of Child Health and Human Development, 2000). It is also now well accepted that children learn to read more easily in alphabetic orthographies (writing systems) with highly consistent spelling-to-sound correspondences (e.g., Finnish) than in less consistent orthographies (e.g., English; Seymour, 2005).

Our focus is on a cognitive level of explanation for reading development. A cognitive explanation focuses on the processes that underlie learning to read. Much of the evidence relevant to this approach comes from studies of the factors associated with individual differences in reading ability. We consider three classes of evidence:

1. Comparisons of children with dyslexia with typically developing children help generate causal hypotheses about factors that may be responsible for difficulties in learning to read.
2. Longitudinal studies that examine cognitive variables predictive of later variations in children's reading skills can help establish causal precedence (i.e., whether putative causes operate prior to the development of reading).
3. Training studies build on the findings of longitudinal studies and provide the best evidence for causal effects. After a theoretically plausible causal factor is identified, training in this skill should bring about improvements in reading. For example, if training in letter knowledge results in faster progress in learning to read, this provides evidence that it is one causal influence on learning to read.

We would emphasize that causes can never be directly observed, but always have to be inferred from studies based on a sound theoretical foundation. It is also important to

emphasize that causes do not operate in an all or none fashion, but rather increase or decrease the probability of an outcome (e.g., smoking increases the chances of getting lung cancer, but not all smokers get the disease). Moreover, developmental interactions between causes are likely: Reading is highly heritable, but genetic effects on reading have their impact in the context of environmental influences. A child who carries a genetic risk of dyslexia is not only likely to have problems learning to read but also to self-impose restrictions on the literacy activities he or she experiences (Snowling, Muter, & Carroll, 2007).

Individual Differences in Children's Early Reading Skills

Reading, like many other characteristics (e.g., IQ, height), is distributed normally in the population. This is consistent with the idea that many different genetic and environmental influences contribute small effects to the continuous variations in reading ability that are observed. Such distributions also underline the fact that when we talk about dyslexia, where we place the boundary between the disorder and the rest of the population is to a large extent arbitrary.

Three main predictors have been identified in efforts to account for these individual differences in the early reading skills: letter knowledge, phoneme awareness, and rapid automatized naming (RAN; Caravolas et al., 2012; Lervåg, Bråten, & Hulme, 2009).

Phoneme Awareness—Many concurrent and longitudinal studies have assessed the relation between phoneme awareness and children's reading ability. Measures of phoneme awareness involve children manipulating or making judgments about phonemic units in spoken words or nonwords. A commonly used task is phoneme deletion (e.g., say the word "CAT" without the /k/ sound—response "AT"). Melby-Lervag, Lyster, and Hulme (2012) conducted a meta-analysis of studies on phoneme awareness and its relation with reading skills in children. The review included both extreme group comparisons (comparing poor readers with typically developing children) and correlational studies of unselected samples. The results from extreme group comparisons indicated that children with dyslexia show a large deficit on phoneme awareness tasks in relation to typically developing children of the same age (pooled effect size estimate $d = -1.37$) and to younger children matched on reading level (pooled effect size estimate $d = -0.57$). Analyses of studies of unselected samples showed that phonemic awareness was a strong correlate of individual differences in word reading ability, and that this effect remained reliable after controlling for variations in both verbal short-term memory and awareness of the onset-rime components of words. This shows that phoneme awareness has a close association with variations in reading skills in children, but does not on its own establish that this is a causal connection.

Letter Knowledge—Letter knowledge, the other essential component for understanding the alphabetic principle (the notion that letters in printed words map on to phonemes in spoken words; Byrne & Fielding-Barnsley, 1989), also predicts variations in children's ability to read words. Moderate correlations have been reported between letter knowledge assessed at the beginning of first grade and word reading skills measured at the end of the

school year (e.g., Bond & Dijkstra, 1967; Lervåg et al., 2009; Muter, Hulme, Snowling, & Stevenson, 2004).

Letter knowledge may predict learning to read for either of two reasons. First, mastery of the alphabetic principle provides the child with a self-teaching strategy whereby unknown words can be decoded by “sounding out” on a letter-by-letter basis (Share, 1995). This is unlikely to be the complete explanation, however. Learning letter names and sounds provide a measure of visual-phonological associative learning that is fundamental to learning to read (learning to read a word aloud involves creating in memory an association between the printed form of the word and its pronunciation). For example, skill in learning visual-verbal paired associates (i.e., associating abstract shapes with a nonsense word) predicts individual differences in reading skill (Hulme, Goetz, Gooch, Adams, & Snowling, 2007). Similarly, studies of children with dyslexia have shown them to have impairments on such paired-associate learning tasks (Mayringer & Wimmer, 2000; Messbauer & de Jong, 2003). Such visual-verbal paired-associate learning is directly analogous to the process of learning to associate letters with their sounds or names. These findings suggest that variations in letter knowledge may tap into a basic associative learning mechanism that is a fundamental component of learning to read.

Phoneme Awareness and Letter Knowledge: Issues of Causation—Phoneme awareness and letter knowledge are closely linked to learning to read. Both these effects operate longitudinally from an age when reading skills are very limited (e.g., Muter et al., 2004), which suggests that they may reflect causal influences on learning to read. Direct evidence for causation requires training studies and indeed, training children in phonemic awareness is effective when coupled with appropriate phonically based reading instruction in helping improve word reading skills. For example, a meta-analysis reported an effect size of $d = 0.67$ (based on seven studies) for training phonemic awareness on word reading (National Institute for Literacy, 2008).

A recent study by our own group (Bowyer-Crane et al., 2008) sought further evidence for the causal role of phoneme awareness and letter-sound knowledge in learning to read by delivering a phonology with a reading intervention program that provided training in letter-sound knowledge and phoneme awareness alongside direct reading instruction. This intervention produced significant improvements (in comparison to a control group who were given an oral language intervention) in later word-level reading and spelling skills. Furthermore, reanalysis of data from this study (shown in Figure 1) revealed that the improvements in letter-sound knowledge and phoneme awareness measured at the end of the intervention fully accounted for the improvements seen in the children’s reading and spelling skills measured 5 months after the intervention had finished (Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012).

Because this study randomly assigned children to two different interventions (a phonology and reading program or an oral language intervention program), we have good evidence that the improvements seen in letter knowledge, phoneme awareness, and literacy skills are causal effects. However, perhaps more critically, the results of the mediation model provide support for the theory that motivated the intervention—that weaknesses in letter knowledge

and phoneme awareness are two causes of difficulties in mastering reading and spelling skills, and these skills will improve to the extent that these two underlying skills (phoneme awareness and letter–sound knowledge) improve following training.

RAN—The last important predictor of variations in reading development is RAN, in which children name as quickly as they can a list of pictures, colors, letters, or numbers. Children with dyslexia perform poorly on RAN (Wolf & Bowers, 1999) and in unselected samples of children, there are reliable concurrent and longitudinal correlations between RAN and children’s reading skills (see Bowey, 2005; Kirby, Georgiou, Martinussen, & Parrila, 2010, for reviews). The fact that using even RAN with pictures and colors, measured before children can read, is predictive of later variations in reading skills (Lervåg & Hulme, 2009) indicates that this effect cannot be just a consequence of differences in letter knowledge, and the fact that it predicts reading accuracy as well as fluency indicates that it is not just a measure of speed of processing. Whatever RAN taps into, it is statistically independent of letter knowledge and phoneme awareness as a predictor of reading development. However, we would emphasize that there is no evidence from a training study to clinch the argument that RAN plays a causal role in constraining the rate of reading development; on the contrary, training in rapid letter naming appears to affect neither RAN nor reading reliably (see Kirby et al., 2010).

At the moment, the relation between RAN and letter knowledge and their putative causal role in learning to read is a little uncertain. Lervåg and Hulme (2009) argued that RAN is an index of the efficiency of a left-hemisphere brain circuit that underlies object naming and that this circuit is recruited to form the basis of the visual word-recognition system. However, in cognitive terms, both these tasks would seem to depend upon the same cross-modal associative learning mechanism (associating what is seen—a letter or a picture—with its name) and hence they show a substantial correlation with each other. Thus, we would argue that both RAN and letter knowledge may predict how well children learn to read because they both reflect a common cross-modal (visual–verbal) associative learning mechanism that is central to the process of learning to read. In addition to this, however, letter knowledge probably also plays an additional more direct role in reading development as it is one component needed for developing a “phonic” strategy that can be used to decode unfamiliar words. Evidence from Hulme et al. (2012) is consistent with this in showing that the degree of letter knowledge and phoneme awareness acquired at the end of an intervention are both critical determinants of the level of word reading achieved some months later.

DOES READING DEVELOP IN SIMILAR WAYS IN DIFFERENT ALPHABETIC SCRIPTS?

As noted earlier, English is more inconsistent in its mappings between letters and the sounds in words than other alphabetic orthographies that have been studied. This has led some to argue that the relative importance of variations in letter–sound knowledge, phonemic awareness, and RAN as predictors of reading ability would differ in English in comparison to languages whose orthographies have more consistent spelling–sound correspondences.

Wimmer, Mayringer, and Landerl (2000) argued that in consistent orthographies, RAN is the predominant predictor of variations in reading ability (which is usually measured by speeded measures of reading fluency), whereas phoneme awareness and letter–sound knowledge are much less important. A wide range of studies have been conducted examining the predictive relation between RAN and reading in different languages, with rather complex and inconsistent results (for reviews, see Caravolas et al., 2012; Kirby et al., 2010). These inconsistencies likely reflect the fact that different studies have used different measures of reading and RAN.

To try to reconcile these apparent inconsistencies, Caravolas et al. (2012) conducted a large-scale longitudinal study of learning to read in four languages (English, Spanish, Slovak, and Czech) in which directly comparable measures were used in all languages. The study began just before, or soon after, children started formal reading instruction and assessed the relative importance of phoneme awareness, letter–sound knowledge, RAN, and verbal memory span measured at the beginning of the study as predictors of reading ability some 10 months later. The findings revealed a remarkably clear pattern, with phoneme awareness, letter–sound knowledge, and RAN (but not verbal memory span) being reliable predictors (with similar relative importance) of later reading skills in all four languages. Furthermore, phoneme awareness was at least as strong as a predictor of both reading and spelling development as RAN in the Caravolas study, even when reading was measured by speeded tests. In sum, this study suggests that the cognitive processes involved in learning to decode print are essentially identical in English and the three other much more consistent European orthographies studied. Further research is needed to establish whether letter knowledge, phoneme awareness, and RAN are truly universal influences on reading development in different alphabetic orthographies, but current evidence is consistent with this idea (see also Ziegler et al., 2010).

We should note that we are not arguing that phonemic awareness, letter knowledge, and RAN are the only cognitive factors that influence children’s reading development. Other language abilities such as vocabulary knowledge and morphological awareness (understanding the way in which morphemes—units of meaning—can be combined to form words) are likely to influence learning to read. We believe that these “higher level” language skills may become relatively more important for reading development as children get beyond the initial stages of learning to read that we have been discussing here (see Kirby, Desrochers, Roth, & Lai, 2008, for a review).

SUMMARY AND CONCLUSIONS

The work we have summarized here is important, theoretically and practically. Theoretically, learning to read in alphabetic orthographies appears to depend on at least three key cognitive skills: letter knowledge, phoneme awareness, and RAN. Practically, we know that the first two of these skills can be directly taught, and recommendations to this effect are already embodied in current educational recommendations in both the United States (National Institute of Child Health and Human Development, 2000) and the United Kingdom (Rose, 2009). It is clear from well-controlled randomized trials for children with reading difficulties that teaching that involves letter–sound knowledge and phonemic

awareness training can bring about statistically reliable improvements in word reading skills with moderate effect sizes. We therefore have evidence about what works for children with reading problems, and such evidence derives from and helps support current theory in this area.

But it is also clear that this evidence could be improved. Most of the interventions that have been evaluated are relatively short term (20 weeks or so is typical) and the effect sizes are moderate. Further research is badly needed with longer term, possibly more intensive, interventions to see if such effects are durable and whether they can be improved upon. It also must be acknowledged that the problems we have identified as important causes of early difficulties in learning to read (particularly weaknesses in letter knowledge and phoneme awareness) are highly heritable (Byrne et al., 2009). We have shown here that short-term interventions in relatively young children can produce reliable improvements in these underlying skills, which are associated with improvements in reading. We should emphasize, however, that such interventions do not amount to cure reading problems; on the contrary, many children are likely in need of ongoing support for many years to help to overcome their inherited predisposition to become poor readers.

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Figure 1.

Path model showing that the effects of a phonology + reading intervention are mediated by its effects on phoneme awareness and letter knowledge (from Hulme et al., 2012).