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Abstract—When people read silently, they unconsciously translate what they read into a speech-like code that facilitates word identification and the creation of meaning. This article examines that phenomenon—known as silent speech—based upon the published research of cognitive psychologists and psycholinguists. The author develops a phonological model of reading based upon published results of experimental investigations to determine the relationship between cognition and silent speech. The author then applies the model to technical communication. The applications include the use of punctuation, pronouns, and abbreviations, as well as introducing new words, writing to satisfy the speech instinct, cultivating a human voice, and revising technical documents.

INTRODUCTION

The well-documented phenomenon of “silent speech” during silent reading involves the reader in an unconscious translation of written words into a speech-like code, which is an essential component of the reading process. One cliché about silent speech associates it with bad readers who move their lips as they read. However, this cliché does not hold up to scientific evidence. *All* readers exhibit signs of silent speech to some degree. Why we recode speech during silent reading is disputed. Some feel that silent speech is an affliction caused by current teaching practices. Others feel that it is simply the whir of the reading machinery and has no bearing upon cognition. These views, however, are in the minority. The literature on this subject converges on the conclusion that silent speech helps readers identify and remember words, as well as process those words to create meaning.

Because phonics frequently plays a central role in reading instruction [1, 2], technical writers should consider the latent, residual effects of such instruction upon the competent reader.

Learning to read through speech is as old as reading itself. In fact, until the twelfth century A.D. or so, reading silently was practically unknown. Saint Augustine, in his *Confessions*, recounts the time when he entered the study of Saint Ambrose to discover that "while reading, his eyes glanced over the pages, and his heart searched out the sense, but his voice and tongue were silent" [3, p. 110]. Saint Augustine speculates about why Saint Ambrose read silently. For instance, Saint Ambrose may have feared that reading aloud would draw an "attentive hearer [who] should ask him to expound upon it," or perhaps "the preservation of his voice, which was very easily weakened, might be the truer reason for his reading to himself" [p. 110]. Saint Augustine's astonishment at Saint Ambrose' achievement of silent reading marks the beginning of a slow decline of reading aloud, but the voice within persists.

Our linguistic brain requires that we read with our ears as well as with our eyes. After all, "writing is only a conventional device for recording sounds" [4, p. 16]. More significant for technical writers and editors is the conclusion that silent speech during silent reading "occurs more with difficult than with easy material" [5, p. 337]. Therefore, the ability to easily pronounce the words we read in difficult texts—such as technical documents—plays a crucial role in understanding those words.

This article reviews research related to general reading theory and the phenomenon of silent speech. In the context of developing a model of reading that includes a phonological component, the article explores the specific ways in which the speech code affects word identification and word synthesis. The article then applies the new model of reading to technical writing, specifically illustrating how to avoid introducing into a text elements that are not readily translated into speech and how to use silent speech to improve the revision process.

HOW WE READ

Reading is the process of looking for, identifying, and synthesizing written words to create meaning, a process that takes place, more or less, inside a black box. Cognitive psychologists and psycholinguists cannot wrench open the cranium of a human subject to observe the reading

machinery at work. They can supply an input—what they call visual stimuli—and observe the resulting output, but that's about it. However, by ingeniously selecting and manipulating input, they can induce the inner workings of the reading process.

Based upon what researchers have discovered about reading, theories have been created to explain the relationships between the components of the reading process. Figure 1 shows a simplified model of the reading process, indicating its three stages: (1) looking for words, (2) identifying words, and (3) synthesizing words to create meaning.

According to Grunig, Ramsey, and Schneider, among the components of the reading process are three types of memory:

- sensory memory, which preserves. . . visual images for a few seconds;
- short-term memory, which allows people to keep information in a special active state but which has limited capacity—seven plus or minus two bits of information; and
- long-term memory, which has infinite capacity to hold information but whose holdings are not accessible to people unless they can bring the information back into short-term memory [6, p. 103].

Other components of the model include the optical system, visual encoder, comparator, and parser. The following descriptions of the three stages of the reading process refer to Figure 1, a construct of the reading process.

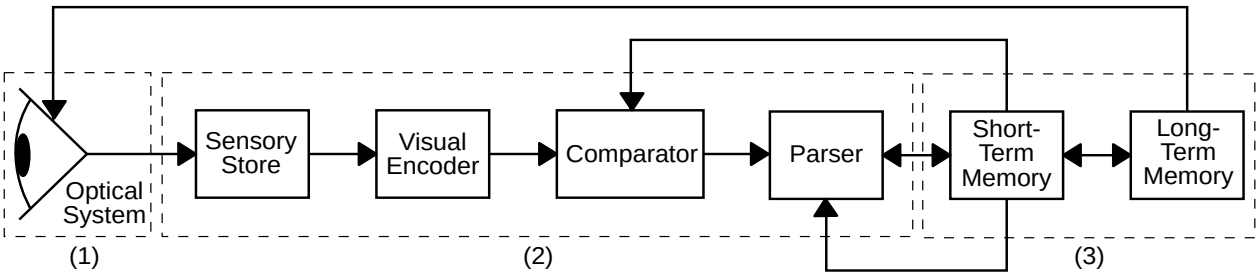

Figure 1. A model of the reading process

(1) Looking for Words

The average reader can read about 250 words a minute [1, 7]. However, the speed and accuracy of reading depends upon many factors, including the difficulty of the text and, most importantly, what the reader brings to the text. The context in which a reader and text meet is defined by not only the text itself but also the reader's level of reading competency, purpose, general knowledge of the world, and specific knowledge of the subject promised by the text.

According to Frank Smith, meaning is "the largest and most efficient unit of analysis that we can bring to bear from what we know already to what we are trying to read (or hear) and understand" [1, p. 53]. In other words, the content of long-term memory guides the reading process from the very first moment we address the text. According to Robbins, the agenda—or set of assumptions—a reader brings to the text can enhance or obstruct the reader's understanding of the text. The reader approaches a text with a reading strategy depending upon the kind of information the reader is looking for. "Research," says Robbins, "shows that what readers get from a text depends in part upon their purpose in reading" [8, p. R-249–50]. Skimming a text, for instance, will yield a different understanding of the text than carefully attending to every word. Once the reader enters a text, the reader may change reading strategies at any moment [9], depending upon the reader's original expectations and how the text alters those expectations, among others. The line connecting long-term memory to the eye in Figure 1 represents the way the content of long-term memory affects the way we look for words.

Upon entering a text, the reader engages the automatic reading process. The eye does not move smoothly across the page but in quick hops and jumps called *saccades*. Information is picked up when the eyes rest upon the page. These *fixations* involve focusing the fovea centralis—the point of sharpest vision on the back of the retina—on the surface of the page. The reader stores the resulting sensory information in the first few hundredths of a second at the beginning of a fixation. Between fixations, the visual information is processed. The time it takes to read does not depend upon the time between fixations but upon the time to process the information gathered from the fixation, which may be less or more than the time between

fixations. If the time to process exceeds the time between fixations, the reader is probably reading too fast or is skimming to answer specific questions (looking for key words, for example). The average reader fixates three to four times per second [1, 10].

The level of detail the reader is looking for and the difficulty of the text determine how the eye skips across the page. “For example, readers who decide to study the [text] will focus their eyes on every bit of information it contains, perhaps even moving their eyes back over passages they did not grasp at first” [9, p. R-249]. These backward motions, called *regressions*, are symptoms of failure to “grasp” information during the reading process. As we become more competent readers and are able to anticipate words, the number of fixations and regressions decreases. About 23 percent of all fixations that first-graders make are regressive, as opposed to 15 percent of college students [10]. The less competent the reader and the more difficult the text, the more fixations and regressions per second.

(2) Identifying Words

Once the eyes rest upon a word, the sensory store holds “a decaying image that persists beyond the point where stimulation has terminated” and that “disappears within a few hundred milliseconds” [11, p. 97]. Because meaning cannot be created from the raw visual information from the optic system [10], the information held in the sensory store is encoded. The comparator then checks the visual code against the 50,000 or so words stored in the reader’s internal lexicon. How the words in the internal lexicon are stored and retrieved and how they are compared to the visual code is a disputed sub-process.

For years, many researchers of the reading process assumed that words are processed serially, that is, that letters in a word are observed and recognized individually. However, scientific evidence has since discounted the “beaded-string” theory. First, serial processing of words would take too long, yielding much fewer than the 250 or so words per minute achieved by the average reader. Second, eye movements during reading contradict the smooth, linear sweep of the eyes required by serial processing. The prevailing theory of word identification is

that we recognize whole words by their features. Both reading speed and eye movements support the "whole-word" theory of word identification.

The whole-word theory assumes that when we read, we not only recognize a word at one glance (fixation) but also "look through words for the meaning beyond, and unless there are noticeable anomalies of meaning, or unless we have trouble comprehending, we are not aware of the words themselves" [1, p. 162]. Whole-word identification allows readers to grab word meanings with every fixation and quickly process them.

The next component of the word-identification stage is the parser, a mental program that analyzes sentence structure during reading. As we read, we make continual predictions about the meaning and function of the words we have not yet reached. For instance, based upon semantic predictions, we may substitute a word we read with a different word that has a similar meaning. The content word "rock" in "He threw the rock at the wall" may be substituted by a content word with a similar meaning: "He threw the *stone* at the wall." Likewise, the function word "at" may be substituted by another function word with a similar meaning: "He threw the rock *against* the wall." The parser's role in this stage is to test hypotheses about the meaning and function of an identified word based upon the reader's predictions. The parser can simply pass encoded words or send a red flag to short-term memory based upon the answers to the questions raised by the reader's predictions.

(3) Synthesizing Words To Create Meaning

Short-term memory is the workhorse of the reading process. However, its storage capacity is limited. Whereas the capacity of long-term memory is practically infinite, short-term memory can hold only about seven meaningful items at once [12]. Additionally, the stream of words from the word identification stage must be swift and continuous to keep up with the incredible speed and evanescent nature of short-term memory, or items will be forgotten. Lieberman, in *The Origins of Language*, illustrates the point by describing the failure of an experimental reading machine for the blind [13]. The machine was designed to identify alphabetic characters

in printed texts and convert them to sound. However, it was so slow that the blind "readers" would forget what a sentence was about before they heard its end. Thus short-term memory could not keep the elements of the sentence active long enough to synthesize them.

Bringing together all of the elements of a sentence is the primary function of short-term memory. "As a sentence is read, each clause is held in short-term memory (STM) until it is assigned a meaning. Once a meaning has been assigned, it is moved into long-term memory (LTM) and the next clause entered into STM" [8, p. R-242]. "Assigning meaning" may be a counter-intuitive notion because we assume that the meaning of a text is in the text itself. However, the results of reading research demonstrate that "meaning does not reside in surface structure [that is, the writer's arrangement of words on a page]. The meaning that readers comprehend from text is always relative to what they already know and to what they want to know" [1, pp. 157–58]. Words from the word identification stage do not simply click together in short-term memory like box cars on a railroad track. In short-term memory, the first word picked up by the reader does not become the engine car, nor the last word the caboose. Rather, short-term memory uses the internal grammar of the brain to transform the words on a page (surface structure) into a deep structure akin to the language of the mind, what Pinker calls mentalese [14].

The universal rules of transformational grammar have been hotly disputed since Chomsky introduced the notion in the early 1960s. But for the purposes of exploring reading theory, it is sufficient to recognize that short-term memory synthesizes words from the word identification stage and information from long-term memory to make sense of a phrase, clause, or sentence. We might call the resulting synthetic units of meaning *understanding*.

To understand how long-term memory affects the synthesis, consider the arrangement "the results of the current project." Based upon the analysis of one reader, this arrangement may seem to have only one possible meaning: "the data from the work being conducted now." However, what if another reader, an electrical engineer, knows that there are two projects being conducted now, one to characterize the voltage of a computer and the other to characterize its current. In

such a case, her short-term memory may synthesize the words from the word identification stage *and* information from long-term memory to create a different meaning: “the data from the work to characterize computer current.” Therefore, different readers may create different deep understandings from the same surface structure.

When the Reader Stops Reading

The genius of effective reading is that readers are never aware of the reading process. When words, instead of the concepts that words represent, spring unbidden into the reader’s consciousness, the reading process stops. One of the many ways to throw a monkey wrench into the reading machinery is to introduce a word that does not conform to the semantic and syntactic predictions of the reader. The parser flags a word that does not fit the reader’s expected meaning or function.

Another way to stop the reading process is to tie the reader’s tongue, a frequent problem with difficult technical writing. For instance, reading a cloinflamawcture—an unanticipated word such as the nonce word *cloinflamawcture* you just read—can pull the reader from the text. Attending to a word whose pronunciation is difficult or unfamiliar stops the reading process dead cold. When readers stop looking for words and dwell on the spelling patterns of a word they cannot readily pronounce, they stop reading. An unfamiliar word with unrecognizable spelling patterns requires even closer scrutiny and an even more radical departure from the text.

The reason readers are thus separated from their texts is intertwined with the way readers identify words, by their features. Readers cannot see words and spelling patterns at the same time because, as Frank Smith points out, “we cannot see things in more than one category at a time” [1, p. 61]. Words, spelling patterns, and letters are different categories of things. For instance, we cannot identify the letters *d*, *o*, and *g* and the word *dog* at the same time.

Figure 2 illustrates the concept. As we look at the ambiguous illustration, we can see either the profile of two faces (one category) or the outline of a vase (another category), but we cannot see both at the same time. When the reader starts looking for spelling patterns or letters, she is

looking for something that will aid pronunciation but will not bear meaning to the reading process. Because the speech instinct during silent reading is strong, the reader may languish over the letters trying to decipher the pronunciation of the word, which in effective reading is automatic and unconscious. The result is an overload of short-term memory, a loss of information, confusion, uncertainty.

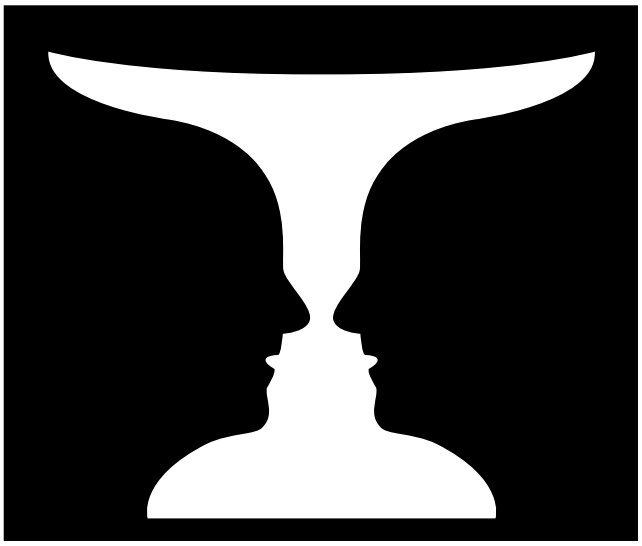

Figure 2. Ambiguous illustration

THE RELATIONSHIP BETWEEN SPEECH AND LANGUAGE

According to linguists and other language scholars, language is a system that relates sounds to meanings according to a grammar, which is itself a system of syntactic, semantic, and phonological rules [14, 15, 16, 17]. For example, consider the following ungrammatical constructions based on the sentence "The animals ate the mice."

- Ungrammatical *Syntax*: "Ate animals the mice the." This is an example of improper word order; that is, the typical order for an English declarative sentence is subject–verb–object, and for a noun phrase it is modifier–noun.
- Ungrammatical *Semantics*: "The beds ate the mice." This is an example of improper meaning; that is, beds can't eat.

- Ungrammatical *Phonology*: “The animalés ate the mice.” This is an example of improper pronunciation; that is, English speakers do not pronounce the plural suffix of a noun ending in *l* /és/; they pronounce it /z/.

To communicate clearly, performers of language must obey all three types of rules. When people perform language by speaking, they automatically and unconsciously obey the rules of grammar. After all, if we had to concentrate on the myriad rules that govern the efficacious use of language, we would not have enough residual mental capacity to remember what we wanted to say in the first place. The act of writing, however, is alien to our automated biological processes. As Darwin said, “man has an instinctive tendency to speak, as we see in the babble of our young children; whilst no child has an instinctive tendency to brew, bake, or write” [18, p. 55].

Whereas we carefully obey those syntactic and semantic grammar rules we can nudge to consciousness when we write, edit, and revise, we generally omit phonology—an instinctive component of language performance—from consideration simply because the speech instinct is not associated with the act of writing or silent reading. However, a number of scientific investigations have revealed that the speech instinct is alive and well during the act of “silent” reading.

SILENT SPEECH DURING SILENT READING

Ever since Huey’s seminal study of the reading process was published in 1908 [10], linguists have been intrigued by the intricacies of the reading machinery. And while researchers have traditionally given short shrift to the study of silent speech, experiments conducted in the 1960s, especially by McGuigan in 1964, rekindled the interest in this phenomenon first noted by Huey. In the 1970s, the journals of cognitive psychology and psycholinguistics swelled with reports of silent-speech experiments and debates over their results. Indeed, researchers could not agree upon a name for silent speech. Among its many aliases are inner speech, subvocalization, speech recoding, phonemic recoding, phonological recoding, and acoustic recoding. Nevertheless, even

for these disputing researchers, the question wasn't whether silent speech took place, but rather how and why.

In *The Psychology and Pedagogy of Reading*, Huey describes his efforts to scientifically determine how readers processes a text and his efforts to develop pedagogical principles based upon the results [10]. In one classical experiment, Huey had subjects read passages from a novel using four methods: (1) the way they liked to read, (2) saying it to themselves, (3) reading aloud, and (4) thinking of how it would sound aloud. Methods 3 and 4 yielded the slowest reading rates. However, the reading rate for method 1 was about the same as for method 2. When questioned about the results, the subjects were not surprised, claiming that inner speech, as Huey calls it, was part of their normal reading behavior.

In 1964, McGuigan used a technological approach to verify silent speech and its effects upon the reading process [19]. He attached one end of electrodes to the lips and chins of 120 subjects, one at a time, whose ages ranged from the first grade to college. He attached the other end of the electrodes to an amplifier and recorder, and asked the subject to read silently. McGuigan's results demonstrated that silent speech was "quite general among subjects, though less marked in the case of older (college) students" [p. 12]. Lip and chin movement increased as the difficulty of the text increased. However, contrary to the cliché about the phenomenon, good readers moved their lips and chins during silent reading as much as bad readers. In fact, McGuigan found that the "amount of lip movement and breathing rate during. . . reading increase as intelligence increases" [p. 28].

Results of seminal experiments were not only dispelling misconceptions but were also verifying hunches, unscientific knowledge about the reading process. For instance, when asked about silent speech, most people will acknowledge it to some degree. People can hear themselves with the mind's ear as they read silently. Even when researchers "disable" the silent speech of their subjects by having them say a word aloud over and over again as they read, the subjects say that they can still hear the inner voice. Try reading the next passage while saying aloud *the* over

and over again. “Most people report that they can still ‘hear’ the text they are reading,” says Baddeley, Eldridge, and Lewis, “although they are presumably not articulating it” [20, p. 443].

Simple experiments demonstrate that we use silent speech during the reading process. Forr ecsample, iff yew kann sowned owt thiss sentunns, yu wil komprihenned itt, altho thair iss nott e wirdd en itt. If we identify words by their visual features alone, then how *do* we comprehend the sentence above? Certainly, we use silent speech to identify words to some extent. But if so, where in our reading model do we place the speech encoder? Before or after the word identification stage? That is the question that modern cognitive psychologists and psycholinguists are still trying to answer.

How Silent Speech Affects Word Identification

Somewhere in the reading process is a sub-process that automatically converts printed words to a phonological code that obeys the rules of ordinary speech and, ultimately, produces a physical signal that activates the speech apparatus [15]. Some argue that phonological recoding occurs before word identification. For instance, Hulme and Richardson cite the argument that “the reader must first translate the printed word into a speech-like (phonological) code” [21, p. 121]. This code is used to identify words, taking a “lexical route” to short-term memory [22].

Opponents of the lexical-route theory argue that patients suffering from deep dyslexia are unable to carry out phonological recoding of printed words but can still access the meanings of those words. McCusker, Hillinger, and Bias, strong opponents of the lexical-route theory, argue that the “existence of ideographic writing systems, such as Chinese, demonstrates that there is nothing inherent in the human cognitive processing system that precludes lexical access without phonological mediation” [23, p. 220]. Since their conclusion, experimental investigations using native speakers of Chinese have demonstrated that during the silent reading of Chinese, “the phonological shape of a word—some aspect of its pronunciation—is automatically activated as the word is accessed from a graphic input” [24, p. 642], and that this phonological information from ideograms is “kept available in working memory to support comprehension” [25, p. 1092].

McCusker and others argue that the speech code takes the “non-lexical lookup route,” so that, according to Campbell and Besner, “the lexical representation of the written word is first accessed” and then “used to pronounce known words” [22, p. 375]. As evidence, McCusker, Hillinger, and Bias point to an experiment that demonstrated that subjects could recognize letters within a word easier than the same letters in isolation. They conclude that words are identified as whole units, rather than letter by letter, but they also conclude that phonological recoding must take place *after* lexical access because letter-by-letter word identification is a “necessary step for phonological recoding” [23, p. 220].

Let us explore their second conclusion, which is not supported by the prevailing theory of word identification. In the section on word identification, I glossed two competing theories: the beaded-string theory, which states that a word is recognized by its sequence of letters, and the whole-word theory, which states that whole words are recognized by their features. As mentioned, eye movements during silent reading contradict the beaded-string theory, and such a method of word identification would take too long. Then how do we pronounce written words? In 1977, Johnson reported the results of an experiment to determine which model of word identification was the most accurate [11]. In this experiment, subjects were asked to identify words and letters in words. Because the subjects identified words faster than they identified letters within words, Johnson concluded that the whole-word model was more accurate.

According to Lieberman, “the linguist’s traditional concept of phonetic elements comprising a set of ‘beads on a string’ clearly is not correct at the acoustic level” [13, p. 7]. In fact, the theory dissolves not only under scientific but also under ordinary analysis. Consider, for example, the word *bead*. If we pronounce this word by the accumulation of sounds represented by individual letters, then we must start with the letter *b*. However, the sound represented by the letter *b* cannot be pronounced in isolation. If you try to pronounce an isolated *b*, you end up saying /bee/, or /bi/, or /buh/. The same is true for the sounds represented by the following letters: B D G H J K L M N P R T W. Note that these letters, none of which can be pronounced in isolation, are all consonants.

According to Gelb, the determining letters in a word that suggest its pronunciation are consonants [26]. For instance, n rdng ths sntnc, y wll fnd th bst prf tht th nglsh lngug cn b wrttn wthut vwls. Vowels connect one consonant to another, and the tonal value of the vowel plays a supporting role in determining the pronunciation of a word. Vowels are the more malleable phonetic element of a word, often homogenized in unstressed syllables. Chomsky noted this general process of reducing an unstressed vowel to a schwa [15], the all-purpose vowel sound such as the *u* in the word *fun*.

The difference between consonant-vowel pairs, known as syllables, creates meaningful articulations. The vowel and the consonant have a dynamic relationship. As Pinker says, “Each phoneme’s sound signature is colored by the phonemes that come before and after. . .” [14, p. 182]. Consider the *n* in *signature* and the *n* in *finger*. The context in which *n* is used determines its phonemic value. In fact, the “information about each component of a word is smeared over the entire word” [14, p. 161]. The phonemic value of all letters depends not only on its letter context but also on its semantic context. For instance, depending upon the meaning of a sentence, we pronounce the word *read* either /reed/ or /red/. Therefore, because the sounds that letters represent cannot be isolated, pronunciation of words during reading depends upon whole-word identification. And, further, whole-word identification does not preclude phonological recoding before lexical access, as McCusker, Hillinger, and Bias argue.

Including phonology in a word-identification model causes a serious problem for those who believe that phonological recoding occurs *before* rather than *after* whole-word identification: How can a reader pronounce a word before she identifies its whole? The proponents of a phonological path to word identification offer as evidence an equally intriguing question: “How is it that we can recognize a word whose pronunciation we know but cannot spell?” [27]. The answer, they say, is that we phonologically recode the word and then locate it in our internal lexicon based upon our pronunciation of it. Who is right? Proponents of the direct path to word identification or proponents of the phonological path? Based upon recent research, the answer is both.

Based upon his experimental investigations, Baron concludes that the phonological path "is used in parallel with the direct path" to word identification [28, p. 203]. The reliance on one path or the other, he further concludes, depends on the difficulty of the material and the individual. Both visual and phonological paths supply working memory with word information. To illustrate, Baron offers the following analogy:

> If we imagine the two paths as hoses that can be used to fill up a bucket with information about meaning, we can see that the addition of a second hose can speed up the filling of the bucket even if it provides less water than the first [p. 203].

Campbell and Besner demonstrated how word information from the internal lexicon determines the way readers pronounce non-words [22]. Therefore, the visual and phonological paths interact to supply information to the word identification stage. Rubenstein, Lewis, and Rubenstein also experimented with non-words to determine how the two paths interact [27]. When the phonological path was not as active (such as when their subjects read known words and unpronounceable non-words), subjects quickly identified visual stimuli. The results suggest that both paths interact to supply information to the word identification stage, as evidenced by the longer time to identify homophonic non-words such as *slic*, which phonologically but not visually matches a word. In such a case, the reading process is slowed down because of contradictory information carried to short-term memory by both paths (match versus non-match). Experimental investigations conducted by Van Orden demonstrated how potent is the influence of phonological recoding on word identification [29, 30]. Homophones, such as *hare*, and homophonic non-words, such as *sute*, were often falsely identified as belonging to a particular category, such as "part of the human body" and "an article of clothing."

The collective evidence from these experimental investigations strongly suggests that (1) the reading process includes both a visual and a phonological path to word identification and (2) the two paths interact in a complex, dynamic way.

How Silent Speech Affects Synthesizing Words To Create Meaning

Although the exact relationship between vision, silent speech, and memory is a subject of controversy, most researchers agree that silent speech plays an essential role in the word synthesis stage of the reading process. According to McCusker, Hillinger, and Bias, silent speech enables "the activation of individual lexical entries to persist long enough for semantic integration" [23, p. 241]. A great body of evidence suggests that the form of words stored in our internal lexicon is more phonological than visual [5]. In fact, even a word learned from reading may be stored "in a form we would expect if the stimulus had been heard instead of seen" [27, p. 645].

Kleiman concludes, however, that silent speech is not involved in all semantic tasks but rather only those tasks that place demands on memory, such as reading difficult material [5]. In this case, the phonological path complements the visual path to enable short-term memory to process difficult material. The confusing interaction between the two paths is cited as an example of parallel processing. When a person reads the sentence "I can't write cents eye broke my hand," the two paths carry contradictory information. The phonological path carries information that matches the words *since* and *I*: a phonological, syntactic, and semantic match. However, the visual path carries information that matches the words *cents* and *eye*, which are not syntactically and semantically appropriate.

Baddeley, Eldridge, and Lewis explored the way silent speech influences comprehension by using a technique known as concurrent articulation [20]. Subjects were required to repeat unrelated words while reading, which ties up the articulatory mechanisms. The researchers wanted to know whether concurrent articulation inhibited short-term memory, so they had subjects read long, complex sentences while counting aloud and then indicate whether the sentences were semantically acceptable. Whereas suppressing silent speech in this way did not affect the speed of reading, subjects were much more likely to accept semantically faulty sentences as meaningful when they were counting. Levy conducted concurrent-articulation experiments with similar results [31]. His experiments demonstrated that suppression of silent speech greatly decreased comprehension when the subjects read silently.

Bringing words into short-term memory through the phonological path helps to keep them active longer. According to Baron, “the phonemic code is more useful in the memory conditions,” especially “when reading difficult scientific papers” [28, pp. 195–96]. Baron also used concurrent articulation in a number of experiments that tested the reader’s ability to understand and remember relationships defined by two sentences (for example: John is taller than Jack. Jim is shorter than Jack.). The experiments demonstrate that phonemic codes have an advantage over visual codes when the reader has to remember the words before she understands them. The easiest way to remember words, Baron concludes, is phonemically.

A New, Phonological Reading Model

The cogency of the literature covered in this article greatly depends upon the assumption that silent speech is a generalized phenomenon, especially one experienced by the reader of this article. With that assumption, one can generally conclude that considering silent speech during the writing and revision processes will enhance the reader’s experience and better the chances for successful, meaningful communication. One can specifically conclude that:

- Silent speech during silent reading helps lexical access by transforming a surface phonemic representation (a printed word) into a deep phonemic code that speeds up word identification.
- Silent speech helps short-term memory keep meaningful units of information in an active state so that the information can be semantically integrated with other information from long-term memory.
- The more difficult the reading material, the more the reader uses silent speech to create meaning from text.
- When silent speech is disrupted or suppressed, lexical access, the parser, and short-term memory are significantly impaired, decreasing comprehension and the ability to detect errors.

The model of the reading process I propose, shown in Figure 3, includes a phonemic path to both the word identification stage and short-term memory. For technical communicators, this "dual-path" model implies quite a few practical applications.

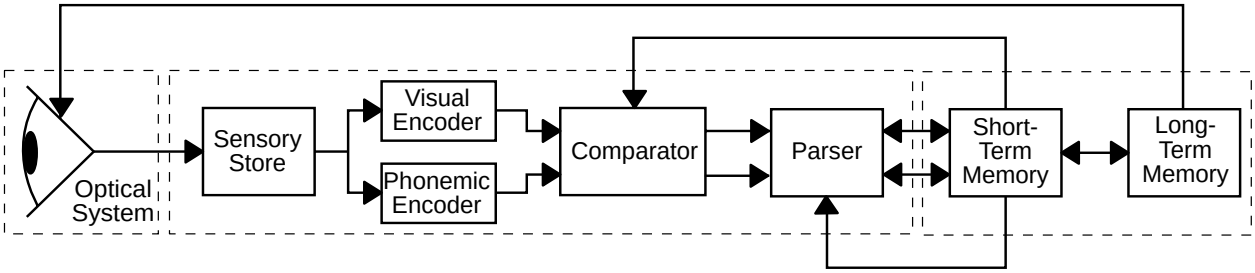

Figure 3. A dual-path model of the reading process

APPLYING THE DUAL-PATH MODEL TO TECHNICAL COMMUNICATION

Introducing New Words

Essentially, technical writing is about conveying new information, and often such information contains terms unknown to the reader. Some unknown words can be easily pronounced because they have familiar spelling patterns, which become the rule for pronunciation for readers encountering new words [22]. Some new words are simply new combinations of words and affixes we already know and can readily pronounce. But why is pronunciation of new words so important? Two reasons.

First, because the speech instinct is so strong during silent reading, languishing over the pronunciation of a word pulls the reader from the text. Also, according to the results of experimental investigations, people do not integrate novel words into their vocabularies until the word is heard or translated into a phonological code [28]. Therefore, pronunciation of new words is essential to understanding, especially the understanding of "difficult, infrequent, or unfamiliar material" [23, p. 241].

Many reference books include a pronunciation key to help the reader pronounce unknown words. English dictionaries conventionally integrate pronunciation symbols into the words they

define. In some cases, the omission of a pronunciation key can have adverse consequences, especially for reference and religious books that contain foreign words and phrases. An English translation of *The Tibetan Book of the Dead*, for example, includes a pronunciation key in the full-sized version. However, in the compact version, the key is omitted. The reader is up to his own wit to decipher words such as "Dödül-Dorje" and "Gyurme-Tenphel," which have unfamiliar spelling patterns.

The second reason why pronunciation of new words is so important involves one of the purposes of reading in the first place: to build a usable (executive) vocabulary. Because spelling and sound only roughly correspond in English, a reader left on his own to pronounce an unknown word may integrate the word into his vocabulary with the right spelling but the wrong pronunciation. As an illustration, pronounce the nonce word *mough*. Did you pronounce it like *through*? *cough*? *bough*? *rough*? *dough*? *trough*? All six of those words can be used analogously to pronounce the nonce word *mough*. So which is right? In this case, it is up to the writer to make the decision for the reader: "mough (pronounced like *cough*)."

Correct pronunciation is important for a number of reasons. But perhaps the most important reason is that readers often appropriate new words from a specialized discourse—such as the vernacular of linguistics, political science, or technical communication—so that they can use those words in conversations with their peers, or with people they hope will be their peers. While fluently speaking the language of your peers tends to solidify communion, inconsistent pronunciation alienates. For instance, let's say I wish to enter a group by speaking their language—a group of computer engineers—and I say, "The new PowerPC chips make the six-eight-oh-ex-oh processor look like a horse-and-buggy technology." I would immediately be branded an outsider because the correct way to pronounce 680X0 is *68-kay*. How do I know? Because Lon Poole, the author of "PowerPC Preview" in MacWorld Magazine, told me: "In the next few months, Apple plans to trot out the first Macs running on IBM/Motorola PowerPC RISC processors rather than on Motorola 680X0 CISC processors (680X0 is pronounced *68-kay*)."

Because Poole prefaced the 26 occurrences of that word with a key to its pronunciation, I properly integrated it into my vocabulary, allowing me to communicate effectively with my peers. Here are some other examples of thoughtful writers helping readers integrate new words into their vocabularies.

- "The 't' in Nicot is silent, so *Nicotiana* should sound like Nick-oh-she-anna, with the accent on the second syllable."

  —Rob Proctor, *Annuals: Yearly Classics for the Contemporary Garden*

- "The Practical Conference on Communication (PCOC, pronounced 'peacock') is sponsored by the Society for Technical Communication/East Tennessee Chapter (STC/ETC). . . ."

  —Society for Technical Communication/East Tennessee Chapter, "Call for Papers: 19th Annual Practical Conference on Communication"

- "People talking about WAIS (pronounced 'ways,' I hear) tend to use the terms 'source,' 'server,' and 'database' interchangeably, and so do I."

  —Adam C. Engst, *Internet Starter Kit for Macintosh*, 2nd ed.

- "Spoken , the acronym for universal resource locator—URL—sounds like 'you are ell.' A few folks may try to pronounce URL as if it were 'earl,' but you shouldn't let them get away with it."

  —The Cobb Group, *The Page*, Issue #95

- "Nowadays, Jews prefer the original terms for such things: not 'Booths,' but Sukkot [soo-KOTE]; Shabbat [shah-BAHT], not 'the Sabbath.' A glossary (with a pronunciation guide) lists all such words, providing a practical lexicon of Jewish life. I provide a pronunciation key whenever a new term is introduced, or even (on occasion) when I think it has been a particularly long time since the term was encountered (there is nothing more frustrating for readers than to see a technical term and not even to be able to pronounce it silently as they read down the page)."

  —Rabbi Morris N. Kertzer, *What Is a Jew?*

Abbreviations

Much of technical writing these days is replete with abbreviations of one type or another. Some texts look like alphabet soup when held at arm's length. For example, consider these two sentences taken from a pollution-prevention document:

> Many of these WMAs have been conducted on waste streams at the RFP and at local businesses throughout Colorado. In addition, the FRCC HAZMATT program has assisted in the development and implementation of similar programs at several DOE weapons sites.

These two sentences alone contain four initialisms (a group of letters, created from the initial letters of words, that is not pronounced as a single word) and one acronym (a group of letters, created from letters of a group of words, that is pronounced as a single word). Yet we would all agree that abbreviation is an indispensable way of transforming the sprawling polysyllabic jargon of science and industry into packages that the reader can manage. However, technical writers are sometimes too quick to condense such jargon without giving thought to the way they are picked up during the reading process. An anecdote will illustrate the point.

I once read a report that suggested adding 15-15-15 fertilizer to the soil just before sowing a winter cover crop. I remember how awkward and time-consuming it was to say fifteen-fifteen-fifteen again and again in my head. When I went to a garden supply vendor to buy some of this fertilizer, the clerk pronounced it "triple-fifteen." His creative approach to pronouncing the otherwise awkward, monotonous 15-15-15 illustrates how speakers of awkward words in a specialized vocabulary often simplify pronunciation. The problem with terms such as 15-15-15 is two-fold.

First, they are repetitive. Baddeley, Eldridge, and Lewis demonstrated how a series of repetitious sounds takes longer to process than a series of different sounds [20]. They discovered that a sentence such as "Crude rude Jude chewed stewed food" took longer to process (understand) than a sentence of equivalent semantic complexity without repetitious sounds, such as "Dark-skinned Ian ate boiled meal." According to Williams, the way we identify meaningful

parts of sentences and words “involves finding contrasts between pairs of utterances that include differences in expression” [17, p. 7]. Successive like-sounding vowels inhibit the flow of speech required for effective silent reading. Speakers tend to understand this notion. They do not pronounce NAACP en-ay-ay-see-pee; they say en-double-ay-see-pee. They do not pronounce IEEE eye-ee-ee-ee; they say eye-triple-ee. They do not pronounce SCSI es-see-es-eye; they say skuh-zee, inserting a schwa in the middle to render an acronym from an initialism. Illustrating a simpler way to pronounce otherwise dissonant initialisms is a good way to bring the reader closer to the text.

The second problem with terms such as 15-15-15 is that they are monotonous. When initialisms contain more than a few letters, they tend to inhibit any rhythm a sentence may have. Most consonants when pronounced by name either end in /ee/ (b, c, d, g, p, t, v, and z) or begin with /e/ (f, l, m, n, s, and x). Initialisms containing more than a few contiguous consonants can obstruct the flow of words. Consider the staccato CTGTS, which stands for cradle-to-grave tracking system. The first four consonants all have the same trailing /ee/ sound. The trick here is to recognize the staccato nature of the initialism and recreate it based upon the need of the reading process to move items quickly from visual sensory store to short-term memory. Whatever term the writer uses to abbreviate cradle-to-grave tracking system, it must enable the speech instinct, not frustrate it. Shortening it by removing unnecessary letters will help (CGT), but instilling a new term with a familiar spelling pattern will be even better (Crave, for instance).

Sometimes, what *appears* to be a correct use of an initialism—that is, what conforms to a prescriptive grammar—does not *sound* correct. Take this sentence: “A RC filter enabled the clock to keep accurate time.” It appears correct, but does not sound correct. The problem here is a misapplication of the rule for the indefinite article. The rule for selecting *a* or *an*, as I have heard and sometimes read it, depends upon the succeeding letter. If the letter that follows the indefinite article is a consonant, then use *a*; if a vowel, use *an*. Understand, however, that the rule is not bound by visual information (printed words) but phonological information (spoken words). The rule is properly stated: If the *sound* of the letter that follows the indefinite article is

a consonant, then use *a*; if a vowel, use *an*. Bolinger noted that "multiple consonants and multiple vowels are harder than alternating vowels and consonants" [32, p. 39], which may be the raison d'être of the two forms of the indefinite article.

When we pronounce initialisms, we pronounce the name of each letter, not the sound each letter represents. "A RC filter" does not sound correct because we pronounce the name of the letter *R*, which begins with a vowel sound (/ar/), instead of the sound the letter *R* represents, which is a consonant sound. The sound following the article is therefore a vowel. The correct article is *an*: "An RC filter." The same reasoning can be applied to initialisms beginning with the vowel *u*, which is pronounced /yoo/, as in USDA. Instead of taking *an*, as it would when used in a word, the vowel *u* takes *a* when used at the beginning of an initialism.

One application of the phonological model of the reading process may seem marginal, but is nonetheless worth noting in this context. The putative practice of pluralizing initialisms is to simply add an *s* to the end, regardless of how the end of the initialism sounds. Just smacking on an *s* to the end of CTGTS, for instance, not only disregards the way we pronounce abbreviations, but also breaches the phonological rule of grammar that requires us to add *es* to indicate a plural of a word ending in /s/ (as in the letter *s*, pronounced /es/), /ch/ (as in the letter *h*, pronounced /aych/), and /ks/ (as in the letter *x*, pronounced /eks/). Thus when Doug Dorr writes, "Ironically, certain standby power systems (SPSes) can also cause this kind of logic voltage drop," he breaks convention but obeys grammar (from "Ten Symptoms, Solutions to Common Power Problems," *LAN TIMES*).

Punctuation

The mechanics of language can be expressed in two ways. Speech expresses mechanics by tonal inflections and, more rarely, pauses. "In the speech sound wave," says Pinker, "one word runs into the next seamlessly; there are no little silences between spoken words the way there are white spaces between written words. We simply hallucinate word boundaries when we reach the edge of a stretch of sound that matches some entry in our mental dictionary" [14, pp. 159–160].

The rise and fall of the speech stream determines the mechanical relationships between words in a sentence and between sentences themselves.

The other way to express mechanics is through punctuation, which, in the history of human language, is a relatively novel idea appearing just before the invention of the printing press [33]. Most punctuation marks directly correspond to a speech phenomenon, whereas other marks are more intellectual than phonetic. Terminal punctuation marks (period, question mark, and exclamation point) correspond directly to undulations of voice pitch. For instance, Bolinger says that the natural untensing of the vocal cords indicate the end of a complete thought [32]. A descending pitch signals the end of a declarative sentence, whereas an ascending pitch signals the end of an interrogative sentence. Semicolons, em dashes, and slashes are examples of intellectual punctuation marks, which indicate complex relationships between written words, phrases, or clauses that cannot be conveyed through ordinary speech. Here are some suggestions for applying a few of the most troublesome punctuation marks based upon the phonological model of the reading process.

The Comma Although it is common practice, omitting a comma after an introductory element can create confusion. The very thing that makes such commas unnecessary in the mind of the writer makes them necessary to the comprehension of the reader. The writer cannot recognize the need for a comma after an introductory element because he articulates the element as he crafts it. Meaning and articulation are fused in the writer's mind. He cannot see, or hear, that the element can sprawl into the rest of the sentence.

Here is an example of such a sentence: "As the input voltage continued to drop the output voltage finally reached near nominal." If this sentence were to come to us via speech, the speaker would indicate the end of the introductory element, "As the input voltage continued to drop," by a falling pitch. As it is written, however, it sprawls into the rest of the sentence. The last word in the introductory element ("drop") is often used as a transitive verb. Without a comma after "drop," the pitch of the reader's silent speech may not fall. He may therefore

misread “the output voltage” as the object of “drop” instead of the subject of “reached,” as I did when I first encountered the sentence. Omitting the comma created what linguists call a garden-path sentence, which denies the reader’s predictions about how succeeding words function in a sentence.

Consider another example of how omitting the comma after an introductory element can create confusion for the reader: “In this case only the subject was able to understand the command.” Because the writer omitted the comma, the sentence has an ambiguous meaning that cannot be resolved without help from the writer. Does the comma go after “case,” which renders one meaning, or after “only,” which renders another? Does “only” modify “In this case” or “the subject”? In this case, only the writer knows.

The Hyphen Hyphenation is a thorn in the collective side of technical writers. To hyphenate or not to hyphenate? That is a question writers must frequently confront, often with dubious results. Ubiquitous in technical documents, the noun-string poses a difficulty for the average writer. Most writers do not even address hyphenation in noun-strings, assuming that readers are smart enough to figure out the relationship between words. However, when the reader *starts* figuring things out, he *stops* reading. Further, without hyphens to guide the reader to the correct interpretation of a word-string, consecutive nouns “can be read either as a phrase or as a compound” [14, p. 133].

Again, here is an example to illustrate the point: “The man eating fish was caught just offshore.” Here, the omission of the hyphen between “man” and “eating” creates an ambiguity. Did the man who was eating fish get caught? Or did a fish that eats men get caught? Hyphenation removes all ambiguity by properly indicating the stresses of each syllable. The resulting tonal information leads the reader to the correct meaning: “mán-eating fish,” not “mán eáting fish.” In the same vein, a “dry cleáning agent” is Ajax, whereas a “dry-cleaning agent” is benzine. “Small búsiness woman” is a derogatory term, whereas “small-business woman” is a respectful one. “American hístory teacher” is a teacher of history who is an American, whereas

"American-history teacher" is a teacher of American history. Notice that in all of the above comparisons, the unhyphenated modifiers have slightly different stress contours than the hyphenated ones.

Hyphens are also used to break words at the end of a line. End-of-line hyphenation is bound by phonics because words are broken at syllabic junctures. Sometimes, there is not enough information in the first part of a broken word to identify the whole word. If a word is broken at the first syllable and that first syllable is identical to the first syllable of other words, the reader has to guess, relying only upon his semantic and syntactic predictions to hedge his bet. Consider the following example:

> Some feel that the ingredients of the president's health care plan are a rec-
> ipe for disaster.

The *c* in "recipe" can be pronounced soft, as in "recipe," or hard, as in "recommended." The ambiguity can be easily repaired by breaking the word between the *i* and the *p* (dictionaries allow the word to be broken after the *c* or the *i*). We instinctively know that if an *i* follows a *c*, the *c* is pronounced softly. Plus, the additional letter narrows our choices considerably. Although not at all common, I have noticed this end-of-line-hyphenation problem more with double-spaced manuscripts and manuscripts produced using word processors with automatic hyphenation.

Finally, the hyphen is often used in a way that inhibits speech. For example, in the following sentence, the hyphen conceals the relationship between the two words it joins: "Lowering line-pole grounding resistance made a real improvement." When we read this sentence, we say "line pole" instead of "line to pole" as the writer intended. A writer may intend for a hyphen to equal *to*, but the latent word *to* is not translated into the speech code. Therefore, the reader does not make the logical connection between the two words. The same can be said about hyphens used to indicate a range, such as "20–30%." To enable the reader's silent speech, write "line-to-pole" and "20 to 30%."

The Apostrophe One dubious rule for the use of the apostrophe is that only animate nouns can take an apostrophe because inanimate things cannot possess. Although apostrophes should not be used in some cases, the decision to use or not use an apostrophe plus *s* should have nothing to do with whether the noun refers to animate or inanimate things. The decision should be based upon the way the end of a noun sounds. Generally, if a singular noun ends with a sibilant (/s/, /z/, /sh/, /zh/, /ch/, /j/), the apostrophe and *s* should not be used because the /z/ of the apostrophe *s* clashes with sibilants [32]. Instead, use the possessive word *of* to indicate possession. For example, write "Many died in the wake of the disease," not "Many died in the disease's wake." Note that *The Chicago Manual of Style* suggests simply using an apostrophe and omitting the *s* when the noun ends with a /z/. However, unless the noun is a proper name, the apostrophe *looks* misplaced (disease' wake) and the possessive noun *sounds* like an unpossessive one used adjectivally (disease wake). Thus the relationship between possessor and possessed is lost.

Pronouns

Readers often pay the price for a writer's political correctness. In order to be non-offensive, writers embrace the whole of humanity with neutered contrivances. The use of the singular subjective pronouns *he* and *she* have undergone quite a radical evolution in a very short time. *He* once encompassed *she*. Then *she* gained a condescending acknowledgment, accompanying *he* inside parentheses like so: *he (she)*. Soon, *she* came out of the parentheses: *he or she*. The two danced around the slash, as in *he/she* and *she/he*. And now the two have fused to form *s/he*. The problem with *s/he*, as you might have guessed, is that the reader cannot pronounce it. In a jest that reveals the frustration of negotiating political correctness, some writers have recommended using the all-inclusive pronoun *s/h/it*.

Merriam-Webster now says that using *their* instead of *his* or *her* is grammatically acceptable [34]. Of course, speakers have always known that *their* is acceptable. Yet writers are often reluctant to follow the ways of ordinary speech. In some cases, however, the use of *their* is appropriate despite a prescriptive insistence on using a singular pronoun. In the sentence

"Everyone returned to his/her seat," the term "his/her" should be "their," not because Merriam-Webster says or because it is the iconoclastic thing to do, but because it is classically grammatical. Consider that a pronoun must match its antecedent in number and gender. As long as the number is plural, we have no problem, which is what we have here. The antecedent of the pronoun in this case is not "Everyone" but "people." Where is "people"? The same place where "You" hides in the sentence "Hand me the book." The sentence is elliptical. The complete sentence with all of its parts—expressed and implied—is "Everyone [of the people] returned to *their* seats." The word "people" is the antecedent. Therefore, it takes a plural pronoun.

The point remains that when writers wield contrivances such as s/he and his/her, they wield the sword by the blade, trading something valuable to the reader—the speech-enabling quality of a simple pronoun—for reputations as politically sensitive writers.

Liberating Silent Speech

Euphonics is the acoustic effect produced by words so formed or combined as to please the ear. Yet pleasing the ear has a much greater consequence than simply making the act of reading more pleasurable. Euphonics also impinges upon our understanding of a text. The following techniques will help unify speech and meaning.

Avoid Using Latinates The sound of some words can directly clash against their meanings. Pulchritudinous sounds hideous, but means beautiful. Homunculus is a giant word, but means little man. These two words have something in common: They are both Latinates, words derived from Latin. The problem with Latinates is that "when we use Latinate, the words clog the reader's cognitive intake pipes because of the onslaught of syllables, as well as the necessity to think through the meaning of many Latinate words" [35, p. 457].

Latin is an atomic language, in which words are created from atoms of meaningful syllables. Therefore, to the ancient Roman, polysyllabic words were the norm. Words from our native language, Anglo-Saxon, rarely stretch beyond three syllables. Moreover, although Latin and

English have a common alphabet, the spelling-to-sound correspondences of each is different from the other. According to Baron, a consistent spelling-to-sound correspondence makes it easier to extract a phonemic code from text and "speeds up the extraction of the phonemic code itself" [28, p. 202]. Baron also notes that words that follow English orthographic rules, as opposed to Latinates, are easier to pronounce when encountered in a text. Thus, Latinates and other borrowed words are more difficult to pronounce and should be rejected when an English word of a similar meaning can be used.

Use the Dollar Sign with Caution An ideogram is a written symbol that represents an idea or object directly rather than a particular word or speech sound. Even so, we habitually pronounce ideograms when we read silently. And for all but one, these symbols conform to the syntax of speech. The term "#1" is pronounced "number one"; "3 x 3" is pronounced "three times three"; and "the range from 1000 to •" is pronounced "the range from one thousand to infinity." However, consider the term "$300." The dollar sign ($) comes before the figure, yet its pronunciation comes after; it is syntactically irregular, which can cause a clash between sound and meaning.

When reading a figure prefaced with a dollar sign, the reader must (1) hold the dollar sign in short-term memory, without a phonological code to help keep it active, (2) articulate the figure, (3) place the dollar sign before the next word to be read, and (4) articulate "dollars." Short figures in a sentence, such as "$300," do not greatly tax short-term memory. Larger figures in a sentence, such as $347,000, do, because the robust phonological information (three hundred forty-seven thousand) may supplant the weaker visual information ($).

Consider this sentence: "Hunter says about 10 percent of the $180 billion consumers spent on insurance last year was wasted on unnecessary policies." Because the reader must first get through "one hundred eighty billion" before he recursively articulates "dollars," the reader may read the sentence "one hundred eighty billion consumers spent. . . ." Then, the reader is looking for an object of "spent": What did the 180 million consumers spend? What the reader gets,

however, is the word “on.” The parser, that part of the reading process that compares what we read to what we expect to read, sends a red flag to short-term memory, and the reader stops reading. This garden path sentence was created because of two reasons. First, the dollar sign is forgotten by the time the reader gets to the end of the long figure. To solve this problem, the figure could be re-written “180 billion dollars.” Second, the word “that” required to introduce a restrictive clause is omitted at a crucial point. To solve this problem, the sentence could be re-written “. . . the $180 billion *that* consumers spent. . . .”

A blanket solution to this problem is to always spell out “dollars” when a figure is long or can be misconstrued as modifying something that follows it, as in the example above. But such a routine will come at a price. Those dollar symbols stand for money, money is important to people, the dollar symbol is easy to pick out when scanning text, and if you always spell out “dollars,” you impede the reader’s ability to pick out important information.

Avoid Optional Plurals How do you read the following sentence? “The grounding electrode(s) is a crucial element of good power quality.” We see the *s*, so we pronounce the *s*. If we get meaning from the phonological path as well as the visual path, then the word “electrode(s)” is plural. Yet, the verb is singular. The parser may quickly send a red flag to the short-term memory of the reader. To fix the sentence, change the verb to match the plural subject and remove the ambiguity-causing parentheses from around the “s” in “electrode(s).” And because the sentence declares an abstraction, the optional plural does not bear upon meaning. If the optional plural bears upon the meaning of the sentence, then the meaning should prevail through careful revision or, if necessary, retaining the optional plural.

Put Adverbs Where They Go Naturally in Speech Yes, English speakers split infinitives. Unlike Latin, which has one-word infinitives, English infinitives are created from two words: *to* plus the base of a verb. Because Latin infinitives could not be split, the English grammarians who based our grammar upon Latin prescribed that one should never split an infinitive. English

speakers also intuitively place many adverbs between a verb and its auxiliary. We would not say, "A loop antenna also was used." We would say, "A loop antenna was also used." Yet, many technical writers insist upon unifying a verb and its auxiliary at the expense of satisfying the reader's speech patterns.

Don't Forget the Articles Articles not only enable the reader to determine whether a noun is definite (the book) or indefinite (a book), but they also infuse a text with rhythm. Read these assembly instructions for a self-propelled lawnmower: "Lift idler assembly, re-attach drive gear, and insert peg into higher or lower hole in frame." Now read the instructions re-written for rhythm: "Lift the idler assembly, re-attach the drive gear, and insert the peg into a higher or lower hole in the frame." The text no longer sounds as if Tarzan was the principal author, and the articles act as rhythmic bridges, connecting sound to sound.

Cultivating a Human Voice

Many technical writers feel that the degree of formality required by the genre of technical communication crowds out the notion of "talking about something." But formality does not necessarily mean equalizing or leveling the voice of technical prose to the point of depersonalizing it. No matter how scientific or technological the subject of a text is, people are always behind the words. People invent, research, test, and generally do the things that technical writers write about. And whereas the invasive jargon of science and industry can be found on street corners and in living rooms, a well-turned phrase rarely finds its way into technical prose.

As Darlington puts it:

> The theory that scientific discovery is impersonal, or so it is called, objective, has had several evil consequences. One is that the style of describing and publishing the results of scientific research which is fashionable today has been developed to sustain it. One should write, one is told, in the third person, in the passive voice, without betraying conviction or emphasis, without allusion to any concrete or everyday object but with the

> feeblest indifference and the greatest abstraction. This practice has proved to be so readily acquired that it has now, for a whole generation, been debauching the literary language of the world. The result has been that science, instead of being a source of strength and honesty, is in fact robbing the common speech of these very qualities. [36, p. 420]

To cultivate an authoritative, consistent persona, every mark of technical prose on the page should remain within the compass of a human voice developed by the writer. That does not mean that the voice should mimic the physical speech mannerisms of the writer. The literary voice of a writer rarely resembles his language mannerisms. A writer creates a literary voice consciously. For instance, interjecting a verbal tick is an effective and *deliberate* way to craft a particular voice, especially if such verbal mannerisms are consistent and without cliché. Consider the following sentence: "When you look at a hologram of, say, a model airplane, all you see is a somewhat fogged film, with no indication of a picture." The interjection "say" humanizes the sentence with a rhetorical, speech-like quality. That does not mean that a writer should interject ticks such as "say" here and there willy-nilly into his prose; readers can recognize an insincere voice just as children can recognize the condescension of an admonishing adult. No, writers must carefully pick their moments to establish and maintain the complex relationship between two people—the implied author and the reader—brought together by a text.

Remember that writers are handicapped in communicating to their readers. There are no gestures, eye contact, or audible inflections to indicate irony and emphasis, among other things. The communication achieved by those physical acts must somehow be simulated in the text. For instance, quotation marks can indicate a direct quote or title, but they can also be used to ironize a word or phrase. If I write, "Some feel that the novel is interesting," you may think that I agree with that sentiment, or perhaps not. Who knows? You won't know until you read on. However, if I write, "Some feel that the novel is 'interesting,'" the quotation marks around the word "interesting" convey the same thing an ascending tone and perhaps other gestures convey: irony. The quotation marks separate the opinion of "Some" from the opinion of the author.

Many people use capital letters, especially in the new technical medium of e-mail, to indicate emphasis. However, such a use invites trouble. What the writer intends as emphasis, the reader can phonologically recode as a screaming voice: “Approval from the appropriate project manager is MANDATORY before printing. DO NOT PRINT UNTIL APPROVAL HAS BEEN RECEIVED.” The voice here can be construed as angry and offensive. In this case, carefully considered rhetoric would serve the author better than mutated typography.

Finally, the author should conform to the reader’s expectations. Readers devour metered prose. Rhythmic sentences proceed faster from the eyes to memory; arrhythmic sentences, such as the monotony of consecutive consonants in initialisms, grate against the mind’s ear. This does not mean that we should start writing everything in iambic pentameter. Still, revise with an ear tuned to detect discordant combinations of words. As Gabbert says, “certain word combinations produce an ear-pleasing rhythm, whereas the same concept can be expressed in wording that sounds harsh and disagreeable” [37, p. 335]. Gabbert points to a particularly pleasing combination of words he calls the euphony-of-three, such as “of the people, by the people, and for the people.” Paying attention to patterns of speech that please the ear empowers the speech instinct and enables the reader to better understand the text.

Silent Speech in the Revision Process

According to Olson, revision is the place where writing happens [38]. Revision is the only place a writer can fulfill his promise to himself and, perhaps, to his audience. However, revision by professional technical writers and editors may be systematic to a fault, in fact backwards. In the academy, we learn the rules and then learn how to apply them—for clarity’s sake, we assume. To be clear is to adhere to rules that promise clarity. When we ply our trade, many of us proceed from cause to effect, using the prescriptions we learned in the academy as our basis for making decisions about sentence-level changes. We detect a breach of convention, apply a rule (the cause of clarity), and assume a resulting enhancement of clarity (the effect of the rule).

The unquestioning endorsement and use of this loose collection of prescriptions may be an impediment to successful revision. Writers and editors may cling to convention for justifications of changes that may not hold up to reasonable scrutiny. Always match *data* with a plural verb, never begin a sentence with a "sentence modifier" such as *Clearly*, and never split an infinitive are just a few examples of unreasonable conventions.

Revision is not simply a process of looking for errors, looking for breaches. Revision is a process of re-hearing as well as re-seeing. A number of times, someone has reviewed something I have written and commented about a passage, "It just doesn't sound right." And that's the best kind of editorial commentary a writer can receive from a reviewer, because that's the kind of criticism a reader will conjure when he stumbles through a passage that just doesn't sound right.

Consider, then, proceeding with revision not from cause to effect but from effect to cause. Not only to detect errors of many sorts, but also to improve the fundamental *sound*ness of a text, carefully listen to the silent speech created by the reading process. Then, monitor your reactions to that voice in your head. An adverse reaction deserves a close scrutiny of the wayward passage, as well as a fundamental question: What went wrong? As Gabbert says, "there is a way—a beautifully simple way—to obtain a reader reaction to your writing. Read it aloud; or, even better, have someone else read it aloud while you listen" [37, p. 336].

And if we are in a stage of the revision process that limits our investigation of a text to looking for errors (such as proofreading), there again silent speech is a valuable asset. As Baddeley, Eldridge, and Lewis concluded from their experimental investigations, silent speech "provides a source of information that is useful in detecting errors" [20, p. 446]. Use the speech instinct to your advantage by letting a text tell you what's wrong.

CONCLUSION

De Beaugrande says that "a theory of writing cannot be sensibly formulated without regard for theories of reading; what writers do depends on what they expect that their readers will do" [39, p. 128]. Indeed, for years technical writers have been innovating techniques to anticipate

reader reactions. In the 1970s and ’80s, readability formulas promised to verify the efficacy of a text before it was committed to the printing press by quantifying word and sentence length [40]. However, readability formulas are too clumsy and time-consuming, as well as inaccurate, to be routinely useful to technical communicators with deadlines and commitments.

On the other hand, writing techniques foregrounded in reading theory empower technical communicators with a genuine foreknowledge of reader reaction. The literature and results of experimental investigations discussed in this article demonstrate that readers react to the way texts sound, and that readers rely upon that sound to comprehend technical concepts. I have outlined a few ways to apply a phonological model of the reading process to technical communication. Other innovative applications will surely improve the readability of technical prose in more ways than I have explored in this article.

REFERENCES

1. F. Smith, *Understanding Reading: A Psycholinguistic Analysis of Reading and Learning to Read*, 2nd ed., Holt, Rinehart and Winston, New York, 1978.
2. Gateway Educational Products, "Hooked on Phonics" Advertisement, Orange, California, 1994.
3. Saint Augustine, *The Confessions of St. Augustine*, J.G. Pilkington (tran.), International Collectors Library, Garden City, New York, 1876.
4. A. Baugh and T. Cable, *A History of the English Language*, 3rd ed., Prentice-Hall, Englewood Cliffs, New Jersey, 1978.
5. G.M. Kleiman, Speech Recoding in Reading, *Journal of Verbal Learning and Verbal Behavior*, 14, pp. 323–329, 1975.
6. J. Grunig, S. Ramsey, and L. Schneider, An Axiomatic Theory of Cognition and Writing, *Journal of Technical Writing and Communication*, 15:2, pp. 95–130, 1985.
7. N. Banton Smith, *Speed Reading Made Easy*, Warner Books, New York, 1983.
8. J. Robbins, Improving the Understandability of Technical Text: Some Practical Implications of Recent Psycholinguistic Research, in *Proceedings of the 27th International Technical Communication Conference*, Society for Technical Communication, Arlington, Virginia, pp. R-241–45, 1980.
9. P. Anderson, Research About Reading: Its Practical Uses in Technical Writing," in *Proceedings of the 27th International Technical Communication Conference*, Society for Technical Communication, Arlington, Virginia, pp. R-247–51, 1980.
10. E. Huey, *The Psychology and Pedagogy of Reading*, M.I.T. Press, Cambridge, Massachusetts, 1968.
11. N. Johnson, A Pattern-Unit Model of Word Identification, in *Basic Processes in Reading: Perception and Comprehension*, D. Laberge and S. Jay Samuels (eds.), John Wiley and Sons, New York, pp. 91–125, 1977.
12. G.A. Miller, The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information, *Psychology Review*, 63, pp. 81–96, 1956.
13. P. Lieberman, *On the Origins of Language: An Introduction to Evolution of Human Speech*, Macmillan, New York, 1975.
14. S. Pinker, *The Language Instinct: How the Mind Creates Language*, William Morrow and Company, New York, 1994.
15. N. Chomsky, Phonology and Reading, in *Basic Studies on Reading*, H. Levin and J.R. Williams (eds.), Basic Books, New York, pp. 3–18, 1970.
16. D. Hindle, Discourse Organization in Speech and Writing, in *Writing Talks: Views on Teaching Writing From Across the Professions*, M. Siegel and T. Olson (eds.), Boynton/Cook, Upper Montclair, New Jersey, pp. 71–86, 1983.
17. F. Williams, *Language and Speech: Introductory Perspectives*, Prentice-Hall, Englewood Cliffs, New Jersey, 1972.
18. C. Darwin, *The Descent of Man, and Selection in Relation to Sex*, Princeton University Press, Princeton, New Jersey, 1981.
19. F. McGuigan, *Silent Speech During Silent Reading*, Hollins College, Hollins, Virginia, 1964.
20. A. Baddeley, M. Eldridge, and V. Lewis, The Role of Subvocalisation in Reading, *Quarterly Journal of Experimental Psychology*, 33A, pp. 439–454, 1981.

21. C. Hulme and J. Ryder Richardson, The Effects of Articulatory Suppression on Reading Ideographic and Alphabetic Numbers, *Quarterly Journal of Experimental Psychology*, 33A, pp. 121–132, 1981.
22. R. Campbell and D. Besner, This and Thap—Constraints of the Pronunciation of New, Written Words, *Quarterly Journal of Experimental Psychology*, 33A, pp. 375–396, 1981.
23. L. McCusker, M. Hillinger, and R. Bias, Phonological Recoding and Reading, *Psychological Bulletin*, 89(2), pp. 217–245, 1981.
24. C. A. Perfetti and S. Zhang, Phonological Processes in Reading Chinese Characters, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 17(4), pp. 633–643, 1991.
25. S. Zhang and C. A. Perfetti, The Tongue-Twister Effect in Reading Chinese, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19(5), pp. 1082–1093, 1993.
26. I. Gelb, *A Study of Writing*, University of Chicago Press, Chicago, 1963.
27. H. Rubenstein, S. Lewis, and M. Rubenstein, Evidence for Phonemic Recoding in Visual Word Recognition, *Journal of Verbal Learning and Verbal Behavior*, 10, pp. 645–657, 1971.
28. J. Baron, Mechanisms for Pronouncing Printed Words: Use and Acquisition, in *Basic Processes in Reading: Perception and Comprehension*, D. Laberge and S.J. Samuels (eds.), John Wiley and Sons, New York, pp. 175–216, 1977.
29. G. Van Orden, A ROWS Is a ROSE: Spelling, Sound and Reading, *Journal of Memory and Cognition*, 15, pp. 181-198, 1987.
30. G. Van Orden, J. Johnston, and B. Hale, Word Identification in Reading Proceeds from Spelling to Sound to Meaning, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 14:3, pp. 371–386, 1988.
31. B. Levy, Reading: Speech and Meaning Processes, *Journal of Verbal Learning and Verbal Behavior*, 16, pp. 623–638, 1977.
32. D. Bolinger, *Language, the Loaded Weapon*, Longman, New York, 1980.
33. P. Saenger, Silent Reading: Its Impact on Later Medieval Script and Society, *Viator*, 13, pp. 367–414, 1982.
34. *Merriam-Webster's Collegiate Dictionary*, 10th ed., 1993.
35. T. Altom, Why We Use Big Words: A Historical Perspective, *Technical Communication*, pp. 456–458, 1993.
36. C. D. Darlington, *The Facts of Life*, Unwin Brothers Limited, Working, Great Britain, 1953.
37. W. Gabbert, Factors Influencing Readability, in *Proceedings of the 22nd International Technical Communication Conference*, Society for Technical Communication, Arlington, Virginia, pp. 333–336, 1975.
38. T. Olson, Teaching Writing Where It Happens, in *Writing Talks: Views on Teaching Writing From Across the Professions*, M. Siegel and T. Olson (eds.), Boynton/Cook, Upper Montclair, New Jersey, pp. 3–13, 1983.
39. R. De Beaugrande, Cognitive Processes and Technical Writing: Developmental Foundations, *Journal of Technical Writing and Communication*, 12(2), 121–145, 1982.
40. C. Tekfi, Readability Formulas: An Overview, *Journal of Documentation*, 43, pp. 261–273, 1987.