Introduction

"The occasion is piled high with difficulty," said Abraham Lincoln as he contemplated the consequences of a divided Union. Were he to utter those words today, he could just as well be standing over an instruction manual for assembling a barbecue grill, contemplating the union of Bolt C and Nut H. Every day, someone somewhere verifies the applicability of the axiom "The more the writer works, the less the reader has to"—especially to technical communication. The world is awash with anecdotes about poorly conveyed technical information. Somewhere, the digital display on a VCR blinks incessantly "12:00 AM" in testimony to the difficulty of conveying technical information to the laity.

Is it any wonder that the laity expects bad things from technical documents, when the difficulty of a technical task is so inextricably fused to the text that bears its description? How can writers and editors restore the reader's faith in technical documentation? One way to achieve the universal goal of clear and logical communication is to better understand how readers read technical documents. To that end, the field of technical communication draws from many established disciplines, including the physical sciences, social sciences, psychology, and linguistics.

Yet the question remains: Are researchers in technical communication doing enough to determine how technical readers read, to determine the efficacy of the rules that practitioners use to develop readable texts? Over the past five years, the three most popular journals in technical communication—*Technical Communication, Journal of Technical Writing and Communication*, and *IEEE Transactions on Professional Communication*—published a mere seven articles describing the results of reading experiments. Of the seven articles, one deals with text formatting (Boekelder 1996), one deals with figurative language (Mulder 1996), three deal with computer-presented text (Wenger and Payne 1994; Magilsen and Maes 1996; Wenger and Payne 1996), and only two deal with the sentence level of text (Shubert et al 1995; Spyridakis and Isakson 1998b).

I am suggesting that researchers in technical communication conduct more reading research at the sentence level, where inherited prescriptions of grammar and mechanics are brought to bear. Moreover, we should strive to maximize the external validity of our reading experiments—that is, maximize the degree to which one can apply experimental results to real readers in their natural environments.

In the following sections, I explore the possibility that our readers—technical readers—are unique among all readers. Using schema theory as the foundation of my argument, I establish the power of schema theory to predict a type of reader who expects difficulty and adjusts his or her reading behavior to account for that perceived difficulty. This technical reader exhibits highly superstitious behavior by slowing down and rereading a passage to increase his or her understanding of a technical text, despite *not* increasing it. This deliberate reading strategy is the hallmark of a technical reader, a rhetorical role that the reader dons to negotiate difficult textual terrain. This reader, I propose, is the reader for whom our reading experiments should be designed.

First, I will review the elements of schema theory and then apply the theory to the reading process. After demonstrating the flexibility of the reading process, I will show how technical readers invoke a problem-solving schema to negotiate technical texts. Finally, I will recommend techniques for conducting reading experiments in technical communication.

Elementary Schema Theory

Memories are arranged into networks that help a person understand an object, event, or situation. The term most widely used to describe these generic knowledge structures of human memory is *schema,* or *schemata* in the plural form. However, these structures have also been called frames (Minsky 1975), scripts (Schank and Abelson 1977), idealized cognitive models (Lakoff 1987), and image-schematic gestaults (Johnson 1987). Schemata help us reduce uncertainty by categorizing experiences. Schemata are conjured by the mind and are modified by the environment even as they are forming an interpretation of that environment. They are, therefore, very flexible and adaptive.

Rumelhart et al (1986) propose that schemata are used not only to understand but also to recognize. When sensory information matches a schema-generated hypothesis about an experience, a schema is said to be *instantiated.* Rumelhart uses the term "relaxation" to describe the process of matching an experience to a flexible schema. The better the experience fits a schema, the less uncertainty. Schemata are therefore "recognition devices whose processing is aimed at the evaluation of their goodness-of-fit to the data being processed" (p. 36).

Recognition of an object or event not only precedes understanding but also constrains the way the object or event is understood. That is, schemata constrain our interpretation of an experience. For example, contrast schemata for two types of rooms, a schema for a bedroom and a schema for a kitchen. According to schema theory, each schema has variables—or slots—such as size, furniture, walls, and so on. Each slot may contain default values. For example, the default size of a bedroom may not be absolute but relative, such as bigger than a bathroom but smaller than a living room. Each schema may have many interconnected subschemata, such as bed, alarm clock, and closet for a bedroom schema.

Applications of Schema Theory to the Reading Process

Let us consider the notion of reading. 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.

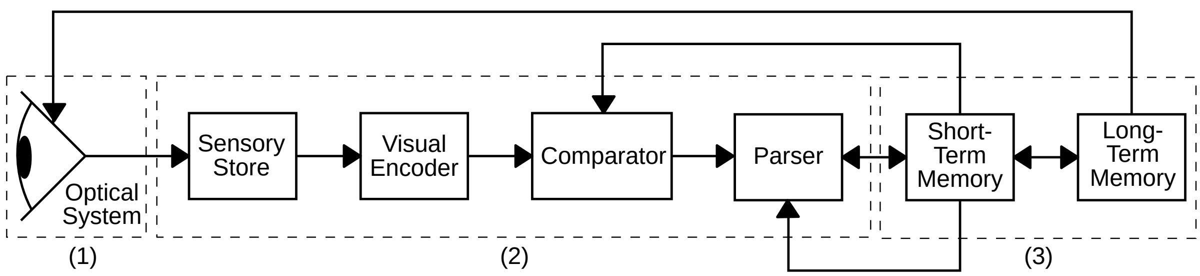

Figure 1. A Simplified Model of the Reading Process

The line connecting long-term memory to the optical system in Figure 1 represents the way schemata guide the reader's attention. 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*. Progressive saccades move the eyes forward from one fixation to the next. During fixations, the reader picks up information and stores the resulting sensory information for a few hundred milliseconds. Between and during fixations, the visual information is processed. Backward motions, called *regressive saccades*, are symptoms of failure to "grasp" information during the reading process.

Visual images in the sensory store are translated into both a visual code and a speech-like code. The comparator then checks the visual and phonological codes against the 50,000 or so words stored in the reader's internal lexicon. The next component of the word-identification stage is the parser, a mental program that analyzes sentence structure during reading. The parser can simply pass encoded words or send a red flag to short-term memory if the reader's predicted function or meaning of a word does not fit the actual function or meaning of the word.

Bringing together all of the elements of a sentence is the primary function of short-term memory. 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.

During reading, schemata afford interpretation, inferences, and expectations. For example, Rumelhart (1975) demonstrates how schematic knowledge affects the interpretation of the italicized portion of the following two sentences:

a. The statistician could be certain that the difference was significant *since all of the figures on the right side of the table were larger than any of those on the left.*

b. The craftsman was certainly justified in charging more for the carvings on the right *since all of the figures on the right side of the table were larger than any of those on the left.* (p. 586)

The different passage contexts in the two sentences above evoke different schemata. The meaning and even the pronunciation of words and phrases depend upon the context in which a particular schema is invoked (Rumelhart 1975; Schank and Abelson 1977; Smith 1978; Pinker 1996). The research of Bransford and Johnson (1973) demonstrates how activating a relevant schema before reading a text helps the reader comprehend the text. For example, simply reading the title of a text can be enough to activate an appropriate schema to facilitate understanding.

The interpretation of a text evolves as the reader invokes various schemata to account for passages. Readers are more active in creating meaning than mere information processors. In fact, Beers (1987) argues that readers should be thought of as meaning designers instead of information processors, with schemata acting as “evaluative guides, presenting concepts that organize material for the understanding and providing criteria by which readers can select and arrange that material” (p. 375). Specifically, schemata primarily bear upon the reading process in the following four ways.

1. They Provide Slots for Schema-Congruent Details

Schemata direct the reader’s attention to schema-significant elements. As Anderson, Spiro, and Anderson (1978) propose, “a high-level schema provides slots for selected categories of text information: If information fits a slot it will be instantiated as part of the encoded representation for the text” (p. 438). Gordon et al (1978) conducted experiments that support the notion that slots in a schema for a particular type of text direct the reader’s attention: “When a schema is activated, as a result of sensory input or ongoing processing, then that schema can itself direct the flow of processing” (p. 11).

The selective-attention hypothesis of schema theory is one proposed explanation for text-processing strategies. According to this hypothesis, a reader “selects important or relevant text elements and then devotes more time to these than to other less important elements (Birkmire 1985, p. 316). The reader thus spends more time on schematically important elements so that those elements can be incorporated into the active schema (Goetz et al 1982).

Bower (1976) proposes that schemata act as text anchors, and our memories for schema-congruent stories are therefore better than for schema-incongruent stories. For example, Bower claims that recall of details from experimental fiction such as Joyce's *Finnigan's Wake* is not nearly as good as recall of details from folk tales such as the *Canterbury Tales* because people have schematic scaffolding for the latter and none for the prior. The memory experiments conducted by Bartlett (1954) in 1932 bear out this proposition.

2. They Help Readers Fill in Missing or Implied Information

The default values of scripts or schemata can provide a tremendous amount of information when a text is silent on details (Schank and Abelson 1997; Freebody and Anderson 1983). Schank and Abelson's conceptual-dependency theory states that "any information in a sentence that is implicit must be made explicit in the representation of the meaning of that sentence" (p. 11). Thus, when authors omit detail because of assumptions about the reader's knowledge, they are relying on the reader to activate relevant schemata to fill in the missing or implied information.

Understanding a story or passage is an instance of fitting the story or passage to a schema. The failure of a reader to understand a passage may be explained by the lack of an appropriate schema for that passage. Even when a situation is analogous to a schema and not a literal instance of it, such metaphoric use of schemata can help readers supply missing or implied information. Whitney (1987) calls such inferential story interpretation "elaborative inference." Using schemata, readers extrapolate general knowledge about the world to comprehend a particular situation. For example, a reader may invoke a "changing-a-bicycle-tire" schema to comprehend a passage about someone changing a wheelbarrow tire.

However, schemata for story forms will likely not aid the technical reader. The dominant schema for a technical text may not be instantiated until the reader is well into the text or even at the end of it. In other genres, the dominant schema may be recognized early, and therefore schemata will help the reader construct a beginning, middle, and end for the story. A reader's store of story structures does not enable the technical reader to interpret a technical text, such as an instruction manual.

3. They Enable Readers to Make Correct Logical Inferences

Consider the following example from Collins and Quillian (1972):

The policeman held up his hand and stopped the car.

Because the reader is likely to have a schema for manual traffic control, the reader does not interpret the sentence literally. For example, the reader does not infer that the policeman has telekinetic powers that enable him to stop moving objects without touching them. Instead, the reader invokes a schema for manual traffic control in order to logically interpret the sentence: The car has a driver, the driver sees the policeman hold up his hand, the driver understands that the policeman wants him to stop, and the driver applies his foot to the brake pedal, stopping the car.

Of course, had the reader been reading a comic book about Superman, and had the comic book revealed that the policeman was actually Superman in disguise, then a different schema would have produced different logical inferences, indeed attributing telekinetic powers to the policeman. The invocation of a schema always depends upon the context of the passage.

4. They Provide an Economical Storage and Retrieval Mechanism

Comprehension and recall of textual information has been shown to be positively influenced by schematic knowledge (Spiro 1997; Anderson, Spiro, and Anderson 1978; Spilich et al 1979; Goetz et al 1982; Freebody and Anderson 1983; Baldwin, Peleg-Bruckner, and McClintock 1985; Faris and Smeltzer 1997; Schwartz and Ellsworth 1998). For example, Anderson, Spiro, and Anderson (1978) found that recall of textual information was higher when highly structured schemata, such as “dining-in-a-restaurant,” are evoked than when a less structured schemata, such as “shopping-at-a-supermarket,” are evoked. During the recall phase of their experiment, the subjects who read a dining-in-a-restaurant story recalled more food and beverage items than those who read a shopping-at-a-supermarket story.

Freebody and Anderson (1983) and Spilich et al (1979) conducted experiments to determine whether existing topic schemata enabled readers to better recall information from a text. Subjects who were familiar with the topic of a text were better able to recall the specific details of the text than subjects who were not familiar with the topic. For example, subjects who know about baseball are better able to remember the details of a particular baseball game because, Freebody and Anderson propose, the subjects familiar with baseball have schematic slots in which to store details. However, these researchers concede that the differences in recall can be attributed to either superior storage or superior retrieval afforded by schemata.

Faris and Smeltzer (1997), who are researchers in business communication, conducted an experiment to determine the effect of schematic knowledge and text organization on text comprehension. The results of their experiment demonstrate that schematic knowledge does indeed enable readers to comprehend text better. However, their results also show that text coherence did not affect comprehension, suggesting that comprehension of a text relies more on what is in the reader's head than how the text is composed.[1]

Evidence for Flexible Reading Strategies

Before moving from the effect of schemata on text comprehension and recall to the effect of schemata on reading behavior, I will first attempt to establish with empirical certainty that readers do indeed vary their reading strategies. Although some published information claims that the average person reads for comprehension at about 200 to 300 words a minute (Smith 1978; Carver 1990), the speed and accuracy of reading depends upon many factors. Besides variation in reading speed from reader to reader, there is also the potential for variation within each reader. The ability to willfully change reading rates is called *flexibility*.

Positive flexibility is a *decrease* in reading rate as the difficulty of the reading task increases. Negative flexibility is an *increase* in reading rate as task difficulty increases. McCracken divided reading flexibility into two types: external and internal (McCracken 1965). External flexibility is flexibility between texts, whereas internal flexibility is flexibility within the same text. Researchers have shown that internal reading flexibility depends upon the purpose for reading (Letson 1959; Herculane 1961; Smith 1963; Rankin 1970–71; McConkie, Rayner, and Wilson 1973; Dee-Lucas 1979; Rothkopf and Billington 1979; Reynolds and Anderson 1982); knowledge of the topic of the text (Jackson and McClelland 1975; Birkmire 1985); reading skill

[1] For a more thorough discussion on the effects of prior knowledge on text comprehension and recall, see Dutke (1996).

(Underwood, Hubbard, and Wilkinson 1990); maturity of the reader (Shores 1960; Ramsel and Grabe 1983); and difficulty of the text (Letson 1959; DiStefano and Noe 1981).

Text difficulty has been correlated with the activation of silent speech. During silent reading, printed words are automatically converted to a phonological code, which produces a physical signal that engages the speech apparatus (Connatser 1997). Although silent speech may not be involved in all semantic tasks of the reading process, it is likely to be highly activated during tasks that place demands on memory, such as reading difficult material (Kleiman 1975; Baron 1977). In other words, when readers encounter “difficult, infrequent, or unfamiliar material” (McCusker, Hillinger, and Bias 1981, p. 241), pronunciation of words is essential to understanding. Because the phonemic channel of the reading process carries information more slowly than the visual channel, silent speech is a prime candidate for partially explaining internal flexibility.

However, there remains stiff opposition to the idea of internal flexibility (Carver 1983). Experimental results that support internal flexibility may be flawed because those experiments induced highly improbable readers. For example, subjects are often given ambiguous or vague pre-reading instructions. Subjects are told to read a passage rapidly but carefully (DiStefano 1981), to read quickly while learning as much as possible, “to read the passage as fast as possible, consistent with good comprehension” (Jackson and McClelland 1975, p. 568), or “to read the selection as rapidly as possible and still understand it sufficiently to answer questions afterwards” (Letson 1959, p. 238). On the other hand, “If no purpose is given, students will not know whether they should read for overview or for detail” (DiStefano 1981, p. 605). The result is a “laboratory reader,” a reader who tries to conform his reading behavior to perceived desires of the experimenter. Differences in measured reading speed may therefore be an artifact of the measurement rather than real differences (Carver 1983).

Some of the experiments in internal flexibility included instructions that emphasized reading time to the subjects. Emphasizing reading time creates a demand effect, which is the subjects' interpretation and enactment of what the experimenter is looking for. Thus if subjects know that reading time is an important element of the experiment, they may quickly run their eyes across the page without really reading. When reading rates are self-reported, the demand effect is compounded. Given the high probability of demand effects, self-recorded reading times are likely to be distorted (Reynolds and Anderson 1982).

Although the data supporting internal flexibility are ambiguous at best, external flexibility enjoys nearly unanimous support. Even Carver, an exceptionally vehement opponent of the internal-flexibility hypothesis, accepts the theory of external flexibility, calling it the "gear-shifting premise" (Carver 1990, pp. 17–23). Just as drivers shift gears in expectation of different terrains, readers shift strategic gears depending on the purpose for reading. "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" (Anderson 1980, p. R-249). On the other hand, reading for specific information (skimming) may be twice as fast as reading for comprehension.

Much of external flexibility may be explained by conscious changes in reading strategies. For nearly a century, reading teachers have instructed their pupils to read texts flexibly depending on purpose and text type (O'Brien 1921; McDonald 1963). For example, McWhorter (1992) suggests three reading rates based on purpose:

1. Reading for a Test: 150 to 250 words per minute

2. Reading for Pleasure: 250 to 400 words per minute
3. Reading for a specific fact: 600 words per minute or higher

Carver (1990), on the other hand, is more exacting. He suggests five basic reading *processes* based on typical reading rates of college students:

1. Scanning: 600 words per minute
2. Skimming: 450 words per minute
3. Reading for Comprehension (Rauding): 300 words per minute
4. Learning: 200 words per minute
5. Memorizing: 138 words per minute

While the vast majority of reading-flexibility experiments depends upon conscious, willful changes in reading strategy, there is strong evidence that readers unconsciously adapt to various readings tasks. For example, readers bring an agenda—or set of expectations and assumptions—to every text they read, which can enhance or obstruct the reader's understanding of the text. Reader expectations about certain reading tasks are formed incrementally during the reader's experiences with various types of texts during various conditions. Psychological constructs for each experienced text type, or genre, are thus formed. Expectations that surface from these constructs may influence comprehension and recall (Munro, Lutz, and Gordon 1979). Recognizing a genre enables the reader to quickly access prior knowledge about that genre to set a reading strategy.

Schema-Activated Rhetorical Roles

Reading flexibility resulting from schematic knowledge is unconscious and powerful. The reader, based upon experiences with various genres, imposes a structure on every text, viewing a text from an established cognitive framework (Pichert and Anderson 1977). During years of experience with diverse texts, readers develop schemata for different types of texts. For example, “from experiencing hundreds of such stories [folk tales] over their lifetime people acquire this abstract framework about simple stories” (Bower 1976, p. 532).

Studies show that consciously evoked points of view affect comprehension and recall, as well as reading speed (Goetz et al 1982; Pichert and Anderson 1977). These studies support the notion that a reader may assume a different rhetorical role for each particular genre in his or her repertoire of reading experiences, thus fixing a reading strategy according to the perceived demands of a text. By predicting the level of difficulty, the reader enters a text and navigates with a level of deliberation evoked by a particular schema.

Coney has been exploring the idea of *rhetorical roles* in technical communication for two decades (Coney 1978; Coney 1987; Thompson and Coney 1995). Asserting that readers always read within a role, she and Thompson posited an intriguing conclusion of recent research, “that a significant force in determining and controlling the role of the reader originates in the reader, and that this force is quite independent of the role created by the author through the text” (Thompson and Coney 1995, p. 108).

The purpose for reading also influences the rhetorical role of a reader. For the sake of illustration, consider the purpose of reading three types of text: technical writing, fictional stories, and news articles. Reading technical material is a means to an end, whether that end is building skill and knowledge, assembling a bicycle, creating a theory, troubleshooting a malfunctioning computer, studying for a test, or operating machinery, to name a few. Technical readers look for details in a text that are consequential to future activity. Spiro (1977) proposes that the integration of new information, which requires more work than passive reading, depends upon whether the reader considers the information to be useful in the future. Updating knowledge would waste effort and memory if the reader deems the information useless. As Gordon et al (1978) propose, “When a text gives instructions on how to accomplish something, readers should experience an activation of their instructions schema” (p. 6). Problem-solving is the typical purpose of the technical reader.

Readers of a fictional short story, on the other hand, do not expect a test of knowledge. For them, reading a short story is an end, not a means. The fiction reader satisfies a desire to escape, relax, or be entertained. Reading news articles is both an end and a means. It is an end in that it satisfies the desire for people to be aware of their environment. Thus it satisfies a conscious curiosity about the world. A second-order effect of reading news is that it greases the cogs of social integration by providing people “with the words and phrases they can use to defend a point of view” (Noelle-Neumann, p. 173). Therefore, reading a news article is also a means to an end.

I propose that readers of technical texts invoke a problem-solving schema based upon their purpose of reading and recognition of a genre, and that this problem-solving schema is in effect a rhetorical role that controls the reader’s behavior. Rhetorical roles set the boundaries for reading strategy. For example, during the leisurely act of reading fiction for pleasure, a reader may make expansive assumptions and predictions, whereas the reader of technical prose may make cautious and deliberate movements in the text. The emotionally charged curiosities of the fiction reader may hop over wayward punctuation, skirt ambiguities, and cut through linguistic entanglements that would separate a technical reader from a text, thereby stopping the reading process. The consequences of not fully retaining the details of fiction are negligible, whereas not fully retaining the details of a technical document could have adverse and even perilous consequences.

Why Technical Readers Work So Hard

Have the various failures of technical communicators to communicate clearly hardened the technical reader against the technical genres, reinforcing expectations of difficult, problematic reading? Are expectations of technical difficulty a road sign that cautions wordfaring people to "Reduce Speed Ahead"? Is *genre* a legitimate psychological construct that bears upon the reading process and alters reading strategies? Schema theory predicts "yes" to these questions.

Readers who read-to-do anticipate an encounter with unfamiliar information. When readers encounter this unfamiliar information—that is, when they find no schema to fit the information—schema construction ensues, requiring deliberate, hard work from the reader. This difficulty is the earmark of technical reading. Typical technical readers must struggle through an often overwhelming flow of new information so that schematic structures may be understimulated. In other words, the technical reader must work harder to conjure relative sense-making knowledge to comprehend a text. While technical communicators have learned to use analogues and metaphors over the years to help readers comprehend complicated ideas, reader expectations of difficulty persist.

Bartlett (1954) enables us to imagine how the schema for an instruction manual—any instruction manual—has a default slot of "difficulty level: high." One of the functions of a schema is to network with other schema to form "underlying organising tendencies," which “may account for the association of materials possessing surprisingly diverse characteristics” (p. 307). The laborious and trying process of assembling a bicycle, then, can become associated with the text that specifies the assembly. Even if the text is lucid and well-constructed, the difficult act of assembly may be associated with the schema “reading-an-instruction-manual.” Thus, schemata for reading-to-do and reading-to-learn may predict difficulty because of association rather than essence.

Schemata, such as the kind of schemata responsible for text expectations, may also be socially reinforced to some extent. According to Rosch and Mervis (1975), categories in long-term memory include those that have “evolved in culture” (p. 577). As Bartlett (1954) says, “that kind of recall which is directed and dominated by social conditions takes a colouring which is characteristic of the special social organisation concerned, owing to the play of preferred persistent tendencies in the group” (p. 309). In the national culture of the United States, jokes on late-night television about technology, instruction manuals, and the ubiquitous blinking clock on the VCR are responsible for reinforcing the stereotype of technical communication.

Evidence for Superstitious Technical Readers

The findings of Gordon et al (1978) and Munro et al (1979) lend empirical support for the hypothesis that readers recognize text genres and respond differently to different text genres. Gordon et al (1978) hypothesize that “people have a schema for texts of [a] type. That is, they expect that a given text will have certain structural characteristics—both in terms of the sequence of its major constituents (the text structure) and in terms of the meaning relationships that hold among those constituents (the text semantics)” (pp. 8–9).

To support their hypothesis, they used three types of text in their reading experiments: stories, definitional explanations, and instructions. After reading one of these three experimental texts, subjects were asked to recall as much as they could. Propositions were recalled better after reading stories than after reading definitions and instructions, and propositions from instructions were recalled better than from definitions. Subjects were also asked to classify the particular text they read into a category. One hundred percent of the story readers agreed on the story classification, while 91.6 percent of the instruction readers and the same percent of the definition readers agreed on the classification of those genres.

Using the same three types of texts as Gordon et al, Munro et al (1978) conducted an experiment to determine whether text type is a psychological construct of readers. Their hypothesis was that the reader’s expectations of text type would influence comprehension and recall. “When the reader encounters a certain type of text, the successful reader recognizes the type and automatically uses prior knowledge about the structure of this type of text to facilitate further reading and memory” (p. 7). They found that subjects recalled information from stories most, then instructions, and then definitions. Additionally, the subjects agreed upon the classifications of the text types they were given.

Pichert and Anderson (1977) instructed subjects to read from a particular perspective, thus inducing a particular rhetorical role. Subjects were told to read a text either as a home buyer, burglar, or from no perspective. The perspective a reader took affected recall of details: Those details deemed significant to a particular role were best learned and recalled. The high-level schema induced by the experimental condition provided what Pichert and Anderson call “scaffolding” for storing text elements and affording a retrieval plan.

Rothkopf and Billington (1979) tested the effect of giving readers a goal before reading. One group of subjects was given particular themes to focus on, while another group was given no goal. Although they found no difference in average reading rates, they did find that having a goal affected reading pattern: “Somewhere in a goal-relevant sentence (probably after reading about two thirds of it in our passage) the subject detects its goal-relevance. This results in additional processing activity. . . , enough to reread a sentence approximately 1.97 times at the average inspection rate of the control group” (p. 319). Subjects with a goal read incidental (non-thematic) information more quickly and goal-relevant information more slowly, which accounts for the similar reading speeds of both experimental and control groups. Also, subjects with goals had more progressive and regressive saccades and longer fixation durations when they detected goal-relevant information.

Rothkopf and Billington suggest that spending extra time on goal-relevant information may have little or no bearing upon comprehension and learning, calling the time spent on goal-relevant information “superstitious processing.” Some of the subjects in the experimental group acquired as many technical details without spending extra time on goal-relevant information as subjects who spent extra time on goal-relevant details. Other studies support the conclusion that recall and comprehension actually decrease as reading speed decreases (Tinker 1945; Birkmire 1985; Herren 1992). The intriguing psychology of superstition, which is basically irrational belief, is the heart of the rhetorical role of the technical reader. As shown in the experiment by Rothkopf and Billington (1979), technical readers wrongly believe that spending more time processing technical information will enhance understanding and memory. Perhaps part of what makes reading technical prose so difficult is the reader’s expectations of difficulty.

Recommendations

So far, I have attempted to show how schema theory predicts very careful technical readers who engage in superstitious reading strategies to cope with difficult texts. Therefore, I recommend not only that we conduct more reading research but also that we conduct it according to the particular behavior of technical readers. Doing so will increase the external validity of experiments, which is the degree to which one can apply experimental results from a sample of a population to the entire population. The population of interest here is the readers of technical texts. Here are four recommendations for conducting such reading experiments:

1. Prime Experimental Subjects to Induce the Proper Rhetorical Role

Reading researchers in technical communication should prime their subjects to induce the rhetorical role of technical reader. Otherwise, "If no purpose is given, students will not know whether they should read for overview or for detail" (DiStefano and Noe 1981, p. 605). The result is a "laboratory reader," a highly improbable reader who tries to conform his reading behavior to perceived desires of the experimenter. Differences in measured reading speed, for example, may therefore be an artifact of the measurement rather than real differences (Carver 1983).

One way to induce a technical reader is to promise some post-trial activity, such as the assembly of resistors in a circuit, a technique used by Marcus, Cooper, and Sweller (1996). Another way to induce a technical reader is to prime the subject to value the text—as a *real* technical reader would do. For example, promising a test of knowledge would induce the reader to value a text.

2. Use Prototypical Texts

Reading researchers in technical communication should use experimental texts that are *typical* of technical communication. What is typical? Consider the ideas of Eleanor Rosch, a leading experimental psychologist who studies the creation of categories and the relationships between members of a category.

In the classical theory of categories, all members of a category share the properties that define the category and have equal status in the category. However, what about categories that have fuzzy boundaries or members that do not have easily definable characteristics? Consider, for example, the category *game* or *pornography*. We may recognize members of these categories when we see them, but we will be hard pressed to find characteristics that are shared by all members of the categories. How, then, do we determine members of a category?

Rosch and Mervis (1975) demonstrated that all members of a category do not have equal status. Instead, categories have an asymmetrical structure, with certain members considered more representative of the category than other members. Rosch called this the "prototype effect." Prototypes are "those category members to which subjects [in experiments] compare items when judging category membership" (p. 575). For example, a robin is considered a better representative of the category BIRD than are chickens and penguins. Robins are therefore a prototypical member of the category BIRD. Rosch and Mervis conclude that the frequency of an item contributes to the formation of prototypes.

Think of the prototype effect in terms of playing the game show $10,000 Pyramid. As a contestant, your goal is to articulate members of a category to a celebrity, who tries to guess the category. If the category is "things you take on a camping trip," then you are likely to think of and express the most representative members, such as *tent, sleeping bag, lantern,* and so on. You are just as likely to bring a shirt on a camping trip as a tent, but *shirt* is not a prototypical member of the category.[2]

Lakoff (1987) also demonstrates how some categories have degrees of membership, such as TALL MAN, and some may have no clear boundaries. For example, the boundaries of technical communication may extend to include any text that can be read technically. Lakoff proposes that categories are nested into hierarchies, such as the following:

- Superordinate: Animal
- Basic-Level: Dog
- Subordinate: Retriever

Likewise, technical writing is a nested basic-level category of text:

- Superordinate: Expository Writing
- Basic-Level: Technical Writing
- Subordinate: Instruction Manual

For a reading experiment in technical communication, the text should be a prototypical member of the basic-level category. Consider the 1998 reading experiments conducted by Spyridakis and Isakson (1998a; 1998b). In the first set of experiments (1998a), they wanted to

[2] See Lakoff 1987 for a worthy explanation of the prototype effect.

determine the effect of text variables—such as active voice versus passive voice—on recall of ideas in a text. However, the texts used in the experiments were taken from *Scientific American*—decidedly not prototypical members of technical writing. However, in another study (1998b), they improved external validity by using two technical monographs, one on real estate and another on resettlement and population, because they “wanted to be able to apply our results to aid technical editors” (p. 169). This is the direction I am advocating: to use texts that lay readers consider “technical writing.” As Spyridakis and Isakson point out, this has not been the practice of reading researchers: “Except for our work. . . , only three studies have been conducted with technical passages and they did not use naturally occurring passages” (p. 164).

I recommend that reading researchers in technical communication use some sort of instructions as experimental texts. For example, Gordon et al (1978) used technical instructions in their reading experiments. They defined instructions as an expressed goal followed by directions for achieving that goal. Marcus, Cooper, and Sweller (1996) used instructions because of their particular demand on working memory, which they call “cognitive load.”

However, reading experiments in specific fields of technical communication, such as risk communication or life-science communication, may require texts that are particular to those fields. For example, Faris and Smeltzer (1997) used a chairman’s letter to the shareholders from an annual report in an experiment in business communication. Such a letter would be highly typical of business communication.

3. Measure and Account for Prior Knowledge

Experiments demonstrate that schematic knowledge will affect comprehension and recall of a text (Spiro 1997; Anderson, Spiro, and Anderson 1978; Spilich et al 1979; Goetz et al 1982;

Freebody and Anderson 1983; Baldwin, Peleg-Bruckner, and McClintock 1985; Faris and Smeltzer 1997; Schwartz and Ellsworth 1998). Therefore, prior knowledge should be measured and accounted for in reading experiments. According to Schwartz and Ellsworth (1998), "prior knowledge is important as a variable to consider because, according to schema theory, it provides learners with a relevant, searchable context in which to interpret, comprehend, make inferences from, and remember information presented in a passage" (p. 70).

Marcus, Cooper, and Sweller (1996) discovered that text difficulty and prior knowledge interact. They asked subjects to connect electrical resistors to form simple or complex circuits. Some of the subjects were taught the rudiments of resistor connection, while others were not. Therefore, the subjects either had prior knowledge or not. They found that when subjects were instructed to create a simple circuit (low cognitive load), prior knowledge had no effect on understanding the instructions. However, when subjects were instructed to create a complex circuit (high cognitive load), the subjects with no prior knowledge had difficulty assimilating the instructions. Marcus, Cooper, and Sweller concluded that "understanding instructions depends on the degree of element interactivity unless the elements can be incorporated into preexisting schemas that reduce cognitive load" (p. 60).

Experimenters can control prior knowledge either experimentally—by grouping subjects according to their prior knowledge—or statistically—by using the variable *prior knowledge* as a covariant in analysis of variance.[3]

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[3] For more information on the validity of using covariants in statistical analyses, see Cochran 1957; Cox 1957; Feldt 1958.

4. Avoid Using Readability Formulas to Equalize Experimental Texts

Some reading experiments involve multiple texts that must have equal levels of difficulty. However, text difficulty simply cannot be determined from a surface structure (Connatser 1999). Even if reading were simply a bottom-up serial process, writers and editors still could not mechanically predict text difficulty. Consider the two texts in Table 1. The second text was created from the first by randomly scrambling all the nouns. Table 2 shows how the two texts match up. Even though a Pearson product-moment correlation procedure indicates nearly equal text characteristics (r = 0.99999), it is hard to deny that the differences are immense, with Version 1 representing a reasonably readable text and Version 2 representing gibberish.

Table 1. Two “Equal” Texts

Version 1	*Version 2*
We must control light if our eyes, or our cameras, are to form images of objects. You cannot simply place a square piece of film in front of a person and hope that an image of him will appear on the film. The rays of light bouncing off the person would disperse all over the film, which will cause a featureless exposure on the surface of the film rather than the likeness of the person. What one needs to form the likeness of the person on the film is some sort of device that refracts the rays of light from an object onto the film. All lenses do this basic job; they collect light-rays coming from a scene in front of the camera, then project them as an image onto a sheet of film at the back. To render sharp photographs, a lens is thicker in the middle than at the edges. Lenses can merge many rays of light from a single point and bend them straight toward each other, so that light converges at a focal point.	We must control persons if our likenesses, or our objects, are to form likenesses of persons. You cannot simply place a square exposure of film in front of an image and hope that a device of him will appear on the film. The light of edges bouncing off the job would disperse all over the person, which will cause a featureless middle on the point of the rays rather than the image of the film. What one needs to form the lens of the rays on the objects is some eyes of sort that refracts the film of photographs from a light onto the scene. All backs do this basic camera; they collect pieces coming from a film in front of the light, then project them as a lens onto a camera of point at the sheet. To render sharp light, a film is thicker in the light-rays than at the light. Surfaces can merge many persons of rays from a single image and bend them straight toward each other, so that film converges at a focal lens.

Table 2. Comparison of Text Characteristics

Text Characteristic	*Version 1*	*Version 2*
No. of Words	179	179
No. of Syllables	231	232
No. of Characters	724	727
No. of Lines	11	11
Vocabulary Difficulty	698	698
No. of Different Words	99	96
No. of Pronouns	11	11
No. of Dependent Clauses	6	6
No. of Compound Sentences	1	1
No. of Terminals	7	7
No. of Colons	0	0
No. of Commas	6	6
No. of Semicolons	1	1
No. of Hyphens	1	1
No. of Dashes	0	0

To adequately measure sentence difficulty, one would have to discriminate between content and non-content words, abstract and concrete words (Vachon and Haney 1991), technical and non-technical words. But even if someday we innovate an adequate measuring stick for sentence-level difficulty, we will probably never devise an objective method for measuring the difficulty of an entire composition. Because readers are the meaning makers, the difficulty of understanding a composition—that is, text difficulty—is in the eye of the reader, not in the digits of a formula. Meaning is always construed through the prism of a personal psychology (Smith 1978), and the concept of “readability” has social and cognitive elements that formulas cannot resolve (Moore 1997). Therefore, any index of text difficulty would have to be qualified by individual or group characteristics.

The content of a text may be the most elusive and confounding of its elements, defying quantification altogether (Klare 1976). Readability predictions based upon formulas do not involve the content and vary widely from formula to formula (Smith 1984). The premise behind most of these formulas is the equation between sentence length and reading difficulty. However, short sentences may be a false characteristic of a readable text. According to Pinker (1994), as “long as the words in a sentence can be immediately grouped into complete phrases, the sentence can be quite complex but still understandable” (p. 203). For example, “The House That Jack Built,” a well-known nursery rhyme, concludes with a 71-word sentence with 13 relative clauses (“The House That Jack Built” 1950). Although this nursery rhyme would rate a low readability score by most readability formulas, it nevertheless remains in the canon of pre-school treasures. Also, assigning a level of difficulty to a word based upon its frequency of use may be a faulty metric. For example, “many words that [are] infrequent, like bow-wow and popcorn, [are] not that hard to understand" (Bush 1998). Table 3 shows some assumptions made by readability formulas.

Table 3. Some Assumptions of Various Readability Formulas

Topic	*Assumption*
Active vs. Passive Construction	Active Is Better
Sentence Length	Shorter Sentences Are Better
Declarative vs. Relative Clauses	Declarative Clauses Are Better
Syllabification	Fewer Syllables per Word Is Better
Word Length	Fewer Letters per Word Is Better
Frequency	More Frequently Used Words Are Better

I have saved this caution about using readability formulas to the last because readability formulas implicate the very things that researchers in technical communication should be exploring: the assumptions shown in Table 3 as well as the other inherited prescriptions of English composition. These assumptions and prescriptions are, for the most part, untested by researchers and undoubted by practitioners—they have evolved into embedded beliefs. The discipline of technical communication will therefore benefit from the empirical testing of these embedded beliefs, either to dispel or verify their efficacy.

Conclusion

As an adolescent field of research, technical communication suffers growing pains and identity crises. Unless researchers in technical communication establish and grow a robust research program, practitioners will remain beholden to other, established disciplines to develop best practices. However, these other disciplines—cognitive psychology, linguistics, rhetoric, and the like—do not have the technical reader at heart.

For decades, researchers in technical communication have thus been developing best practices. Redish (1988), for example, has been using the findings in cognitive psychology to develop user manuals and tutorials. Dutra (1993) applies schema theory to writing reference manuals. Additionally, many researchers in technical communication use technical tests to conduct readability experiments. For example, Shultz et al (1997) studied how users create metaphors while negotiating an instrument, and Thompson and Coney (1995) used a usability technique called “ethnomethodological approach” to study technical readers in a reading-to-do environment.

A research program in technical communication should—in addition to these worthwhile studies—include reading research at the sentence level. For example, Spyridakis and Isakson (1998a, 1998b) recently studied the effects of sentence structures such as nominalizations and passives on the technical reader. Other sentence-level research projects should address the effect of silent speech on technical reading (Connatser 1997), how readers recall technical elements versus non-technical elements, and how well putative writing practices really work on the technical reader (Connatser 1999). However, such studies will have questionable external validity unless experimental materials and methods are adapted to the technical reader.

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