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CHAPTER SIX

Learning Words in Zekkish: Implications for Understanding Lexical Representation

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Reading skill has, as its core, single words. When we consider phonology, we talk about the sounds of a language and their combination into words. When we consider orthography, we talk about the spelling of single words and the overall language structure that dictates spelling rules for single words. When we consider semantics, we talk about qualities of a word's meaning that give it its place in the lexicon. Even when we consider comprehension, we discuss the feeding of word-level, lexical information into a system that can build and maintain a representation of text that is being read.

To be sure, there are many other processes that contribute to skilled reading comprehension. These processes have been shown to be stronger in skilled readers than in less skilled readers. Researchers have associated keen inference-making abilities (Long, Oppy, & Seely, 1997; Oakhill, Cain, & Yuill, 1998; St. George, Mannes, & Hoffman, 1997), large verbal working memory spans (Cohen, Netley, & Clarke, 1984; Oakhill, Cain, & Yuill, 1998), good attention and motivation (Jonkman, Licht, Bakker, & van den Broek-Sandmann, 1992; O'Neill & Douglas, 1991; Whyte, 1994), and strong metacognitive skills (Cornoldi, 1990; Oakhill, 1994; Vauras, Kinnunen, & Kuusela, 1994) with skilled text comprehension. However, each of these contributory skills can actually be associated with broader domains of functioning than reading, and even, in many cases, than language processing. Understanding that skills such as working memory and attention apply to more than reading does not make their contribution to reading any less important, but it does imply their status as moderating, rather than mediating, associates of reading skill. Further, it illustrates the necessity of identifying reading-specific processes that can account for reading disabilities in the absence of more general language or processing problems. For example, while preschool children with Specific Language Impairments (SLI) often have reading difficulties as they get older (Bishop & Adams, 1990; Catts, Fey, Tomblin & Zhand, 2002; Scarborough, 1990; Snowling, Bishop, & Stothard, 2000), and while reading can certainly be delayed along with other general processing delays, many children with SLI go on to have reading skills in the normal range, and not all children with reading disabilities have other processing delays. And coming full circle, understanding deficits specific to reading impairments can suggest how those same mechanisms are used for skilled reading.

Two of the strongest and most replicated findings in the reading literature are that children (and adults) with reading disabilities have deficits in word decoding, often in the absence of any other reading-specific or general deficits (Felton & Wood, 1992; Osmon, Braun, & Plambeck, 2005), and that lexical skill (orthographic, phonological, and semantic) covaries with reading comprehension skill (Gernsbacher, 1990; Perfetti, 1985; Stanovich, West, & Cunningham, 1991). These associations can be found across writing systems, particularly those with deeper orthographies, when better decoding skills are necessary to navigate less reliable spelling-sound mappings. For example, decoding and lexical skills have been associated with reading comprehension in Chinese, Japanese, and Arabic (Ho, 2003; Paradis, 1989; and Abu-Rabia 2003, respectively; also see overviews by Aaron & Joshi, 1989; Perfetti & Bolger, 2004). Shallower orthographies like Greek and German, with more reliable mappings of spelling to sound, do not show these associations (Nikolopoulos, Goulandris, & Snowling, 2003; Wimmer, 1996, respectively), presumably because the decoding system is required to utilize fewer rules to systematize the mappings (e.g., i before e, except after c…). The associations between decoding skill and reading comprehension can also be found across languages; decoding skill in a first language (L1) predicts decoding skill – and comprehension skill – in a second language (L2; Oren & Breznitz, 2005; Wade-Woolley, 1999). Decoding skill and comprehension skill are related even after early elementary school, when decoding is more automatized than when children are learning to read (Miller-Shaul, 2005; Vellutino & Scanlon, 1988).

Because words serve as an important base for reading skill, it is crucial to identify the qualities of a word that affect its utility in the lexicon. Some of these qualities come from the language structure itself – consistency of letter to sound mappings (grapheme-phoneme correspondence, or GPC), frequency with which phonemes occur together (e.g., bigram frequency), and the extent to which words share qualities with other words (neighborhood effects), for example. Some of these qualities come from the language use of both the individual and the population as a whole. Written word usage within a population determines the frequency with which each word is encountered; the reading experience of each individual modifies the written frequency of each word into a personal frequency set of word encounters.

In this chapter we will discuss the Lexical Quality Hypothesis (Perfetti & Hart, 2001, 2002), a framework for understanding how lexical quality is built, the characteristics of language experience that can produce higher or lower lexical quality lexical representations, and how higher quality lexical representations can support better text comprehension. We will discuss, in detail, three types of words that are lower in lexical quality and their implications for word and text processing – homographs, ambiguous words, and homophones.

We will then focus on studies that use homophones to examine the lexical quality differences in more-skilled and less-skilled comprehenders. We will report findings by Gernsbacher (Gernsbacher, 1990; Gernsbacher & Faust, 1991; Gernsbacher, Varner, & Faust, 1990) that less-skilled comprehenders have a different pattern of responses to homophones versus non-homophones. We will then report three of our studies replicating, extending, and suggesting a causal link for Gernsbacher's original results.

THE LEXICAL QUALITY HYPOTHESIS

We (Perfetti & Hart, 2001, 2002) have attempted to illustrate the qualities of lexical representations that allow them to support efficient comprehension in the Lexical Quality Hypothesis. Lexical representations are the word entries in the lexicon, or mental dictionary. Words are acquired and added to the mental dictionary as they are learned through spoken or written language. Their meanings are fleshed out and their places in the lexicon are fortified by hearing, using, and reading the words multiple times in a variety of contexts. Their strength and stability in the lexicon define their lexical quality.

The Lexical Quality Hypothesis is built on modifications of two theories of Perfetti (1985, 1992). In *Reading Ability* (1985), Perfetti outlined Verbal Efficiency Theory. High quality lexical representations have been built from good phonological and semantic information, usually fortified by multiple word encounters, which further strengthens the phonological and semantic information. The strong lexical representations can be quickly re-activated when they are read, which makes the lexical information available to comprehension processes. In The Representation Problem in Reading Acquisition (1992), Perfetti revised the definition of high-quality lexical representations to include two new concepts. Lexical representations need to be specific; they need to associate a single orthographic representation (spelling) with a single lexical item. For example, the specificity of "bank" is low because the single orthographic representation is associated with the lexical entries meaning "river edge" and "financial institution." Lexical representations also need to be built and accessed with redundant information. That is, sound information from speech and from print need to be associated with the same lexical entry. For example, "sow" receives information from speech that is only partially redundant for each of two lexical entries. The two pronunciations, meaning "female pig" and "plant crops," each support the same spelling but two different lexical representations. Both of these lexical representations have low redundancy.

The Lexical Quality Hypothesis (Perfetti & Hart, 2001, 2002) describes lexical entries as having three constituents: orthography, phonology, and semantics; all three are necessary for a coherent lexical entry. Lexical entries are described as being coherent when the three constituents are synchronous. When the orthographic, phonological, and semantic information associated with a word are activated simultaneously, the impression is that the lexical item is being activated from three sources. Repeated encounters of the triads of orthographic, phonological, and semantic information increase their coherence as a unitary lexical entry. The greater the coherence, the higher the likelihood that the particular combination of lexical constituents will activate one and only one triad, or lexical entry. That is, a coherent lexical representation allows the reader to pull from the lexicon the exact word that is printed, instead of bits of the word that may be associated with other words as well.

The Lexical Quality Hypothesis also includes an assertion that fast activation of high quality lexical representations is required to support efficient comprehension. Only words efficiently and effortlessly activated are able to free processing resources for building a text representation and comprehending the resulting structure. Thus, factors involved in building high quality lexical representations are a likely site of impairment in readers with reading disabilities, and possibly more specific to reading processes than factors such as verbal working memory span or motivation. Again, words serve as a basis for understanding skilled and impaired reading processes not just at the lexical level but also in smaller units at the sublexical level and in larger units at the level of structure building and text comprehension.

HOMOPHONES, HOMOGRAPHS, AND AMBIGUOUS WORDS

Several naturally occurring patterns in most language systems afford researchers a clever and sneaky way to quantify the process of lexical access, which occurs on the order of milliseconds. One way to measure lexical quality (and the resulting lexical access) is to occasionally intentionally degrade the process of lexical access by sneaking words of low specificity and/or redundancy into experiments and comparing performance with these words to words of higher lexical quality. Scientists can then capitalize on these sneaked-in words by devising experiments with parameters designed to elucidate particular qualities of the activation process. That is, the specifics of the experiment will determine the consequences of the lower lexical quality.

Homographs

Homographs are words that have a single orthographic representation, but two phonological representations and two semantic values (See Figure 6.1 for representations of orthographic, phonological, and semantic connections in homograph representations). For example, *bass* can be pronounced with a short a sound to mean a fish, or with a long a sound to mean a musical instrument. This is not a specific representation. When the orthographic pattern is presented, there is not a single

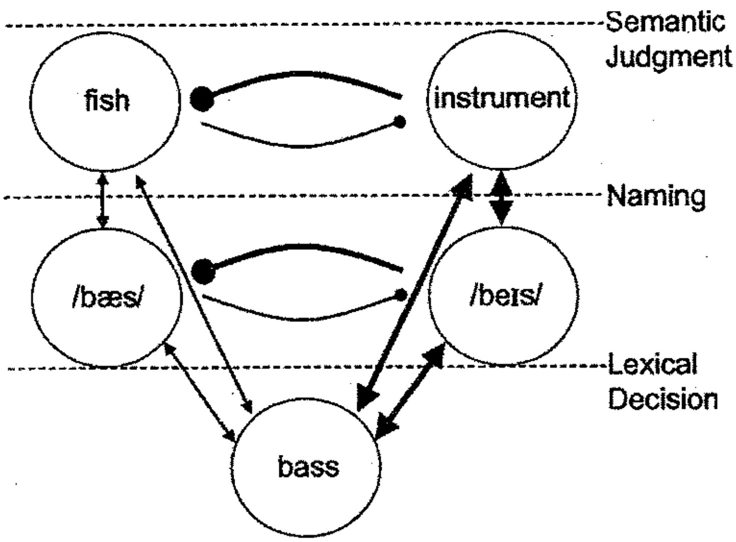

FIGURE 6.1 Connections among orthographic, phonological, and semantic components of homographs.

unique triad that is activated; instead there is a rise in activation for two lexical items. The coherence of the representation dictates the speed and rise of the activation. A fisherman is likely to have a coherent representation for the fish meaning, and a less coherent, less efficiently activated representation for the instrument meaning, because he is likely to have encountered the orthographic pattern more often when it is associated with the long-a phonology and the fish meaning. The more coherent representation is called dominant, and the less coherent representation is called subordinate. A musician is likely to have the opposite pattern of dominance. The result in both cases is that the activation of one lexical entry competes with the activation of the other lexical entry, leading to a period of lexical indecision. In the case of homographs, the context in which the word appears is necessary to disambiguate the meaning, dampening the activation of one homograph lexical entry and raising the activation of the other entry, although the relative coherence of the entries from word experience (Gorfein, Viviandi, & Leddo, 1982) can provide a useful clue.

Homograph Naming. Tasks that require the naming of homographs usually show a slowed response time for homographs compared to control words. This is a reflection of the competition between the phonological representations that are activated from the orthography. Gottlob, Goldinger, Stone & Van Orden (1999) found that response times were slowed regardless of whether the word meaning was dominant or subordinate. Pronunciations from orthographies that are more frequent improve reaction times. The more dominant meaning is often the one that has an irregular orthography; that is the word which is most often encountered is the one that is pronounced with a phonology that is less often associated with that orthography. For example, on average, the lexical entry for a musical instrument is dominant for the "bass" orthography, but the long-a pronunciation is less often associated with an *a* in a consonant-vowel-consonant(s) (CVCC) word. This increases reaction time, illustrating again that naming occurs at a lower level than semantic judgment (Kawamoto & Zemblidge, 1992).[1]

Homograph Semantic Judgments. Tasks that require semantic categorization of homographs can show fairly normal response times for the dominant meaning, and dramatically slowed response times for the subordinate meaning, because the much higher activation of the dominant meaning must be overcome before the ambiguity is resolved. For example, making the decision that "affect" and "influence" are related in meaning is easier than making the decision that "affect" and "emotion" are related in meaning. The difference is that the first pronunciation, with the accent on the second syllable, is much more frequently encountered than the second pronunciation.[2]

Including homographs in experiments can elucidate the role of inhibitory connections such as those between dominant and subordinate meanings, of statistical likelihood of pronunciation and meaning, and of personal experience with each meaning.

Ambiguous Words

Ambiguous words have a single orthographic representation and a single phonological representation, but two semantic values (See Figure 6.2). For example, the word "spring"can mean a metal coil or the season between winter and summer. Again, this is not a specific lexical representation. When the orthography and phonology are activated, there is a rise in activation for the lexical items of both meanings. With ambiguous words there is no phonological competition; however, the context and the extent of bias in the context in which the word appears (Vu, Kellas Petersen & Metcalf, 2003), word-specific qualities such as word structure (Almeida & Libben, 2005), and the relative frequency of use of each of the meanings (Collins, 2002) remains necessary for choosing among multiple activated lexical entries.[3]

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[1]While irregular pronunciations increase reaction time, there is also a top-down effect of meaning dominance; Kawamoto & Zemblidge (1992) found a similar response time to the naming of dominant and subordinate homographs, which can be construed as an interaction of pronunciation and meaning frequencies.

[2]The easily recognizable pronunciation difference is the shift in the accented syllable. This shift changes the pronunciation of the vowels as well. They are pronounced as the short vowel sound when the syllable is accented, and as a schwa when it is not.

[3]This is actually an oversimplified representation of ambiguous words, because many ambiguous words have more than two meanings competing for dominance. For example, "jam" can mean jelly, blockage, predicament, crush, or stop working. Some of the definitions share semantic qualities, however. It is also the case that homographs and homophones can have more than two meanings associated with them. This quality of multiple meanings is not dealt with in this paper.

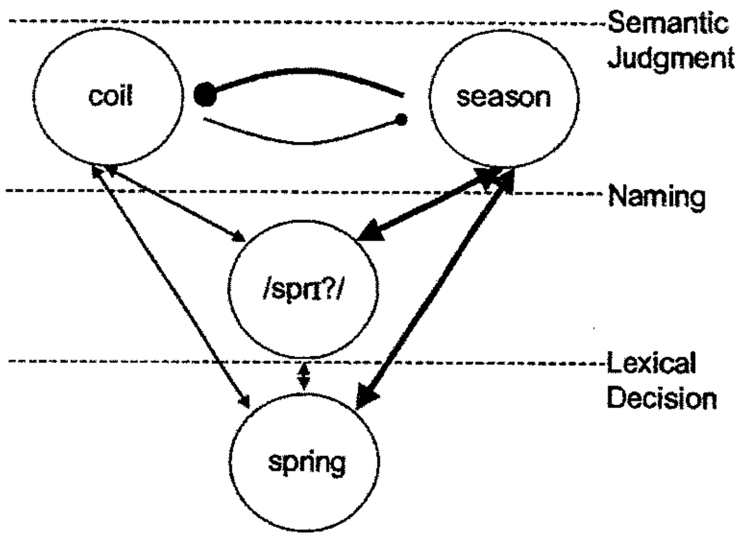


FIGURE 6.2 Connections among orthographic, phonological, and semantic components of ambiguous words.

Ambiguous Word Naming. Naming of ambiguous words sometimes produces no increase in response time, because word production does not require disambiguation of meanings before a response can be made (Rodd, Gaskell, & Marslen-Wilson, 2002). In fact, some experiments actually show an advantage for ambiguous words, because the activation of both meanings feeds back to the phonology, while control words have positive feedback from only one meaning (Balota, Ferrara, & Connor, 1991).

Ambiguous Word Semantic Judgments. Unlike naming tasks, categorization tasks involving ambiguous words often show an increase in reaction time for the subordinate meaning. This is because no decision can be made until one meaning has been settled on, and inhibitory connections between the meanings lengthen the time it takes a single meaning to reach some activation threshold. There is some debate as to the power of biasing contexts to speed the response time for subordinate meanings. For example, can reading "bank" in a sentence like "There were crocodiles sunning themselves on the bank" improve response times to the river meaning of bank more than sentences like "We took a picture of the bank," for which either meaning of "bank" can be appropriate? Martin, Vu, Kellas & Metcalf (1999) claim that strongly biasing context can override word meaning biases from frequency, whereas weakly biasing context cannot. Binder & Rayner disagree with the power of strongly biasing context; they find that strongly biasing context does not have enough strength to increase the activation rate of lower frequency word meanings.

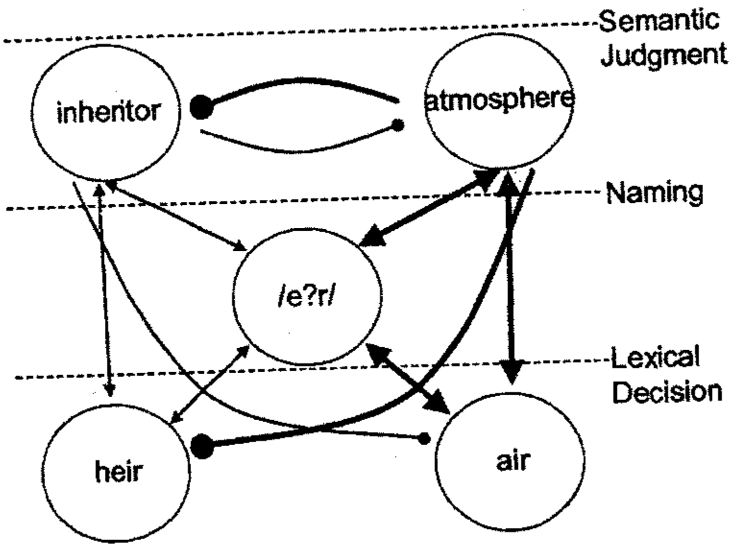


FIGURE 6.3 Connections among orthographic, phonological, and semantic components of homophones.

Homophones

Homophones have two orthographic representations, one phonological representation, and one semantic value for each orthographic pattern (See Figure 6.3). For example, "heir" and "air" have the same phonological representation (/eyr/), but the first orthographic pattern means "one who inherits" whereas the second means "atmosphere." Homophones threaten lexical quality because there is competition between the two meanings as well as between the two orthographic patterns. "Air" is the more frequently encountered word (except perhaps for an estate lawyer) so it is more quickly and efficiently activated than "heir" because of the strong connections that have been built for "air." Unlike homographs and ambiguous words, sentence or text context is not necessary for disambiguation; the orthography can do that all by itself.

Context can influence the speed and efficiency of activation of the appropriate meaning by pre-activating the semantic constituent appropriate for the context. Context can thus improve the speed and efficiency of activation of both dominant and subordinate homophone meanings (Perfetti & Hart, 2001).

HOMOPHONES AND READING SKILL

Differences in response time patterns between reading disabled readers and fluent readers can indicate processes contributing to the reading difficulties of the impaired group (Gernsbacher & Faust, 1991; Gernsbacher, Varner & Faust, 1990; Perfetti & Hart, 2001, 2002).

Suppression

Gernsbacher (Gernsbacher, 1990; Gernsbacher & Faust, 1991; Gernsbacher, Varner, & Faust, 1990) has studied the dual activation of homophone lexical entries and the subsequent meaning disambiguation. She presented more-skilled and less-skilled text comprehenders with sentences in which the final word was a homophone. The sentence context was designed to be non-biasing. Some examples are "He examined his sole" and "She took the yolk." Sentences were presented one word at a time, followed by a probe word. On critical trials the probe word was related to the alternate version of the homophone. The probe word followed the final word by approximately 450 ms or 1350 ms; a time differential known as the stimulus onset asynchrony (SOA). Compared to sentences in which the final word was not a homophone, all participants showed slower reaction times to homophones at 450 ms SOA. This is evidence that lexical entries for both homophones had been activated, and that disambiguation had not yet taken place. By 1350 ms SOA, more skilled comprehenders showed similar reaction times for homophones and controls, while less skilled comprehenders continued to show longer reaction times for homophones. Gernsbacher's conclusion was that less-skilled comprehenders have a less efficient suppression mechanism, which resulted in less-skilled comprehenders' inability to effectively dampen activation for the lexical entry of the inappropriate homophone. An inefficient suppression mechanism results in more words remaining active, producing an over-complex text structure with irrelevant and sometimes even misleading information, and, consequently, less efficient comprehension.

Disambiguation

We (Perfetti & Hart, 2001, 2002) replicated and extended these results. First, homophones and control words were presented in isolation so that sentence contexts could not unintentionally bias a reader toward one homophone over the other. Second, the 450 ms SOA was retained but both earlier (150 ms) and later (2000 ms) SOAs were added. Further, we examined high frequency and low frequency words separately, because frequency is also a manipulation of lexical quality. We replicated Gernsbacher's results at 450 ms. Both more-skilled and less-skilled comprehenders showed homophone interference. At 150 ms, only more skilled comprehenders showed homophone interference (the opposite result of Gernsbacher's 1350 ms SOA). At 2000 ms, no comprehenders showed homophone interference.

The conclusion we drew from this study was that more skilled comprehenders simply activated both homophone entries and settled on the correct activation, dampening the other one, more efficiently and quickly than less skilled comprehenders. In other words, the activation function was simply shifted earlier for the more skilled comprehenders. This explanation not only supports the lexical quality hypothesis, but is also parsimonious in that it does not require the invoking of an additional suppression mechanism. In addition, the more skilled comprehenders showed this effect only for low-frequency words while the less skilled comprehenders showed this effect only for high frequency words. Less-skilled comprehenders, who also tend to be less frequent readers, have a lower relative frequency for all words. What is a high frequency homophone for a more skilled comprehender is likely a low frequency word for a less skilled comprehender. What is a low frequency word for a low skilled comprehender might not be in less skilled comprehenders' vocabularies at all.

Manipulating Lexical Quality

Two aspects of our homophone experiment led us to an individualized training design. First, in the prior experiment, the same stimulus set was used for all participants. It is likely that each participant would have had some percentage of words that were simply unknown to them. This has implications not only for increasing error variance, but also for changing homophone dynamics. A high frequency homophone for which its lower frequency mate is unknown has no homophone interference at all and acts as a control. Exactly which words are unknown to each participant was not tested and cannot be inferred from responses, because even when guessing, participants had a 50% chance of giving the correct answer. Second, less-skilled comprehenders will have more unknown words than more skilled comprehenders, an assertion made from the patterns of responses for high and low frequency words in the previous experiment. What we felt we needed was a control of relative frequency, individualized by participant.

We interviewed sixteen more skilled and ten less skilled text comprehenders. We asked them to spell homophones (spoken aloud to them) two different ways, and to provide the definition for each spelling. We then asked them to rate each homophone according to their familiarity with the words. From this information we developed a stimulus set for each individual subject consisting of twelve homophone pairs for which one was rated as very familiar, and the other was rated as known but very unfamiliar. Creating these stimulus sets effectively removed the differences between groups in relative frequency. It also ensured that all words were known to participants, so homophone dynamics were maintained.

Participants were tested using Gernsbacher's experimental design. They were then trained on the meanings of half the low-frequency homophones in three 45 minute game-like sessions. Then they repeated the testing. Prior to training, all participants showed homophone interference for low frequency homophones at 150 ms SOA that was gone by 450 ms SOA. Equating personal frequency also equated the performance of the skill groups. After training participants still showed homophone interference, but for the high frequency homophones. Some simple training reversed the relative frequency pattern of the homophone pairs. From this experiment it is clear that there are a number of risks to lexical quality: homophony, written frequency, relative homophone frequency, and personal word frequency. Comprehension skill does not appear to be a risk except for its association with lower personal word frequencies.

Our experiment manipulating lexical quality using some simple learning procedures did not completely control for all likely sources of differences between comprehension groups. Familiarity as a proxy for personal frequency is only as good as the participants' perceptions and reporting. In addition, knowledge of English spelling patterns, reading strategies, and other variables that apply to words in general can affect performance. To control for the effects of these variables as much as possible we developed a training experiment using an artificial orthography called Zekkish.

The purpose of the Zekkish experiment was to control the effects of English reading experience in order to examine the development of homophone effects, specifically homophone interference and recovery from interference in a semantic task. An artificial orthography allows reading experience to be tightly controlled. The artificial orthography was as different from English as possible so that participants would not apply their knowledge of English to the reading of Zekkish. Using an artificial orthography also gave us complete control over other word effects such as frequency, word length, and frequency of semantic values of the Zekkish words.

Participants and Screening Sample. Over the course of several semesters we have built a database of scores on reading tests from nearly 800 undergraduate Intro Psych students at the University of Pittsburgh. These students took a variety of reading tasks which assessed their levels of orthographic, phonological, and text comprehension skill, the size of their vocabulary, and the extent of their English reading experience. The scores from each test were standardized, and from these z-scores we calculated a composite variable measuring reading skill. The resultant variable is normally distributed. The 45 subjects that participated in the current experiment were drawn from across the distribution of reading scores, and there was no significant difference between the reading skills of these 45 students and the remainder of the group ($F(1, 795) = 1.84$, $p > 1$).[4]

Artificial Orthography Training. A distinct advantage of using an artificial orthography is the ability to take a great deal of artistic license in setting up a cover story for the language. In this experiment, participants were told that they were to be Earth Ambassadors to the Planet Zek, and that they needed to speak enough Zekkish to interact with the Zek Ambassadors to Earth. The three ambassadors served as incentive (participants got attached to their favorite Zeks), and as stimuli. They were the actors in the scenes that provided the semantic values for each

[4]Participants were also divided into more- and less-skilled comprehenders and more- and less-skilled decoders based on these tests. Data on the Zekkish tasks have also been analyzed using this two by two design, and the results will be reported elsewhere.

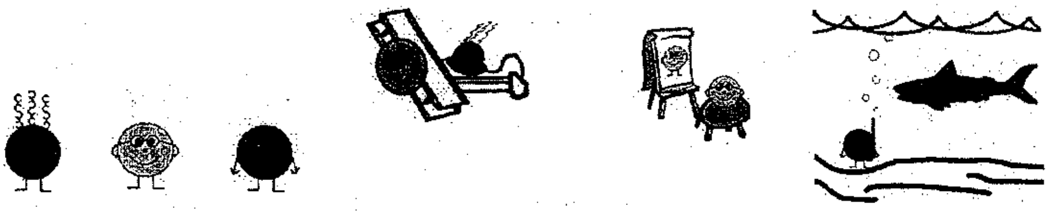


FIGURE 6.4 Zek characters (Teb, Dek, and Gep), and sample vocabulary concepts.

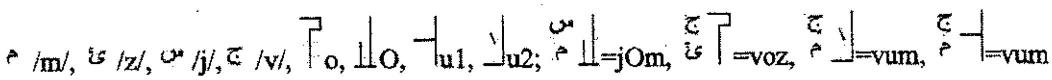
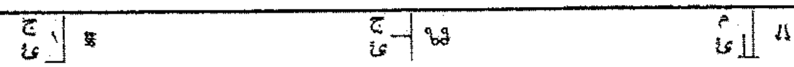


FIGURE 6.5 Examples of Zekkish letters and words.

Note: o = short o, and O = long o.



Vuz, Teb.	**Vuz, Dek.**	**Moze, Gep.**
Flying plane, Teb.	**Painting portrait, Dek.**	**Snorkeling shark, Gep.**

FIGURE 6.6 Examples of Zekkish sentences.

Zekkish word, and they were the stimulus probes in the subsequent testing phases. The three Zeks are shown in Figure 6.4, along with three sample concepts

The orthography itself was fairly simple. All words were of CVC format, with two consonants stacked on top of each other to the left of a vowel. Words were read clockwise from the top consonant. Homophones were created by having two vowels make the same sound. Frequency was differentiated by having half of the words presented three times as often as the other half. Letters and sample words are shown in Figure 6.5, and sample sentences are shown in Figure 6.6.

Sentences were written with the concept word (subject/direct object) followed by the name of a Zek to set up the experimental task based on Gernsbacher & Faust's (1991) semantic judgment task and Perfetti & Hart's extensions of this task. Note that the homophones involve two different Zeks doing two different things. This characteristic provides homophone interference (e.g., Who performs the action?)

Development of Homophone Interference. Participants were trained to decode words, retrieve word meanings, and read simple Zekkish sentences, over approximately 20 hours. The goal of training was not only to prepare for testing sessions, but also to watch the unfolding of homophone interference.

As homophones were encountered at low frequency and high frequency, and as the lexical quality of each lexical representation was increased with repeated trials, the high frequency lexical representation caused more and more interference during the activation of the low frequency homophone. The buildup of interference occurred because the lexical quality of the lexical entry for the high frequency homophone was strengthened faster than that of the low frequency lexical entry given the 1:3 low frequency to high frequency presentation ratio. Further, the functional frequency difference of the words changed, even though the absolute frequency difference remained 1:3. In other words, when both words were of fairly low lexical quality (e.g., 2 trials: 6 trials), there was less reliable interference than when both lexical entries were of relatively higher frequencies (e.g. 20 trials : 60 trials).

Another bonus of the Zekkish training paradigm is that once participants began learning the meanings of the words, two responses were necessary, the first for naming the word and the second for providing the meaning of the word. Thus Zekkish allows us to test the pattern of response times at two of the three choice points shown in Figure 6.3. Recall that homophone naming has the advantage of a facilitative effect from semantic-phonological feedback which improves naming of homophones relative to nonhomophone controls. Homophone semantic judgments are subject to inhibitory connections between semantic values which slow response times, especially for low frequency homophones.

All participants reached the appropriate accuracy criteria for letter-sound learning and pseudoword decoding, so by the time they began to learn the vocabulary, they were already fairly accurate decoders for all words and the decoding results reflect this (See Figure 6.7). In this graph and the graphs to follow, homophone accuracy has been subtracted from control accuracy, and control response time has been subtracted from homophone response time. Higher numbers indicate greater interference. By the time semantic values of the words were introduced, there was little homophone interference left when participants were decoding. Meaning results, however, clearly show an effect of interference secondary to inhibitory connections between the semantic constituents (See Figure 6.8). Here, low frequency is a liability. By their second experience with the vocabulary words, the lexical quality difference between low frequency and high frequency words already caused much slower and less accurate responses to low frequency homophones compared to their controls.

When they are first confronted with word meanings, in groups of 12 words at a time, participants already show a facilitative effect of homophony on naming of low frequency words, and an inhibitory effect of homophony on recalling meanings of all homophones, with the effect increasing rapidly for low frequency homophones. In the next stage of the experiment, participants were confronted with all 48 words at once. Accuracy continued to increase for decoding responses because this task did not change. Accuracy decreased and response times slowed at first for meaning responses because of the increased load of differentiating 48 word meanings instead of 12. Here again there is a marked increase in homophone interference for

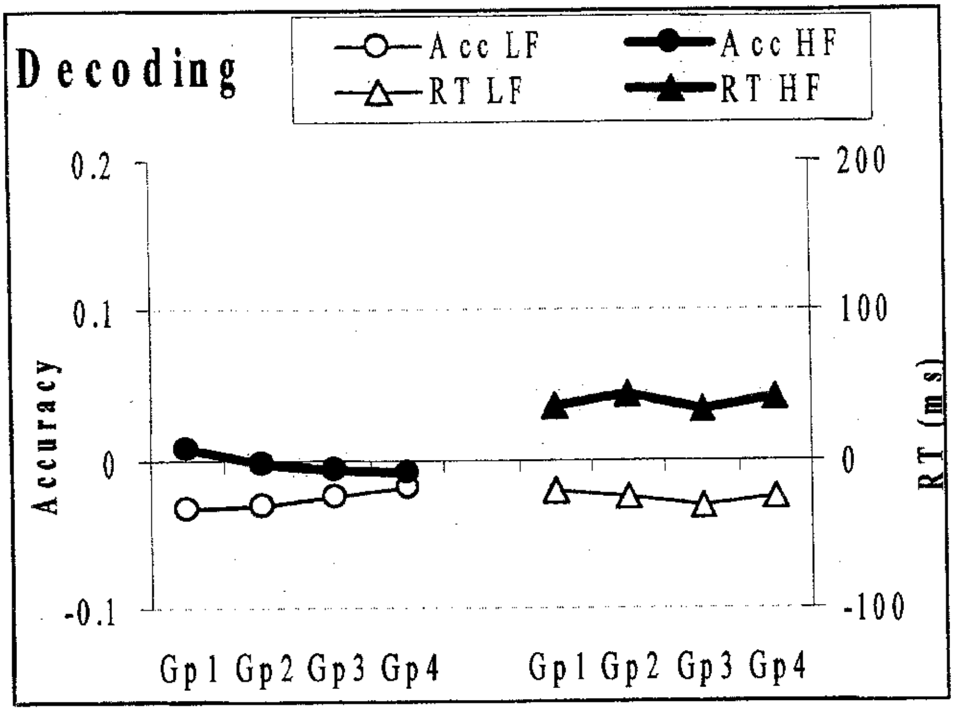


FIGURE 6.7 Homophone interference for word decoding during vocabulary learning.

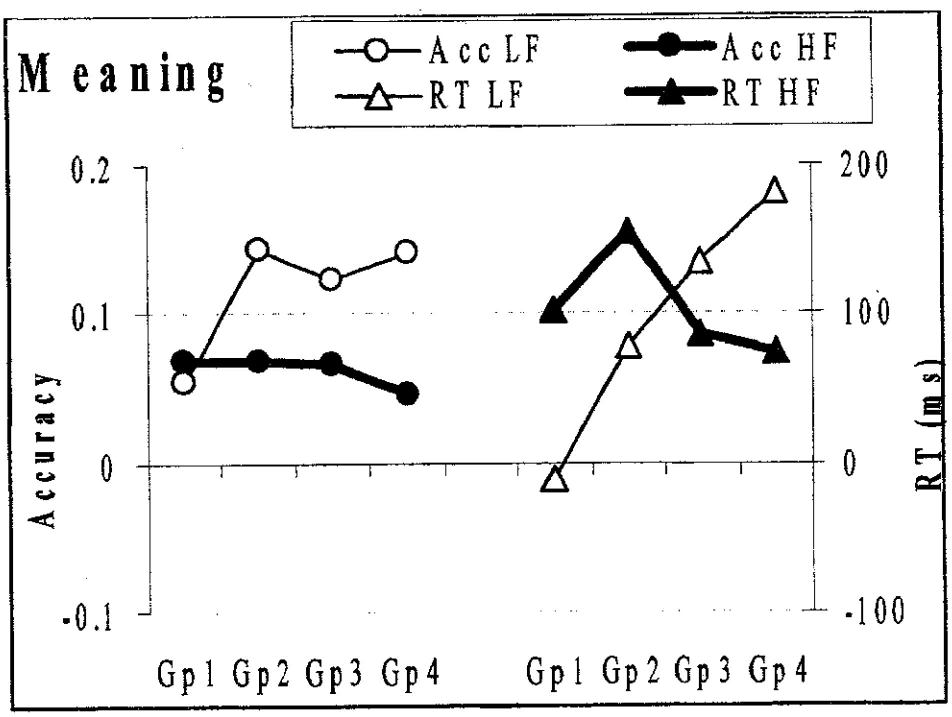


FIGURE 6.8 Homophone interference during early vocabulary learning.

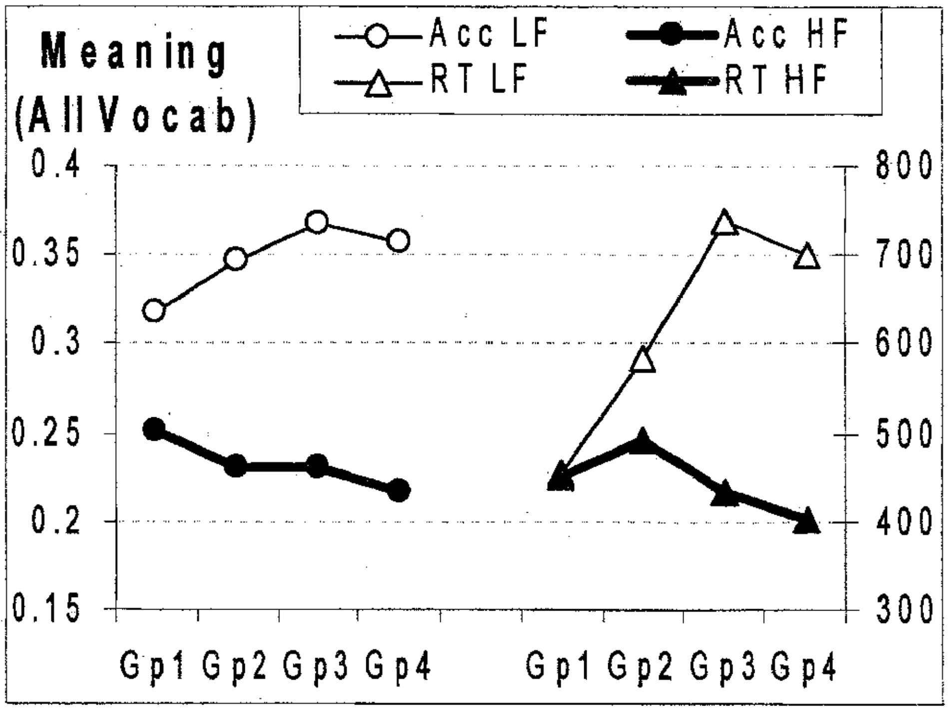


FIGURE 6.9 Homophone interference during early vocabulary learning with a heavy learning load: 48 vocabulary words.

low frequency homophones. There is a decrease in homophone interference for high frequency homophones as well, as the relative lexical quality between low frequency words and high frequency word changes over time. The development of homophone and frequency effects is clear both in accuracy and in response time (See Figure 6.9).

These data provide a clear example of how word frequency increases the coherence and efficiency of activation of lexical items, i.e. how reading experience builds lexical quality. The lexical quality of high frequency words increases to the point that their activation is protected from being unduly affected by interference from low frequency competitors. Homophone interference decreases with experience. The lexical quality of low frequency words is incremented (because performance on control words improves), but not nearly as quickly as for high frequency words. Consequently, the inhibitory influence the high frequency competitors have on the lexical activation of low-frequency homophones increases over time.

This pattern of facilitation and inhibition continued over the next session, when participants were learning the grammar of Zekkish, and after the first testing session, when participants were gaining additional experience with Zekkish in order to make the processes of reading and activating meaning, if not automatic, then highly efficient. One particularly high-performing subject, bored and with nowhere to improve, having hit nearly 100% accuracy and an asymptote on response time by the end of the first experience session, complained "I can't even read the words without automatically getting the meaning anymore."

Participants were tested on a variety of different tasks, including the standard semantic judgment task, at two time points. First, they were tested when they reached a minimum criterion of 85% accuracy while they were still novices with Zekkish. Second, they were tested after extensive practice reading and relating the meanings of Zekkish sentences. At the "novice" testing session, participants had encountered low frequency and high frequency words an average of 20 and 60 times, and at the "experienced" testing session, they had encountered the words an average of 40 and 120 times.

Having demonstrated the process of building lexical quality through experience with individual words, and the ways in which interactions between words of varying qualities differ because of homophony and frequency characteristics, we now turn to a replication of Gernsbacher and Faust's (1991) study of skilled and less skilled readers, and Perfetti & Hart's subsequent extensions of the experiment. In this case, rather than having two participant groups, one of more-skilled readers and one of less-skilled readers, we assert that participants with little experience reading Zekkish are less-skilled readers of Zekkish. With practice, they become more-skilled readers of Zekkish, thus making reading ability essentially a within-subjects variable.

Gernsbacher & Faust demonstrated that manipulating the SOA between a homophone and a probe word resulted in homophone interference at 450 ms SOA for all readers and at 1350 ms SOA for less-skilled readers. Skilled readers had resolved the dual homophone activation by 1350 ms, and no longer showed longer response times to homophones than to controls. Perfetti & Hart showed that extending the SOA revealed a difference in time course for skilled and less skilled readers, but that no suppression mechanism needed to be invoked to explain the pattern of results. Skilled readers had homophone interference by 150 ms SOA that disappeared by 1350 ms SOA. Less-skilled readers had homophone interference by 450 ms SOA that disappeared by 2000 ms SOA. Both studies defined their reading groups based on reading comprehension, which suggests that reading comprehension depends at least in part on lexical quality.

Replicating this experiment in Zekkish allows us to test the hypothesis that the reading skill difference that was measured by these researchers is based on reading experience. It can be posited that the less skilled readers in these semantic judgment experiments had spent less time reading than the skilled readers, resulting in a lower functional frequency for them, for all words. If this is a plausible explanation then the Zekkish experiments should show a shift in the activation/deactivation curve from the "novice" testing session to the "expert" testing session as the readers increase their relative frequencies with all the words, mimicking the shifts between less-skilled and skilled readers in Perfetti & Hart's experiment.

Figure 6.10 shows the results of the "Novice" testing session, when participants had learned the Zekkish language, but only to a minimum criterion of 85% correct. These participants could also be called inexperienced readers, or slow and effortful readers, or, we claim, less-skilled or poor readers. In this figure and the one to

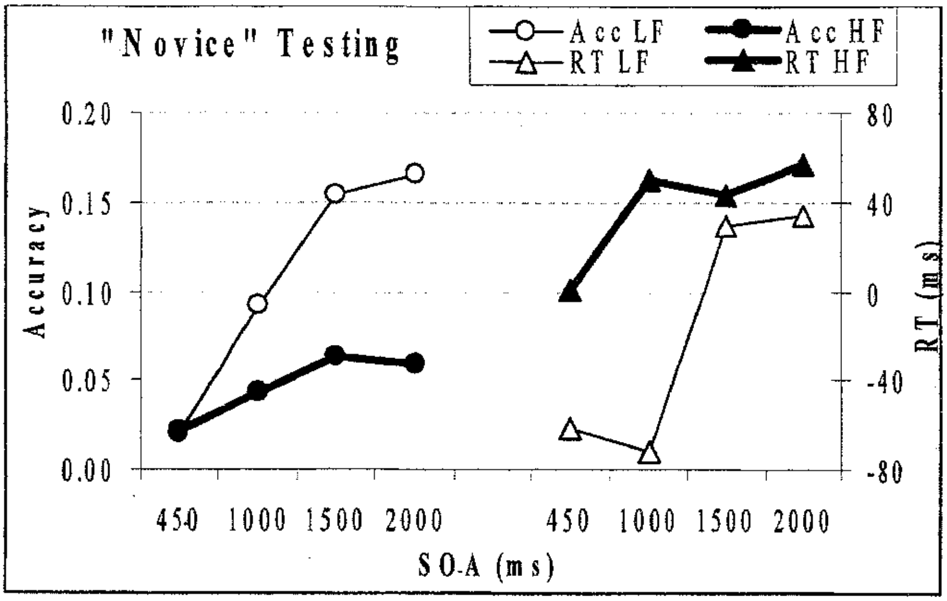


FIGURE 6.10 Homophone interference (and facilitation) effects early in training, while participants were still "novices" with the language.

follow, we have plotted the difference between homophone and control performance to indicate the degree of homophone interference. For accuracy, homophones were subtracted from controls. For reaction time, controls were subtracted from homophones. This produced a difference score for which more homophone interference is related to higher difference scores.

When these readers were less-skilled, with enough time to decode the word, they were more accurate for controls than for homophones. We chose to increase the first SOA from the Gernsbacher experiments because these readers were much less skilled than typical less-skilled college students reading English. Even with this longer SOA most of the participants claimed they had barely seen the word in 450 ms, much less read it. Their accuracy performance shows that they had not yet activated their Zekkish lexical representations by 450 ms. By 1000 ms, however, their accuracy scores indicate that some interference was present – but only for low frequency words. This is much like the pattern we found in our original experiment; readers were more accurate to controls than to homophones and to high frequency words than to low frequency words. And as SOA increased, the frequency difference between homophones and controls increased.

Reaction time at the novice testing session tells a different story. Homophone interference first occurs at the second SOA, occurs earlier for high frequency words than for low frequency words, like the less-skilled comprehenders in our original experiment. However, unlike our previous experiment, these readers are actually showing a homophone *advantage* at the earliest two SOAs for low-frequency words. Homophone advantage is typical of experiments in which a response can be made based only on

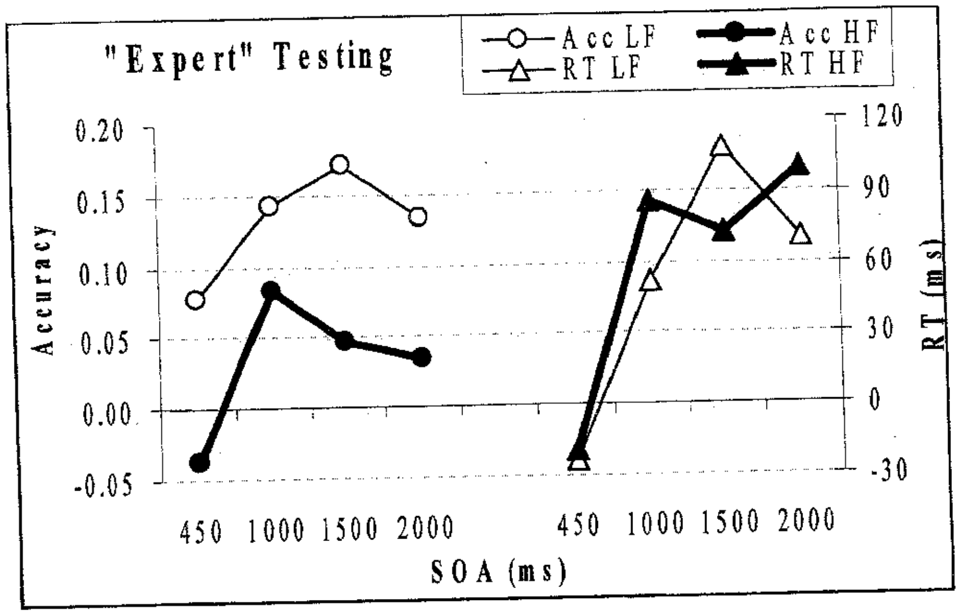


FIGURE 6.11 Homophone interference effects after multiple training sessions, when participants were "experts" with the language.

orthography and/or phonology, such as lexical decision and naming tasks.[5] This suggests that at the earlier SOAs readers may actually be using the phonological information, but only reaching semantic activation for high frequency words. For low frequency words, they do not activate the complete lexical item, for either homophones or controls, so the more supported, stronger phonological activation of the homophones results in a faster response to homophones than to controls.

So with the "novice" testing session, we replicated the findings of our original experiment, except that we included an SOA short enough to show some pre-activation homophone advantage for low frequency words.

The "expert" testing session (See Figure 6.11) was designed to model the performance of more-skilled English readers, because between the novice and expert testing sessions, participants gained a great deal of experience decoding words and accessing their meanings. As a result, the activation curve shifts, with activation occurring earlier and homophone advantage disappearing. The accuracy data show the frequency difference by the first SOA, and it continues throughout.[6]

The reaction time data also shows a shift in the activation curve. The homophone advantage is gone, and there are true indications of homophone interference by the

[5]This is not to say that experiment participants never use semantic information in lexical decision and naming tasks, nor that back-propogation from semantics to orthography cannot take place. Sometimes it does, resulting in interference, but the typical pattern of responses shows either no homophone-control difference (usually high frequency words) or a homophone advantage (usually low frequency words).

[6]Note that the differences are much more significant at the expert testing session. This is due to a dramatic decrease in performance variability.

second SOA. New data patterns also arise. There is no evidence of a recovery from interference, and interference occurs for both high frequency and low frequency homophones.

There are two likely reasons that interference does appear until the second SOA. The first reason is simply that we did not choose the optimal SOAs to accurately capture the entire activation/deactivation curve. While we're calling our participants experts by the second testing session, and while they are much more fluent in Zekkish than at the novice testing session, there is still a world of difference between our expert Zekkish readers and the typical college reader of English – regardless of English reading skill. Our participants show a pattern typical of an intermediate stage; some expertise, but not true automaticity. We hypothesize that with more training the pattern of results would become more and more like that of the more-skilled readers in our previous experiments. It is also possible, however, that beyond two seconds to view the Zekkish word some qualitative aspects of the process might change. For example, the time to read each word would become irrelevant and the time to search long term memory for the Zek linked to the word would become more important.

SUMMARY

In this chapter we have asserted that lexical quality is the basis for efficient word reading skill, and efficient word reading skill, in turn, is at the heart of good reading comprehension. We have discussed ways to test this assertion by sneaking words of lower lexical quality into experiments (homophones, homographs, ambiguous words), and the pattern of results that come from these experiments. We have discussed a series of our own experiments based on one by Gernsbacher & Faust (1991), and made the following claims based on the results of these experiments.

- By adequately covering the range of activation/deactivation of word meanings with the appropriate SOAs, we can elicit responses that occur prior to activation, during activation, and after activation.
- By varying reading skill and word frequency, we can demonstrate shifts in this activation curve. We claim that both reading skill and word frequency are manipulations of experience with words.
- By assuring that experiment participants know word meanings of both members of homophone pairs, performance of skilled and less skilled readers can be equated.
- By training participants on the lower frequency member of a homophone pair, we can reverse the pattern of interference such that the trained word becomes the higher frequency word.

In short, it appears that lexical quality can be enhanced or threatened by a number of different factors that are associated with word experience. Word frequency, as well as shared orthography, phonology, and meaning, affect lexical quality from the structure of a language's lexicon. Reading experience, including specific training, can affect individuals' lexical quality. Regardless of the origin, better lexical quality is associated with reading at multiple levels, from decoding to fluency to comprehension.

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