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5

The Lexical Basis of Comprehension Skill

Charles A. Perfetti and Lesley Hart

How shall we understand the source of individual variation in comprehension skill? What is it that skilled comprehenders do during reading that less-skilled readers do not do? Or vice versa: What do less-skilled readers do that skilled readers do not?

In this chapter, we revisit this question from a long-range perspective coupled with some new research. Fifteen years ago, Perfetti (1985) suggested an answer to this question roughly as follows: Although skilled comprehenders differ from less-skilled comprehenders in a number of ways, at least some of these differences arise from a foundational processing factor: the effectiveness of basic word identification skill. The bases of this claim lay in a program of research that consistently found that when either children or adults were separated by their scores on a reading comprehension test, they sorted themselves also on their speed of written word and pseudoword identification. Of course, even with a long list of studies with the same result, the causal connection between the lexical process variability and the comprehension variability could not be established. This problem, we believe, was not just the usual conundrum that blocks causal inferences from correlational data but was intrinsically part of how skill is acquired in reading: Lexical skills allow comprehension, comprehension allows reading practice, reading practice strengthens lexical skills, and so on. The recurrent nature of component interactions in the process assured an intimate connection between lexical and comprehension skills.

Nevertheless, the natural privilege in the genesis of the recurrent accumulation of skill belonged to the lexical processes. Although it was possible to imagine being able to read words without comprehending the texts that contain them, it was more difficult to imagine being able to comprehend the texts without reading the words. So we summarized the relationship in the *verbal efficiency theory*. The core idea was that many—not all—problems in comprehension arose from ineffective lower level processes needed for the identification of words. Rapid and perhaps modular word identification was important for a comprehension system of limited capacity.

The question we address here is, roughly, does some part of this idea remain tenable? And what more specific instantiation of the general idea is now possible? In what follows, we first review the background of verbal efficiency theory and then illustrate the concept of lexical quality and the lexical quality hypothesis, the central ideas that link lower and higher level reading processes. Then we summarize experiments on simple meaning judgments, whose outcomes, including some nonobvious ones, are predicted by this hypothesis.

Verbal Efficiency and Lexical Knowledge

In its earlier formulation, verbal efficiency was elaborated in two compatible ways. In the first, its source was lexical processing efficiency, and in the second, it was functional working memory (Perfetti, 1985, pp. 112–115). Both of these hypotheses have received ample attention in research, although distinguishing them clearly has not seemed to be a high priority. Research on adult comprehension focusing on memory differences (e.g., Carpenter, Miyake, & Just, 1994) has tended to ignore lexical factors. The solution to the question of whether there are multiple low-level causes or a single one remains a difficult question. If it is to be a single mechanism, it needs to account for two facts: (a) the pervasive association of lexical skills with comprehension skills in adults as well as children and (b) the association (only slightly less pervasive) of listening and reading comprehension skill. The obvious problem here is that it is not straightforward to convert a fundamental problem in written word identification into a cause of listening comprehension problems. So the unparsimonious two-factor theory may be required: (a) limitations in word identification efficiency and (b) limitations in functional working memory (perhaps with a phonological component).

In discussing the single- versus two-mechanism alternatives, Perfetti (1985) offered a one-factor conjecture based on linguistic code manipulation. The basic idea was that, in any modality, efficiency is the rapid retrieval, from inactive memory, of codes that are part of a stored linguistic symbol. And "to the extent retrieval is effortful and the retrieved codes low in quality, the processing is inefficient" (p. 118). Whether by spoken language or by written language, a low-quality code retrieved with effort would jeopardize comprehension processes that depend on a high-quality representation. However, the additional linguistic step in reading—mapping an orthographic form onto a lexical representation—could make the problem more noticeable in reading than in listening.

Lexical Quality

The question of code quality, in this account, becomes central. The original suggestion was that the retrieval of a lexical representation is high in quality "to the extent that it contains both semantic and phonetic information sufficient to recover its memory location. . . . [This quality must be retained] long enough for subsequent processes to perform their work. Thus a 'name' without meaning and a meaning without a 'name' are both low quality" (Perfetti, 1985, p. 118). This idea was developed further in a theory of reading acquisition by reference to lexical *specificity* and *redundancy* (Perfetti, 1992). A lexical representation has high quality to the extent that it has a fully specified orthographic representation (a spelling) and redundant phonological representations (one from spoken language and one recoverable from orthographic-to-phonological mappings). If a lexical representation is specific and redundant, its retrieval is more likely to be *coherent* and *reliable*. By coherent, we mean that the constituents are available synchronously at retrieval, giving the impression of a unitary word perception event. (The contrast is constituent asynchrony, a fragmented appearance of constituents and parts of constituents, as when an effortful speech recoding occurs followed by meaning retrieval; see Perfetti, 1985, p. 114.) The consequence of reliability is that multiple encounters with a given word tend to produce a common core representation consisting of a nexus of orthographic phonological and semantic information. To put it approximately, these defining features of high quality allow the reader to get exactly the word that is printed rather than parts of it that may also be parts of other words. Confusion about word meaning and word form is minimized by high-quality representations.

One should be able to detect variation in quality in a number of ways: For example, inconsistency in attempts to spell and hesitant or effortful retrieval of pronunciations or meanings reflect low-quality representations. A reliable, coherent, high-quality representation is retrieved easily and consistently. Figure 5.1 represents a high-quality representation by indicating a tightly bonded set of word constituents: the orthographic (OR), phonological (PH), and semantic (SE) specifications of the word. The identification of the word is the retrieval of these *constituents*.

It is useful to consider the implications of *constituent* as opposed, to say *component* or *level*—a common reference in hierarchical models. A constituent in a linguistic or algebraic representation is not merely a part of a larger whole; it is a necessary or defining symbol, a variable. Thus, a sentence is a noun phrase plus verb phrase (NP + VP), major constituents that can assume specific values. Analogously, a word is an unordered triple of PH, OR, and SE. The specification of each is subject to constraints from a relevant system. Those involving phonology are of special interest in word identification but are beyond our purpose here. (See Berent & Shimron, 1997, for an example of constraints on phonology that may be relevant for reading.) Similarly, SE constituents reflect basic conceptual and grammatical constraints. One consequence of the constituent idea is that it encourages the view that the word identity is both unitary and compositional. Thus, the lexical representation of the word *cat* is the (unitary) linguist object such that it has spelling C-A-T, phonology œ, and meaning (whatever it is that cat means). In general terms, all words are triples of {PH, OR, SE} specification. The SE constituent, however, is incomplete in the *cat* example, because it ignores grammatical information. To avoid a fourth constituent, we can stipulate that SE is actually a collection of meaning and grammatical information. Thus, it includes the lemma, the abstract grammatical frame that appears necessary to understand the production of speech (Bock & Levelt, 1994), and a conceptual structure that links to the lemma.

We can now state the key idea about individual differences: People vary in the quality of their lexical representations. Any representation that does not specify the value of one of its constituents is low quality. Consider the following examples:

1. Presented with the word *incarcerate*, the reader can pronounce it accurately and knows it has some negative meaning but is not sure what that meaning is.

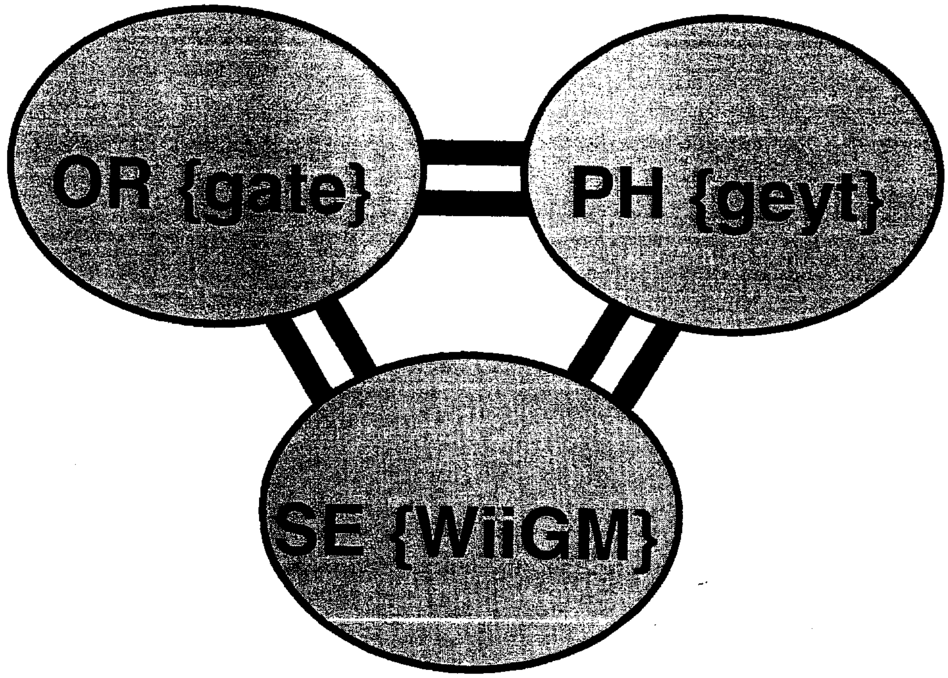

Figure 5.1. A high-quality representation for the word *gate*. Lexical representations (for a literate mind) are triples of orthographic (OR), phonological (PH), and semantic-syntactic (SE) constituents. Quality is the extent to which each constituent is fully specified (constants instead of variables for OR and PH form constituents) and conceptually and syntactically differentiated (for SE constituents). Here quality is indicated more crudely as concatenation links between constituents. These links are not to be understood as activation links, but as bonding links. Thus, *gate* is the word such that its OR, PH, and SE constituents are specified as given in the diagram and mutually bonded into a unitary lexical object.

2. Presented with *incarcerate*, the reader stumbles on its pronunciation, producing something like *in-cark-rate*.
3. Presented with *incarcerate*, the reader can pronounce it and indicate that it means something like "to confine in prison." When attempting to speak the word to produce a message about someone going to jail, however, the reader sometimes produces *incarcerate* and sometimes something more like *incarsate*.
4. A reader can perform all the tasks failed variably in 1, 2, and 3 above but can spell the word correctly only on some attempts.

The examples indicate several unreliable representations of the word {*incarcerate* [inkarsreyt], (verb trans; put in jail)}. They will have differential consequences in different tasks. Case 4, for example, is one familiar to many individuals of high literacy—the feeling of semantic and phonological competence coupled with a spelling block. Case 1 may represent a skilled reader of limited experience who can "decode" a word that he or she does not really know, although the reader has heard it pronounced and thus has some phonological representation.

One thing should be made clear, given these examples. Illustrating the basic idea with a low-frequency word generalizes it. Even skilled readers have low-quality representations for some words. What skilled readers have are foundational resources to help retrieve impoverished representations and add information (about spelling, pronunciation, or meaning) to those representations. The gain in this analysis is the focus on words: It is not individuals, but word representations, that vary in quality. A skilled reader, in addition to having foundational resources (decoding, spelling, and grammatical skills), is one who has many high-quality word representations. A less-skilled reader is one who has fewer high-quality word representations. Examining the genesis of the number of quality word representations is another matter. Certainly, basic and explicit phonological knowledge supports early progress in reading, and subsequent practice in reading, listening, speaking, and writing promotes more high-quality word representations. Whatever the source of variation in any set of individuals, the key idea is that there is a continuum of lexical knowledge, and this continuum is bisected when researchers refer to skilled and less-skilled readers.

As a general methodological point, progress in understanding lexical knowledge and especially in relating it to comprehension skill requires more individual (reader- and word-specific) assessment than is typical in research. For example, to detect unreliability of word representations, one may need more than one sample of easy-to-give recognition tests for spelling or multiple-choice vocabulary tests. Fortunately, the kind of assessment we have in mind can be crudely approximated by such tests as a starting point.

Homophones and Lexical Quality

Words with multiple meanings on single forms are interesting because they risk lexical quality. Quality is at risk because there is a lack of one-to-one mapping among one or more form and meaning constituents. There are three possibilities:

1. *Ambiguity*: single OR form, single PH form, multiple meanings. This is the most general case and has been the staple of research addressing meaning selection process. Example: *count* (1. enumeration; 2. feudal title).
2. *Homophony*: two OR forms, one PH form. This has been the staple of research on phonological processes and has been relatively neglected in research on meaning selection. Example: *seed, cede.*
3. *Homography*: one OR form, two PH forms. There are few cases in English, and indeed these are rare across writing systems. This rarity is consistent with the universal privilege gained by phonology as a reliable mapping for orthography (Perfetti & Tan, 1998). Example: *bass* (1. voice or instrument of the lower pitch; 2. type of fish).

One can capture the possibilities of form-meaning divergence more simply by defining a two-way classification of phonological and orthographic sameness.

Ambiguity is then same phonology and same orthography. But that leads to infelicitous phrasing, such as homographic homophones, nonhomographic homophones, and nonhomophonic homographs. So, we prefer the three-way classification above.

To illustrate how homophones place stress on lexical representations, Figure 5.2 expands the representations of Figure 5.1 by adding the word *gait*. Although each orthographic specification is associated with a unique meaning specification (at least for our purposes), a single phonological specification links to two spellings and two meanings.[1] These are not low-quality representations because they are specified as fully as they can be. Thus, they can be considered the limiting case: high-quality word knowledge characteristic of a skilled reader. There is potential for confusion here. If one encounters the spoken form [geyt], both *gait* and *gate* might be activated, along with their different meanings. Context will select the right one, and the confusion will be of no real consequence for comprehension. Less obviously, in reading, confusion also can result even though the spelling uniquely identifies the word. Thus *gait*, despite being beyond dispute as to its identity, can cause its homophonic partner *gate* to be activated, leading to momentary activation. So the case for a skilled reader is that the written presentation of homophones can lead to the activation (retrieval) of two words. Although the representations are as good as they can be, the momentary retrieval of these representations can yield confusion, even for skilled readers as Gernsbacher and Faust (1991a) have shown.

If the potential for confusion exists for the skilled reader, it is even stronger for the less-skilled reader. According to the lexical quality assumption, a low-quality representation could be observed for *gait*, for *gate*, or for both. Imagine a reader whose skill is low enough that the word *gait* is completely unknown. No spelling, no meaning. This reader has no confusion when *gate* is presented. Or, more carefully, the only problem with *gate* is due to its representation quality independent of *gait*. It should be no different from a control word, one that is not a homophone. However, a more typical case might be a reader with an unreliable low-quality representation for *gait*. Now there is the increased potential of confusion beyond what one might see from a nonhomophone. This is because the representation for *gait*, no matter how impoverished, can be partially activated by a spelling, a pronunciation, or a meaning when *gate* is presented.

Frequency must be taken into account. Not only is word frequency an important determinant of word processing, but it is specifically implicated in disambiguating processes. Reading the more frequent member of a pair of homophones may occur without leading to access of the less-frequent member of the pair, a finding that has long been observed in research with ordinary semantically ambiguous words (Duffy, Morris, & Rayner, 1988; Hogaboam & Perfetti, 1978). According to the lexical quality hypothesis, this frequency result is a consequence of the benefits of experience for the higher frequency meaning,

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[1]One important feature of meaning is not represented in Figure 5.2 or in our discussion to this point. Meaning is relatively indeterminate at the lexical level. Semantic specification is no more than referential pointers or category indicators. Meanings, in the usual sense, are context-dependent in a way that orthographic and phonological forms are not.

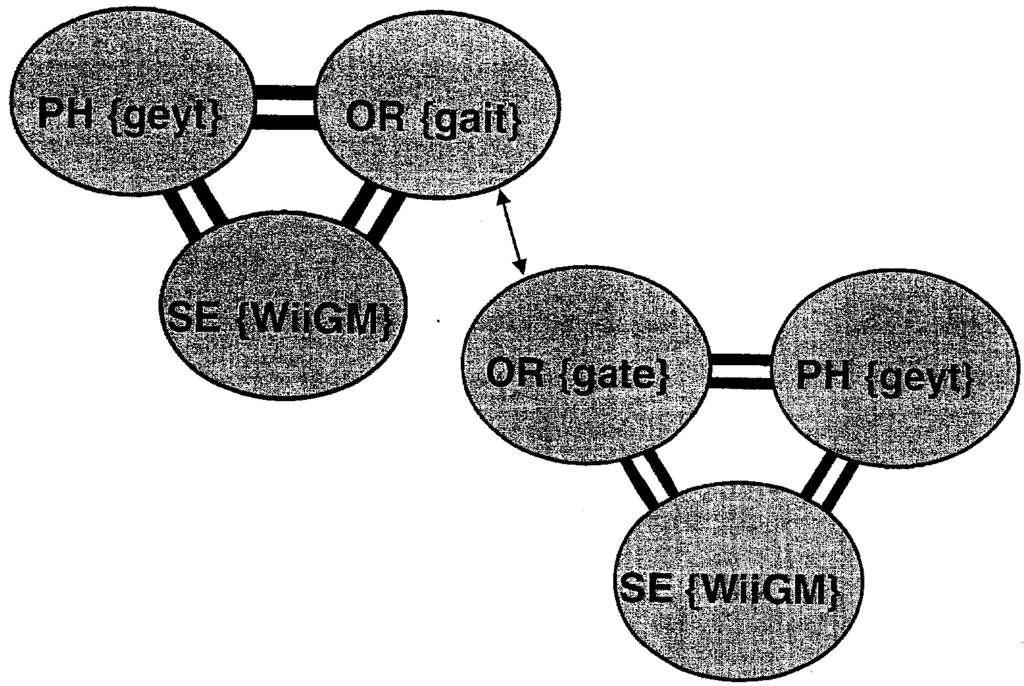

Figure 5.2. Representations for *gate* and *gait* as lexical processing units. The bonding links of Figure 5.1 are replaced by activation links (nondirectional), with stronger links represented by thicker lines. Thus, the high-frequency word *gate* has stronger internal activation links than the lower frequency word *gait*. The orthographic (OR) and phonological (PH) links are stronger in both than other links. Note the two words do not share a constituent. The idea is that each word in an autonomous lexicon strives to maintain a unique identity. The similarity relation between the two words arises from connections between their PH constituents rather than from some shared PH component.

making it a more stable part of the word, compared with the lower frequency meaning. Moreover, if we consider word representation quality to be distributed across individuals the way we have suggested, then high-frequency words may be less a source of confusion for skilled readers than for less-skilled readers. This is because a word that is high frequency according to a corpus count may have rather different functional frequency characteristics for skilled and less-skilled readers, who differ substantially by college age in the amount of reading they have done. Thus, a word that is functionally high frequency for a skilled reader may be functionally a low-frequency word for a less-skilled reader. We illustrate this point in Figure 5.3.

Functional Identifiability and Context

The basic idea illustrated in Figure 5.3 is functional identifiability. A word is identifiable to the extent a reader has had sufficient experience with the word so as to allow its constituents to be fully specified and linked. Familiarity (functional frequency) can be considered a proxy for identifiability. For a given reader,

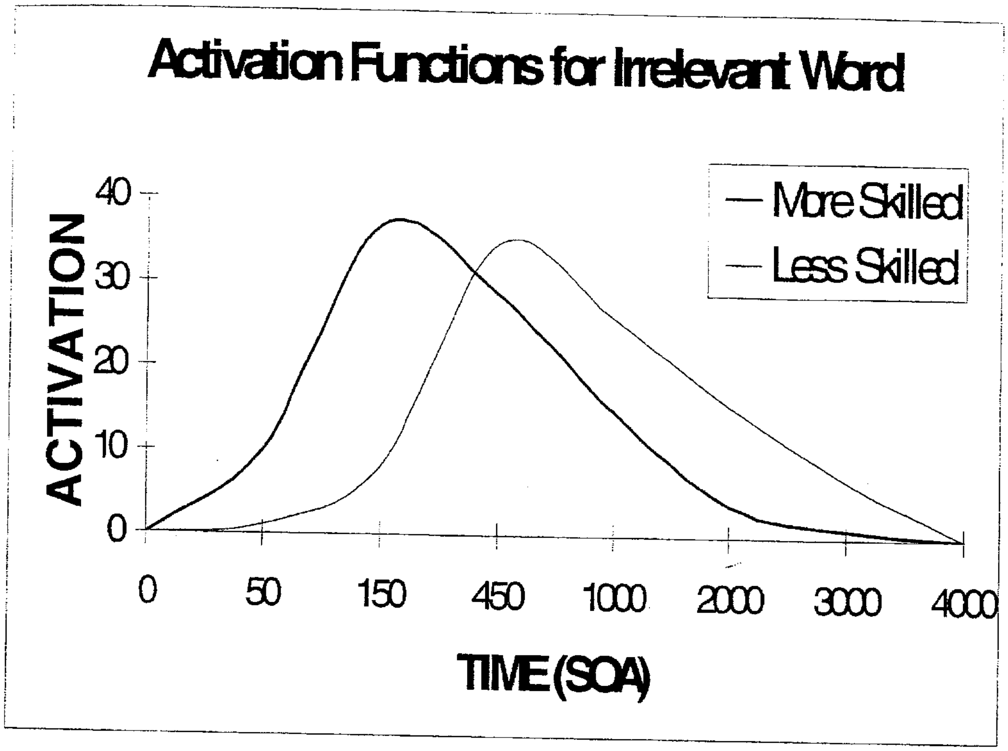

Figure 5.3. Hypothetical lexical activation functions. For a given word, the function for a skilled reader rises rapidly and deactivates accordingly. For a less-skilled reader, the activation and deactivation occur more slowly. Equivalently, given a reader, the more rapid function is for a higher frequency word and the delayed function is for a lower frequency words. SOA = stimulus onset asynchrony.

a functionally high-frequency word has a more rapid activation function—reaching an identification threshold more quickly—than a low-frequency word. And for a given word, a skilled reader will show a more rapid activation function than a less-skilled reader. Thus, words and readers are interchangeable in the identifiability functions.

There is an empirical basis for this interchangeability assumption. Perfetti and Roth (1981) summarized data from several conditions across experiments on the relationship between word naming in context and reading skill. Across conditions, there was variability in the constraint provided by context, word frequency word degrading (varied to examine bottom-up stimulus effects), and reading skill. Then, all these critical variables were ignored so as to examine the relationship between the time to identify a word in context as a function of the time to identify the same word in isolation. The result was a strong linear relationship between the time to identify the word in isolation and the time to identify it in context. In other words, one does not need to know the frequency of the word, the skill of the reader, or the visibility of the stimulus. To predict the time to identify the word in context, one needs to know only the time it takes to identify the word in isolation. This general function accounts for certain facts about individual differences. For example, the fact that identification times of less-skilled readers are aided more by context than are skilled readers is because their identification times are slower for the same words in isolation (Perfetti, Goldman, & Hogaboam, 1979; Stanovich & West, 1981; West & Stanovich, 1978).

The theoretical implication of these observations is that the identifiability of words in isolation can be a basis of predictions about comprehension of text segments that contain these words. It also means that we cannot expect variables defined only at the reader level or only at the objective text level (e.g., word frequency) to be complete. The functional identifiability is critical, and this can vary for the same word across readers and for the same reader across words.

We have, then, the basis for some nonobvious predictions about homophone confusions. The relationship between reading skill and homophone confusion effects should have different time courses and should show different frequency effects. First, because a skilled reader has higher quality representations for more words than does a less-skilled reader, the mutual activation of homophones should occur more quickly than for the less-skilled reader. Because both members of a homophone pair (e.g., *gate* and *gait*) are more identifiable for the skilled reader, activation will spread more quickly from the one to the other. This can lead to a homophone confusion more quickly for a skilled reader than for a less-skilled reader. However, this same assumption—that the skilled reader has better quality representations of homophones as for all words—leads to the assumption that this confusion will be short lived. The presented word will quickly have more activation than its unpresented homophone mate. For the less-skilled reader, confusion should build more slowly (because of a lower functional identifiability of both homophones) and release more slowly. This description referring to confusion and release from confusion is more general (and more theoretically neutral) than one referring to suppression (Gernsbacher & Faust, 1991a). We leave open the possible operation and failure of a suppression mechanism, although it is not required by our analysis of the process of homophone meaning selection.

The effect of word frequency is also implicated by this analysis. A skilled reader, whose knowledge of the high-frequency member of the pair (e.g., *gate*) is of very high quality, should show little interference from a presentation of that high-frequency word. For the low-frequency member of the pair (e.g., *gait*), the skilled reader's representation is of lower quality; so the presentation of *gait* allows confusion activation to spread to the better known *gate* before comprehension of *gait* is complete. Compare this with a less-skilled reader, who, by assumption, has lower quality representations for both the higher and lower frequency member of a homophone pair. The presentation of a high-frequency member of the pair will now allow confusion. Because its functional identifiability is lower than it is for the high skilled reader, this allows activation of *gate* to spread to the incomplete representation of *gait*. For this to occur, we need to assume that *gait* is partially represented, not entirely absent.

The Lexical Quality Hypothesis

To summarize, we have reintroduced a theoretical framework that has organized observations about individual differences in reading comprehension. In its earlier form, the theory focused on the efficiency of lexical processes as a causal component in comprehension variability. In this form of the theory, word-level efficiency allows processing resources to be directed to comprehension, especially the encoding and integration of propositions. In its subsequent and current elaborations, efficiency of word identification remains an important part of the explanation. However, it is not to be understood as fundamentally about speed of processing or even resource allocation but rather about the quality of lexical representations—detailed knowledge about word forms and meanings. High-quality representations are what drive rapid processing. More importantly, they are responsible for automaticity (or at least efficiency) of word identification, which is what allows processing resources to be devoted to higher level comprehension.

The quality of lexical representations can be defined reasonably well in terms of the full specification of word constituent information: triples of phonology, orthography, and semantics (and syntax). Assessments of individual differences have seldom been thorough enough to test the role of lexical quality against alternative hypotheses of comprehension differences. However, it is possible to approximate some of these assessments with traditional assessments of lexical processing, which is what we have done in the study summarized below. And it is possible to draw out the implications of the lexical quality hypothesis for processing homophones, which put additional pressure on lexical representations to be of high quality. Homophone processing should vary among readers of varying skill in systematic ways that reflect lexical quality.

Experimental Support for the Hypothesis

A test of the implications of the lexical quality hypothesis comes from two studies of meaning decisions. The main study uses simple word-pair decisions, in which only word form is informative, providing the main support for the lexical quality hypothesis. A second study examines decisions in sentence contexts. In both studies, our samples are drawn from college students across a wide range of comprehension skill, assessed by a time-limited version of the Nelson–Denny Reading Comprehension Test. We refer to higher scoring students as "skilled readers" and lower scoring students as "less-skilled readers."

Meaning Decisions

In the meaning decision experiment, the key questions center on readers' judgments that two words are related in meaning. When presented with the word *king* followed by the word *royalty*, the participant's decision should be "yes"; for *evening* followed by *royalty*, the decision should be "no." According to the lexical quality hypothesis, skilled readers should be faster than less-skilled readers in both the "yes" and the "no" judgments. This is because skilled readers have higher quality lexical representations, which make their critical constituents available more coherently and reliably, with less confusion.

Consider now the word *night* followed by the word *royalty*. The decision is "no" as it is for *evening–royalty*. But *night* is a homophone, and we expect potential confusion to arise because its phonology is shared with *knight*. So it might take longer to make a decision. To complete the picture, of course, we want to know about *knight–royalty*, *night–dark*, *king—dark*, and *evening–dark*—a full comparison of "yes" and "no" meaning judgments for homophones and nonhomophone controls.

Let us consider for a moment what we are not doing in the meaning decision task. We are not assessing sentence comprehension, a task used by Gernsbacher and Faust (1991a) to examine skill differences in homophone processing. In their study, participants viewed sentences, such as *He had lots of patients,* and then decided whether a probe word was related to the sentence meaning. The probe word *calm* should be given a "no" response here, but confusion can arise from the homophone *patience*. Thus, readers were slower to reject *calm* following a sentence with a homophone than following a sentence with a nonhomophone control word (*He had lots of students*). Gernsbacher and Faust (1991a, Experiment 3) found that both skilled readers and less-skilled readers were slowed in decisions to the homophone sentence at the shorter of two intervals between sentence and probe (450–500 ms between sentence final-word onset and probe onset). At a longer interval (1,350 to 1,400 ms between sentence final-word onset and probe onset), only less-skilled readers showed longer decision times, relative to control sentences. We think our word meaning decision task is tapping some of the same processing as the sentence task. However, it requires attention to word form only, making for a more direct test of a hypothesis based on lexical knowledge. In fact, it demands that the decision be made only on the word form. It allows no additional confusion to arise from sentence comprehension processes beyond the word level.[2]

What results do we expect on the basis of the lexical quality hypothesis? First, less-skilled readers should show slower decisions across the board. This means for control words as well as homophones, one should see the basic cost of lower quality representations. Second, recall that we suggested two predictions concerning homophones from the lexical quality hypothesis: (a) Skilled readers should show homophone confusions sooner than less-skilled readers, and (b) skilled readers should show confusions mainly for the less-frequent member of a homophone pair, whereas less-skilled readers should also show confusions for the more frequent member of the pair. Each of these results received strong support in the experiment.

First, consider the time course. The time between the onset of the first word (the target) and the onset of the second (the probe) was varied at three values: 150-, 450-, and 2,000-ms stimulus onset asynchrony (SOA). The first word always disappeared prior to the presentation of the probe. Thus, we can also describe the presentation sequence in terms of an initial (target) duration plus an interstimulus interval (ISI): 150-ms SOA, target duration = 100 ms, ISI = 50 ms; 450-ms SOA, target duration = 350 ms, ISI = 100 ms; and 2,000-ms

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[2]Because less-skilled readers, by definition, are less good at comprehension, there is some risk of their performance in a sentence task to reflect comprehension strategies in interaction with word knowledge. In particular, if less-skilled readers use context more to support reading, as the evidence suggests, they may try to use the sentence to support word identification, even when the sentence is intended to be unhelpful for this purpose.

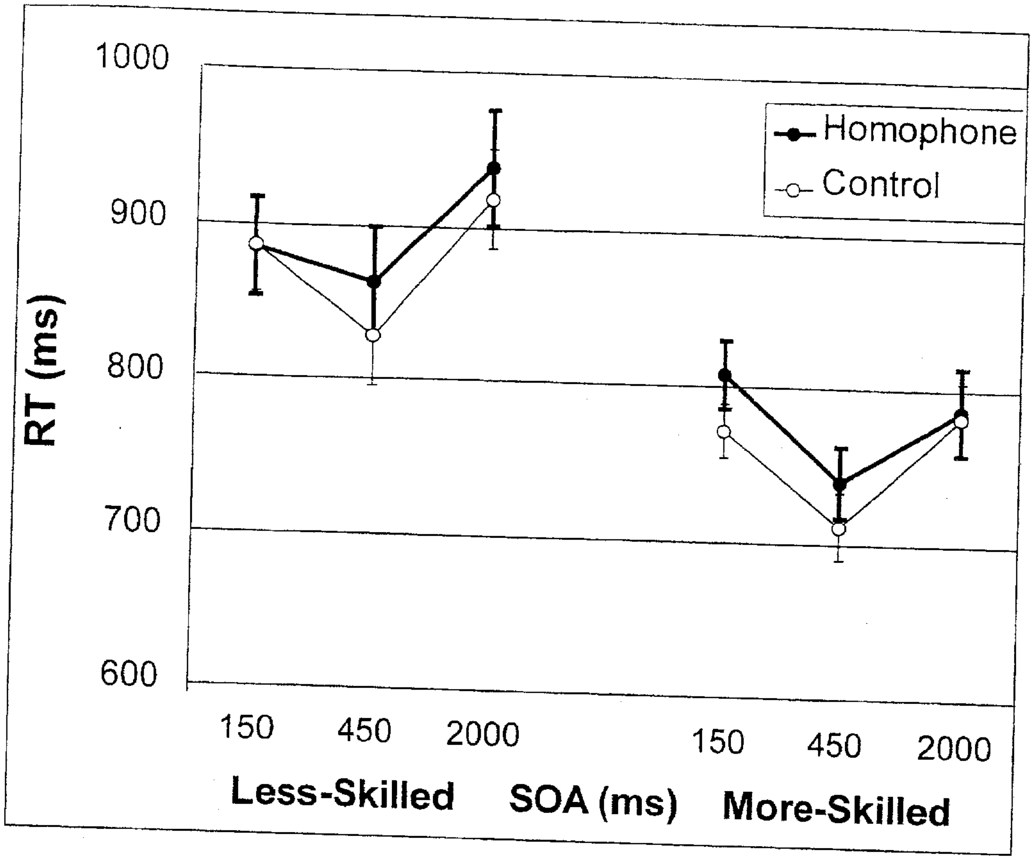

Figure 5.4. Decision times for homophone and control words across three stimulus onset asynchronies (SOAs) for skilled and less-skilled readers. Skilled readers showed reliable homophone interference at 150 ms only; less-skilled readers showed reliable interference at 450 ms only. RT = reaction time.

SOA, target duration = 350 ms, ISI = 1,650 ms. (The second word, the probe, remained viewable until the participant responded.) The 450-ms SOA approximates the shorter of the two ISI intervals used by Gernsbacher and Faust (1991a) to allow a comparison.

Figure 5.4 shows the main results for two groups of participants defined by their scores on time-limited version of the Nelson–Denny Reading Comprehension Test. In defining reader skill groups, we first administered the comprehension test to 300 undergraduates. For the experiment, the high-skill group were 44 participants in the top third of this distribution; the low-skill group were 38 participants with scores in the bottom third of the distribution. We carried out the experiment over a fuller range of comprehension skill that included 119 participants. But we excluded participants in the middle of this distribution to focus on the more highly contrastive groups of skilled and less-skilled readers, as is common in individual-differences research. However, our assumption is that we are dealing with a continuum of reading skill, and for other purposes, we can include the whole set of 119 participants.

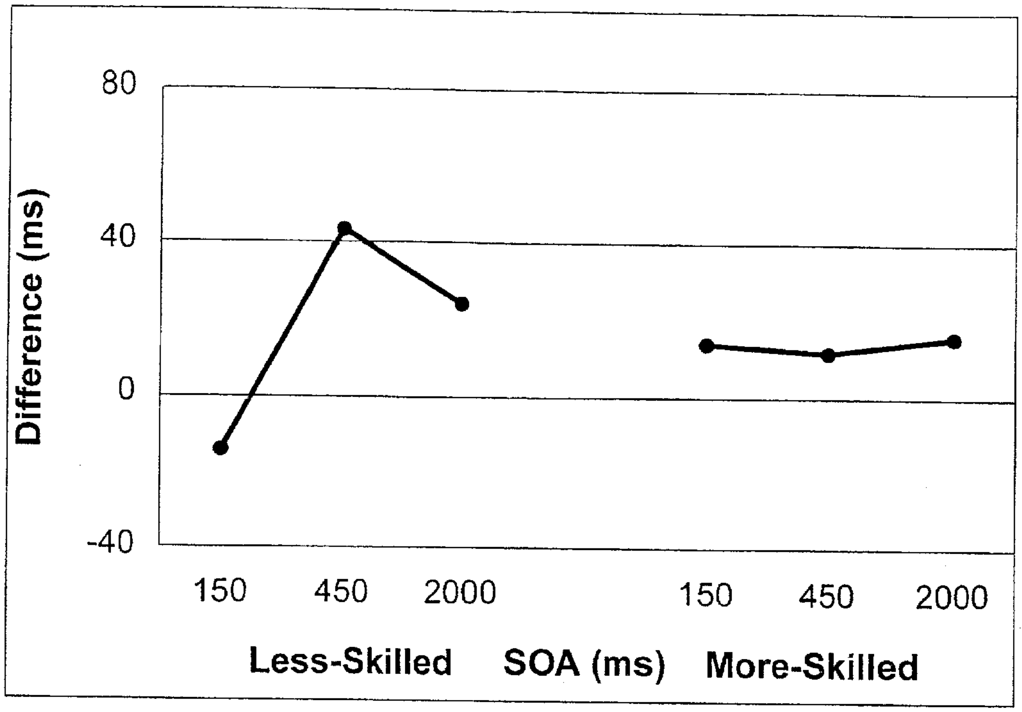

Figure 5.5. Decision time difference scores (homophones–controls) for high-frequency words. Skilled readers show no reliable homophone interference effect at any stimulus onset asynchrony (SOA). Less-skilled readers show a reliable homophone effect at 450 ms only.

Two main things can be seen in Figure 5.5. First, as predicted, less-skilled readers are slower than skilled readers on control words. Although this result may seem obvious enough, it is important theoretically. According to the lexical quality hypothesis, the general lexicon of skilled readers contains more high-quality representations than that of the less-skilled readers. All other lexically based differences, including those from homophones, arise from this fact.

And indeed homophone differences are seen. In relation to control words, skilled readers showed longer decision times at the shortest SOA of 150 ms. The homophone effect disappeared by 450 ms and did not return. The less-skilled readers showed no homophone confusion (beyond their confusion for control words) at 150 ms. However, they did at 450 ms. By 2,000 ms, they showed release from confusion. Note that there is a small and unreliable difference remaining at 2,000 ms for the less-skilled readers. As is usually the case, however, nonsignificant differences can be traced to individual reader and word differences that affect variance estimates. Because such differences are the heart of individual-differences research, we return to these in the next section.

For now, the general point is that rapid confusion leads to rapid release and delayed confusion leads to delayed release. The rapid confusion–release pattern is characteristic of the skilled readers and the delayed confusion–release pattern is characteristic of the less-skilled readers. A highly general activation–deactivation function is sufficient to explain this pattern. As a word is activated, its identification occurs at a sufficiently high level of activation. Along the way, activation can spread to other words that have formal or semantic links to it. Deactivation of nonidentified words occurs naturally in this process.[3] No additional mechanism such as suppression failure (Gernsbacher, 1990; Gernsbacher & Faust, 1991a) is needed. Less-skilled comprehenders take longer to show confusion and, accordingly, take longer to show release from it.

A second prediction concerns word frequency. Figure 5.5 shows the results for high-frequency words and Figure 5.6 shows the results for low-frequency words.

In both Figures 5.5 and 5.6, difference scores between decision times to homophones and controls are shown. A confusion effect is represented by a score above the zero baseline. Figure 5.5 shows that homophone confusion for high-frequency words occurred at the middle SOA (450 ms) for less-skilled readers. (We again see a nonsignificant difference at 2,000 ms.) No reliable homophone confusion occurred for skilled readers at any SOA.

For low-frequency words, a different pattern can be seen in Figure 5.6. Less skilled readers show no reliable homophone confusion, whereas skilled readers show confusion at the shortest SOA, 150 ms, which is maintained at 450 ms before releasing. Although the interference effect is small and unreliable for less skilled readers, the effect is above zero (especially at 450 ms). We think this effect is small because less skilled readers' problems with low-frequency words are very general, and simply processing any less-familiar word absorbs the effect that otherwise can be seen for homophones. Less-skilled readers' decision times for low-frequency control words across the three SOAs was around 900 ms for the shortest and longest SOAs and about 830 ms at 450-ms SOA, where one sees the largest difference between controls and homophones in Figure 5.6.

To put these results in terms of our *gate/gait* example, skilled readers are confused by *gait* but not *gate*. Less-skilled readers are confused by *gate*; they are probably confused by *gait* as well; but they are also confused by *stride*, a low-frequency control word, and thus have little opportunity to show a confusion that is specific to homophones.

These results not only are consistent with the assumptions of the lexical quality hypothesis but also provide evidence for specific nonobvious predictions concerning the time course of homophone confusion and differential patterns for high and low frequency. The temporal pattern has two interesting elements. One is the more rapid confusion and more rapid release from confusion shown by skilled readers, as predicted. A second is that the less-skilled readers not only showed a slower confusion, but they generally did show release from confusion by 2 s. Gernsbacher and Faust (1991a) found that less-skilled readers showed confusion at a shorter interval, about 1350–1400 ms after the final word of a sentence. It appears that confusion may not be a permanent affliction for many less-skilled readers, although we qualify this conclusion below.

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[3]The process that produces the confusion effect in meaning decisions is not entirely clear. In particular, the probe word should reinitiate activation of the presented word and possible reactivation of its homophone. Obviously this "backward priming" possibility applies equally to probes following sentences. Although our discussion has not explicitly taken this process into account, the same activation and deactivation concepts will apply, but in a more complex way. We are developing computational models that can stimulate meaning decision data, including homophone interference effects, in both "no" and "yes" responses.

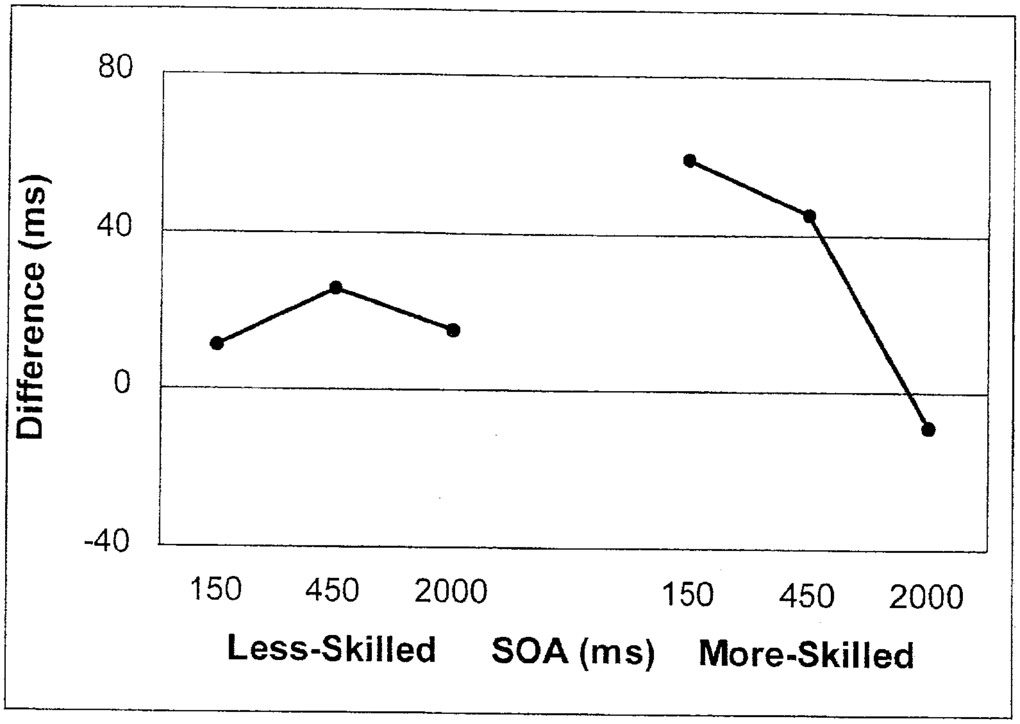

Figure 5.6. Decision time difference scores (homophones–controls) for low-frequency words. Skilled readers show reliable homophone interference effect at both 150 and 450 ms. Less-skilled readers show no reliable homophone interference. SOA = stimulus onset asynchrony.

Lexical Knowledge and Meaning Decisions

If it is true that the sources of the comprehension skill differences lie in lexical knowledge, we may be able to find further evidence. In the course of carrying out this study, we obtained assessments of comprehension skill and lexical knowledge for some 445 students. Although this larger group provides confirming evidence for the interrelationships among various lexical and comprehension skills, we focus on the assessments for just the 119 participants who made the timed meaning decision judgments. Can we predict meaning decision times from some of these assessments?

Our assessments were crude judged by the standards we have suggested in this chapter. Instead of thorough assessments about the specific words used in the meaning decision task, we have general tests of spelling, decoding, and vocabulary that serve as rough indicators of an individual's knowledge of phonological, orthographic, and semantic constituents of a general sample of words. The tested words were not the words of the decision task, and their assessment did not usually meet the standard (e.g., actual spelling and actual meaning analysis) we think is appropriate for careful assessments of lexical quality. Instead they are generally multiple-choice tests that assess the student's ability to select, for example, a correct spelling or meaning. An exception is that our test of phonological decoding requires the participant to decode a pseudoword.

In brief, our tests were as follows:

1. A multiple-choice, timed vocabulary test.
2. A phoneme manipulation test, in which participants repeated a word, deleting a phoneme. For example, *stay* without the /t/.
3. A multiple-choice spelling test, in which the participants chose from five alternatives.
4. A homophone discrimination test, in which participants chose which of two homophone fit into a sentence. For example, *The deep Arctic Ocean is inhabited by ____ (a) wails (b) whales.*
5. A pseudoword-decoding test, based on a computerized adaptation of the Word Attack Subtest of the Woodcock–Johnson Psychoeducational Battery. The test orders items in difficulty from very easy (e.g., *hap*) to more difficult (e.g., *phigh*). Items were presented one at a time.
6. A word identification test, based on a computerized adaptation of the Word Identification Subtest of the Woodcock–Johnson Psychoeducational Battery. Items were presented one at a time. Accuracy and naming times were collected on all but the first two tasks. Only accuracy was measured for the phoneme manipulation test, and only the total number correct was measured on the vocabulary test.

The general results for reading skill are what would be expected. Skilled readers' performance reliably exceeded that of less-skilled readers on all measures. This merely confirms what has been found before: Comprehension skill, even in adults, is associated with lexical skill. The lexical quality hypothesis leads to some more specific predictions, however. For example, the hypothesis predicts more rapid homophone confusion as a function of identification skill, and indeed skilled readers showed early homophone confusion at 150 ms. But what about less-skilled readers? A key idea in the lexical quality hypothesis is that there is a continuum of skill and a continuum of functional word identifiability. Do some less-skilled readers also show early homophone confusion?

The answer is yes, and it tends to be those who have higher decoding skill, as measured by the assessment of pseudoword reading. This correlation, along with a handful of others that were reliable, is shown in Table 5.1.

The correlations in Table 5.1 are quire modest, but it must be emphasized that what is being correlated is a difference score: performance on homophones minus performance on controls. Difference scores show modest correlations when the major factor in reading skill—the ability to identify words—has already been removed. In effect, one sees only the residual effect of homophone confusion. Nonetheless, rapid homophone confusion—a homophone effect at 150 ms—is *positively* correlated with pseudoword decoding speed. Equally interesting is the fact the continuation of confusion at the longest SOA is *negatively* correlated with pseudoword decoding speed. Thus, there are some possibly interesting individual differences rather than mere "error" in the tendency for less-skilled readers to show a nonreliable homophone-control difference at the longest SOA (see Figure 5.4). Although some participants indeed showed release from

Table 5.1. Correlations of Lexical Variables With Homophone Interference (Homophone-Control Reaction Times) at 150- and 2,000-ms SOA for Less-Skilled Readers

Reading group and variable	150-ms	2,000-ms
Less-skilled readers		
Homophone discrimination HF		–.36
Homophone discrimination LF		–.37
Pseudoword reading	.38	–.35
Comprehension[a]	.36	
Skilled readers		
Homophone discrimination HF		–.31
Homophone discrimination LF	.30	

Note: All correlations, $p < .05$. SOA = stimulus onset asynchrony; HF = high frequency; LF = low frequency.
[a]Assessed by the Nelson-Denny Reading Comprehension Test.

confusion by 2,000 ms, some did not. And the correlations tell us that those who failed to show release from confusion were those slower at decoding. We see a similar pattern for the homophone-spelling test. A failure to show release from homophone confusion was associated with slower and more error-filled performance on a task that required participants to choose the correct form of two homophones, given the meaning of one.

Overall, the correlations add support to the hypothesis that lexical quality is responsible for homophone interference. Not only are the patterns of experimental effects—the temporal patterns and the frequency patterns—predicted by the hypothesis, the correlations further suggest that even the "error" in the data is systematically related to measures of lexical processing that are related to the lexical quality assumptions in sensible ways.

Homophones in Context

Finally, we return to a brief discussion of context. In the meaning decision experiment, we found specific patterns of homophone interference that distinguished skilled and less-skilled readers. The results support the lexical quality hypothesis. In the larger sample factor analysis, we obtain evidence for the lexical processing differences as a function of reading skill, further suggesting that specific assumptions of the lexical quality hypothesis might be reasonable. If all this is more or less correct, it becomes of interest to examine homophone interference when the constraint of sentence meaning reinforces the evidence in the word form that it must be this word rather than that word—that it must be *gait* rather than *gate*. If top-down comprehension strategies are available to less-skilled readers (Perfetti, 1985; Stanovich, 1980), we may see a reduction of interference.

For this test, we carried out a second meaning decision experiment with a new sample of participants defined as in the first experiment. SOAs were varied as in the first experiment. The only difference was that a constraining sentence was presented, ending in a homophone and followed by a test word after a varying SOA. For example, *Because of his leg injury, the man walked with an unusual gait*. The key comparison is between a decision to a word related to the meaning of the homophone mate (*fence*) and a control word. The design was complete and fully counterbalanced, replicating the first experiment. The results showed several interesting outcomes. For one, although the two groups of readers were very accurate in making these decisions, skilled readers were faster, not just for homophones but also for control words. This skill difference was a main effect that did not interact with SOA. Both groups were faster to make correct decisions at 450-ms SOA than at either the shorter (150-ms) or longer (2,000-ms) SOA. Most interesting is the result that neither group showed any effects of homophones measured in the difference between controls and homophones plotted in Figure 5.7. The confusion we observed when the word itself was the only source of information is now eliminated, both for less-skilled readers and for skilled readers.[4]

We must keep in mind that we have a different group of readers here than in the first experiment. Nevertheless, it is striking to see the disappearance of the confusion effect when a sentence context is available. This is certainly consistent with the findings that even less-skilled readers use context. Its implications, when coupled with the results of the lexical experiment, are clear: Homophone confusion depends on comprehension skill. However, the effect of comprehension skill is mediated solely by lexical factors and is not visible in sentence comprehension itself. This seeming paradox is resolved as follows: The comprehension task here was targeted to the single final word. In effect, the semantic component of the word is reinforced sufficiently to override any unstable orthography and phonology. Less-skilled readers may be more dependent on meaning (because of weakness elsewhere in their lexical representations), thus providing more cues to the meaning is very helpful. More directly persuasive, however, is the clear fact that this group does not comprehend as well as the skilled group. The groups were defined this way. Thus, their general comprehension problem has a clear lexical basis. It can be overcome only in certain tasks that are not typical of ordinary comprehension.

There is nothing in this account to suggest that less-skilled readers have a problem in suppression. In terms of the structure building framework (Gernsbacher, 1990), one could say that our context effects demonstrate the enhancement of structures is something that less-skilled readers can do well. The verbal efficiency theory makes the same prediction, based not on enhancement but on basic lexical identification. The slower the process (because of lexical quality), the more room for context facilitation. Moreover, this idea generalizes to account for the facts of homophone confusion when there is no context.

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[4]The slight effect shown by skilled readers at the shortest SOA is not reliable, although it might be interesting. Recall that skilled readers showed this short SOA effect for the word-only experiment. At least some skilled readers may have a brief activation to the phonology of the presented word that is sufficient to interfere with a probe that is only 150 ms later. Indeed, if this difference were reliable, we would be tempted to note its parallel in the research on processing ambiguous words in context. Does the encounter of a word with more than one meaning briefly activate all its meanings, even when spelling disambiguates the word?

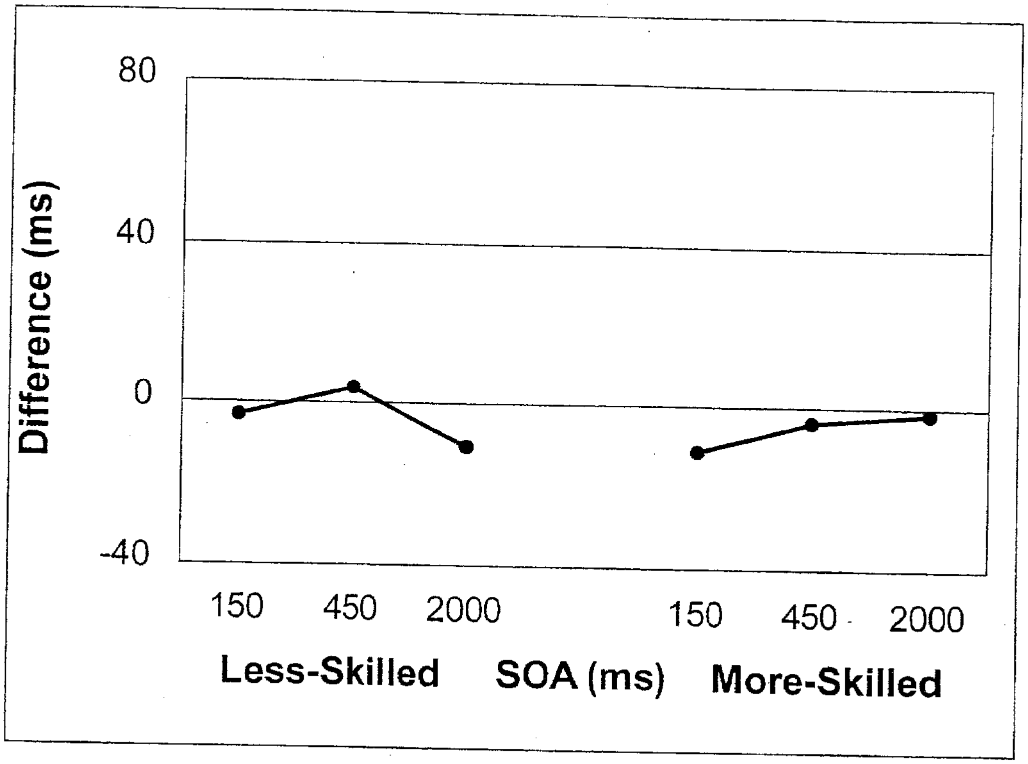

Figure 5.7. Constraining sentence context experiment: Decision time differences between controls and homophones for skilled and less-skilled readers. No effect of homophones was found for either group. SOA = stimulus onset asynchrony.

When the reader is solely dependent on word form, weaknesses in word form are revealed. This fact results in the pattern of experimental results we observed: slower activation and deactivation by the less-skilled reader and confusion restricted to more familiar word forms.

Thus, we do not need to add a suppression mechanism to the explanation. To do so, one would have to say that less-skilled readers have low-quality word representations and faulty suppression mechanisms. Of course, that might be the case. Another possibility is that suppression is nothing more than a prolonged period of competing activations. But what would be the source of this prolonged competition? A defective additional mechanism that suppresses the unwanted competitor? Or the single-word identification problem that has caused the competition in the first place? It is possible that suppression will continue to be a necessary mechanism to understand related phenomena in nonlinguistic tasks and even in other language comprehension tasks (Gernsbacher, 1990). But in this one case, words with partially identical forms, it is not necessary.

If we are right, then we need to reemphasize the lexical foundations of reading comprehension. Although there are many other component skills in comprehension and an enormous contribution from conceptual knowledge, word identification is the central recurring event of reading. A lot depends on the lexical knowledge that drives it.

Conclusion

We have argued that the quality of lexical representations is a critical factor in reading and that lexical quality can explain individual differences in simple reading comprehension tasks. Variation in lexical quality—the extent to which individual word forms and meanings are represented reliably and coherently—produces variation in identifying a specific word from among words that share orthographic, phonological, and semantic information. Experiments can expose lexical quality with words that share forms or meaning, thus putting pressure on lexical quality. Our experiments used homophones, which share phonology, to study the simple comprehension of word pairs with a focus on the time course of confusion effects. The important findings, consistent with the lexical quality hypothesis, were that skilled comprehenders showed a more rapid build up of confusion and a more rapid release from this confusion compared with less-skilled readers. Furthermore, skilled readers, but not less-skilled readers, avoided confusions for the high-frequency member of a homophone pair. A second experiment found no confusions for either skilled or less-skilled comprehenders when the homophone was in a sentence context consistent with its meaning. The results demonstrate that variations in lexical quality produce variation in simple comprehension performance that correlates with overall reading comprehension skill. Accordingly, they provide new and partly nonobvious evidence for a specific lexical knowledge explanation of individual differences in comprehension.

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