6 The Representation Problem in Reading Acquisition

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In 1976 a series of three conferences on the "Theory and Practice of Early Reading" was held at the University of Pittsburgh's Learning Research and Development Center. The published proceedings required three volumes for its 45 contributions (Resnick & Weaver, 1979). The conference focused on *early* reading rather than skilled reading because more was known about early reading. As Resnick and Weaver (1979) observed in their introduction to the published proceedings, "It is in recognition of the differential state of scientific knowledge about decoding and comprehension that we choose to limit the focus of these volumes to early reading" (p. 5).

I have been skeptical about this assumption that decoding is well understood and comprehension is not. (Of course after a long period of research on comprehension any disparity should be greatly reduced.) The principles controlling printed word recognition remain the subject of scientific contention, and the alphabetic and phonological knowledge sources that underlie the acquisition of these processes are only now beginning to be fully appreciated. Moreover, the contrast between decoding and comprehension is not necessarily the only important one for beginning reading. What is critical is the difference between the processes of the learner and those of the skilled performer. The most important question for reading acquisition is how a child moves from the initial learning state to more advanced stages of reading skill.

Seen from this perspective, the areas of knowledge and ignorance in the scientific study of reading are not, respectively, decoding and comprehension but rather skilled reading and the processes of becoming a skilled reader. What we know a lot about is *skilled* word recognition and *skilled* comprehension. What we still know much less about are the processes of word recognition (and comprehension) that serve a child as he or she learns how to read. Even less is known about the processes by which the learning reader acquires higher levels of word recognition skill, moving from "novice" to "expert."

The central theoretical questions for beginning reading in this view are these: How does the child mentally represent printed words at each point of reading development? How does the child access these representations during encounters with print? How do word representation and word access change with experience and instruction? That is, how does learning occur? It is my impression that answers to these questions are not very well developed, although there are a number of promising beginnings. There is no doubt that we know a lot about beginning reading in some ways; there are lots of data. However, these data do not allow much specifically to be said about *representation, access,* and *change of representation.* In what follows I hope to make clear why these are the central questions and what it might mean to begin to answer them.

THE REPRESENTATION QUESTION

The general form of the representation question is: How are words represented in the mind? It may be possible to have a theory of reading acquisition without addressing the representation of words, as Gibson and Levin (1975) appear to have done by focusing on the acquisition of distinctive visual features as the essential process of learning to read. But behind any process of pattern recognition is the form of knowledge that allows recognition. This is the representation question. Reading cannot be addressed without at least an implicit assumption regarding this question. The access question is how a printed word comes to cause a reader's mental representation of a word to be activated and accessed by a printed stimulus. Although the representation question and the access question are intertwined, in empirical terms almost hopelessly so, they can be conceptualized and described separately for some purposes.

Although several debates remain active, years of research have provided important empirical generalizations about access to printed words. Prominent among the important facts is that word recognition is holistic in appearance and nonholistic in reality.

The appearance of holistic word perception goes back at least to Cattell's (1886) studies of word perception and the word superiority effect. The idea that words are perceived as "wholes" has been influential. Advocates of meaning-emphasis instruction pointed to evidence that words are read as a whole and to Gestalt psychologists' demonstrations of holistic perceptual processes (Williams, 1979). Cues of word shape and word length, along with partial information from letters, would constitute holistic perception.

It is now fairly clear that, whatever the appeal of the whole word hypothesis at the phenomenal level, word identification is mediated by letter perception. The

individual constituent letters of the word are the units of its identification. Cues of word shape and word length appear to be of some significance, but they carry a very small share of the identification burden compared with letters.

Exactly how word recognition processes use the information of constituent letters is the central theoretical question in word identification. There are a number of models concerning word identification that provided a central role to constituent letters. Some models are strongly interactive (Rumelhart & McClelland, 1981), and others are more weakly interactive (Morton, 1969) or somewhat more bottom up (Gough, 1972; Massaro, 1975). The model of Forster (1979), which emphasizes a functionally isolated autonomous lexicon, is a particularly interesting contrast to the more fully interactive models of Rumelhart and McClelland. Although the bottom-up model of Forster is incompatible in its details with a fully interactive model, there is an interesting common ground in a hybrid model. I refer to this hybrid as the *Restricted-Interactive model* of word recognition.

THE RESTRICTED-INTERACTIVE MODEL

There are both autonomous and interactive components in the identification of words. Each of these becomes important for the development of reading. However the general preference for interactive models among reading researchers has partially masked the important autonomous aspects of word recognition. These autonomous aspects of word recognition are reflected in constraints on how context contributes to skilled reading. The Restricted-Interactive model reflects these constraints while allowing interactive processes.

A restricted-interactive model incorporates the fully interactive connections among representations of words, letters, and phonemes (Rumelhart & McClelland, 1981). It can allow a threshold mechanism that is raised or lowered by local semantic influences (Morton, 1969). The representation of letters and words in a hierarchical system having both top-down and bottom-up activation proves to be a powerful system as Rumelhart and McClelland have shown. Most important is the fairly natural way this system captures intraword context effects. The word superiority effect, the superior perception of a letter when it is in a word, and a range of related phenomena are elegantly explained by the principles of bidirectional activation (letters to words and vice versa). It demonstrates that phenomenologically compelling holistic word perception is mediated by perception of constituent letters while retaining in some sense the idea that not all the constituent letters need to be "seen." Some letters get a relatively high proportion of their activation from perceptual features and others get a relatively high proportion of their activation from the word.

The power of fully interactive models may be enhanced further by their connectionist successors, which assume that a words' representation is distributed over a matrix of connections rather than occupying a specific higher level node (McClelland, 1986; Seidenberg & McClelland, 1989; Seidenberg, this volume). These parallel distributed processing models offer a very powerful inductive machinery for learning to recognize complex patterns.

Although it can be argued that these interactive models are too powerful (i.e., they contain too many free parameters or too few *a priori* constraints), I want to assume that the principles they embody are the correct ones for word reading. Indeed, because I want to argue for constraints on interactions, assuming the correctness of the interactive framework makes things more interesting.

Now for the constraints. There are three of them that converge on a general principle: *The semantic output of word recognition is only weakly constrained by context.* (1) The early stages of word activation include a general nonselective set of semantic and syntactic attributes. Prior context does not preselect the semantic value of a word but rather influences which meaning will be carried over to the next stage of the reading process (i.e., comprehension). (2) The mechanism for these contextual influences is constrained. It relies on activation that spreads through a lexical network. It does not readily admit influence from outside the links of this network. For example, general knowledge or the theme of a discourse does not influence the early stages of lexical access. (3) In normal skilled reading, lexical access is so rapid that contextual influences are minimal. Thus the constraints of (1) and (2) that context does not preselect word meaning and that it does not include import of general knowledge are applicable to rapidly executing processes. Slowly executing processes are more permissive of broader influences.

There is a fair body of research that supports these constraints on lexical access. That word meaning is not preselected by context is consistent with the research of Swinney (1979), Tanenhaus, Lieman, and Seidenberg (1979), and Seidenberg, Tanenhaus, Lieman, and Bienkowski (1982). Although this conclusion appears to be challenged in experiments by Glucksberg, Kneuz, and Rho (1986), there are enough questions about methodological issues in this research (Seidenberg et al., 1982) to allow us to retain this constraint against prior selection of meaning by context.

As for the scope-of-influence constraint, there are two components. First, that lexical access is not influenced by imported knowledge has been shown by Seidenberg et al. (1982) and by Kintsch and Mross (1985) in priming experiments. Kintsch and Mross (1985) for example found no priming effects in a lexical decision task when words used as primes were thematically related through the discourse to the target word but were not lexically related to it. For example, replicating Swinney (1979), Kintsch and Mross (1985) found that in a text about a man running to catch a plane, the reading of the word *fly* primed both its contextually appropriate associate, *plane,* and its inappropriate associate, *insect,* but not an unassociated word that could have been activated by the theme of the discourse, *gate*. The second constraint of this type is that the spread of

activation may be restricted to one link in a lexical network. DeGroot (1983) found that priming did not occur between words that were linked only through an intermediate word (e.g., *bull—[cow]—milk*). Although such effects extend to two-word links in other experiments, the conclusion remains that the spread of activation is limited.

Finally, because the evidence concerning constraints on lexical access comes from experiments that depart in some ways from actual reading, the question of their applicability to normal reading can be raised. Mitchell and Green (1978) argued that reading was too rapid for context effects. Indeed, word identification occurs too rapidly in skilled reading for context to have much advance effect on meaning selection. This is consistent with evidence from crossmodal priming experiments. However, it is perfectly possible for identification thresholds to be momentarily affected by local contexts, and it is inevitable that eventual meaning selection be completely determined by context. There remains doubt only about the locus (on the activation level of words before they are seen?) and the source (only from immediately preceding words?) of context effects. If the source is truly limited to preceding lexical associations then context would have a very limited effect, because only highly redundant word sequences could provide context facilitation.

Even if these limits on context are as severe as they appear, this does not trivialize the role of context in actual reading. It simply would make clear that context does its work postlexically. Meanwhile, the eye-movement evidence of Ehrlich and Rayner (1981) should be kept in mind. They found that both the duration and the probability of a fixation were influenced by a word's predictability. Effects on durations can be considered postlexical, but effects on probabilities of fixations require a different level of explanation. (Although note that one cannot easily argue that a word's threshold has been modified by context when it has not even been fixated.) Word skipping effects may represent responses to *regions* of text redundancy rather than to context effects on specific words. In any case, there seems to be every reason to assume that context effects operate at the lexical level in ordinary reading.

Thus I am arguing for two characteristics of word reading that are superficially contradictory. One is that word recognition is interactive, permissive of multiple sources of information that are mutually activated without constraints. The other is that word recognition is autonomous, not widely permissive of influences beyond highly constrained sources perhaps internal to the lexicon. There is nothing incompatible about these claims. The Restricted-Interactive model combines the interactive principles of McClelland and Rumelhart (1981) and the autonomous principles of Forster (1979). The lexicon is an isolable language subsystem. Some operations within this subsystem, such as word recognition, are not easily penetrated by information *outside* it. But the information *within* it can operate interactively. Interactive and autonomous processes coexist. It is just a matter of where the constraints are.

Phonemic and Orthographic Information

The Restricted-Interactive Model as described so far is silent on two questions that are critical for learning to read: What about speech codes, and what about orthographic rules? The interactive model of Rumelhart and McClelland (1981) allows a phonemic level but does not use it. It does not allow orthographic rules or even multiletter units. Connections are between position-coded individual letters and words. (But see Seidenberg & McClelland, 1989, for a connectionist model that uses multiletter units and a phonemic level.) It is a general characteristic of connectionist models that they do not represent rules. Rules are considered emergent properties of systems of connections that show rule-like behavior. A reader may behave in accordance with an orthographic rule or a rule mapping orthography to pronunciation, for example, pronouncing *mane* with a long vowel, but this rule is not used in accessing the word or even in producing it.

I embrace the idea of an emergent rule in this sense: The processing mechanism is ignorant of the rule's existence. The rule is knowable by a somewhat more reflective cognitive component. Skilled word recognition, like any process that executes rapidly, is based on direct contact with input not on reference to rules. Of course the concept of rules has had a different tradition in psychology and especially in psycholinguistics. This tradition holds that rules represent implicit knowledge and must have psychological reality to account for rule-like performance. Such psychological reality is almost axiomatic in explaining syntactic and phonological abilities. However for processes such as skilled word recognition that are primarily perceptual and require virtually no integration of information over time, rules have a different status. They essentially reflect probabilistic co-occurrence relations acquired through print experience. A reasonable claim for orthographic rules in short is that they constitute an important kind of information that skilled readers have but use only indirectly as they get instantiated in particular lexical representations.

For phonemic information my claim is similar but different in important ways. I believe that in skilled reading lexical access involves phonemic information obligatorily. Neither "direct access" nor "speech recoding" quite captures this idea of obligatory speech activation. It is not that letters are recoded into phonemes and then phoneme strings are used to access a word, and it is not that a string of letters directly accesses the word. Rather phonemic information is activated *during* lexical access as an intrinsic part of the process. This activation of speech codes occurs almost always because speech codes are part of the lexical representation. However, because letters and letter strings are also associated with phonemes, the opportunity for phonemic activation is doubled: activation of phonemes by letters and activation of phonemic word shapes by words. An interactive model extends naturally to allow such activation.

By this account, whether speech codes are "prelexical" or "postlexical"

depends on the definition of access and how rapidly it occurs. (For one kind of evidence that prelexical speech processes occur, see Perfetti & Bell, 1991, and Perfetti, Bell, & Delaney, 1988; for another, see Van Orden, 1987.) When words are unfamiliar or when readers are unskilled, a rather high level of phonemic activation may build up before semantic codes are sufficiently activated. Whether this semantic activation ought to be equated with "lexical access" is a different question. But in real reading, as opposed to lexical decision tasks, it is hard to imagine what "lexical access" can refer to except a point at which the reader is prepared to name the word or to make some judgment about its meaning. (The reader certainly does not decide whether it is a word.)

Whether the name of a word is available before its meaning attributes is a meaningless question in general. The answer surely depends on a more precise characterization of meaning. When reading a sentence such as *John brought his dog with him,* there are several meaning features that might be aroused as part of the access of *dog—animal, four-legged animal, domestic four-legged animal, family pet,* and so on. Why should all these potential meaning features be aroused before the name *dog* is aroused? Or after? Some may precede, some may follow, but the name *dog* is inevitably and quickly aroused in some form.

To complicate things realistically, suppose the preceding text has referred to John's dog *Sam.* Will the reader recognize the referential identity of *dog* and *Sam* before the name *dog* is aroused? The answer is not clear, but it is surely an unprincipled answer, that is, one that depends on particular circumstances. The point is that when contextually relevant meanings, or references, are considered along with static lexically based semantic features, these questions of "recoding" and "direct access" get very cumbersome. Automatic phonemic activation as part of access at least handles matters in a straightforward way. The name code is always quickly accessed. Some meaning features may precede this name activation but certainly not all of them and, under some circumstances, probably not many of them. (For more on why this is a good way to think about speech processes in reading, see Perfetti & McCutchen, 1982, or Perfetti, 1985, Chapter 4.)

An important implication of this model is that there are no qualitative differences in the representation of words. In particular, the distinction between "regular" and "irregular" words has no bearing on representation. Expert representations comprise specific words and their constituent letters, whether they have more or less predictable pronunciations. The empirical basis for a regularity effect, in which words with fully predictable pronunciations based on grapheme–phoneme correspondences are supposed to be accessed more quickly than words with less predictable pronunciations, has been undermined by experiments by Seidenberg et al. (1982). Regular words have an advantage only at low frequencies. For words that have been encountered with high frequency the links between word representation and letters are strong enough that there is little time for build up of activation between letters and phonemes. However for a low-frequency word this activation is helpful for a regular word and less so for an irregular word.

A final issue is whether expert representations serve both production and perception, that is, both spelling and reading. My assumption is that they do. A specific word representation contains information about its constituent letters. It is this representation that is consulted for both spelling and reading. The access routes are different in the two cases, but the representation is the same. Indeed, *the quality of the lexical representation is reflected in idealized spelling performance.* (I say "idealized" because actual spelling reflects information processing constraints of sequencing, memory, and pattern verification, all of which can go awry.) This means that even for skilled readers many words, those that cannot be spelled, are imperfectly represented.

Summary

The characterization of an expert representation system is an important part of a theory of acquisition. In the case of reading acquisition, the critical representation system is a visually accessible lexicon. There are a number of models of adult word recognition that are consistent with most of the facts of word recognition. The model I propose is not another model of word recognition but rather a set of principles that embodies a class of models that I refer to as the Restricted-Interactive Model. The principles are that in skilled reading there are *restrictions* on the use of nonlexical knowledge in word identification. General knowledge and expectations have little or no influence on the initial access of a word. At the same time the identification processes are *interactive* in the use of intralexical information. That is, links between letters and words, letters and phonemes, and phonemes and words permit reciprocal activation. It is likely also that multiletter units and multiphoneme units are established as part of the lexical component. Phonemic activation always occurs as a part of lexical access. A single representation serves both reading and spelling, and the quality of the representation is indexed by idealized spelling performance.

THE ACQUISITION QUESTION

The acquisition question is: How does a child come to have a representation system something like this Restricted-Interactive system (or any other candidate for an expert system)? Answering this question proves to be rather difficult, partly because the question has not been asked in this way. Researchers have asked whether phonics or whole word teaching is better, whether letter names should or should not be taught, and whether various skills are prerequisites for learning how to read. Such questions are very important, but the research on them seems to have had little contact with theoretical issues and hence has had limited impact on fundamental theoretical issues.

In recent years however some important theoretically guided research has begun to shed light on fundamental issues. The acquisition question has been addressed by Ehri in her theory of word amalgamation (1978, 1980, 1984), by Gough and Hillinger (1980) in their two-stage theory of acquisition, by Liberman and Shankweiler (1979; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979) in their arguments for the centrality of speech codes in acquisition, and by Bryant and Bradley (1980) in their claim that reading and spelling draw on different representations, to name just a few examples. (See also the theoretically motivated papers by Byrne, 1991, Stanovich, 1991, and Gough & Juel, 1991.) Each of these lines of research has contributed to our understanding of acquisition. Furthermore, there have been some bold attempts, less successful perhaps, to answer the acquisition question by characterizing stages of development (Chall, 1967; Ehri & Wilce, 1983; Marsh, Desberg, & Cooper, 1976).

A descriptive theory of acquisition and eventually some explanatory theory of acquisition are exactly what is needed, although the attempts so far must be judged as preliminary. The fact is that there is as yet an inadequate database for anything beyond the most general theory of acquisition. Given the vast amount of research on early reading, this probably seems an extravagant claim. We lack theoretically motivated detailed studies of children in various stages of progress in learning to read that will tell us about lexical representation. Again, there are some exceptions to this generalization, and recent research by Ehri (Ehri, 1991; Ehri & Wilce, 1985) provides a good example of how children in different stages of prereading and early reading might exhibit different word representation strategies.

Nevertheless, the general state of affairs means that a theory of representation acquisition has some general constraints but few particular ones. In what follows I describe what I think an acquisition theory might look like, in general terms, noting also at least some empirical support for the theory. Because the phrase *representation acquisition* is a bit awkward, I refer simply to *acquisition*. However, the issue is representations—what are they like? How does a reader acquire them? How do they change with increasing skill?

There are two general components of the acquisition of lexical expertise to be addressed. First is the general course of acquiring a *functioning* lexical representation system. Second is the course of acquiring an *autonomous* lexical representation system. The first entails attention to a number of important issues. What is the role of phonological awareness in acquisition of a functioning lexicon? Of orthographic knowledge? Of rules, both of grapheme–phoneme correspondences and of orthography? Do production and perception use the same representation?

ACQUIRING FUNCTIONAL LEXICAL REPRESENTATIONS

Although I assume that reading is essentially a linguistic process and that linguistic processes are implicitly rule governed, I suggest that rules have a minor role in the acquisition of lexical representations. *The major essential development in learning to read is the acquisition of individual word representations.*

To simplify the argument, assume that three arbitrary levels of reading skill can be identified. Level 1 corresponds to an average midyear first-grade student; Level 2 perhaps corresponds to a second- or third-grade student; and Level 3 corresponds to a fifth-grade student. (The grade levels are quite arbitrary.) Here are the fundamental changes in the lexicon to be seen with increasing skill level: (a) the number of lexical entries increases; and (b) the quality of lexical representations improves. I consider each of these in turn.

Increasing the Number of Entries

The number of words that can be read increases with experience. There are three possible ways to account for this increase. First, with age children learn more words through both printed and aural exposure. Increased size of the lexicon merely reflects the acquisition of new words, that is, vocabulary growth. Second, the number of entries increases generatively, that is, because the child learns decoding rules that are based on grapheme–phoneme correspondences and orthographic regularities that extend his or her aural lexicon to his or her printed lexicon. Third, the number of entries increases because the child has increasing exposure to specific words. The words the child sees are the words he or she acquires.

Each of these explanations is incomplete at best. The first is actually empirically false, because some of the words that get added to the printed lexicon were originally available through spoken language. Some words that are fairly common in the child's language are added to the print lexicon fairly late; *ache* is probably an example of this. Still, it is obvious that a significant portion of new entries into the printed lexicon are new entries into the general lexicon. The proportion of new entries (relative to other sources of lexical growth) probably increases with reading experience.

The second and third explanations are not easily dismissed, but they are incomplete. The second, that new entries reflect increased scope of decoding rules, fails to explain the acquisition of so-called "irregular" words that show less frequent grapheme–phoneme correspondences. Clearly such words are acquired throughout the period of learning to read. The third seems to restrict acquisition to specific word learning and does not generalize to words not specifically learned. It is possible that a reader does not have a high quality representation of a printed word without having experienced it visually, but the decoding

system allows the reading of previously encountered words already represented through spoken language.

Because the decoding model and specific word learning model have complementary problems, a sensible model for acquiring new words might seem to be a dual-mechanism model, with one mechanism that is based on decoding rules gradually acquired and expanded and made context sensitive and the other that is based on specific pattern learning. The dual-mechanism learning model is thus parallel to dual route lexical access models that postulate both a "recoding" route and a "direct" route to the lexicon (Baron, 1977). (See Stanovich & West, 1989, for evidence that children acquire both generalized, phonologically based and experience based, word-specific representations.)

By this dual route account the difference between Level 1 and Level 2, for example, is this: Level 1 has some decoding principles and some specific words; the Level 2 reader has a larger lexicon (a) because of learning more specific words, and (b) because of increasing the power of decoding rules. But this, if it means anything, must mean that the influence of (b) is on words yet to be encountered in print. That is, decoding rules generatively increase the potential of the lexicon. At Level 2 some new words might have been added to the lexicon through decoding and by Level 3 still more words have been added. A word, once acquired, may be represented strictly as a specific unit.

The point is that the number of lexical entries may increase both because of decoding and specific word learning; however the effect of the decoding mechanisms is on the number of specific words acquired. They have no other significance, at least for the acquisition of a lexicon. If they are to have further significance, it will have to be in allowing an alternative access route to specific words.

It is important to notice what is at issue here. Decoding rules of some sort are important in providing a backup process in reading never-encountered words. (Context has this value also.) But as a word becomes represented in the lexicon, decoding becomes only indirectly important. That is, it has provided the links between letters and phonemes that can be activated to assist recognition. However with increasing word familiarity, these links lose their ability to be of much assistance.

Figure 6.1 illustrates the suggestion I am making about acquisition. The general course of acquisition is one of increasing the number of entries. Both regular and irregular words increase. There is some increase also in the power and scope of decoding rules, which become increasingly context sensitive. (If someone prefers to call these analogies rather than decoding rules I have no quarrel with that; however I doubt that we can agree on the ultimate decidability of rule-governed versus analogic nature of processes in general.)

Thus there are two interdependent acquisitions across observation levels. The number of actual lexical entries increases and the potential number of entries increases. These two acquisitions are mutually facilitative. The more powerful

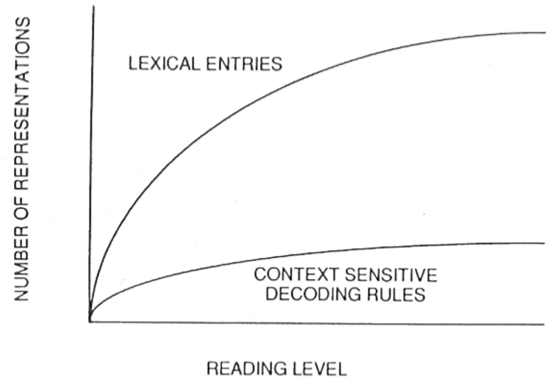

FIG. 6.1. Two growth trajectories that describe increases in the reader's lexicon. See text for explanation.

the context-sensitive decoding rules (or analogic capabilities), the more entries the learner can acquire. And the more entries , the more powerful the decoding rules. Lexical learning (as opposed to lexical access) is highly interactive.

Finally, although these two acquisitions are interactive, their trajectories are probably different. The acquisition trajectory for specific words continues throughout the reading life of the individual, probably as an exponential function. The acquisition trajectory for rules is a lower one, perhaps asymptoting fairly early for practical purposes.[1] It appears that I am suggesting that acquisition of the lexicon is essentially a matter of what is often called "sight" vocabulary. Indeed this interpretation is not too far off, although this may seem out of character for a linguistically based view of reading. The notion of sight vocabulary is a bit imprecise, however, in terms of what the child comes to know; it implies, for example, holistic patterns. The present account emphasizes the acquisition of specific (but abstract) letter patterns, reinforced by sublexical links with phonemes. There is no possibility in this account for holistic patterns playing a major role in recognition. This observation leads directly to the next major acquisition, the change in the quality of lexical representations.

Increasing the Quality of Representations

Increasing skill not only brings about more entries but also produces changes in the representations. There is always a question in development as to whether

[1]Actually a distinction between rule-governed and analogic might suggest two possible trajectories. Analogical processes should be constant, and hence potential analogic lexical entries should increase with the number of actual lexical entries and would have a longer trajectory than that for a rule-based process.

developmental changes are fundamental, reflecting restructuring of knowledge, or incremental, reflecting assimilation of new knowledge by existing structures. I am not sure whether such a question is decidable even in principle. I am more certain that I am in no position to decide it in the specific case of lexical acquisition. However, I can suggest that the idea of representation quality can be usefully applied to learning to read.

There are two principles that characterize the development of lexical representation quality: precision and redundancy. These principles are developed as follows.

Precision. The precision principle is that fully specified representations are superior to partially specified ones. Representations that become more fully specified can be said to be more precise. The advantage of a fully specified representation is that it is *determinant* with respect to the input features that will trigger it. In the case of word reading this means that a given letter string will be sufficient to activate a specific word and to quickly bring about the recognition of that word rather than some other word. It also means that there can be less reliance on context. In short, only in a system with fully specified representations can the input features, the constituent letters in this case, easily control recognition.

In contrast to precise representations are variable representations. The variable representations include free variables in the positions where the precise, fully specified representations include specific letters (or "constants"). (One might also think of precise representations as having bound variables rather than free variables.)

To illustrate what this means for word reading, Fig. 6.2 shows three levels of precision for the words *iron, tongue,* and *ukulele,* which are three irregular words from a commonly used sight vocabulary list. The three levels correspond arbitrarily to the same hypothetical first-, third-, and fifth-grade readers as before. The reader at Level 1 has imprecise representations for all three words. For *iron,* the identity of the second vowel is a free variable rather than a constant. For *tongue,* not only is the identity of the vowel letter unknown but the number of letters following the *n* is also unknown. (However, the reader knows something follows the *n*.) Over the levels, the representations for all words increase in precision. *Ukulele,* by this example, undergoes a reversal in which a precise but incorrect letter is represented at Level 2 and replaced by a variable at Level 3.

There are several nonarbitrary choices in the representation changes depicted in Fig. 6.2. One is that early representations for English words are likely to include initial letters, a well-established fact of beginning reading (Marchbanks & Levin, 1965; Williams, Blumberg, & Williams, 1970). A representation with variables is more likely to have these variables in medial and final portions of the word. A second assumption is that vowels are more likely to be variables than are consonants. Evidence for this assumption is indirect and is based on findings that

LEVEL 1	LEVEL 2	LEVEL 3
ir*n	iron	iron
t*g*	t*ng**	tongue
uk*	ukil*	uk*l*l*

FIG. 6.2. Change in representation precision over three hypothetical skill levels in the acquisition of reading for the words *iron, tongue,* and *ukulele.* Asterisks denote free variables in the representation. For example, at Level 1 the reader's representation for *tongue* does not include precise knowledge concerning the second letter nor concerning how many letters follow the *n.*

reading errors are especially frequent for words with complex vowels (Liberman, Shankweiler, Orlando, Harris, & Berti, 1971) and on the fact that vowel letters enter into more variable phonemic mappings than do consonants.

An important principle is that phonemic values play a large role in determining which letters get represented. It is the phonemic variability of vowels that makes them more likely for variable representations. However, phonemic principles also make predictions concerning the representation of consonants. For example, nasal consonants that precede stop consonants are more likely to be unrepresented or to be represented by assimilating a preceding vowel, for example, *tongue* may be missing the *n* or the *o* or more generally represent the nasal vowel nucleus as a variable, as shown for Level 1 (Fig. 6.2). As examples of phonemic influences, consonant clusters, for example, *string* and medial syllables of multisyllabic words (see *ukulele,* Fig. 6.2), may be prone to variable representation.

There is a question here of how to understand the concept of variable representation. The essence of the concept is the instability and changeability of the representation. It is applied to a representation that is in a state of change. It does not necessarily imply a representation that includes incorrect letters. However, cases in which a learner seems to have an incorrect representation probably should be thought of as variable except for those rare conditions in which a reader, for some reason, has a deeply held faith in an incorrect spelling. Such an incorrect representation will be very difficult to establish as a string of constants because actual inputs will never contain those specific letters. "Variable" does not imply only momentarily incorrect spellings. It entails also incomplete representations. Thus the precision principle is that lexical representations evolve toward completeness and specification.

Redundancy. The second principle of qualitative changes in representation is the redundancy principle. Just as representations become more fully specified, they also increase in their inclusion of redundant information sources. The main source of redundancy is between letters and phonemes and, more generally, between orthographic strings and phonemic strings.

Consider the immature representation. It is not only imprecise in its orthography, but it is also more dependent on it. Phonemic information is less reliable because the learner is gradually acquiring the mapping system. In fact, one can think of the phonemic information connected to grapheme strings as having the same kind of variability illustrated previously for the orthography. There are two major changes in quality that have the same effect. First, the representation of phonemes changes. How it changes is a complex affair perhaps dependent on method of instruction. Figure 6.3 illustrates just one possibility across three hypothetical levels of skill not necessarily identical to the levels of Fig. 6.2. (To emphasize this possibility, the three levels are illustrated as Levels 0, 1, and 3.) At Level 0 the representation reflects the reader's knowledge that the letter *i* is associated with the phoneme /ay/, its name. That means there is imperfect phonemic help in accessing the word. Still there is some, and the /ay/ might assist restricting the search space for recognition to *i*-initial words. This level may correspond to the stage of phonetic-cue reading identified by Ehri and Wilce (1985). At Level 1 things are different because the reader has experienced quite a bit of print and, in some cases, perhaps some direct "phonics" instruction. Either from direct learning or from indirect induction the representation now includes multiple phonemic values for each letter in *iron.* Some are the names of the letters, but in general there is the array of phonemes contained in the language associated to letters in a many-to-one and many-to-many fashion. This representation provides some phonemic assistance to lexical access, but it is limited. The limitations arise from the fact that phoneme–grapheme mappings are weak and not yet context-sensitive. The letter *r,* for example, causes activation of a diffuse set of phonemic representations: /ar/, /r/, and perhaps /ru/, /ro/, and other representations that include inappropriate vowel environments. Thus there is a diffuse activation at the phonemic level with the result being a relatively low net activation of the word.

By Level 3 there has been a reversal in phoneme proliferation with fewer phonemes now represented. Phoneme representation has become context sensitive. A finer picture of this representation would be to show intermediate orthographic units. That is, letter strings intermediate between individual letters and words could have a separate representation. (This is not reflected in Fig. 6.3 to avoid clutter and because the effect of an intermediate level is readily repre-

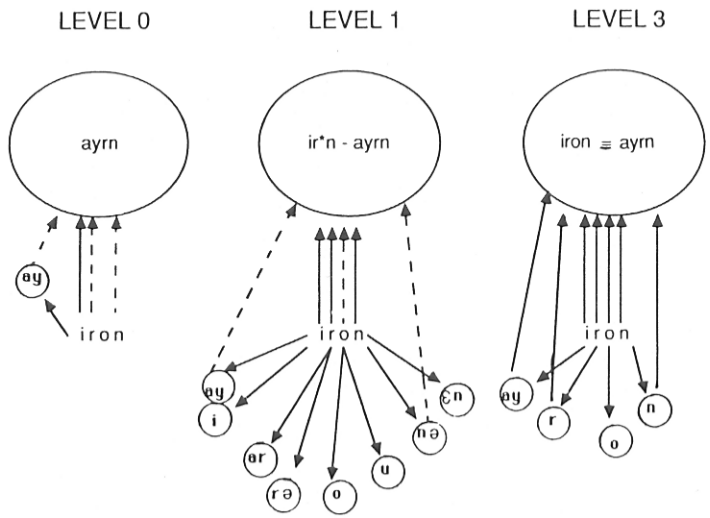

FIG. 6.3. Development of redundant phonemic information over three hypothetical levels of reading acquisition. The levels are not necessarily identical to those of Fig. 6.2. The large circles are word representations containing spellings and pronunciations (a pronunciation only at Level 0), and the small circles are phonemes and phoneme sequences that are associated with specific letters. Thus each level represents the word *iron,* but the form of the representation begins as a phonemic object at Level 0, includes variable orthographic information at Level 1, and at Level 3 includes a fully specified orthographic representation "bonded" to the phonemic representation. (An analogy to chemical bonding is intended.) Meanwhile, the representation of phonemes changes in two directions, beginning impoverished at Level 0, proliferating at Level 1, and by Level 3 reducing to mainly those that are sensitive to the orthographic context imposed by the word *iron.* The solid arrows indicate strong activation patterns and the dashed arrows weak ones.

sented by a more restricted connection at the single letter level.) In effect, the representation now includes knowledge that *ir* at the beginning of a word is strongly mapped to /ayr/ and that final *n* is always /n/. Notice that this first mapping will later be modified to accommodate new acquisitions (e.g., *irritate*). To illustrate that the representation system is still developing, the letter *o* activates the phoneme /o/, one of its context-free phonemes. But the overall effect is that there are now word-specific phoneme values to assist word access. The second development is the bonding of orthographic with phonemic representations. At Level 0 there is no orthographic representation at all, so this could be thought of as a very early encounter with a word known to the child through

spoken language. At Level 1 the representation includes an underspecified orthographic representation, in the spirit of Fig. 6.2. Because of its variable representation, it is only weakly bonded to the word *iron* (/ayrn/). By Level 3 the reader has had enough experience with *iron* or with related printed words that the orthographic representation consists solely of constants and is strongly bonded to the word *iron* (/ayrn/), as represented in Fig. 6.3 by the double bond.[2] These two developments, the strengthening of context-dependent grapheme–phoneme connections and the bonding of orthographic and phonemic representations, are not independent. Indeed they are virtually the same thing described at two levels. This is the development of redundancy. At the constituent level phonemes are redundant with respect to the letters. At the word level the pronunciation is redundant with the spelling. Across levels the letters are redundant with the spelling and the phonemes are redundant with the pronunciation. Notice that any *one* kind of representation can be eliminated and lexical access can still occur in principle. The string of letters *i-r-o-n* is sufficient to trigger a bonded representation (*iron*-/ayrn/) and so is a string of phonemes. The redundancy advantage is that redundancy overdetermines lexical access. The redundancy advantage is important in reading both for bootstrapping the identification of unfamiliar words and for the rapid automatic recognition of familiar words.

In summary I take the acquisition of a functioning lexical representation system to involve increases in the number of orthographically addressable lexical entries and increases in the quality of the lexical representations. In short, the child comes to know more words and to know more about these words. The increase in quantity comes primarily through the acquisition of specific words. The increase in quality is a matter of gains in precision and redundancy of lexical representations. Fully specified orthographic and phonemic representations replace variable and unreliable ones. In the next section I take up the question of bringing this functional lexicon to a level of autonomy.

ACQUIRING AN AUTONOMOUS LEXICON

The functional lexicon represents words so that they can be visually accessed. Beyond this the representation system of the skilled reader acquires the property of autonomy. In terms of the Restricted-Interactive Model the lexicon acquires some restrictions on its access. The lexicon changes from a wide-open public tavern in which anything goes to a private club in which access is restricted to elite members with proper orthographic credentials.

This private club metaphor goes awry if it implies a lexicon of *less* flexibility.

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[2]This bonding idea, I now recognize, is approximately the same concept as Ehri's (1978, 1980) "amalgamation" of information sources. Ehri especially emphasized the combining of visual orthographic information with phonetic information in the child's acquisition of word recognition.

Surely the advancement of reading skill leads to more access not less. The restrictions, thus, are not on absolute access but on access privilege: First access rights go to correctly specified grapheme strings then only to the other sources of information.

The main characteristic of an autonomous lexicon is its impenetrability. By definition, knowledge and expectations cannot penetrate an autonomous lexicon. This characteristic does not apply to the functional lexicon of the beginning reader for whom knowledge and expectations, and context in general, contribute heavily to the activity of identifying words. This interactive access process also is characteristic of older readers of low skill (Perfetti & Roth, 1981; Stanovich, 1980). The question is how does the lexicon acquire impenetrability? And, fundamentally, what exactly is it that is impenetrable?

Before considering these questions it is useful to clarify why an impenetrable lexicon is of value to the reader. Superficial analysis indeed leads to the opposite conclusion, namely that it is a fully interactive lexicon that is valuable. Such a lexicon allows information from all sources to penetrate lexical representations and makes the job of recognition easier. However this is a misleading analysis. The reader is served by expectations, knowledge, and beliefs in forming interpretations not in recognizing words. If expectations, knowledge, and beliefs actually penetrated the lexical representations, the identification of a word could become a hit-or-miss affair. Only if the graphic input has privileged status in access can accurate word identification take place. Merely postponing the influence of expectations, knowledge, and beliefs a few precious milliseconds, so that it is the output of the identification process that is influenced, will make a more efficient system. It is characteristic of the young reader and the low-ability older reader to be rather context dependent in word identification (Perfetti & Roth, 1981; Stanovich, 1980). The general principle is that a slow identification process will enable penetration of expectations to occur, and readers of low skill have slow identification processes. Moreover, even skilled readers will show contextual influences when their basic identification processes are retarded by altering the identifiability of the words (Perfetti & Roth, 1981).

The acquisition of a context-free autonomous lexicon thus must be part of learning to read. However it has not been clear what such an acquisition entails except experience with words. I propose that the critical events for the acquisition of autonomy are the acquisition of *fully specified and redundant* lexical representations. Autonomy follows naturally from the acquisition of such representations. As lexical entries become fully specified they also become "encapsulated." Because the graphic representation has no "holes" in it, it can be triggered by graphic input in a totally deterministic way. It is the encapsulated, self-contained character of a representation that makes it a specialized data structure responsive only to appropriate input features. (This claim of course is in the spirit of Fodor's, 1983, modularity thesis. See also Perfetti, 1990, and Stanovich, 1990, for applications of modularity to reading.)

Identifying representation quality as the critical element for autonomy appears to ignore practice. Although it may be necessary, how can a fully specified and redundant representation be sufficient for autonomy? Practice is indeed important. However, practice has already taken place on route to establishing the fully specified and redundant representation. As continued access to this representation occurs there should be some consequences. The speed of access should increase, for example. Speed of access, however, is a by-product of highly skilled automated recognition not its defining characteristic. Thus the question reduces to how much practice is required for autonomy? Certainly practice extended over years of reading helps maintain the autonomy of access and continues to add new entries to the autonomy subsection of the lexicon. However, it is possible that the practice that is sufficient to establish the high quality (fully specified and redundant) representation is sufficient to make it autonomous. Thus my suggestion is that the reading lexicon contains two sublexicons: a developing functional lexicon with representations under specified, and an autonomous lexicon with representations fully specified and redundant. A given word moves from the developing functional lexicon to the autonomous lexicon just when it becomes fully specified and redundant. This is essentially a word-by-word process.

This again raises the question of how to decide what the quality of a given word representation is. The key measure, I suggest, is spelling, and the concepts of variability and facility have to be applied. The idealized situation is a spelling test in which all possible performance constraints are reduced: Paper and pencil are available; the words are short; and the subject has the opportunity to verify his or her spelling. Variability and facility enter in the following way. It is not sufficient for the child to spell the word correctly one time. The child must spell it correctly repeatedly over different testing situations. And it is not sufficient for the spelling to be uncertain or effortful. Perhaps speed of correct spelling can be taken as an index of facility along with distractibility—how easily a subject can be influenced to change his or her mind about the correct spelling given two or three plausible alternatives. The details of defining an individual reader's representation quality is a tricky matter. On the other hand the principle seems clear enough. Reliable, confident, and facile spelling is an index of high quality representation. By hypothesis it is also an index of an autonomous representation.

My proposal then is that the reader's lexicon can acquire impenetrability as a result of the quality of its representation, which in turn is the result of knowledge (orthographic and phonemic) and practice (at lexical access). One question is whether there is anything in this claim that is not included in the concept of *automaticity?* The difference between automaticity and acquired impenetrability is a matter of entailments. Automaticity entails either processes that occur without allocation of resources or processes that are not easily inhibited. Thus research on the development of automaticity relies either on dual task methods to demonstrate automaticity as processing low in resource demands or Stroop-inspired interference methods to demonstrate automaticity as processing that resists inhibition. The literature on reading includes mainly research of the latter kind, in which pictures of objects with words printed on them are presented to children (Guttentag & Haith, 1978; Rayner & Posnansky, 1978; Schadler & Thissen, 1981; Stanovich & West, 1981). With familiar words, there is an interference effect when children are asked to name pictures and ignore words. This interference has been found by the end of first grade (Guttentag & Haith, 1978; Schadler & Thissen, 1981; Stanovich, Cunningham, & West, 1981). However, if the automaticity question is cast in terms of resource allocation rather than processing without intention, automaticity is largely acquired between first and second grade but continues to develop through adulthood (Horn & Manis, 1987).

The entailments of acquired impenetrability are slightly different. Impenetrability leaves open the question of whether resources are required by the impenetrable process. It assumes that the impenetrable process cannot be penetrated or inhibited. A younger reader might have impenetrable processes that nevertheless require resources. However, it is generally the case that the potential for resource savings is a function of the representation quality just as impenetrability is. Where representation quality is low, the reader may direct more resources to lexical access. Where representation quality is high, resource demands are reduced because access is overdetermined by input features. However, the supposition that word reading can in general be completely attention free might not be correct. Even the simplest letter comparison processes seem to demand attention (Posner & Boies, 1971). It is best to think of resource costs as a matter of degree and not as an all-or-none distinction between attention-free and attention demanding. Speed of processing is commonly used as an index of automatized responding. In the present account speed of access is a result of representation quality and an intrinsic characteristic of impenetrability. Only rapidly executed processes can be computationally autonomous. Slower processes reflect higher-level contributions to some process that is intrinsically altered by being slowed down. For example, when a novel word is read it is processed outside the autonomous lexicon, which fails to serve up a representation to the lexical processor. The problem solving component, after some time, gains access to what the lexical processor has, which is a novel string of letters and some decoding rules.[3]

Phonological Knowledge

Phonological knowledge is clearly critical in skilled reading. The heart of lexical access is the activation of a phonologically referenced name code. Although this

[3]This description of a "lexical processor" and a "problem solving component" reflects the structure of language processing outlined by Forster (1979).

assumption does not appear to be universally shared, it should be without contention. Thus I want to focus not on the importance of phonological information, which I merely assume, but on the role of explicit phonemic knowledge, which I think cannot be so easily assumed.

The issue simply put is whether explicit reflective phonemic knowledge is necessary to learn to read an alphabetic orthography. By my account the answer is "yes and no." A distinction between *computational* and *reflective* knowledge is important here. Computational knowledge is simply connections between phonemes (or letter names) and letters that allow pronunciations of grapheme strings to be partly or wholly computed. Reflective knowledge is an awareness of the basic nature of these connections, that is, they depend on the fact that words comprise meaningless speech segments. Some computational phonemic knowledge is necessary to gain a functional lexical representation system of any size, and explicit reflective knowledge, or "awareness," is a sign of a more powerful learning mechanism than implicit knowledge. However, explicit reflective phonemic knowledge is not necessary to begin the acquisition of a functional representation system. All that is necessary is the ability to represent some of the graphemes of a word and to use these to compute the word's phonological representation. Because the essence of a grapheme string is its orthography not its pronunciation, it is possible in principle to acquire some word representations in ignorance of connections between letters and phonemes. Thus it is possible that initial progress in acquisition could be based only on visual information (Gough & Hillinger, 1980). However, this is not what really happens or at least not for very long. Children do acquire phonemic mappings to letters and this serves the acquisition of word representations. Indeed, Ehri and Wilce (1985) have shown that children just starting to read are disposed to take advantage of grapheme–phoneme connections even when their knowledge of phoneme values is little more than letter names. But taking advantage of these connections is to use essentially computational knowledge rather than reflective knowledge.

Thus the very early computational use of phonemic information characterizes learning how to read. Furthermore, we know that providing children with phonemic instruction can improve their reading. Bradley and Bryant's (1983) study showed that training backward readers in an orthographic-phonemic task improved their reading performance. Treiman and Baron (1981) also reported effective training that was based on segmentation knowledge. (See also Lundberg, Frost, & Peterson, 1988). Such studies demonstrate a causal connection between phonemic knowledge and reading skill and strengthen the conclusion from many correlational studies that show beginning reading success is predicted by prereading measures of phonological knowledge (e.g., Lundberg, Olofsson, & Wall, 1980; Mann & Liberman, 1984; Stanovich, Cunningham, & Cramer, 1984; see Wagner & Torgesen, 1987, and Tunmer, 1991, for reviews; for recent research on these issues see the collection of papers in Rieben & Perfetti, 1991 and in Brady & Shankweiler 1991.)

Nevertheless, explicit reflective phonemic knowledge is not a prerequisite to reading. Perfetti, Beck, Bell, and Hughes (1987) found that first-grade children showed progress in simple word and pseudoword reading *before* they showed progress in a task of *explicit* phonemic awareness. (The task was phoneme deletion in which the child produces, for example, cat without the /k/ or without the /t/.) Because progress on a simple computation-type synthetic phonemic task ("blending" phonemes into words and syllables) preceded progress in word reading, we concluded that the relationship between explicit phonemic knowledge and reading is reciprocal in a sense. Some rudimentary phonemic knowledge—not reflective analytic knowledge—is causally necessary for progress in word reading. However a deeper reflective kind of phonemic knowledge, the kind most researchers have in mind when they refer to "phonemic awareness," has a more complex reciprocal relationship. Such awareness comes through experience with alphabetic stimuli. The typical child does not have such knowledge, or at least not in a very useful form, that is based only on his or her spoken language experience.[4] Indeed, it is hard to imagine exactly where it would come from. The child begins to treat words as having separable constituents when he or she notices that printed words have such constituents in the form of letters. When the child also notices that these alphabetic symbols have speech sounds, the child is in a good position to develop phonemic awareness. With this development comes the potential for further gains in reading. Indeed Perfetti et al. (1987) found that gains in awareness, although initially preceded by gains in reading, were then followed by further gains in reading. In short, the pattern of time-lag correlations supports a reciprocal relationship between explicit and analytic phonemic knowledge and learning to read.

Downgrading phonological awareness from causal status to reciprocal status does not diminish its importance for reading. Indeed, it allows it to be seen as a central component of reading instead of as a prerequisite. The problem with prerequisites is that there is an implication that they must be met before progress is made. If phonemic awareness and learning to read are reciprocal, phonemic awareness is no longer a prerequisite that has to be met (and cannot be met by most children) but an achievement of learning that then facilitates further learning. The glue for the redundant lexical representation and, perhaps more important, the basis for a fully specified lexical representation comes from phonemic knowledge along with alphabetic knowledge.

Nevertheless, there is the evidence of the training studies to consider. On the one hand is a clear indication that children make significant progress in word reading prior to exhibiting explicit analytic phonemic knowledge (Perfetti et al., 1987). On the other hand, there are training studies that demonstrate gains in word reading following gains in phonemic knowledge produced by training

[4]Actually I would stress the accessibility of the knowledge as the problem. Very young children show speech play that indicates experimentation with the meaningless sounds of language even before their speech is very well developed.

(e.g., Bradley & Bryant, 1983; Treiman & Baron, 1981). However, this is only an apparent contradiction not a real one. If we see the relationship between two competencies as prerequisite or if the overall knowledge structure is hierarchical then there is a contradiction. Phonemic knowledge and reading must have an orderly sequence. By one account, this sequence is first phonemic knowledge and then word reading. By the alternative account, the by-product account (because phonemic knowledge comes as a by-product of learning to read), the sequence is reversed: Word reading comes before phonemic knowledge.

Suppose instead that the relationship is not hierarchical but interactive. There is abstract knowledge concerning words, namely that words are systematically decomposable into meaningless segments. The segments constitute a finite generative vocabulary for words, and there are both printed segments (letters) and spoken segments (phonemes). Knowledge about the two kinds of segments can develop in tandem and probably does in many cases. Which develops more quickly may depend on the linguistic environment of the child. Either because demonstrating phonemic knowledge is difficult or because the knowledge in fact is fully inaccessible (i.e., implicit), many children will not show it until they begin to read. Some will read poorly and continue not to have access to phonemic knowledge. If they are now trained on phonemic knowledge, it might improve their reading, as the training studies suggest. If so, it does so by affecting their computational phonemic knowledge, that is, their abilities to make connections between letters, which they have already learned about, *and* phonemes, about which they have only dim inaccessible knowledge. Phonemic awareness training does not merely give them access to phonemic knowledge, but it also makes the structure of words clearer: Spoken words contain phonemes; written words contain letters; and letters and phonemes correspond. This does not mean however that phoneme knowledge is a prerequisite to reading. Instead, the child who makes normal progress in reading acquires access to his or her knowledge that letters comprise words at the same time that he or she is acquiring access to the knowledge that phonemes comprise words. From our study, we conclude the beginning reader acquires some of the print knowledge slightly in advance of *some* phonemic knowledge. A finer grained study might show something slightly different, but it probably would not show that all levels of phonemic awareness had to come first. A sensitivity to rhymes comes very early and is predictive of beginning reading (Maclean, Bryant, & Bradley, 1987), but it is not the level of phonemic analysis that we think develops alongside of reading. (See also Alegria & Morais, 1991.)

Spelling and Reading

Because my account assigns a large role to orthographically specified representations, the issue of spelling is raised. The precision principle is essentially identified with correct spellings. I assume that spelling and reading are processes that share the same lexical representation.

There are, however, apparent cases of children spelling words that they cannot read (Bryant & Bradley, 1980; but see Gough, Juel, & Griffith, this volume). Moreover, there are studies that appear to have shown that some children spell phonetically while reading nonphonetically (Frith, 1980; Jorm & Share, 1983). On the other hand, Waters, Bruck, and Seidenberg (1985) found that third-grade children, regardless of reading skill, tried to use spelling–sound correspondences in both reading and spelling.

In a study of college-age dyslexics we (Bell and Perfetti, unpublished manuscript) have been able to find only a few instances of accurate spelling of words by subjects who failed to read them. Fifteen low-ability readers were given 56 words varying in frequency and regularity to read and spell on separate occasions. (Half the words were read first and half were spelled first.) We found only 6 cases out of 640 opportunities in which a subject misread a word he or she spelled correctly, and each case was produced by a different individual reading a different word. The reading errors were generally easily understood as misreadings rather than access failures (e.g., *conscience* for *conscious* and *corpse* for *corps*). Phonemic strategies were in evidence for reading even though in other tasks these subjects showed themselves poor in lexical representations including phonology. I suggest that lexical representations of experienced readers, even readers of low ability, include phonemic and orthographic information no matter how imperfectly. For adults phonemic information plays a role in everyone's spelling.

Whether this is true for children who are learning to read remains a controversy among those who study children's spelling. There are claims that nonphonemic spelling strategies distinguish a subclass of developmental dyslexics, Boder's (1973) dyseidetics. I find the claim that there are individuals, whether normal or developmentally dyslexic, who use only a visual strategy for spelling unconvincing at best and incoherent at worst. There is a large visual component to spelling because a spelling is a spatial array of letters. Furthermore, because English spelling has a one-to-many mapping for any given phoneme or even any syllable, a grapheme–phoneme spelling rule is in principle inadequate. Correct spelling must be guided by knowledge of letter sequences.

However, the phonemic information in the word must force a phonemic component to spelling. A child who correctly spells *a-c-h-e* is not merely demonstrating a "visual" strategy that reflects how the word appears, but the child is also demonstrating phonemic knowledge that tells him or her, in some sense, the word might be spelled *a-k-e* but is not, which amounts to saying that the child learns that /k/ is sometimes spelled with a *ch* as well as a *k*.

If this assumption is correct, and it seems inevitably so to me, why have some researchers identified visual spellers and phonemic spellers as if there were two basic ways to spell that one could somehow choose, rather than two components

to spelling that everyone used to a greater or lesser degree depending on the circumstances? I think one problem is that researchers have often failed to take note of this fact: If someone is not good at something, he or she has many options for how to display their weakness. Children with impoverished word representations are not good at spelling or reading.

Dyslexics in particular have this problem. When given a spelling task they have a problem because they do not know how to spell. They will try to find a representation for a word but there will not be much there. What do they do? They try to satisfy the demands of the examiner by producing a string of letters. The examiner then studies the incorrect spelling and decides that it has high or low phonemic overlap with the target or that it has high or low "visual" (orthographic) overlap with the target. There are several serious problems with this approach. First, the orthographic and phonemic information does not come in neatly separated packages. A string of letters is all you get, but these letters also have specific phonemic values in specific contexts. This is true for the letters in all but the most irregular words. Thus, the misspelling game itself is intrinsically probabilistic and statistical, and this is seldom taken into satisfactory account. A second related problem is that the reliability of the child's spelling errors is hardly ever assessed. But such assessment is important, because if the child misspells *ache* one time as *ake* and one time as *acke*, what does that mean for his or her classification as a phonemic or visual speller? Probably it reflects the child's variable coping strategy for dealing with his or her lack of knowledge. The child suspects that he or she does not have this knowledge because when he or she accesses /ek/ on the basis of its sound the child finds an impoverished representation. The child does have other knowledge however. He or she knows that some words have faithful, predictable mappings of letters and sounds and others do not. So the child tries different things and possibly gets a premature classification as a visual speller or a phonemic speller that is based on momentary manifestations of highly variable strategies. As for normal readers, I think the same argument applies in general. It is important not to overestimate a child's devotion to an alleged basic processing strategy when it might be a momentary state of an extremely variable response to inadequate knowledge.

Whatever the correct understanding of individual differences, how children spell and read remains important for an account of reading acquisition along the lines I am proposing. Bryant and Bradley's (1980) suggestion is that reading develops along visual routes and that spelling develops along phonemic routes. Their report that children could spell but not read *bun, mat, leg,* and *pat,* all regular words, is consistent with this hypothesis. However it is especially interesting that this phenomenon was readily altered by task demands. When the children read a pseudoword list that included the nonread words they were able to read them. Thus it is not a question of basic ability but either a strategy or a momentary state in response to ignorance. Bryant and Bradley prefer the strategy explanation, which is that the orthographic route is the preferred reading strategy.

My account for this phenomenon is that the child who *reliably* fails to read words that he or she can spell correctly has no lexical representation for the word or else has one that he or she is unwilling to trust. By contrast, the spelling task encourages the child to consult directly his or her phonemic knowledge and to generate correspondences. With increasing knowledge, more and more words are represented directly even if imperfectly. There is a convergence of spelling and reading, and the phenomenon observed by Bradley and Bryant disappears even for poor adult readers, as I have suggested.

Thus, on this account there is a single representation that serves both reading and spelling. It does so throughout the course of development. Because spellings can be generated without lexical access, occasional discrepancies can be observed before the number of lexical entries has grown large enough.

CONCLUSION

I have argued that the central theoretical question for a theory of reading acquisition is the development of lexical representations. My goal here has been to outline what I see as the general form of such a theory.

First, the representation system of the skilled reader requires a class of models that I call the Restricted-Interactive Model. It restricts the influence of imported knowledge on lexical access while permitting the interaction of information from within the lexicon. The acquisition of a functional representation system entails an increase in the number of lexical entries and an increase in the quality of lexical entries. Quality is a matter of upgrading representations so that they are more fully specified and redundant. Access to this lexicon becomes increasingly word specific as the quality of specific word representations increases. The acquisition of an autonomous lexicon builds on this same functional lexicon by changing the status of specific words to fully specified and redundant. This means that parts of the lexicon can become autonomous very early in reading.

Two important issues are indirectly handled by this account. In the case of phonemic knowledge, implicit computational phonemic knowledge is central to the quality of lexical representations. In the case of reflective explicit phonemic knowledge, it develops with alphabetic lexical representations and not as precursors to them. Spelling and reading use the same lexical representation. In fact, spelling is a good test of the quality of representation.

Finally there is an important question not addressed. I have described the acquisition of representations as if it were a gradual process of incrementing knowledge. It could very well be a process in which a wider-scope restructuring of the lexicon occurs at various points in response to linguistic and orthographic insights. Either possibility is consistent with our present knowledge.

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7 Cognitive and Linguistic Factors in Learning to Read

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The purpose of this chapter is to discuss how children learn to read and what processes are centrally involved. The chapter is divided into five sections. The first draws attention to the importance of distinguishing between the process of learning to read, the process of skilled reading, and the process of reading instruction. The second describes a model of the proximal causes of individual differences in reading comprehension performance. The third provides a conceptual framework that specifies the relationships between the learning tasks, learning strategies, and cognitive prerequisites of beginning literacy development. The fourth summarizes research on the relationship between metalinguistic abilities and learning to read. And the fifth section presents a cognitive–developmental model of metalinguistic development and reading acquisition.

PROCESS AND INSTRUCTION

A major source of confusion in reading research stems from the failure to keep separate the following three questions regarding the role of any hypothesized component skill or mental operation.

1. What is the role of the skill in learning to read?
2. What is the role of the skill in fluent reading?
3. What emphasis should be placed on teaching the skill in reading instruction?

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