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A COMPARISON OF TESL AND SCIENCE TEACHERS' STYLES IN READING SCIENTIFIC TEXT

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ABSTRACT

A COMPARISON OF TESL AND SCIENCE TEACHERS' STYLES IN READING SCIENTIFIC TEXT

by Carolyn H. Baker

To facilitate collaboration between TESL and science teachers, a study was made of the kinds of knowledge organization and processing strategies (schemata) commonly used by the two groups in reading science information. Reading comprehension oral self-reports were gathered, using a think-aloud method, quantified and compared. Both groups understood the experimental text; however, science teachers relied much more on deductive reasoning and inference than did the the TESL teachers, who used discourse clues as their main comprehension strategy. In written recalls, the science teachers freely decomposed and rewrote the text, while the ESL teachers reproduced or simplified it. Apparently, academic training unconsciously shapes reading strategies, and the TESL teachers were unaware of the advisability of switching styles when reading science information. In the science teachers' style, all information is questioned in detail and absorbed through schemata cross-checking, while the text per se is discarded.

ACKNOWLEDGMENTS

I am extremely grateful to the members of my committee, Dr. Estrella Calimag and Dr. Brian Holmes, for their expertise, assistance, and patience, and to Dr. Denise Murray, Committee Chairperson, for suggesting and having faith in this project during its long development.

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"It seems that only the rare individual teacher can learn another discipline, for each discipline offers a different angle for looking at subject matter, a different kind of thinking."

Spack (1988, p. 38)

CHAPTER I

INTRODUCTION

Since the 1960s, knowledge of reading comprehension has expanded rapidly, receiving attention from specialists in cognitive psychology, anthropology, linguistics, child language development, artificial intelligence, semiotics, rhetoric, literature, philosophy, and brain study. However, the work has been "multidisciplinary rather than interdisciplinary. There is not much attempt to relate the objectives, questions, and interpretations of each discipline to the others. ... And there is too little awareness by scholars in each field of the current work in other fields or the previous work done in reading" (Goodman, 1985, p. 813).

An exception is work done in applied linguistics by Widdowson (1979, 1983), Johnson (1981), Steffensen (1981, 1988), Steffensen and Joag-Dev (1984), and Carrell (1983a,b; 1984a,b,c,d; 1985) on schemata use by readers of English as a Second Language (ESL) and by de Beaugrande and Dressler (1981) and de Beaugrande (1984) on a proposed science of text production. These scholars accepted and integrated into their work the somewhat suspect notion of schemata, which originated in the field of psychology (Bartlett, 1932) and was revived in the 1970s as a tool of cognitive science and artificial intelligence (e.g., Rumelhart & Ortony, 1977; Schank, 1982). Today, the importance of

cultural, rhetorical, and metacognitive schemata in reading in a second language is widely acknowledged but by no means well understood.

The research reported here adds to the discussion yet another discipline, science. Since many ESL students learn English to become scientists and engineers, it seems appropriate to ask whether schemata theory might shed light on the reading tasks these students and their teachers face. However, most work on schemata-theoretical reading issues (e.g., Bransford, Nitsch, & Frank, 1977; Smith, 1982; Bransford, Stein, & Shelton, 1984; Carrell, 1984d, 1987; Rumelhart, 1984, 1986; Anderson, 1985; Anderson & Pearson, 1988) has been based on non-scientific material, such as folk stories (van Dijk, 1977; Kintsch, 1977), stories found in beginning level ESL texts (Casanave, 1988) and reading passages in placement tests (Bransford, 1984).

Scientific text has not been widely used as a basis for ESL schemata-theoretical reading research because its content has been considered too specialized to have applicability to most ESL learning situations. Also, in the field of psychology itself, basic research on science content schemata has been sparse. For example, of the four types of world knowledge distinguished by Britton and Black (1985, p. 3): (a) knowledge about human actions; (b) knowledge about human reasoning; (c) knowledge about objects and locations; (d) knowledge about physical events, only (d) includes specifically scientific material. Britton and Black consider this type of world knowledge the most difficult to investigate.

Of more immediate interest to applied linguistics are investigations of schemata which structure knowledge about human actions, as these include cultural information. Here, the influential work of Schank and Abelson

(1977) on scripts, plans, and goals, and of Mandler and Johnson (1977) on story grammar provided a natural research base for ESL reading studies. Knowledge about human reasoning includes the rhetorical, formal, and metacognitive schemata that linguists such as de Beaugrande were already studying as the phenomenon of coherence in discourse. Knowledge about objects and locations has been a long-standing concern in semantics, including such issues as reference and property coherence relations. Knowledge about physical events, however, includes such specifically scientific schemata as understanding the physical properties and interrelationships that cause the natural world to function as it does. Schemata-theoretical research in the first three domains is clearly appropriate for applied linguistics, the fourth area seems less accessible and generalizable.

The one group that has used scientific text in ESL research is the branch, English for Science and Technology (EST), led by Trimble (1978, 1985) in the United States, and Widdowson (1968, 1979) in England. Within this field, however, empirical studies of science reading comprehension based on schemata theory have only recently been attempted (Strother and Ulijn, 1987; Addison, 1988). American EST research began in the 1960s, before the revival of schemata theory, utilized more traditional types of rhetorical and grammatical analysis, and was pedagogically driven. British interest in EST developed in a different context, one in which the special needs of learners in developing countries and the new idea of the notional/functional syllabus fused. These approaches will be discussed in detail in Chapter 2.

As early as 1968 Widdowson was interested in using science as a vehicle for teaching English, stating in 1979 that "the closer the English teacher's

methodology can be be made to approximate to that of science teaching, the more successful he will be in integrating the two areas of knowledge whose synthesis constitutes relevant English use" (p. 43). Widdowson gradually abandoned this position. His more recent instructional series, Reading and Thinking in English (1980), while utilizing much scientific material, aims primarily to develop metacognitive rather than specific content schemata in the learner. As the Teacher's Guide to the series states:

> The essential characteristics of academic communication are not the topics which are written about (such as microscopes, railways, food) but the devices for structuring and presenting information. These communicative functions are common to many areas of further study. There is therefore no attempt to train students in the English used in any one specific subject area. The authors have found that students can best be prepared to use textbooks in a particular subject by being guided to acquire general strategies for reading and thinking, which they can then transfer to more specialized material.
>
> (p. xiii)

Widdowson has been very influential in convincing teachers of English as a Second Language (TESL teachers) that what all second-language learners critically need are "creative procedures" (inferencing scripts) for making sense out of text, not the isolated notions presented by his earlier EST materials. Most humanities-trained TESL teachers and researchers find this view congenial, and in spite of their interest in cross-cultural issues, have not followed up on the sociolinguistic research opportunities that Widdowson's (1979) characterization of science as an international culture suggests.

A small, international subgroup of EST researchers have taken another approach, trying to build enough specialized knowledge of a field to perform

discourse and register analysis on its textbooks (e.g., Blanton, 1984), instructional manuals (Trimble & Trimble, 1978), journal articles (e.g., Adams Smith, 1984), and posters (e.g., van Naerssen, 1984). Membership in this group confers something of maverick status on the practitioner. Mainstream TESL thinking advises teachers to be experts in language alone, and Spack (1988) warns that in the current enthusiasm for content-based, sheltered or adjunct language programs, we have already gone too far toward expecting TESL teachers to be subject specialists.

The research reported here, however, is based on the belief that TESL teachers have everything to gain from broadening their knowledge of science, the culture of science and technology, and the processing of science content schemata by experienced minds. Not all ESL students are going to become scientists or engineers, but all will enter a complex technological society in which scientific literacy is an urgent need. But what constitutes scientific literacy? What is involved for the ESL student in transferring general reading strategies to science texts? If most TESL teachers avoid such reading, is there anything we can learn from science teachers about it? How do science teachers themselves process technical material? Can schemata theory be helpful here?

The research was designed to address the last two questions. A comparison was made between the self-reported mental processes of science- and humanities-trained native English-speaking teachers reading a short paragraph of botanical information. It was hypothesized that no consistently different reading patterns would be found between the two groups. In order to design such an experiment and judge the results, a multidisciplinary

context had to be developed. In Chapter 2, major theories and types of empirical evidence bearing on the research questions will be reviewed.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Educators who accept schema theory see reading as an interactive process--in many senses (Grabe, 1988). Within the reader and within a text, perceptual, cognitive, and linguistic systems mesh intricately. Reader and writer are intimate thought partners through whose communication culture is reflected and created. The first two sections of this chapter will summarize reading research undertaken from two distinct points of view: (a) reading is seeing graphemes and putting them together, and (b) reading is a sampling of text to reduce uncertainty by the elimination of alternatives. The third section will present discussions of scientific register that support the idea of a recognizable subculture of science and technology.

LANGUAGE-BASED ACCOUNTS OF READING PROCESSES

Sound vs. Word Approaches

Proponents of the "phonic" vs. "whole word" approach to reading comprehension, who can be found as early as 1551 in England (Fries, 1962), believed that the Roman alphabet represented speech sounds on a one-to-one basis (with a few odd exceptions), and that written language was essentially speech ciphered into linear strings. Convinced that the reading process consisted of decoding the letters into sound, blending these into words, attaching meaning to them, and finally listening to the result as inner speech, phonics method practitioners from the writers of 16th Century "spellers" to

the present have stressed the basic and indispensable skill of "sounding out" words. Phonics has received twentieth century support from detailed studies of eye movements (e.g., Just & Carpenter, 1985, 1987) which show that the eyes fixate on one word at a time, moving only slightly forward and back. Just and Carpenter's highly detailed work assumes that the number of milliseconds the eyes rest on a word is also the time needed to relate the word's physical signal to its meaning and that the maximum possible processing of a word is done immediately.

As Fries shows, holistic conceptions of the reading process are not a modern development. In 1850 Webb advised, "The child ... is not to be taught a letter, or to spell a word, but simply to learn the words by their forms, the same as he learns the names of animals, by looking at them as a whole, as an animal - associating the name with the form. The child thus reads naturally ... with ease and pleasure" (p. 16). In 1881 Farnham cited classroom experiments comparing the "phonetic" and "word" methods, concluding that both produced mechanical, not fluent, reading. Arguing that "the unit of thinking is a thought, and therefore ... the sentence ought to be made the basis of reading exercises," Farnham counseled that presentation of the parts of a sentence should be delayed until the whole is understood, and "the phonic analysis of words should have no place in the primary schools" (p. 27).

Early twentieth century historical linguists generally did not comment on the reading debate. In the 1930s, however, Bloomfield (1942) wrote an alphabetic phonetic primer based on the findings of structuralism. In its Introduction, he criticized naive phoneticians for confounding writing with speech. In speech, sounds are not uttered in isolation; phoneme

pronunciation varies substantially with phonological environment. Since the child learning to read can already speak, drill in speech sounds is unnecessary, unnatural, and confusing. Bloomfield did, however, advocate "training" the child to respond vocally to the sight of sequences of letters, or graphophonemes. Unfortunately, this distinction was not clearly understood, and Bloomfield's remarks were generally taken as support for traditional phonics (Bloomfield & Barnhart, 1961).

Using a 20,000-word corpus, Venezsky (1967, 1970) tried to find the most important factors which condition the correspondence between spelling and sound in English. Based on frequency, he concluded that the reader of English must be alert to: (a) the graphemic environment of a phonological unit, (b) the unit's position in a word, (c) stress, (d) morpheme boundaries, (e) syntactic class of morphemes, and (f) morpheme structure constraints. For example, in

1. my ship
2. mishap

the crucial difference is not only the vowels. Perhaps even more basic for the reader is the fact that sh functions as a phonemic unit in (1) but as part of separate morphemes in (2). Venezsky's analysis supports the notion that the reader first relates orthography to a intermediate (morphophonemic) level of knowledge.

Generativist Theories Related to Reading Skills

The Generativists' mentalistic view of language competence did not lead to an abandonment of interest in phonics and morphophonemics but to a deepening of speculation about the causes of seemingly eccentric English

spelling. Chomsky and Halle (1968) suggested that after syntactic rules have produced the surface structure of a sentence, the mind selects appropriate abstract underlying lexical representations (not "words" as we consciously know them) to fill the syntactic string. The ultimate orthograpic and phonological form of these lexical representations is the product of a set of special rules, including stress rules, which make English spelling not irregular, but almost perfect. in its fidelity to the abstract underlying forms, and therefore easier for the skilled reader to comprehend. For example, C. Chomsky (1973) suggested that the visual sameness of underlying forms of phonetically different pairs such as critic-criticism and revise-revision might make quick semantic identification easier, for readers do not have to abstract away from unnecessary phonetic detail.

Chomsky did not succeed in making rules which could account for every graphophonetic anomaly in English (Wolfram & Johnson, 1982). Language change and foreign borrowings are also involved. However, Chomsky's work on the relation of sound and spelling greatly increased our sense of the complexity of readers' phonic knowledge.

The Generativists also investigated how surface structure syntactic constituents contribute to reading comprehension For example, Fodor and Bever (1965) introduced clicks into recordings of sentences. Subjects asked to mark the location of the click placed them closer to major syntactic boundaries than the click had actually occurred, indicating that "the listener is actively engaged in constructing the sentence structure for himself," not merely stringing one word after another in an associative chain (Foss and Hakes, 1978, p. 118). Since reading lacks the prosodic cues of speech, reading

demands even more attention to syntax than listening. Reading researchers connected this finding with eye movement studies, concluding that the observed forward and back motion of the eyes during reading was the reader's search for syntactic boundaries (Adams, 1980).

Theoretical models of the complete reading process in the early 1970s (Gough, 1972; LaBerge and Samuels, 1974) assumed that the transformation of written stimuli into meaning involved a sequence of stages of information processing which were automatic and linear. Gough's model suggests that the reader possesses visual feature detectors which scan graphemic information for "distinctive features" of the visual stimuli. This character stage feeds into a decoding stage in which the reader recognizes morpheme structure by mentally consulting the "code book." This gives the reader a phonemic string which the mental "librarian" can then translate into words. The words are next acted upon by syntactic and semantic rules as they pass from deep to surface structure. Finally, phonological rules apply and the finished script is comprehended. Since the mind is assumed to be a limited-capacity processor, at any moment the reader's "attention center" activates only one code. There must be, then, three memory systems holding three different representations of the input string. The visual memory system holds features, letters, spelling groups, words, and word clusters. The phonological memory system holds phonological representations of spelling groups, words, and word groups. The semantic memory system holds the semantic representation of the words, word groups, and sentences. These systems are independent and parallel; alternate routes may be taken among the systems, but there is no feedback from higher to lower levels. Although

the model was revised to provide for feedback loops, it is interesting that it is still based on the assumption that reading is the reconstitution of speech from written symbols.

La Berge and Samuels (1974) suggested an improvement to the somewhat cumbersome Gough model: the "subskills" approach. They agreed that decoding is a central part of reading, but in skilled readers it becomes so rapid and automatic that it is not detectable in any way.

Reading Theory within Psychology

Evidence cited by Rumelhart (1986) contradicted Gough's parallel processing model. One problem with letter-by-letter visual scanning is the apparently high rates of word processing by fluent readers. Yet it is known that letter-by-letter decoding is a skill employed by young readers and is always an option. It appears skilled readers have at least two perceptual options available: one linear and incremental (perhaps using conscious morphophonemic experiment and experience), the other holistic and inferential (perhaps using intuitive language competence). For example, in handwriting, individual letters are often imperfectly formed. Readers use surrounding letters to help them perceive the unclear ones. In printed material, more letters can be apprehended per unit time when presented in a word rather than in a string of unrelated letters. Also, a letter is more accurately perceived when it is part of a word than when it is a set of unrelated letters. Letter strings formed either by deleting a letter of a word or replacing one or two of the letters are often clearly perceived as the original word. These studies (cited by Rumelhart, 1986) show that letter perceptions are facilitated by the letters being in comprehensible words. Also, readers can

perceive more letters when the letter strings conform to English morpheme structure constraints than when the strings violate them. In fact, the orthographically distorted string is often regularized by the brain to allow us to go on reading, when, for example, we encounter a typographical error.

Other studies cited by Rumelhart (1986) show that perception of words depends on their syntactic environment. Substitution errors in oral reading by children and adults show that there is a strong tendency for the misread word to be the same part of speech as the word for which it is substituted. Miller and Isard (cited by Rumelhart, 1986) found that listeners could report "many more words" (p. 730) when they listened to speech in normal syntactic structure compared with distorted structure.

Perception also depends on semantic environment. Lexical access to a word is facilitated if preceding words are semantically related. Meyer and Schvaneveldt (cited by Rumelhart, 1976) found that subjects responded to pairs of simultaneously presented, semantically related words such as doctor-nurse and bread-butter faster than to unrelated pairs such as bread-nurse. On the other hand, ambiguity slows comprehension because a search of possible contexts is required. This kind of ambiguity is shown by the following examples:

1. They are eating apples;
2. The children are eating apples;
3. The juicy red ones are eating apples.

The phrase, "are eating apples," has the same surface structure form and location in all three sentences, but the reader's background knowledge of the possible connections between the phrase, "are eating apples," and "they," "the

children," and "the juicy red ones" creates a number of mutually exclusive contexts and meanings. Apples are food. But an "eating apple" is a kind of apple suitable for eating raw, as opposed to a "cooking apple," best used in heated dishes. Thus, the first sentence has two possible interpretations:

1-a. Living things are consuming raw or cooked apples;

1-b. The aforementioned apples are good to eat without cooking.

Sentence 2 most likely refers to a context in which children are consuming apples in raw or cooked form. However, the sentence also supports the possibility that the children are costumed as eating apples. In sentence 3, "the juicy red ones" are likely identical with "eating apples"; however, there is nothing to prevent "the juicy red ones" from referring to some sort of slug.

A possible memory storage unit used by the brain to deal with ambiguous language has been called "chunking" (by Smith,1982). A chunk is the most compact (or most meaningful) unit of related information and is stored as a whole. The force holding bits of information together as a natural chunk may be the imagery of a real experience or of a scene we have vividly imagined. Smith demonstrated that we also chunk by linking new information to something already memorized. For example, a list of names can be better recalled by putting them in alphabetical order. We remember the meanings of words rather than the words themselves, indicating, as many theorists suggest, that knowledge is stored in some other form besides words (Mandler, 1985).

Goodman (1973, 1985) saw reading comprehension as the product of interacting systems. He noted that children reading aloud self-correct their miscues when emerging meaning becomes inconsistent with previous errors.

He suggested that all three cuing systems--graphophonic, syntactic, and semantic--are used simultaneously and independently by readers, and that these, along with background knowledge, comprise psycholinguistic universals in reading in all languages.

In Rumelhart's view, the various linguistic knowledge systems, namely featural, orthographic, morphemic, lexical, syntactic, semantic, and discoursal, all feed into a pattern synthesizer or message center. The message center keeps a running list of hypotheses on the nature of the input string. Each knowledge source constantly scans the message center for the appearance of a hypothesis relevant to its sphere, evaluating, confirming, negotiating, until some decision can be reached on the most probable hypothesis to explain the stimuli. Importantly, this view also accommodates the fact that even highly skilled readers do not always understand text perfectly. Their hypotheses and generalizations can lead them astray.

Artificial Intelligence Modeling of Reading Comprehension

Research in Artificial Intelligence (AI) helps identify the more plausible accounts of human reading comprehension processes. To design computers that can "read" natural language, AI workers try to simulate the human brain on a small scale (Dehn, 1984; Schank, 1977). They have found that reading comprehension definitely involves a far more complex algorithm than simply matching words with prescribed meanings in a syntactic string. Before the computer can deal with the syntactico-contextual subtleties of "eating apples," it must sort out the multiple meanings of just one element, such as the verbs in Schank's example:

1. Shakespeare wrote Hamlet;

2. John wrote Mary.

The activity referred to changes radically with the identity of the participants. Shakespeare and John are both "authors," but not in the same sense.

The human reader easily identifies the similarity between:

1. John wrote Mary;

2 John dropped Mary a card.

The machine may be programmed to react to "write" and "drop a card" as synonyms, but simply increasing memory capacity will not produce the same ability the human language user has of knowing when a certain choice among synonyms is inappropriate, as in:

3. Shakespeare dropped Hamlet a card.

Rather, the human lexicon seems to be cross-indexed so that concepts can interpenetrate through informed inferencing.

According to Schank, our inferencing ability is based on experience: children begin very early trying to connect cause and effect, and they see and replicate stereotyped situations (scripts). For a skilled young reader, a simple story such as:

1. John was hungry. He ordered steak.

already makes sense as a fragment of a restaurant script, in which a human being, feeling hunger and having money to pay for food, goes to a place where someone provides cooked meat for sale when asked to do so. The difficulty in designing a machine that can do this leads AI researchers to specify the following skills as basic to human reading comprehension:

1. connecting physically separated bits of information into logical sequences;

2. forming common-sense expectations of human events and likely plans humans use to arrive at goals;

3. interpreting social roles;

4. accounting for typical and unlikely causes as well as unexpected outcomes;

5. using cultural knowledge and belief about the world;

6. recognizing typical forms of written discourse, such as stories or contracts.

If a machine is to simulate human understanding of natual language, all these skills must be present; thus, they must also be present in human reading comprehension. AI research gives clear evidence that the higher level knowledge systems called "schemata" by psychologists must somehow be linked to linguistic processing systems, although existing language-based models of reading comprehension have made little provision for them.

SCHEMATA-BASED READING RESEARCH

General Theory

The term schemata was first used by the psychologist Bartlett (1932) in his classic study of memory. Bartlett had noticed that Cambridge students who read a simple American Indian tale, "The War of the Ghosts," which contained a number of culturally unfamiliar elements that created an unclearly motivated sequence of events, either failed to remember the puzzling aspects when asked to write a recall, or regularized them according to preexisting personal notions of what probably happened. For example, the readers remembered that the Indians were fighting each other, or fighting white people, when in fact they were fighting spiritual enemies. None of the readers grasped the point that the enemies were in fact ghosts, although this was the whole point of the tale.

The readers did realize that this was a story of war in an exotic land, and in retelling, did construct a tale of this general type, freely and unconsciously filling in from their own store of such tales, material to explain murky parts in the original. Each reader's retelling was different. Some individuals actually elaborated upon points not present, drawing upon their own religious bias. Bartlett concluded that readers possess prefabricated knowledge frameworks, or schemata, which they use to understand, store, and recall information, and that while the schemata facilitate comprehension and memory, they can also distort it.

Rumelhart (1980, p. 33) calls schemata the "building blocks of cognition," "knowledge packets," or units into which knowledge is organized. But schemata are not simply concepts or definitions, because embedded in them

are directions about how this knowledge is to be used. These directions include the likely connections that such knowledge normally has with other schemata, and the "typical or normal situations or events that instantiate that concept" (p. 34). Schemata are like theories, "informal, private, unarticulated" (p. 37). We call upon them to make sense of incoming impressions, such as letters and words ("bottom-up processing") and by a process of comparing, predicting, and rechecking the theories against the data ("top-down processing") decide on the most probable match. When the reader accesses and relates schemata as the writer intended, comprehension occurs. However, the reader may also make a mismatch without realizing it, and in this case, has read the words but not comprehended the meaning.

Schemata can be as small as a phoneme or a penny or as big as a symphony or a political system. Schemata must connect and nest, but according to Rumelhart, they do not disintegrate and recombine. Rather, schemata fire off (instantiate) as a strongly associated set of variables that can be bound to different aspects of one's environment, as conditions demand. For example, if I am a tourist in Mexico, I can recognize the relatively stereotyped schemata, buy and sell, money and merchandise, even with minimal Spanish. However, if the schema bargain over price is not part of my repetoire, I would be at a loss if invited to take part in such a "script." I would not really understand the unwritten rules, moves, and implications of bargain in a movie or text incorporating it. People modify their schemata by changing something that was thought to be a constant of the schemata to the status of a variable. For example, to develop a bargain schemata, the elements of buy and sell must be reconsidered. One of the elements of the schemata is the

notion that prices are always set in advance, and buying consists of paying the set price. At least one of the constants in this schemata, set price, must change to a variable, negotiated price. After the constant is changed to a variable, new binding relations will be possible with other schemata , and new knowledge will result. The original schema has become more abstract. When a person faces a completely new situation and has no relevant schemata available to modify, the person must perceive he or she is in a new situation and induce the new schemata from experience.

Once a familiar schemata sequence or script is accessed, one is able to predict the occurrence of likely elements within it without being told about them. For example, in the restaurant story mentioned above,

1. The man was hungry. He ordered steak.

we know that very likely a menu was presented to the man, because in American culture, people only "order" steak (request a specific dish) when there is a choice of dishes. This script is learned from life experience. However, we need not actually experience events to be able to follow their development in a story. Higher level schemata, or inferencing patterns adapted for use in processing narrative, allow us to perceive the genre of a story, understand why one event follows another, and feel a sense of completion at the outcome. Important examples of global processing principles for narrative are:

1. problem-solution;
2. likely plans to arrive at goals.

Cognitive psychologists have shown by conventional story structure diagrams that the sequence of episodes in a story can usually be understood only as the efforts of a character who has a problem to get something done.

In everyday life, higher level processing principles may function on a "default setting" (Collins, Brown, and Larkin, 1977); that is, constraints inherent in schemata propositions are satisfied in the easiest way available. In the following sequence:

1. Mary heard the ice cream man coming;
2. She remembered her pocket money;
3. She ran into the house;

the inferential path of least resistance concludes that Mary, like most people, likes ice cream and intends to buy some from a seller. However, the story might include another line:

4. She drew her revolver and shot him.

In this case, the default interpretation must be questioned, because a sharp opposition of behavioral expectations has occurred, making the default interpretation impossible.

Collins, Brown, and Larkin (1977) explored what strategies subjects would use to account for an apparently unlikely event sequence. Adults read an illustrated text in which a plastic bottle filled with stones does not sink in a pond. They were asked to construct a plausible explanation in which all given facts would converge. In the process of arriving at an explanation, the subjects tested the likelihood of their solutions in terms of (a) consequences, (b) completeness, (c) match between the individual's ideas and the exact words of the text, and (d) high interconnectedness among parts. The

researchers found that "subjects appear to put more belief in the plausibility of their [solution] if the different pieces tie together in more than one way" (p. 44).

Empirical evidence such as this of the operation of high level schemata in readers' comprehension processes lends support to Widdowson's (1984) belief that "the reader applies a schematic frame or scenario to the textual object, samples the information it represents, and makes whatever modification is necessary to incorporate knowledge not previously accounted for into the structure of his knowledge" (p. 225).

It seems that sentences cannot be interpreted without inferencing, and inferencing cannot take place without something like schemata. Schemata themselves come from experience of life when it is stable, and from learning when it is coherent and tied to experience. It is important to remember, as Mandler (1985, p. 35) says, that schemas are not "rigid permanent denizens of a mental system [and may not] exist in the absence of relevant activation, either from the world or in top-down fashion." Schema theory depicts consciousness as a network of discrete networks in which activity can begin at any point and spread rapidly, with schemata stimulating, binding, and constraining one another freely.

Schema theory has influenced, but not been incorporated wholesale into, contemporary experimental psycholinguistics (Tanenhaus, 1988). Linguists remain committed to the idea that the rules and representations of language competence and performance are different in nature and distinct from other cognitive systems (Chomsky, 1980; Carston, 1988). However, applied linguists interested in second language education find schema theory

appealing because it focuses on performance and explores the contribution to reading comprehension of multiple kinds of background knowledge, including cultural knowledge. Research on top-down processing in ESL reading has been carried out vigorously in the past decade starting with Coady (1979) and Widdowson (1979). Carrell and others who will be discussed in detail in the next sections have concentrated on the difficult tasks of integrating schema theory with previous, respected views of discourse analysis and with constructing good experimental designs to test for kinds and interactions of schemata.

Schema Theory and Discourse Analysis

One of the first interdisciplinary tasks Carrell (1982) undertook was relating schema theory to Halliday and Hasan's (1976) established work on cohesion and coherence in text. She criticized Halliday and Hasan on both theoretical and empirical grounds, claiming that they overemphasized the contribution of purely linguistic properties to making discourse coherent. From the schemata-theoretical viewpoint, focussing as it does on interaction of asymmetric knowledge frames in the reader and the text, Halliday and Hasan's claim that coherence adheres in the semantic ties between register choices and cohesive devices misses the reader's contribution of resources. To illustrate how her view differs from that of Halliday and Hasan, Carrell (1980) cites Morgan and Sellner's example:

1. Wash and core six cooking apples;
2. Put them in a fireproof dish.

Carrell believes Halliday and Hasan would say that "them" refers to "six cooking apples," and this anaphor-antecedent relation is one of the basic

cohesive devices of English, creating a coherent whole from two separate sentences. Carrell, however, sides with Morgan and Sellner's view that "them," seen simply as a word on the page, could refer to anything. Readers construe it to refer to "six cooking apples" because of "our background knowledge of cooking and of the author's purpose, as well as our ability to reason, and the assumption that the recipe is coherent. Without this latter assumption, there would be no way of knowing what 'them' is intended to refer to" (p. 483).

Although Halliday and Hasan have claimed that related content words such as

1. mountaineering-Yosemite-summit-peaks-climb-ridge

are not coherent in themselves but require cohesive devices to make them so, Carrell believes that it is the reader's access to relevant schemata that brings these lexical items together, and that cohesion is at best a road map to, not the cause of, coherence. Carrell therefore called for "broader, more powerful theories [than text-bound cohesion and coherence], which take the reader into account." (p. 487).

Johns (1986) believes that coherence is both text-based and reader-based. In text, coherence consists of "ordering and interlinking propositions by use of appropriate information structure (including cohesion)." (p. 251) At the same time, the reader must also be a source of coherence, because writers constantly consider audience background and needs while composing and editing.

Recently Carrell (1987) has related ESL reading processes to the complex, schema-theoretical work of de Beaugrande (1980) and de Beaugrande and Dressler (1981) on the nature of text She believes there is a strong consistency

between research in the two fields. For example, the types of reader background knowledge already identified by ESL research (knowledge of subject matter, genre, sociocultural and general world knowledge and knowledge of linguistic code, p.25) are, according to Carrell, the same phenomena as de Beaugrande's seven standards of textuality (necessary ingredients of comprehensible text) seen from a different perspective.

Studies of Cultural Content Schemata

An influential attempt to isolate the contribution of the reader's cultural background to comprehension is reported by Steffensen and Joag-Dev (1979). They composed two experimental readings in the form of personal letters, each giving an informal account of traditional family weddings--one in India and the other in the U.S. In each, the "writer" assumed the "reader" would have complete familiarity with the cultural context of a wedding in the home country. Syntax was controlled, and the number of idea units (a data analysis method developed from story grammar) counted. Twenty Indian and twenty American subjects read both letters, rewrote them from memory, and answered questions about them. The unfamiliar cultural content clearly interfered with reading comprehension: simplification, overelaboration, incorrect inferences, and distortion in the direction of one's own culture were found in the recalls For example, two Indians thought they remembered traditional expressions of grief at the Indian wedding, but none had been mentioned. An American thought the statement, "the marriage was arranged only one month ago" referred to party plans, not parental negotiations. Most Americans thought that the Indian "wedding feast and reception" comprised one event, even though the text clearly stated that the

feast went on all day and the writer had to hurry to change clothes for the reception. Some subjects achieved coherence in their recalls only by conflating, re-ordering, or ignoring material, while at least one indicated marginally that he knew what he had written about the unfamiliar culture didn't really make sense. As Carrell (1982, p. 485) says, "all the cohesive ties in the world" won't help the text cohere if the reader does not have or fails to access the relevant cultural schemata.

Steffensen (1981, 1988) reanalyzed the same data, hypothesizing that the recalls of subjects familiar with the culture would contain more explicit cohesive devices. Her analysis showed, however, that as far as the categories of reference, repetition, ellipsis, substitution, and conjunction are concerned, the mean proportion of such ties was not significantly different between the native and foreign recalls. Thus, "no support is provided for either the strong claim regarding cohesion--that it creates coherence, or for the weak claim, that it is correlated with coherence" (p. 150).

Johnson (1981) investigated the effect of language complexity and cultural background on the reading comprehension of 46 intermediate/advanced Iranian ESL students and 19 Americans. Stories from American and Iranian folklore (Buffalo Bill and the famous Mullah, Nasr-el-Din, respectively) were prepared in syntactically and semantically simplified and unsimplified versions. Analysis of written recalls and multiple choice questions on both explicit and implicit information showed that the level of linguistic complexity of the text had a lesser effect than the cultural origin on the reading comprehension of the advanced ESL Iranians. For the American group and the lower proficiency ESL Iranians, there was no difference in the

role linguistic vs. cultural factors had in causing errors. Johnson further found that in their writing, the two groups used prior knowledge of their own culture to fill in ideas they did not specifically remember. When the readers lacked the relevant cultural schemata, their recalls had little coherence or gave an interpretation the writer did not intend. Linguistic cues seemed to help the Americans somewhat more, and at times they could reproduce the exact words of the culturally unfamiliar story, but the Americans still distorted the content. At the same time, some American errors seemed to be caused by failure to check the text carefully enough to modify first impressions. Answers to multiple choice questions that required inference were much less accurate for the culturally unfamiliar stories for both groups; also, these answers revealed not simply lack of understanding but a tendency to make wrong inferences based on one's own cultural patterns. While stressing the difficulty of specifying the impact of linguistic vs. cultural unfamiliarity, Johnson nevertheless concluded:

> When reading a story with an unfamiliar theme from a foreign culture, readers are more dependent on the language of the text for interpretation. If they do not recognize a word or a group of words because of the lack of vocabulary or syntax, they may then be unable to confirm or reject their hypotheses; thus they may understand the story only through the screen of their native culture. These interactions of linguistic analysis and conceptual analysis may cause errors in reading in a foreign language a text from a foreign culture. (p. 180)

At the First Midwest TESOL Conference in 1981, Carrell (1987) reported an experiment comparing Chinese and Japanese ESL readers on their

understanding of folktales from European, American Indian, Japanese, and Chinese sources. She found performance differences related to the text's cultural origin, but "it was not possible to determine to what extent these differences were due to content or formal schemata, or to an interaction of the two" (p. 464).

In a subsequent experiment, Carrell (1983a) tried to isolate the differential contribution of not just two, but three components of background knowledge, namely cultural familiarity, context, and specificity of language. She used two stories. One used the culturally universal experience of washing clothes, and the other was novel--the "Balloon Serenade" story created by Bransford and Johnson (1984) for a study conducted in 1972 of schemata use by children. (In the "Balloon Serenade," a modern day Romeo whose girlfriend lives in a highrise apartment serenades her by floating his electric guitar amplifier to her window by hydrogen balloon). In different versions of the stories prepared for the experiment, the three components of background knowledge were manipulated by (a) including or omitting the title and picture page (which gave context necessary for top-down processing), and (b) providing or not providing highly specific content words (linguistic cues used in bottom-up processing). Both native and non-native speakers of English read the stories. wrote recalls, and rated the texts' comprehensibility on a 7-point scale. Statistical analysis showed that native speakers do utilize all three types of content schemata in reading, understanding, and recalling stories. However, the ESL readers did not utilize context or textual clues to the same degree as native readers did. Also, "while native speakers appear to have a good sense of how easy or difficult a text is for them to understand, ... ESL readers do not

have this sense. They may perceive a text as easy but yet not recall it well" (p. 200).

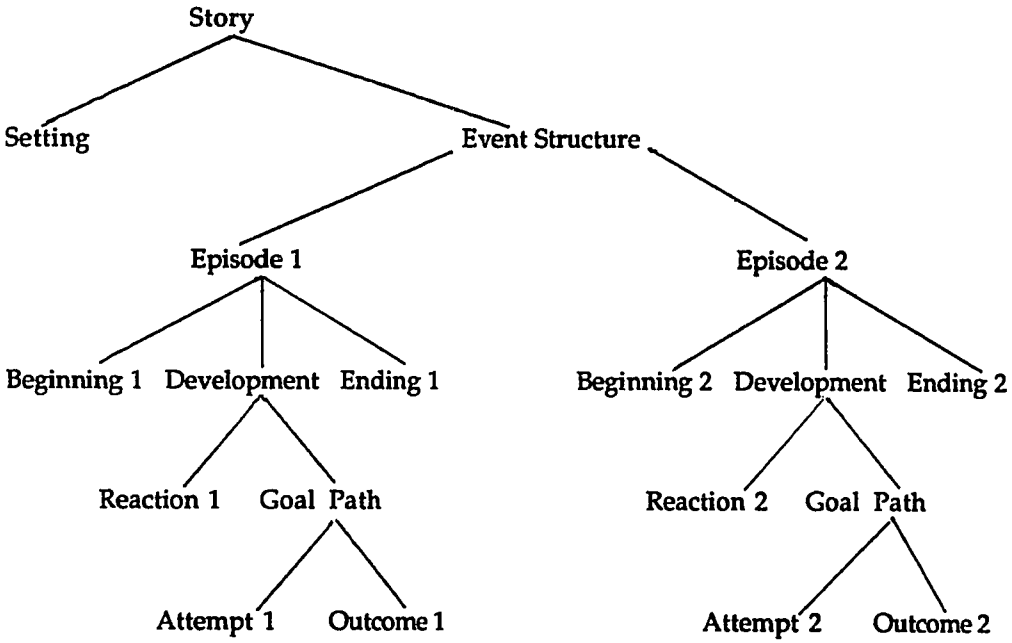
These results are compatible with Carrell's concurrent study (1984c) showing that ESL learners had a weaker grasp of presupposition than of implication when reading sentences with factive and implicative predicates.

Although ESL readers from diverse cultural backgrounds are obviously at a disadvantage linguistically in such experiments and this must be controlled for, their performance when compared to Americans clearly demonstrates the existence of cultural schemata as a component of reading comprehension.

Studies of Formal Schemata

Carrell (1984a, b) defines formal schemata as the "rhetorical organizational structures of different kinds of text," (p. 442) and she studied these structures as they affect ESL readers of stories and expository prose. She began with the idea, adapted from Mandler (1978), that simple stories have an underlying structural schema that can be diagrammed as a tree (FIGURE 1).

FIGURE 1: ORGANIZATIONAL SCHEMATA UNDERLYING SIMPLE STORIES



At the top of the tree, the Story divides into two main branches, the Setting on the right branch and the Event Structure on the left. The Setting comprises a terminal node, while the Event Structure is left-branching. The Event Structure generates any number of Episodes as the next level in the tree. Each Episode then branches into Beginning, Development, and Ending. The middle portion of each Episode, the Development node, further branches into the protagonist's Reaction and Goal Path. Goal Path in turn gives rise to an Attempt to Reach Goal and Outcome. According to Mandler and Johnson (1977), the reader's knowledge of this general set of rules enables him/her to organize incoming propositions into a coherent story. While any reader may misunderstand a well-formed story, the chances of misunderstanding are increased if any story nodes are deliberately misplaced.

Carrell tested whether ESL readers were aware of the formal schemata of story development. She took two stories constructed according to the presumed story grammar rules and presented them to ESL readers in normal and interleaved versions. In the interleaved (deliberately confused) text, sentences from two different stories alternated on the same page. Carrell hypothesized that if ESL subjects are influenced by story schemata, then when versions are read which violate them, the quantity of recall and temporal sequencing of recall will be adversely affected. The recall consisted of asking readers to write the stories from memory on a blank sheet of paper 24 hours after reading. Carrell scored the quantity of recalls according to mean number of episode nodes remembered. The readers did remember fewer nodes of the interrupted stories. However, 38% of her subjects were able to reconstruct the interleaved stories almost perfectly after 24 hours. The only explanation for

interleaved stories almost perfectly after 24 hours. The only explanation for this is that their previous knowledge of story structure allowed them to reorganize the confused input into almost ideal order. (Expository text can also be diagrammed hierarchically, and this will be considered in Chapter 3.)

The conflict between holistic and additive views of reading is by no means over (Samuels & Kamil, 1988). A proponent of schemata theory, Spiro (1977) is sure that

> [m]eaning does not reside in words, sentences, paragraphs, or even entire passages considered in isolation. If connected discourse is analyzed at each of those levels taken out of context, the result is an incomplete understanding of that level's meaning in use. What language provides is a skeleton for the creation of meaning ... that must be enriched .... This process of knowlege-based, contextually influenced, and purposeful enrichment in comprehending language is what is referred to as "construction." (p. 245)

On the other hand, Just and Carpenter (1985) continue to believe

> [t]here is a common misconception that readers do not fixate every word, but only some small proportion of the text, perhaps one out of every two or three words. However the data [here] show that during ordinary reading, almost all content words are fixated. (p. 174)

ENGLISH FOR SCIENCE AND TECHNOLOGY

American Contributions

The pioneering EST research of Trimble and his associates at the University of Washington (begun in 1968 and summarized in Trimble, 1985) was pedagogically driven. To design effective English classes for non-native undergraduate engineering students who had already completed a high school or higher level of preparation for engineering and could read and

converse in English, the Trimble group analyzed engineering texts for those characteristics of scientific writing which were the same as or markedly different from general English. M.T. Trimble (1978) studied the discourse of technical instruction manuals, and eventually, texts from many branches of science and technology were studied. The group found and investigated such grammatical and rhetorical characteristics of scientific writing as the passive/stative distinction and compound nominals, today accepted as distinguishing features of the register.

Trimble decided that the appropriate unit of technical text to be studied is the "conceptual" paragraph (which may include more than one printed paragraph), because the conceptual paragraph has a unique discourse function, such as definition, classification, or description. "Each rhetorical function provides readers with different kinds and amounts of information. As a result, each function is clearly separable and identifiable" (p. 69). Within each paragraph, patterns of development are identified. These include "natural" orders (e.g., chronology, process, space, and cause and effect) and "logical" patterns (e.g., order of importance, comparison and contrast, analogy, exemplification, and visual illustration). These patterns of discourse are largely constrained by the subject matter. Trimble is particularly interested in showing how writers in EST strategically deploy lexis and syntax to accomplish their individual purposes, which can be quite subtle. For example, there are at least three different levels of formality in definition a writer can choose; also, such notions as stipulation or operation may be the basis of a definition. Classification may be done in an explicit or implicit, partial or open-ended way. These choices modify the information the reader

receives and require differential processing. Rejecting a simplistic form/function tie between syntactic choices and meaning, Trimble nevertheless made a close study of syntax, showing that in EST, certain frequently used forms may signal special meanings different from general English. Summing up their work, Trimble listed the following major syntactic differences between EST and general English: (a) passive-stative distinction, (b) non-standard use of modals, (c) non-standard, inconsistent uses of the definite article. (The following illustrations of these special syntactic patterns were located by the investigator.)

Passive-stative distinction:

1. Blood flow through the coronary system is regulated almost entirely by vascular responses to the local needs of the cardiac musculature for nutrition.

2. The term hemophilia is loosely applied to several different hereditary deficiencies of coagulation.

3. Vitamin K is fat soluble and ordinarily is absorbed into the blood along with the fats. (Guyton, 1984 , pp. 99, 299)

The main verb phrases of these sentences consist of BE + PAST PARTICIPLE, the passive voice, but only 1 and 2 refer to an activity performed by an agent. They illustrate Trimble's true passives. Sentence 3 is a "stative," describing a state or condition of the grammatical subject. .No agent is implied; yet there is activity going on. The type of activity in 3 is distinct from that in1 and 2, despite the structural similarity. If non-native readers are unaware of the existence of the stative (and it was not taught before Trimble), they can only assume 3 is a passive whose agent should somehow be obvious, or that the participle in 3 is somehow adjectival.

A folk belief among a few English teachers holds that scientific text relies heavily on the passive because science is intrinsically boring and socially irresponsible. Hanania and Akjtar (1985) have shown that in fact passive predominates only in the methods sections of scientific reports. Also, passive may be more prevalent in certain disciplines, such as chemistry and biology, where previous experiments are frequently discussed in passive, but not as common in physics reports, which by the nature of the subject contain more speculation and fewer references to previous experiments. The passive sometimes marks implied messages: for example, that standard procedures have been followed (Tarone, Dwyer, Gillette, & Icke, 1981).

Non-standard Use of Modals

General English grammatical description (Leech and Svartwick, 1975) distinguishes "should" from "must" in this way: Use of "should" is a tactful way of expressing an obligation which may not be fulfilled (p. 144) in, for example,

You shouldn't talk with your mouth full.

Trimble found, however, that in the rhetoric of instructions in EST, "should" cannot be interpreted as a matter of choice, as the following example from a science teacher training text illustrates:

> The rules for constructing a best-fit line for a set of points on a graph are:
>
> 1. The line should be a straight line or a smooth curve.
> 2. All points should either lie on the line or very near to it.
> 3. There should be an approximately equal number of points on either side of the line. (Funk et. al., 1979, p. 123)

Non-standard and Inconsistent Uses of the Definite Article.

Technical editors usually remove every definite article that can be recovered by experienced native readers. However, even native readers can disagree about article choice. Trimble tested a group of native speaking ESL/EFL MA candidates by removing all the articles from a cloze test paragraph on gas turbines. He found that all 24 of the non-science trained prospective TESL teachers failed to use articles the same way as the original technological text did. The linguistics majors followed general grammatical rules for article use, in which, for example, the first mention of a noun is marked by the indefinite article. In the original text, however, the first mention of five nouns (gas turbine, diffuser, compressor, inlet, and exhaust) was marked by the definite article. Trimble informally asked a science trained group how they understood this article choice. To them, it meant "the machinery being described contained only one of whatever part was being marked by that article " (p. 112).

Master (1987) studied use of generic the at the sentence and discourse level in scientific writing, finding at least five special characteristics. Generic the marks the discourse topic; has a stronger generalizing power than generic a; marks the return to generalized statements after supporting details have been established; and marks the noun phrases that contribute to the author's argument. It is more likely to occur in introductions and conclusions.

Non-temporal Use of Tense

Trimble found the following conventionalized uses of tense:

1. Present tense is used to describe apparatus that is still in use, while past tense is used to describe apparatus that has been abandoned.

2. Visuals in text are referred to in present, although the findings they represent were made in the past.

3. Past tense when reporting previous research indicates that the research is of secondary importance. A shift to present tense in a review of research indicates a "more direct and primary importance to the writer's current work." (p. 126)

Responding to Trimble's call for more research on tense shifts in EST, Malcolm (1987) predicted three tense-function correlations: (a) present tense will indicate a generalization; (b) past tense will indicate reference to a specific previous research study; and (c) present perfect tense will indicate reference to ongoing area of inquiry. These predictions, based on the common wisdom of descriptive grammar, held true in 74, 72, and 61% of cases respectively. This shows that in 26, 28, and 39% of cases, tense choice was made on a different basis. Malcolm concluded that "the temporal location of many references to the research process is one that exists only in the minds, and the verbal and written discussions, of the scientists themselves. An author can choose ... a tense for his or her own rhetorical purposes" (p. 41).

Ard (1985) challenged the "covert" assumption in most American EST studies that authors choose tense partly by discourse rule, partly by "whim." He feels that anomalous tense choices and shifts are not really individual decisions but ones required by the "scientific-technical tradition. ... The scientific community, rather than the individual scientist, provides the authority for the rhetoric. The individual scientist becomes authoritative by following the tradition" (p. 16). Somewhere in the text are shared values, and "texts serve to recreate our cultural context."

British Contributions to EST

EST in the United Kingdom differs from that in America for historical reasons. In the 60s and 70s, British teachers of English as a foreign language in the developing world saw an increasing need for pretechnical courses for learners with much less exposure to science and technology than Trimble's foreign undergraduates had had. Herbert (1965) in the Far East was one of the first to respond to the need for EFL materials based on readings in science and technology, and although he considered himself a layperson, produced an EST text that inspired other teachers to try writing such materials for their own students. In Herbert's text, such topics as "Centrifugal Governors" and "Rigid Pavements" were presented together with grammar items and structural patterns Herbert believed were common in technical material. Herbert's work was innovative in that he attempted to link grammar functionally to his readings, introduced the idea of subtechnical vocabulary, based his learning objectives on unique problems found in authentic technical material, and suggested that language teachers consult with subject specialists. Another authentic touch was his use of many diagrams and schematic drawings.

Ewer and Latorre's A Course in Basic Scientific English (1969) used material selected from ten broad areas of science and technology "on a frequency basis," and claimed that there were no significant differences between the scientific and general varieties of English (p. ix). In this view, only the context of language is seen as special. However, by the 1980s Ewer, who spent 20 years teaching EST at the University of Chile, had accepted a notional/functional basis as best for organizing EST materials and

acknowledged the existence of a special scientific register. He identified 65 "microacts," or basic units of communicative intention found in the language of science and technology and connected them to their indicators (exponents) in formal scientific discourse (1981). He designed and taught an EST teacher-training course at the University of Chile that became a regular part of the undergraduate program. Designed for teachers with a humanities background, the course included all the problematic areas of attitude, concepts, language, methods, and organization which discourage most TESL teachers from teaching EST. A regular program of summer retraining classes continues.

Widdowson's earliest textbook, written with Allen Bates on English in Physical Science (1974) almost attempted to teach physics, chemistry, and ESL at the same time, for the text's main chapter headings took up such subjects as "The Properties of Air," "Acids," and "Matter and Volume." The text assumed the learner already understood the science but needed to awaken his "dormant competence" in general English and connect it functionally with science concepts. Readings were largely self-explanatory; however, in a sentence such as

> Inorganic acids consist only of hydrogen and an acid radical (p. 12)

both learner and teacher were assumed to know the meaning of "radical."

British teachers and materials writers in the Middle East made the most radical changes in EST text format (e.g., Bates & Dudley-Evans, 1976). They presented basic cross-disciplinary concepts from science and technology such as shapes, dimensions, and properties of materials as functions in communication, dropping almost any overt linguistic sequencing and

grading. In an early unit on Shapes, the Nucleus: General Science text shows a labeled drawing of an airplane and asks the learner:

> Say whether these statements are true or false. Correct the false statements.
> a. The airplane's tail is nearly triangular in shape.
> b. The door is flat.
> c. The steps are parallel to each other. (p. 11)

The text does not take up the problem of why we can't say "triangular to each other" or "flat in shape." The fact that adjectives have different shapes is left for the teacher to explain or the student to intuit.

American and British EST discourse and register analysis and classroom-based research do not yet have formal links to schemata theory, although the research often incorporates schema theory informally (Blanton, 1984). How certain language choices manage to instantiate certain scientific schemata and how these bind in comprehension is not known. It does seem that one of the neglected sources of information on this topic could be the science teachers themselves.

CHAPTER 3

METHODOLOGY

To investigate whether science and ESL teacher (TESL) groups use science background knowledge in essentially the same or different ways in science content reading, a three-step procedure was designed. The procedure consisted of (a) a tape recorded thinking aloud interview in which the subject read a specially prepared text, (b) a questionnaire which established group membership, and (c) a written recall. This chapter will begin with a description of the interview method. Next the choice, structure, and special preparation of the text will be discussed. The development of the questionnaire, recall procedure, and recruitment of subjects will follow.

INTERVIEW

The Think-Aloud

The Think-Aloud research method was developed by psychologists to study problem-solving strategies. The investigator gives general instructions for completing a task and allows the subject to proceed at a leisurely speed. Subjects are asked to make a verbal report of their thought processes at the same time they are attending to the problem task. Ericsson and Simon (1980) discuss at length the trustworthiness of such verbal reports as data. They conclude that "verbal reports, elicited with care and interpreted with full understanding of the circumstances under which they were obtained, are a valuable and thoroughly reliable source of information about cognitive processes " (p. 247). If the verbalization takes place while the task is being

attended to, data can be obtained on intermediate inference and generative processes that involve both short- and long-term memory. Although the speed of the performance will be slower than normal, "the internal structure of the thought processes ... is not changed as a result of the verbalizing activity" (p. 229).

The Fillmore Interview

In the interview technique developed by Fillmore (1981; discussed in Connor, 1987) to explore schema awareness in young readers, a story is revealed one clause at a time as the investigator moves a covering device down a printed page. After reading each new segment and linking it visually to previous ones, readers are asked open-ended questions about the mental experience of text processing. Fillmore's questions tap readers' use of schemata in the domains of content, discourse, and genre, and their awareness of point of view; however, data need not be confined to these areas. Because interviews are conducted individually and depend on reader response, conversation between investigator and reader may take different directions. Fillmore cautions the interviewer to strive for consistency from one interview to another, so that valid comparisons can be made.

Combination of the Methods in This Investigation

In this investigation, the text was segmented according to the method described below. Segments were typed on separate pages and placed in a looseleaf binder in their normal order. At the beginning of the interview, all of the subjects were asked to read and sign the Consent Form (Appendix A), which described the experimental procedure. It was repeated orally in an informal, conversational way that the person would be reading a paragraph

in slow motion. He or she was asked to read aloud, one segment at a time, and then freely verbalize any and all thoughts before turning the page to the next segment. Allowed to look back but not forward to assist comprehension, readers were assured that anything that occurred to them during reading was interesting data. It was emphasized that this was not a proficiency test of any kind but a way to explore the reading process in individuals. After the reader spoke the first page or two, a few intentionally vague prompts were used, such as "what are you thinking of now?" "what do you think it is going to say now?" and "why do you think that?" Encouraged to feel free and informal, readers got interested in observing and reporting their thought processes, including knowledge gaps and confusions. The investigator stayed as quiet as possible. If a reader became silent or nervous, the investigator tried to reflect what the reader had said in order to get reporting started again. The complete interview was kept to one hour.

EXPERIMENTAL TEXT

Choice of Material

The following untitled text was used in the research:

> The mistletoe plant grows on deciduous trees, those that lose their leaves in autumn. It is spread by birds as they eat its white berries, and then wipe their beaks on the bark of nearby branches. The sticky seeds put out tiny rootlets, thrust up leaves, and begin an extremely long life. Insects leave mistletoe alone. Winds never blow it down. Wintry ice and parching summers cause it no harm. Virtually indestructible, it dies only when the tree dies. One mistletoe ball was estimated to have survived four hundred years. For the tree, it is only a minor pest, manufacturing its own food from the chlorophyll of its leaves and using the tree simply as a source of liquid and vital minerals.

The text was taken from a recent TOEFL (Test of English as a Foreign Language) test. The TOEFL is an English language proficiency test used by many colleges to judge an ESL learner's readiness to participate in academic work. The reading comprehension section includes of five or six short, expository paragraphs representing various disciplines followed by multiple-choice questions whose answers require background knowledge and inference. Since most international students do not take further ESL courses after university entrance, a TOEFL test science paragraph represents the highest reading proficiency level that most TESL teachers need be concerned with. The TOEFL science paragraph also represents, from the point of view of a science teacher, the bare minimum reading proficiency needed for lower division course work in science. Thus, the TOEFL paragraph is neither too

specialized for the TESL teachers nor too trivial for the science teachers to be interested in. Because instructional levels intersect at this point, it seems an appropriate place to explore whether differences in reading styles between TESL and science teachers exist. The cultural association of mistletoe with Christmas promised enrichment of the data.

Sentence Level Text Structure

To find whether readers are processing text differently, the nature of the text as a problem solving task must be investigated. The mistletoe paragraph was analyzed for the relatedness of underlying schemata and for its formal characteristics. It was found that the paragraph is not helpfully written, and that when read in short segments, will present numerous comprehension challenges.

To begin analysis of the paragraph, the investigator compared it with other sources of the same information. Below, the first sentence of the TOEFL mistletoe paragraph is compared with the first paragraph of the World Book Encyclopedia (1988) article on mistletoe:

1. The mistletoe plant grows on deciduous trees, those that lose their leaves in autumn.

2. Mistletoe is a plant which grows as a parasite on the trunks and branches of various trees. The American Mistletoe and the European mistletoe grow most often on apple trees. They also may grow on other trees, such as the lime, hawthorn, sycamore, poplar, locust, fir, and occasionally on oak. (vol 13, p. 681)

Leaving aside for the moment the fact that the Encyclopedia uses more words, it is still evident that it gives a clearer picture. It mentions the key word, parasite explicitly, so that readers can promptly access this essential underlying schema, or if they do not possess it, be aware of a knowledge gap. The verb phrase grows on in the TOEFL paragraph refers to the same parasite phenomenon, but the humble particle on is easy to overlook. In the Encyclopedia text, the words trunks and branches help readers visualize the host plant, confirming their understanding of parasite. If they do not know this phenomenon, the specific details provide a starting place for new knowledge. The Encyclopedia's list of host trees begins with the most common and ends with the least common, making it more likely that the most common host will be remembered. In the TOEFL text, the phrase deciduous trees, those that lose their leaves in autumn has a spurious air of importance; the Encyclopedia's list, however, shows this conflation of tree types is erroneous.

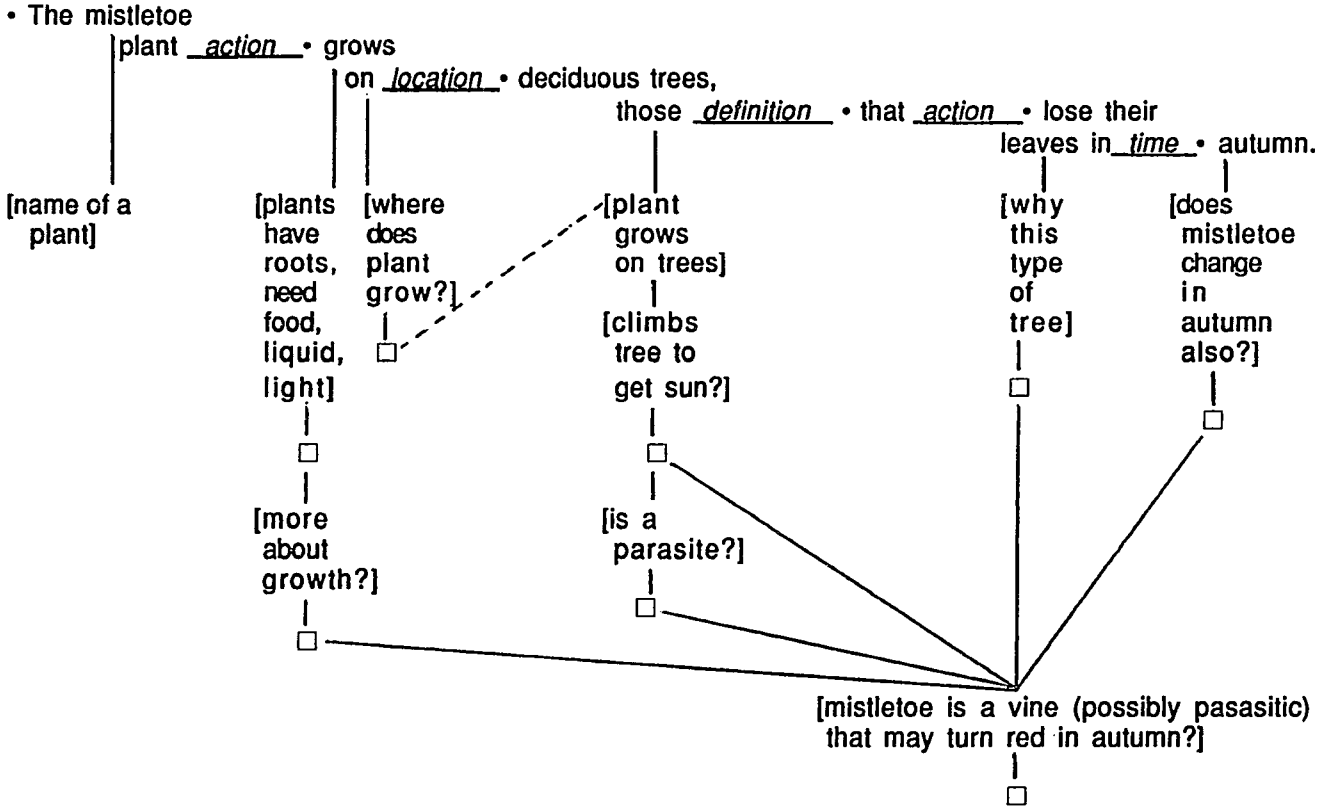
To make a fairer comparison, the investigator condensed the Encyclopedia's information into one sentence containing the same number of words as the TOEFL text (14 words), as follows:

1. The mistletoe plant grows on deciduous trees, those that lose their leaves in autumn (Text used in experiment)

2. Mistletoe is a parasitic plant growing on the trunks and branches of various trees (Encyclopedia condensation)

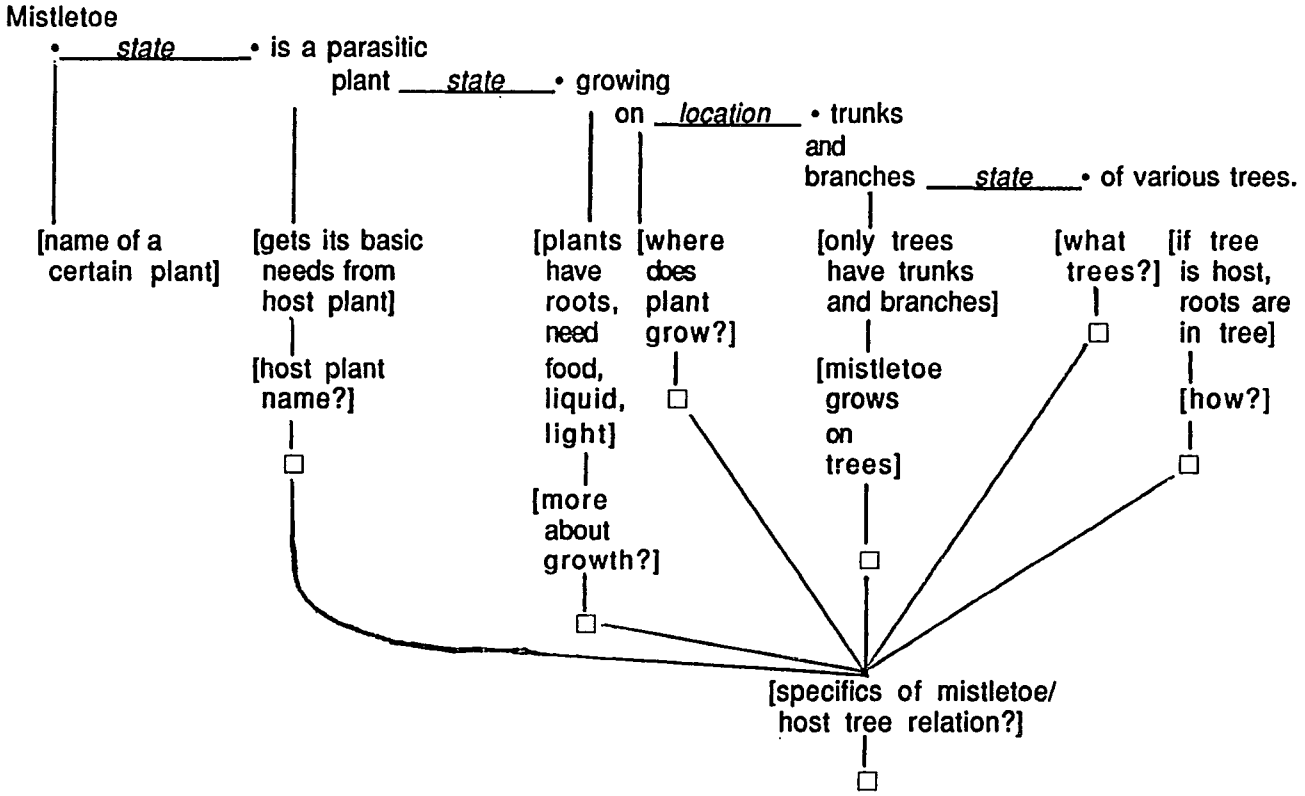
Next the investigator diagrammed the two sentences (after Norman & Rumelhart, 1975, p. 9; de Beaugrande, 1981, p. 99) as logico-syntactic-inferential networks containing the explicit words of the text, their logical links, and at least some of the likely underlying knowledge contributions that would be made by a hypothetical reader (Figures 2 and 3). The educated adult reader supposed by the diagram knows there are such things as parasitic plants but does not know if mistletoe is one of them.

FIGURE 2: DIAGRAM OF SENTENCE USED IN THIS INVESTIGATION
"The mistletoe plant grows on deciduous trees, those that lose their leaves in autumn."



• words given in text
link logical relation
[ ] reader's conclusions and questions
□ receptor box indicating schema variables ready to bind

FIGURE 3: DIAGRAM OF SENTENCE CONDENSED FROM ENCYCLOPEDIA
"Mistletoe is a parasitic plant growing on the trunks and branches of various trees."



• words given in text
link logical relation
[ ] reader's conclusions and questions
□ receptor box indicating schema variables ready to bind

As mentioned in Chapter 2, one of the properties of a schema is that it contains information about how it is to be used (Rumelhart, 1980). This information in part consists of variables which will bind with other schemata. In Figures 2 and 3, the box symbol (Ë) indicates a cluster of schema variables instantiated by the text which are made available for binding as the sentence is read. In both sentences, the word grow gives rise to a receptor box awaiting more information about the life cycle of this particular plant. In Figure 2, five more open boxes have been produced. The particle on has alerted the reader to the importance of location. Learning that the plant grows on trees and using the the common background knowledge that plants root in the ground and climb toward the sun, the reader hypothesizes the mistletoe is most likely a vine. The reader is also aware that grows on could indicate a parasitic relation, but this is much less likely than the first hypothesis. The vine schema awaits further binding, with parasitism a possibility. The text writer's small error about the deciduous trees has created two receptor boxes. The reader expects more input on the significance of the deciduous trees to the life cycle of the plant, and is also open to the possibility that the autumn season brings something important in the life of the plant.

According to Block (1983, p. 482), skilled readers are "integrators." They actively combine word-level data into sensible wholes. To make sense of the input provided in the sentence in Figure 2, the reader has accessed a number of schemata from background knowledge and tentatively combined them in the notion that mistletoe is a vine, possibly parasitic, that does something special in autumn. Upcoming information will be fitted to this basic

hypothesis until contradictions become overwhelming and a new synthesis is tried.

In Figure 3, the specific term parasitic activates background knowledge that some plants get their nourishment indirectly through other plants. This knowledge combined with the trunks and branches suggests that the host plant of the mistletoe is a tree, and the specific mention of trees confirms this. The expectation aroused by grow, that more information will be given about this plant, combines with the conclusion that mistletoe is a tree parasite to create a receptor box that expects more information about the nature of mistletoe as a parasite. The two possibilities raised by various trees are that (a) the type of tree does not matter, or that (b) specific types of trees will be mentioned later. Both of these possibilities converge without strain or contradiction in the one remaining receptor box, creating a rich cluster of internally consistent variables .

In contrast, the integration made in Figure 2 is not consistent. The reader is trying to imagine a plant something like ivy with its roots sort of in the ground and yet taking something from the tree, a plant that might (a) change color and die back in autumn or (b) take the opportunity of the tree's dormancy to put on a growth spurt in autumn. The sentence in Figure 2 makes readers work hard to handle multiple options and yet puts readers on the wrong track. It will take them much more time and effort to clarify the nature of the plant. In contrast, readers of the sentence in Figure 3 are already on the right track, ready to receive specific information to expand the schemata accurately integrated after only 14 words. In the clearer sentence,

specific and accurate bottom-up signals provided by the writer help the reader make the right top-down decisions.

For experimental purposes in this study, the misleading text promises to generate more data on what readers do to achieve clarity than does the more helpfully constructed sentence.

Formal Structure of the Text

The text was investigated as a whole for its discourse structure. Meyer (1977, discussed in Carrell, 1984b) identified five distinct types of rhetorical schemata in expository paragraphs. Of these, Meyer and Freedle (cited in Carrell, 1984b) found that the more highly organized types, Causation, Problem-Solution, and Comparison, are more facilitative of recall than the loosely organized Collection of Facts (a "shopping list" in sentence form) and Description (facts related only by chronology or spatial association). Readers remember more information from the highly organized types because when ideas are more strongly and explicitly interrelated, main ideas are rehearsed more often and more retrieval cues are available. (This could also be said of the sentence in Figure 3). Studying the effects of rhetorical organization on ESL readers, Carrell identified a sixth type, Collection of Descriptions. This type consists of information on a general theme bundled into topics whose order of introduction lacks a compelling logic. Carrell found this paragraph type the least facilitative of recall by her subjects.

The mistletoe paragraph, like Carrell's Collection of Descriptions, does not utilize any strong, recognizable organizational structure appropriate to its content, such as the conventional format of botanical description (genus, species, common name, family, leaves, flowers, etc) or the educative strategy

of moving from known to unknown material, simple to complex, or general to specific (Bower and Hilgard, 1981). Nor does it use the reader's general knowledge of living things to proceed from birth to death.

The six sets of information about the mistletoe plant are: (a) Habitat, (b) Seed Dispersal, (c) Seed Germination and Growth, (d) Hardiness, (e) Cause of Death, (f) Effect on the Host, and (g) Nourishment. Material pertinent to each topic is given. But without a strong underlying presentation order dictated by the parasite schema, the collection of descriptions lacks interest, authority, or significance. Rather, the text rambles from topic to topic by means of surface level association. For example, grows on (Habitat) leads to explanation of how the seeds get on the branches (Seed Dispersal), not to an explanation of the mistletoe's basic dependence on the host tree. The Seed Germination and Growth section says the seeds put out tiny rootlets and the mistletoe begins an extremely long life, again failing to explain clearly that the rootlets embed themselves in the bark of the tree, not in the ground. The phrase extremely long life leads on to a random list of potential threats that do not affect this particular plant (Hardiness). Since the plant is so hardy, it must die somehow, so the Cause of Death is given next. Almost as an afterthought, an example of approximately how long the plant can live is given. This example of long life, widely separated from the first mention of long life, refers to the mistletoe ball without explaining what part of the plant takes this odd shape. Now that the plant has completed its lifecycle, the next idea, for the tree, it is only a minor pest (Effect on the Host)is an almost incoherent statement, because the role of the tree as a host has not been clearly established. Finally, the food production mechanism which makes the plant a semiparasite is

given (Nourishment). Even if readers have accessed the parasite schema in their memory structures, they must wait until the last sentence of the paragraph to be confirmed in their choice. The bottom up information provided by the organization of the text does not facilitate rapid and confident selection of the parasite schema but increases the burden on the reader's comprehension skills.

Another weakness of the text as a whole that may affect the reader is its inaccurate content. Besides the deciduous trees error mentioned above, readers with some science background knowledge will wonder why the text omits the more familiar method of seed dispersal by bird droppings. Readers with folklore background knowledge will find it hard to believe that the mistletoe is only a minor pest. Mistletoe can kill or badly deform host trees, and for this reason European superstition ascribed sinister magical properties to the parasite.

Thus, the paragraph does not qualify as pure scientific discourse or as high quality science teaching material, because it lacks key terms, is loosely organized, and factually inaccurate. According to Addison (1988) and Strother and Ulijn (1987), such weaknesses are the results of "simplification," the work of textbook writers who do not understand the "features that promote comprehensibility, [that is,] interaction and contextual clues (Addison, p. 63). Whether or not this happened here, or whether the comprehension barriers are intentional parts of the test, the mistletoe paragraph offers a frustrating reading experience for both science and TESL teachers, because it will give rise to schema variables that are difficult or impossible to satisfactorily integrate.

Segmentation of the Text

Consisting of only nine sentences, the mistletoe text could be read at a glance by skilled readers. If readers were allowed to skim the whole text quickly and report their thought processes in retrospect, the desired data on schemata use would be lost (Ericsson & Simon, 1980; Cohen, 1984). In order to bring skilled readers' mental processing to consciousness as much as possible, the text was divided into small parts and typed on separate pages as shown in TABLE 1.

TABLE 1: TEXT APPEARING ON CONSECUTIVE PAGES

Page	Segment	Page	Segment
1	The mistletoe plant	25	Wintry ice and parching summers
2	grows	26	cause
3	on deciduous trees	27	it
4	those that	28	no harm.
5	lose their leaves	29	Virtually
6	in autumn	30	indestructible, it
7	it is spread	31	dies
8	by birds	32	only when the
9	as they eat	33	tree
10	its white	34	dies.
11	berries, and then wipe	35	One mistletoe
12	their beaks	36	ball was estimated
13	on the bark of nearby	37	to have survived four
14	branches. The sticky seeds	38	hundred years.
15	put	39	For the tree it is
16	out tiny rootlets,	40	only a minor pest,
17	thrust up leaves,	41	making its own
18	and begin an	42	food from the
19	extremely long life	43	chlorophyll of
20	Insects	44	its leaves and
21	leave mistletoe alone.	45	using the tree
22	Winds never	46	simply as a
23	blow	47	source of liquid and
24	it down.	48	vital minerals.

There is no one agreed-upon unit used to quantify text features and reader responses in think-aloud research (de Beaugrande 1981). This is so because

surface syntactic and semantic information provided by language is represented in long term memory in a more abstract, little-understood form, and this complex mental activity is under investigation by several disciplines. The parts into which an investigator divides text and analyzes data depend on research goals. For example, Fillmore (1981) identifies "idea units" as clauses, as shown in the following sample from his research:

> Once upon a time/there was a rich king/who had three sons (p. 256)

Fillmore's data analysis method attempts to characterize the types of knowledge links (called by him K-links) that young, developing readers create between idea units and the levels of "envisionment" of schemata (literal to imaginiative) they are able to achieve.

Steffensen & Joag-Dev (1984), investigating adults' use of cultural background knowledge, divided text into units as follows:

> The minister/who performed the ceremony/ was an old family friend.
> The auspicious time/told by the priest/was 9:38 in the morning.(p.55)

Syntactically, these idea units are constituent phrases. Schematically, each represents a cluster of necessary cultural background knowledge. Think-alouds and oral recalls of readers were compared on this basis. Carrell (1983a) on the other hand, segmented stories at the sentence level, but scored recalls according to story nodes recalled.

Working in an AI context, Miller and Kintsch (1980) define a "propositional chunk" as their basic unit of text processing, one that is "based on properties of both the text and the hypothetical reader" (p. 338). The chunk is not necessarily a clause, constituent phrase or sentence. Rather, it is a stretch of text containing at least two propositions whose arguments overlap. (A proposition is a conceptual unit consisting of a logical predicate with at least one argument). For example, the sentence from the mistletoe text,

> It is spread by birds, who eat its white berries and then wipe their beaks on the bark of nearby branches.

contains roughly eleven predications (e.g., mistletoe, spread, by, birds), but since their arguments overlap (e.g., mistletoe is spread, spread by birds, birds eat mistletoe berries), the resulting propositions share arguments, and the whole sentence constitutes one conceptual chunk according to Miller and Kintsch's system.

Clauses, phrases, propositions, sentences, chunks all have validity as units of comprehension. However, none of these units was used in this investigation to prepare the mistletoe text. It was felt that simply because these units do have some intuitive coherence, the skilled reader asked to think aloud clause by clause or sentence by sentence will very likely be unable to get a fresh perspective and offer any sensitive insight into his or her use of background knowledge. Such an experience might feel like going back to third grade and cause readers to trivialize their responses. Therefore, the

mistletoe text was fragmented in surprising, unexpected, puzzling ways. As shown in Table 1, the potentially confusing phrasal verbs grows on and puts out are broken up. Many segments break off just before an important content word (as they eat / its white / berries and then wipe [p. 9, 10, 11]), giving readers the chance to fill these in from their own knowledge of the possibilities. Other segments end with a full stop (e.g., p. 19, 20), but there is no explicit material in them to indicate what topic will be taken up next. Subjects are broken off from verbs (p. 22, 23), adjectives from nouns (p. 37, 38), prepositions from objects (p. 43, 44). All of the common units are broken up into new units that are not internally coherent and are not easy to process in short term memory. More than usual reader initiative is needed. In the sentence, Wintry ice and parching summers / cause/ it / no/ harm, the investigator tried to take full advantage of the text's unusual sentence structure to create optimum opportunities for the reader to make guesses, predictions, or express confusion or knowledge gaps. The investigator tried not to fall into any kind of predictable pattern of segmentation which the reader could use as a clue but to force readers to look within themselves to make sense of the text. An attempt was made also to avoid the monotony of going too slowly.

QUESTIONNAIRE

According to Ericsson and Simon (1980), verbal reports take on more validity when looked at in relation to other behavior. The questionnaire developed for this investigation (Appendix B) gathered biographical information about the subject and sampled attitudes toward various issues in

science, arts, and technology. The biographical information, including past academic training, changes of major, and current and anticipated occupation, was included in order to establish that subjects had indeed had extensive and unbroken exposure to their disciplines. The attitude portion was added as a further check. It is still possible that someone who holds a job in a particular field does not identify with it, has strong ties with another field, or has come under a certain amount of influence from another field through family, hobbies, or other unexpected sources. It was anticipated that subjects with a steady record of training and teaching experience in the sciences or humanities would have different attitudes. If two groups did not emerge from the questionnaire, then it would be questionable whether there were in fact two cultural subgroups represented by the subjects.

The statements in the questionnaire were constructed to be moderately controversial and to tap attitudes that would be expected to vary based on affinity to generally perceived differences between science and humanities orientations. Subjects could respond to the statements on a 5-point Likert scale (Nachmias & Nachmias, 1981), which measured a range of reactions from strong agreement to strong disagreement. The statements were phrased in both positive and negative terms and randomly ordered, so that subjects would not fall into a rigid pattern of response.

Another important purpose of the questionnaire was to distract readers' attention before writing the recall. The questionnaire interfered with their short-term memory storage, again forcing them to self-mobilize typical high level processing schemata.

WRITTEN RECALL

The written recall provided data in another medium from the oral interview about the readers' processing styles. It was hoped that given complete freedom to write, with no test-taking apparatus or pressure, the different groups might make different organizational or other choices. Readers were not told in advance that they would write a recall. After completing the questionnaire, they were given a blank sheet of paper and instructed to write as much as they could of the information they had just read about the mistletoe, in any form they wished.

DATA ANALYSIS

Written recalls, like thinking aloud data, can be quantified according to idea units, propositions, or other syntactic categories. However, because the goal of this study was simply to find whether discernable differences of any kind exist between the two groups being investigated, it was decided not to specify the units of analysis of the data before collection. Rather, it was hoped that qualitative evidence would accumulate of individual and group patterns and that an appropriate analysis method would arise from the data. Such a method was recently used by Sarig (1987) to quantify reading process data after collection.

PILOT STUDY

The whole procedure as described above was pilot tested using four native English speaking subjects and one non-native speaker. It was found that the method stimulated readers well, generated interesting data, and did not need

modification for native English speaking subjects. It was decided that non-native readers would not be suitable subjects because the unusual task caused excessive confusion and discomfort.

SUBJECTS

Science teacher subjects were recruited by means of a flyer suggested and sent out by Dr. Brian Holmes of the Physics Department at San Jose State University. TESL teacher subjects were recruited through friends and colleagues of the investigator. The science group consisted of one female and four male teachers of scientific subjects; the TESL group consisted of one male and four female teachers of English as a Second Language. The readers' ages ranged from mid-twenties to mid-fifties, and all were employed as teachers of science or TESL at the university or continuing education levels. All had completed at least one graduate degree in the field in which they were employed as teachers. They were all native speakers of English.

CHAPTER 4

RESULTS

QUESTIONNAIRE

Academic Training, Occupation, and Specialty

The questionnaire (APPENDIX B) established that the subjects represented two differently trained groups, one in the sciences and the other in humanities (TABLE 2).

TABLE 2: GROUPS' ACADEMIC TRAINING, TEACHING EXPERIENCE, AND PROFESSIONAL INTERESTS

	SCIENCE GROUP		TESL GROUP	
	Field	No.	Field	No.
UNDERGRADUATE TRAINING	Biology	1	English Literature	2
	Chemistry	1	History	1
	Mathematics	1	Spanish	1
	Physics and Chemistry	1	Education	1
	Psychology	1		
PAID TEACHING FIELD	Biology	2	English as a Second Language	5
	Chemistry	1		
	Computer Science	1		
	Physics	1		

TABLE 2 (CON'T):

REPORTED SPECIALTY	SCIENCE GROUP	TESL GROUP
	Computer Architecture	Accent Improvement
	Graph Theory (math)	English for Professional Development
	Neurophysiology	
	PC Performance	English for Specific Purposes
	Pharmacology	Child Language Acquisition
	Physical Chemistry	Bilingual Speech Pathology
	Synthetic Organic Chemistry	Inter-American Studies
	Toxicology	

One of the science group readers had majored in psychology as an undergraduate but changed to biology because "I found Psychology imprecise and lacking testable theories." The other readers all reported unbroken development in their chosen field, or a closely associated one. An important additional fact about one of the TESL group, which came out indirectly in the interview, as there was no provision for it in the questionnaire, was that the subject's father had been a teacher of agriculture and a specialist in forestry. The relevance of this will be discussed below in the interview results.

Both groups reported ongoing interest in various specializations within their fields, and unanimously mentioned further professional growth as one of their goals. The pleasure reading choices of both groups were similar (TABLE 3); however, the science group mentioned more specific kinds of reading material, including biography, children's books, and comics.

TABLE 3: PLEASURE READING CHOICES REPORTED BY READERS

Science Group	TESL Group
Atlantic	ethnography
best sellers	journal articles (two readers)
biography	mysteries
children's books (read to children)	New York Times (two readers)
computer science	novels, especially classics
comics	novels
fiction	short stories
magazines related to environmental problems	travel books
New York Times	
newspapers (two readers)	
natural history exposition	
physics	
science fiction	
spy novels	

Attitudes

The controversial statements in the questionnaire asking readers for their degree of agreement or disagreement stimulated the science group to converse with the investigator. One science group subject wanted to comment on all of the questions. Others laughed, sighed, asked for clarification ("I'm not sure I know what an empiricist is"), or said they could talk a long time about this or that question. In contrast, the TESL group did not volunteer any oral reactions to the statements but finished it as soon as possible.

The questionnaire did not reveal any gross or stereotypical differences in attitudes between the two groups. The science group split on such topics as whether scientists are more rational than other people (Question 17) or are good conversationalists (Question 12); they did not all feel the scientific method is the only valid research methodology (Question 13) or that basic science is more important than technological innovation (Question 16). .The TESL group did not all feel that creating new life forms was wrong (Question 8) or that Star Wars didn't need more research (Question 2). These enlightened views may show that extreme statements about the "two cultures" would not be true for academically-oriented people in the Bay Area in the 1980s.

The two groups did clearly split on several questions. Five of these differences seemed to be based on the inclusion of key words: technical (Questions 3 and 7), ambiguity (9), myths [and] mechanisms (11), and the subconscious (18). The science group favored the term technical and downgraded the other terms, while the TESL group did the opposite. The science group showed a strong preference for reading and writing technical material, while the TESL group showed a strong dislike for it. The TESL group thought ambiguity was their cup of tea, that myths are more interesting than mechanisms, and that the subconscious must be considered in the search for truth. The science group strongly separated themselves from these ideas. Perhaps the most important result of this portion of the questionnaire was to reveal that the science group not only had more years of experience with reading and writing technical material but actually enjoyed and sought it out, whereas the TESL group consciously avoided such experiences. This

finding might suggest that the science group would understand the reading research text more easily and quickly than the TESL group. However, given the source and quality of the experimental text, the reverse might be seen.

INTERVIEW

As soon as readers began the think-aloud procedure, they began volunteering background knowledge. TABLE 4 shows all the kinds of background knowledge of the mistletoe plant itself that readers mentioned during the interview.

TABLE 4: KINDS OF BACKGROUND KNOWLEDGE OF THE MISTLETOE PLANT VOLUNTEERED BY READERS DURING INTERVIEW

SCIENCE	FORMAL STUDY OF PLANT	PERSONAL EXPERIENCE OF PLANT IN NATURE	SAW PLANT AT XMAS
Reader 1	x		x
2			x
3			x
4		x	x
5			x
TESL			
Reader 1			x
2		x	x
3			x
4			x
5		x	x

When a reader made a remark such as "My mother pointed it out to me from the road," or "I studied this plant," the investigator expressed interest in hearing more about this experience. Readers were given equal opportunity to mention their prior background knowledge of the mistletoe plant but not specifically questioned about it. This decision was made in order to allow readers the greatest freedom in reporting their thoughts. TABLE 4 shows that the two groups' volunteered background knowledge of the mistletoe plant itself was very similar. TABLE 4 also shows that "scientific training" does not mean that one automatically possess clear and detailed information about everything in the natural world, nor does humanities training totally close the mind to appreciation of natural phenomena. At the end of the interview, one TESL reader who had only seen the plant at Christmas had not grasped that it is a parasite. One science reader was not completely sure.

Readers were encouraged from the first page to make explicit predictions of what content and direction the text would have. Since the subject read each segment aloud and commented before turning the page, the investigator could tell from comparing the subject's tape recorded comments with the text in the binder whether a comment was a prediction. All comments which included explicit predictions were collected and analyzed for common patterns. It was found that predictions could be divided into three general types; that is, predictions based on: (a.) previous, general botanical knowledge not explicit in text; (b) general knowledge of discourse development only; and (c) syntax only. TABLE 5 lists these prediction types and one or two examples of criteria used to place a prediction in a category. Successful and unsuccessful predictions were separated and counted by group.

TABLE 5: SUCCESSFUL AND UNSUCCESSFUL PREDICTIONS BY EXPLICIT USE OF PREVIOUS BOTANICAL KNOWLEDGE, DISCOURSE KNOWLEDGE, OR SYNTAX

SUCCESSFUL PREDICTION

PREDICTION TYPE	SCIENCE No.	TESL No.
a. Uses botanical knowledge of plant life not explicit in text "This is a parasite, and the tree is the host"	31	29
b. Uses discourse clues only "I assume this will explain *deciduous.*"	15	27
c. Uses syntax only "The next word must be a verb." "With a comma, it means there will probably be some other sort of qualifying statement."	8	8

(con't)

TABLE 5 (CONT):

UNSUCCESSFUL PREDICTION

PREDICTION TYPE	SCIENCE No.	TESL No.
a. Uses botanical knowledge of plant life not explicit in text "*the white.* flowers?" "*as they eat.* its red berries?" "I don't know how it's spread maybe by an insect, maybe by a virus?"	34	30
b. Uses discourse clues only "It's probably going to go on saying something about different types ofdeciduous trees." "Maybe it's going to relate the insects to the deciduous trees."	11	13
c. Uses syntax only "When it said *those*, I was still focusing on the mistletoe plant."	3	7

TABLE 5 shows that the background knowledge of the TESL group was equal to the task of successfully predicting material (and thereby indicating comprehension of the information). The TESL group made 61 correct predictions, while the science group made 54. The two groups made almost the same number of incorrect predictions; the TESL group making 50 and the science group 48. Both groups used botanical background knowledge most often to support a prediction. They used textual clues less often, and purely syntactic clues least of all. However, the TESL group's higher number of

successful predictions is a result of their higher reliance on textual clues, as shown in TABLE 6.

TABLE 6: GROUPS' PERCENT OF RELIANCE ON BOTANICAL BACKGROUND KNOWLEDGE VS.TEXTUAL CLUES IN MAKING PREDICTIONS

	Botanical Knowledge		Textual Clues	
Predictions	Science %	TESL %	Science %	TESL %
Successful	57	45	43	55
Unsuccessful	71	60	29	40

Although it is likely that the two groups, if given traditional comprehension questions after the reading, would have had approximately equal scores, a multiple choice test would have obscured the fact that for their successful comprehension, the TESL group was relying more on discourse clues (55%) than on botanical knowledge (45%), while the science group was relying mostly on botanical knowledge (57%) and secondarily on textual clues (43%). If, as seems reasonable, readers were experiencing the most difficulty while making unsuccessful predictions, the results show that in uncertainty, the science readers were relying heavily on botanical knowledge (70%), and the TESL group was strongly relying on textual clues (60%).

Besides explicit predictions, readers made inferences, or attempts like those previously suggested in Figures 2 and 3, to integrate schemata instantiated by single words. Inferences made during the think-aloud interview.were collected and grouped by the same method used for analyzing

predictions; that is, by listening for common patterns across individuals, giving the pattern a name, establishing criteria for inclusion of an inference in a group, and then rechecking to be sure that only clear instances of the type were included in the category. No attempt was made to shape or limit the categories according to predetermined logic or editorial convenience. Thus the patterns shown in TABLE 7 cover a wide variety of mental activities. They are listed according to decreasing frequency of use by the science group.

TABLE 7: COMPARISON OF FREQUENCY OF INFERENTIAL PATTERNS USED BY TEACHER GROUPS

INFERENTIAL PATTERN	SCIENCE No.	TESL No.
1. Volunteers additional information about the plant "It grows on oaks, particularly. I've never seen mistletoe growing on a conifer such as a Douglas Fir or Monterey Pine." "Mistletoe is actually a semiparasite."	29	5
2. Reasons deductively "The birds wouldn't have much reason to be with the mistletoe unless they were eating the berries."	24	6
3. Relates phrase being read to previous statements in text "*out tiny rootlets* - now it seems as though this is parasitic on other trees in some sense. Which was not clear from the first paragraph. I should go back and check that."	14	21
4. Explicitly asks self a question "Why would they wipe their beaks on bark? It just happens or they do that intentionally?" "*thrust up leaves* - I'm not sure whether the mistletoe leaves are coming up from the roots or if the process of the rooting is thrusting up and displacing other leaves." "Does it propagate itself? I don't know." "What does it mean by *extremely long life*'?"	13	13

5. Restates information in more general terms "The evolutionary advantage to the mistletoe now becomes fairly obvious - that allows it to spread over a larger geographical region."	12	7
6. Explicitly answers own question "I guess I'll just have to take that on faith - that they wipe their beaks on branches."	11	10
7. Shows awareness of scientific register "Now I'm sure it's scientific." "Here I expect a description of the plant." "This is aimed at a more introductory level."	10	8
8 Expresses frustration with interruption in syntactic flow "I can't say much about this, because it's one of those connectors and I don't know what it's leading to." "It doesn't mean much without an object in the sentence."	5	8
9. Injects personal anecdote, feeling "I first fell out of a tree trying to get the mistletoe." "My mother pointed it out to me." "I always worry about oak trees dying as a result of the mistletoe plant."	7	12
10. Associates plant with Christmas "When you celebrate Christmas, everyone's exposed to mistletoe plants."	5	5

11. Comments on own background knowledge "I'm not a botanist." "I don't know exactly how it grows." "I never thought about how it spreads from one tree to another or one part of a tree to another."	4	3
12. Restates information in more specific terms "It's a parasite type plant growing in association with other plants." "What a happy existence for the plant. It doesn't have any natural enemies."	3	7
13. Misreads, then corrects self "*one mistletoe ball was* established...oh, *estimated.*"" "*the mistletoe* tree *grows*...oh, *plant grows.*""	2	1
14. Creates an analogy "It's like having one mosquito flying around your head."	1	1

Of the fourteen types of inference that were clearly indicated in the data, seven types were used equally or very nearly equally by both groups (Patterns 4, 6, 10, 11, 13, and 14). Thirteen instances were found in both groups of individuals explicitly asking themselves a question. Almost the same number remembered their questions, and after reading more text, verbalized the answer. Therefore it can be tentatively concluded that during the process of reading comprehension, there is no difference in the tendency of science teachers and TESL teachers to use the text-interactive pattern of self-questioning and answering. Similarly, the two groups equally utilized

cultural background knowledge and knowledge of their own levels of expertise. The two groups self-corrected miscues and created analogies in equally small numbers.

There was a slightly greater tendency by the science group to use knowledge of scientific register, perhaps in order to make the odd text more recognizable as scientific writing and to proceed more comfortably with it. One science reader said, "It's hard to be specific when the text is broken up like this." The science group also showed a slightly greater tendency to be impatient with the fractured syntax of the text, noticing details that were responsible for impeding the flow of information. A chemistry teacher said, "If I could read the end of this, I'd know what it's about."

In contrast to the many similarities between the groups are the large differences found in Patterns 1 and 2, and the exactly opposite amounts recorded for Patterns 5 and 9. The science group used deductive reasoning far more often than the TESL group. The science group also restated text in general terms more often, perhaps as a function of recyling deductions. The TESL group tended more often to restate information specifically and to inject more personal associations into the comprehension process. The science group much more often volunteered general knowledge about the plant and plants in general than the TESL group.did. The additional facts volunteered about the plant were not always 100% accurate, but the science readers seemed to feel it was a natural part of their thought processes to keep adding and explaining information, building up a more complete understanding of the plant's system and place in nature than the text provided.

These quantitative results confirm the investigator's impressions of differences between the groups gathered during the period of weeks during which interviews were conducted. It seemed that the science group was doing more talking than the TESL group, even though the TESL group made more use of personal anecdote. The science group seemed to attack the reading task with more intellectual vigor, showing a strongly competitive spirit toward.solving the text's puzzles. The science group did not rush through the reading, immediately understanding everything, but actually seemed to linger longer over possibilities, make more hypotheses (right and wrong), and to volunteer more about why their hypotheses would be right or wrong. (Some science readers explicitly hedged their predictions; while this type of comment was not quantified, it did add to the investigator's sense that the science group was doing more talking). All science group members expressed the expectation that general points in the text would be followed up by detailed explanations; they expressed disappointment when the text did not provide these. At times they indicated what general type of information the further facts would probably provide.

The TESL group, on the other hand, showed knowledge, interest, and curiosity about the plant but did not pursue detailed knowledge of it with the same tenacity as the science group. They were more often silent. The TESL group seemed more concerned with fitting the fragments of text back into coherent order in their minds, as if when this was done, the puzzle would be solved and the cognitive difficulties would be over. This observation is supported by the finding that the TESL group relied more heavily on textual clues than botanical knowledge when making predictions (TABLE 6) and that

their most frequent inference type was to relate the phrase being read to previous statements in the text (TABLE 7, Pattern 3). The TESL group expressed less frustration with the unusual fragmentation of the text (TABLE 7 , Pattern 8) than the science group did, treating the experience more like a game of guessing what the text actually said than a game of finding out how the plant's life cycle works. One TESL teacher began making very astute predictions after saying, "Oh, it's going to tell me *unusual* facts about the mistletoe." This reader had caught on to something familiar about the text as typical TESL practice reading material. Pleased that predictions were going well, this reader did not question the unusual facts or try to deduce explanations for them.

The science readers who had the least specific knowledge of the plant, however, stated the premises of their deductions over and over, as if beginning again and again a mental process of sorting and cross-checking incoming fragments according to what was solid, if not complete, in their knowledge of basic principles of botany, and expanding the principles as necessary to account for the data. Most apparent to the investigator was the confidence science readers had in the power of deduction. It was as if they believed that going through the process itself again and again would eventually turn up the missing parts, and there was no shame in doing this again and again. The science reader with the most specific botanical background knowledge showed, with more ease, the same behavior, characteristically basing predictions and inferences on broad ecological principles which were cheerfully elucidated for the investigator. TESL group readers, on the other hand, did not seem to repeat, reason, and cross-check to

the same degree, but were more likely to say, "I don't know," and let things go at that. Even the TESL reader who through her father's influence possessed the most botanical background knowledge displayed keener interest in reconstituting the text than in learning details of the plant's life. This reader, expressing a strong love of nature, had moments of deductive reasoning that resembled the science group, but fewer of them. At the beginning of the interview, the reader volunteered the hope that the text would not be technical, saying: "I hate reading technical language. It takes longer. I like reading about scientific subjects, but I don't get the same sort of joy and wonder in technical language." This individual has awareness of what science readers do and think about but for personal reasons choses not to concentrate on this skill. The remark supports the investigator's observation that the science group were doing more talking; something about science reading "takes longer."

Summary of Interview Results

In the think-aloud interview, the two groups showed a clear difference in the importance they attached to building up a correct description of the plant's life cycle and putting this description in its place in the larger context of plant behavior. The science group used energetic deductive reasoning as its main tool to graft the scanty information of the text to known botanical principles. The TESL group paid more attention to rebuilding the text in its original form, using knowledge of discourse clues to jog its memory of isolated plant facts. TESL readers saw text breaks as a cross-word puzzle to be filled in, while the science group saw the breaks as occasions to access

botanical knowledge. The science group took pains to integrate every detail of the information into a systematic description, while the TESL group did not take the same degree of responsibility toward content. To state this observation in terms of schema theory: for the science group, a schema like parasite does not necessarily contain more associations than the same schema in the TESL group, but it does contain the imperative that all its variables must be bound to other schemata in scientifically plausible ways, that is, ways in which cause and effect, interaction and avoidance, are verifiable. The extra energy the science group showed seemed to be motivated by this imperative.

WRITTEN RECALL

As mentioned in Chapter 3 above, readers were given a blank sheet of paper and instructed, "Please write everything you remember about the mistletoe paragraph, in any form you wish." Comparison of subject recalls revealed clear differences between the two groups. The differences were not in the ability to remember per se, but in the underlying assumption of what remembering consists of and what it is for. The TESL group recalls, with one exception, were much more faithful to the original, with all its flaws, than were the recalls of the science group. The science group put more effort into correcting the flaws in the original by supplying key words (such as parasite, dispersal, hardy, extremes), providing more context, and superimposing a higher level organizational framework on the text as a whole and on individual sentences The recalls of the two groups are presented below, exactly as the subjects wrote them.

Science Group Recalls

Recall 1 makes the most extensive improvements over the original text:

Recall 1

The mistletoe is an extremely hardy plant which grows upon the bark of deciduous trees. Oddly enough, even though the source of the mistletoe's "vital nutrients" and water becomes dormant during the late fall and winter seasons, the mistletoe maintains it's growth. The mistletoe grows as a ball on the bark of trees and although it is not a true parasite, killing the tree on which it grows, it is a minor pest.

The manner in which mistletoe is dispersed is not affected by insects as is often the case. Instead, birds who feed off of the mistletoe carry seeds on their beaks to neighboring trees where new plantlets can develop. Initial, dormant seeds, can be maintained upon the barks on which they are deposited because of a sticky coat upon the seed surface. Once growth begins, the mistletoe plant is quite hardy - able to withstand harsh extremes of cold and heat. Furthermore, the period of growth of the mistletoe is extremely long (extending up to 400 years) so long as the tree on which the ivy grows remains alive also.

In addition to the changed order of introduction of main ideas, the subject has imposed higher level structure on individual sentences. The first sentence is in the form of a definition. The second sentence, containing the subordinating phrase, even though, is constructed to show an opposition to the usual state of affairs in life; that is, when nourishment is cut off, an organism dies. This sentence's introductory phrase, oddly enough, calls attention to the strong irony of this fact about mistletoe. The third sentence makes a plausible attempt to integrate the detail of the mistletoe ball. This sentence continues the pattern of contrasting the odd mistletoe with more

usual parasitic plants. The simple words, true and killing, help make the usual state of affairs perfectly clear.

Like all of the subjects, the science reader who wrote this recall was not told that writing would be part of the procedure. As mentioned in Chapter 3 above, the questionnaire was completed as a buffer between the think-aloud and recall. Thus, the reader had neither time nor motivation to preplan an essay. The improvements shown in the recall were made quickly and totally voluntarily. One of these changes is particularly interesting. The person wrote the phrase, "vital nutrients," in quotation marks, as if quoting from the original. In fact, the original text contains the phrase, vital minerals; the term, nutrients, subsuming everything that promotes growth in the plant, is not used in the original. This is evidence that the reader was, while reading, regrouping ideas from the text to pre-existing knowledge frames. The reader *thinks* that nutrients was *in the text*, but this more general term was in fact supplied by schema activation in the reader's mind during reading. This suggests that most, if not all, of the improvements made in the recall were being made at the time of reading.

In the second paragraph of this recall, the recall writer continues the pattern of reminding us of background information against which the odd nature of the mistletoe can be more clearly seen (i.e., insects pollinate plants, but not in this case). Concrete, non-technical terms such as neighboring, plantlets, coat, and harsh extremes, are introduced together with helpful, slightly more specialized terms such as dormant, be maintained, are deposited, and period of growth.

Recall 2 was written by a biology teacher. The three paragraphs of this recall each begin with a topic sentence stating a general truth; explanation and related details follow. The recall does not show a radical regrouping of ideas but introduces important schemata in the topic sentences, a strategy which permits more coherent integration of the original text's details. These new schemata are called into service by symbiotic, interacts with animal life, and adversely affects.

Recall 2

> Mistletoe is a symbiotic plant, that is it lives in a direct association with other plants - specifically it lives on deciduous trees. Mistletoe is dependant on the trees for water and minerals. It does nothing for the tree and it is only a minor inconvenience to the tree.
>
> Mistletoe also interacts with animal life. It is dependant upon the birds which eat its berries to carry its seeds to other locations (i.e. other deciduous trees or other branches of the same tree). Insects, on the other hand, do not eat off of this plant.
>
> Extreme weather conditions do not adversely affect the mistletoe. This heartiness and the lack of insect predators allow this plant to live a very long time. Individual plants have been estimated to be up to 400 years old.

Elaborations added in this recall are that the mistletoe does nothing for the tree and that the seeds may be spread to other deciduous trees or branches of the same tree. The reader mentioned these implications of the text during the interview, taking time in silence to consider before speaking. This reader made an obvious effort to see the plant as a system and as part of a larger ecology.

Recall 3 neatly condenses the material in a coherent paragraph while losing a few details:

Recall 3

> Mistletoe grows on deciduous trees which loose their leaves in the fall. Mistle toe flowers are eaten by birds & then the seeds (sticky) are dispersed as the birds move about. The plants are very hardy, impervious to extreme weather conditions and can live to be several centuries old. Although the plant is parasitic, relying on the tree for it's source of moisture & minerals, it does not stress the tree too much. Mistletoe produces its own energy & is able to live in a kind of equilibrium with the tree until the tree dies.

The condensation is helped by use of explicit terms not used in the original, such as dispersed, hardy, impervious, extreme, parasite, stress, produce its own energy, and equilibrium.

Recall 4, written by a mathematics teacher, boils things down even further:

Recall 4:

> The paragraph relates some elementary facts concerning miseltoe at about a third grade level. It stayed with information concerning reproduction longevity and effects on the host tree while about completely omitting a description of the plant under consideration.

This reader, who had had much personal experience with the plant, several times in the interview expressed disappointment with the text's rambling nature and lack of detail. In the recall, the person apparently felt no responsibility to do the original writer's work for him (or her).

Recall 5 has been reproduced below in order to show the vigor and variety of recall strategies the reader was using.

Recall 5

The misletoe grows on deciduous trees, those which lose their leaves in autumn. ~~It is white~~. Birds eat its white berries, then spread the seeds by rubbing their beaks on other branches.

~~It~~ is virtually indistructible to:
harsh winters + hot summers
insects
strong winds (does not blow off)

It does not harm the tree significantly

→ There it begins a new (long) life cycle. (some mistletoe balls estimated to be 400 years old.) It sends out tiny rootlets (which get water + vital minerals from the tree (and although not stated but implied) which serves as an anchor). The leaves contain chlorophyll (as do all green plants) to photosynthesize food (glucose -> not stated) for the m.

The person who wrote Recall 5 is a physics teacher who reported liking to read and write technical material but knowing nothing about mistletoe except as a Christmas decoration. The subject begins the recall with the exact words of the text. When his pen jumps ahead to white berries instead of the text's it is spread by birds, the subject abandons the effort to recall the exact text and rearranges the facts of seed dispersal in chronological order. He also changes the text's passive construction to an active one. He uses a listing method to recall the conditions that do not harm the tree and begins using parenthesis to show where he is interjecting his own words of explanation. This midsection of the recall, beginning It, lists properties of the plant. Having exhausted this recall method, the subject falls back on something like the exact words of the text, There it begins a new (long) life cycle, drawing an arrow to show that this is a continuation of information mentioned earlier. The arrow leading to the example of long life seems to have been added as an afterthought, as in the original text. The final, rapidly written lines of the recall show an intricate pattern that alternates language of the original text with reader contributions. By the last sentence, the subject is combining general principles of botany, The leaves contain chlorophyll (as do all green plants) with a shorthand almost like a formula, (glucose - not stated) for the m. The subject had said during the interview: "In my lectures I like to explain something right after I mention it. I don't like to just go on to the next thing with no explanation."

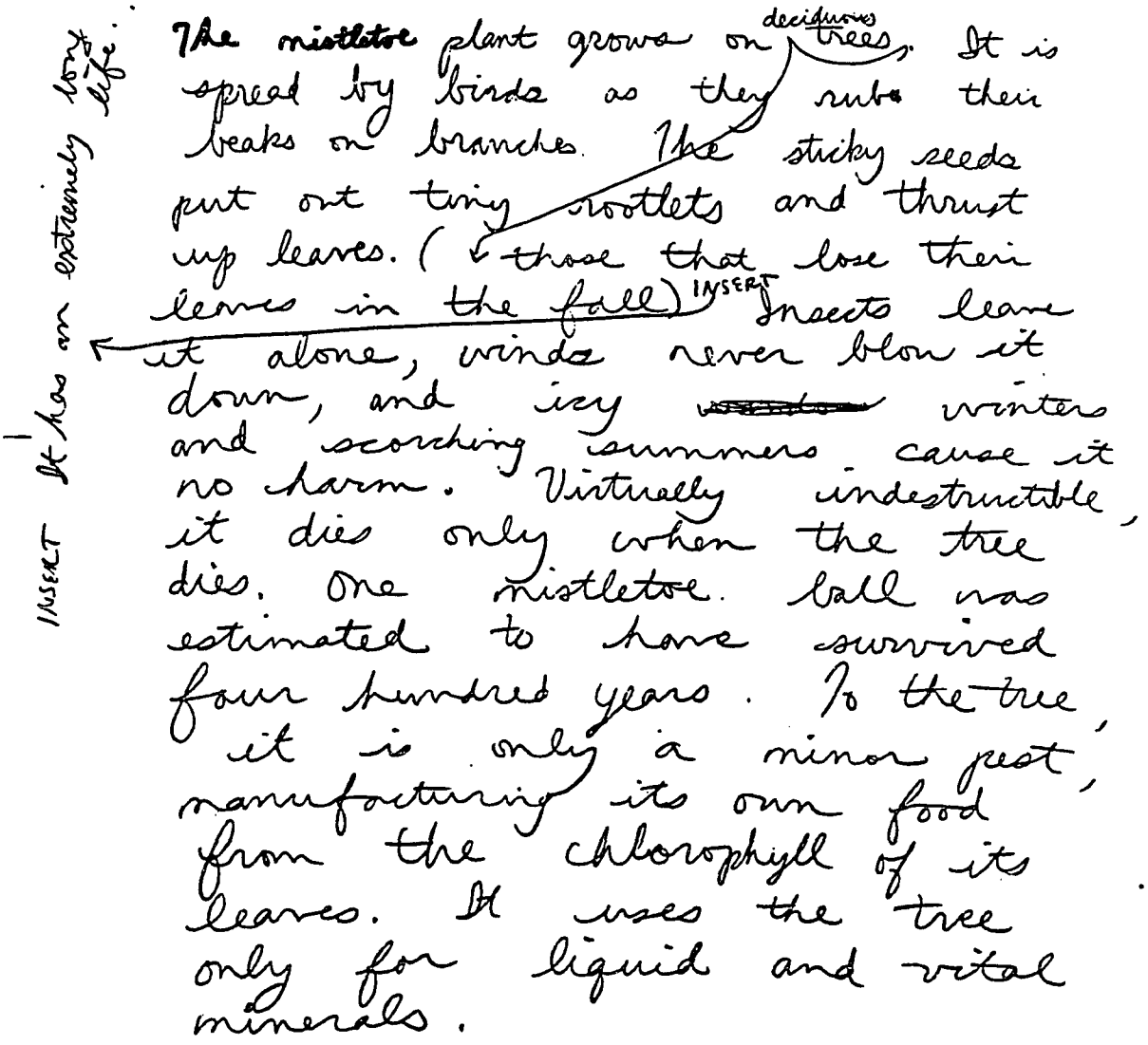
If it is true as claimed above that the science reader who produced Recall 1 must have been actively reorganizing and reintegrating information while reading, and because of this could write without strain a recall that actually

improved on the original, then it must also be true that Recall 5 shows a science reader in the very throes of comprehension, when exact text language is connecting with relevant schemata and coherence is being forged.

TESL Recalls

The most extreme examples of TESL reader recalls that attempt to make a perfect reconstruction of the text are shown below in Recalls 6 and 7.

Recall 6



Recall 7

The mistletoe plant grows on deciduous trees, those that lose their leaves in autumn. ~~It is spread by birds~~ who eat ~~its~~ white berries and ~~The birds~~ wipe their beaks on nearby branches. ~~birds~~ The seeds are spread by birds who eat ball The mistletoe ~~is~~ does not harm the tree. It is only a mild pest to the tree. The mistletoe is long-lived.

~~It is~~ Virtually the mistletoe is indestructible. ~~Scientists~~ One mistletoe was found to be 400 years old. It manufactures its own food from the chlorophyll in its leaves. It ~~only~~ uses the tree as a source of liquid and vital minerals.

These recalls have been reproduced as written in order to show the arrows drawn by the subjects. In both cases, the arrows begin where memory gaps begin. The arrows end at remembered phrases which serve to get the writer back on track. This could indicate that these readers were trying to recall the content of the text by recalling the linear order of its exact words. In both cases, however, once a memory gap has occurred, syntax is simplified. The sentence in Recall 7, Virtually the mistletoe is indestructible (it should be remembered that all the readers in the study are native speakers of English), may represent a conflict in this subject's memory between trying to reproduce the exact text and at the same time ease the difficult task by simplifying syntax. The original reads: Virtually indestructible, it dies only when the tree dies. At this place on the page, the subject has left space, as if sensing that something has been left out that may be remembered later. Also, the subject has crossed out a word that looks like scientists or science, as if starting to write, Scientists found a mistletoe that was 400 years old. This active mode structure was rejected in favor of the passive construction, One mistletoe was found to be 400 years old, which is closer to the original's One mistletoe ball was estimated to have survived four hundred years. It appears that the subject remembered the original text's phrase, was estimated to have survived, as was found to be and realized that if the sentence began with scientists, the verb found would take on a different meaning. Therefore, instead of writing something like scientists estimated that a mistletoe ball had lived 400 years, this subject, who was visualizing scientists in consciousness, edited them out of the recall. The person told the investigator several weeks later, "I remembered what I should have said about the mistletoe," apparently

meaning that the exact words had come back. These characteristics of Recall 7 suggest that this TESL subject strongly interpreted the task as one of pure language recall, and the person's mental apparatus kept searching for the trace of the original words even days and weeks later. This reader had had personal experience of mistletoe in nature and was well aware of botanical facts about it.

The TESL subject who wrote Recall 6 spent time in the interview visualizing birds and plants, but when writing, concentrated on getting the language right, only changing the original's autumn to fall and parching to scorching.

The following recalls (8 and 9) were written by readers who had more periods of silence during the interview than the science readers and who did not question themselves or use deductive reasoning nearly as much as the science readers.

Recall 8

> Mistletoe grows on deciduous trees. (trees that lose their leaves in Autumn. Birds spread mistletoe by eating it's white berries (wiping their beaks on nearby branches with the seeds falling to the ground and taking root.
>
> Mistletoe lives a long time one plant ball being over 400 years old. It can withstand parching summers and icy winters. It manufactures its own food chlorofyll and gets its water and minerals from the tree.

Recall 9

> The mistletoe plant grows on the branches of deciduous trees, those that lose their leaves in autumn. Its seed is carried by birds who eat its white berries and then spread the seed to nearby trees. The mistletoe is shaped like a ball. It gets its food out of its leaves and uses the tree as the source of liquid and minerals. The life span of the plant is about 400 years; insects and changes of the seasons do not do any harm to the plant, and it dies only when the tree dies.

Recall 8 introduces the familiar plant growth schema falling to the ground and taking root (perhaps an example of the "default setting" idea of Collins, Brown, and Larkin [1977]; that is, a reader's tendency to use the more common schemata first). This recall also imports the helpful phrases, withstand and manufacturing its own food. While writing, the subject expressed frustration several times at the contradiction in the facts he was presenting; that is, that the plant was rooted in the ground but somehow got nourishment from the tree. However, the subject was unable to reconcile the facts and gave up with a sigh, displeased with himself. Recall 9 uses the term, life span, and implicitly orders information from the birth to death of the plant. The person who wrote Recall 9 understood that the plant is a semiparasite but did not use the knowledge actively to clarify or integrate facts. This reader expressed disappointment with himself for not being able to remember everything.

The subject whose father was a science teacher produced Recall No. 10. This person has done some interesting rewriting of the original:

Recall 10

> The mistletoe plant grows on deciduous trees by attaching a rootlet to the tree branches so that the liquids and minerals from the tree can support the growth of the mistletoe. The mistletoe has a long life (several hundred years) and is virtually indestructible. It is only a minor pest to its hosts. It has a comfortable existence since it is not affected by winds or extremes of temperature

This recall moves the method of obtaining food from last place in order of ideas to the first sentence, where it is linked to the original's first clause by a cause/result relationship with admirable simplicity and clarity. The subtechnical terms, attaching and support, introduced by the subject, are accurate and helpful. The second sentence groups the three references to long life found in separate sentences in the original, showing that they mean essentially the same thing, with the exact number of years treated as a less important detail. Recall 10 omits the original's obscure reference to a mistletoe ball, and renders the cumbersome syntax of the original in much simpler form (compare: Virtually indestructible, it dies only when the tree dies). The third sentence introduces the important term, hosts, whose common meaning could probably be extended even by a novice reader to the already-established plant/tree relationship. The fourth sentence substitutes the more general idea, extremes of temperature, for the original text's bookish phrase, wintry ice and parching summers, and sums up the relationship with the accessible term, comfortable. Each previous sentence has provided information consistent with the idea that the mistletoe and the host tree live

closely and harmoniously for a long time. The result of these choices and changes is a paragraph that flows quickly and easily, has a botanically correct framework, and presents plant and tree in a sympathetic, interesting way. This TESL teacher has written, without any suggestion at all from the investigator, a paragraph suitable for use with beginning TESL students. The recall does not mention the death of the plants, sticky seeds, insects, parasites, or chlorophyll. Consciously or not, the TESL teacher has done the opposite of the science teacher who preferred to make an explanation of a phenomenon directly following its introduction into the discourse. The TESL teacher did not interrupt the initial picture of the plant with these explanations, which could be discussed in a second paragraph, if desired. Comparison of Recall 10 with Recall 1 shows that a sense of responsibility toward their respective students is a decisive factor in how these teachers recall the same information.

Summary of Recall Results

Each of the science group recalls shows a person taking responsibility for expressing the mistletoe information in a more highly organized and scientifically coherent way than the original does. To do this, the science group freely changed the original language to an enriched blend of general and specific information. In contrast, two TESL readers, quite capable of accessing helpful synonyms and writing in complex syntax, were delighted when they reproduced the text almost exactly. Two other TESL subjects felt they ought to have been able to remember more of the original and were disappointed in themselves. The passivity of the TESL readers who had

comprehension problems contrasts strikingly with the determination of the science group members who also had to struggle to make sense of the text. It was almost as though the TESL readers were operating under instructions not to tamper with the original but to confine themselves to rote recall, simplified condensation, or rewriting at a lower level of difficulty. Both groups acted as though their different approaches to the task were normal and necessary. At least one member of both groups showed that concern for their respective students influences the way they read, remember, and write.

CHAPTER 5

CONCLUSIONS

Systematic exploration of the reading behavior of the two groups revealed a number of obvious differences. Reading and recalling a TOEFL-level science paragraph, the science group actively processed the information in depth, supplied context, key words, underlying connections, and overall organization. The TESL group was less energetic in processing, omitted facts, simplified syntax, and preserved the original structure. These findings are consistent with Spiro's (1977) observation that some readers are more ego-involved in the reading task and show greater "effort after meaning" (Bartlett's term). The observation of Collins, Brown, and Larkin (1977), that readers solving a problem feel better when facts fit together "in more than one way" seems pertinent here; that is, the science readers were not satisfied with their understanding until they had looked at the plant system from different starting points and until the relevance of all the details had been located. For a science reader to have made a comment like one TESL teacher did - "They wipe their beaks on bark? I guess I'll just have to take that on faith," - would have been to admit defeat. If the birds do this, there has to be a reason.

Science readers took responsibility for solving the problems presented by the text, while TESL readers acted as if frozen by a prohibition against tampering with it in any way except simplification. Since both groups behaved as though their own approach was normal and necessary, it would

seem that training and repeated practice in science versus TESL teaching does have an influence on the way one reads.

Science involves transforming perceptions from one channel to another; for example, observations about the size and weight of an object are often changed into the symbols of an equation or the lines of a graph or diagram. Interaction among phenomena is expected (as one science reader said, "In nature, everything interacts; you can count on that"), and details may provide clues to larger relationships. Accuracy with words is obviously an important subskill, but preservation of the written word for its own sake is not.

In contrast, in linguistics and literature, the text is the object of study. Phonology makes use of spectrograms and formalisms, contrastive syntax needs meticulous demonstration, and sociolinguistics uses statistics to handle multiple variables, but these activities would not be possible without a language sample collected and preserved with great care. Literary expertise, too, depends on acute sensitivity to a given text; for example, being able to detect whether a newly found sonnet was written by Shakespeare or not.

Besides the different values the two groups probably attach to the term "text," they are also different in the way they use their training in the classroom. If the science teachers in this study can be considered typical, they are clearly encouraging vigorous scientific thinking in their students by modeling it. In TESL work, however, instructors with linguistic training use it indirectly to create a suitable environment for language acquisition. It is considered ineffective to force ESL learners to be little linguists; one's natural tendency to pass on what one has studied must be fought, sometimes by downgrading theory itself. Thus in the experiment, it was appropriate for the

science teachers to display their knowledge and for the TESL teachers to suppress it.

The literature of science education contains many discussions of the thinking skills to be developed in the science classroom. In one such study, Peltzer (1988) surveyed physicists to find the intellectual factors they believed to be most important to physics students. The four most important abilities were found to be: (a) logic, (b) math, (c) problem solving, and (d) spatial ability (in that order). This list can be intimidating to TESL teachers whose training has not emphasized them, especially if they are seen as static (perhaps God-given) chunks of knowledge. However, Peltzer's purpose was to locate skills that could be encouraged and remediated from the earliest grades; thus they are not irrelevant to language teaching. Two specific skills Peltzer isolated involve implications and inference; here is a connection between science and TESL objectives. The physics skills are:

> 1. To evaluate the conceptual implications drawn from a premise.
> Example: Judging if an explanation of a phenomenon makes sense.
>
> 2. To infer many different possible consequences of a symbolic structure.
> Example: Writing down many different possible solutions to a general equation. (p. 725)

These two formulations of thinking skills suggest the same differences in reading styles between the two groups observed in this investigation. First, in science reading, one cannot proceed without trying one's best to solve the contradiction, for example, of a plant with roots in the ground getting its nourishment from the branches of a tree. This description of the plant's

system does not "make sense" because it contradicts known principles of cause and effect that allow the natural world to function as it does. Effort must constantly be made to bind the schemata of background knowledge and text signals in an organic, multidimensional way.

Secondly, to arrive at the right connections, inferencing must be done. In ESL reading, "inferencing" usually means making connections not explicitly stated in the text and drawing a conclusion. The science skill (2) quoted above, however, says consequences, not conclusion. This describes precisely what the investigator observed the science group doing. For them, an inference was not complete just because it reached a conclusion. That conclusion itself was something that influenced other parts of the explanation and set off changes throughout the whole. Therefore, an inference is not an ending but part of a continual visualization process. Consequences have to be checked to see if their reverberations "make sense;" verifying the correctness of each instance of schemata binding requires testing the whole network of information. The science group relished this activity, but it also may be the reason why the TESL reader said that technical reading "takes longer."

Science education research shows that teachers try to reach all students, but only a few students succeed, with the majority remaining laypeople. Apparently because of training and experience, the TESL group in this study identified themselves so strongly with the lay culture that they felt constrained to avoid using science thinking skills which they may actually possess. The investigator can only speculate about this, but in the TESL group

there was definitely a taboo against talking about principles of plant life, shown by polite avoidance.

As mentioned in the Introduction, at one time Widdowson was interested in incorporating the teaching methods of science into EST but changed his position. Currently a gulf separates mainstream ESL researchers like Spack, who feel that specialized knowledge is not an TESL responsibility, and those few intrepid EST practitioners who tackle the discourse of professional journal articles and experience disappointment (Selinker 1979, working with a university informant on genetics reading). TESL practioners and theorists apparently think joining in the culture of science is unnecessary, undesirable, very difficult, or not even permitted.

This investigator hopes there is a middle ground between avoidance and doom where TESL views of reading and thinking skills can be compared with the realities of the beginning science class or technological workplace. The very assumptions cited earlier in this study, for example, appear somewhat different to the investigator after completing it. For example, Rumelhart's characterization of schemata being "like theories - informal, private, unarticulated" may be misleading when applied to schemata processing by science-trained readers. Also, the notion that readers sample text to reduce uncertainty may very broadly be true, but for the science reader, every word is heavily loaded with implication, and nothing should be overlooked. The research results raise new questions, such as whether pragmatics and the cooperative principle have a different sense in scientific discourse, and, on the practical side, whether the TESL reading teacher's beloved skill of separating the main idea from trivial detail might need rethinking in science

material. Above all, the investigator hopes that TESL teachers working with science learners do not assume that their only job is simplification or that simplification alone makes meaning accessible.

To gain insight into tacit TESL assumptions about reading and learning, collaboration with content area teachers is necessary. The notion of schemata is helpful in this effort. It directs attention away from over-reliance on words and text-surface features to the basic knowledge and thinking skills learners must have to process language. It reminds us that science, or any subject that we don't know much about, is not a minefield of isolated facts but a garden party of schemata reaching out for connection. The investigator found in experimental interviews that science teachers were as anxious to ask as to answer questions that strengthened connections or added to existing knowledge. If TESL teachers approach the potential collaborator with the same friendliness and deference used toward acquaintances from foreign cultures, and if they show as much delight in learning something new as science teachers seem to do, interdisciplinary studies like this one will be more frequent, enjoyable, and educationally useful.

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AGREEMENT TO PARTICIPATE IN RESEARCH
SAN JOSE STATE UNIVERSITY

Responsible Investigator: Carolyn H. Baker

Title of Protocol: Schemata in Scientific Discourse (M.A. Thesis in Applied Linguistics)

As a participant in the reading research study being conducted by Carolyn Baker, I will read aloud a paragraph of informational text. The material has been specially prepared in booklet form so that only a few words at a time appear on a page. After I have read a page and before I turn to the next one, the investigator will ask me my understanding of the incomplete information I have read. She will ask me to describe my mental process of reading comprehension in my own words, and I will do this as fully as possible with her guidance. When the reading is completed, I will fill out a questionnaire containing general questions. The procedure, taking about one hour, will be tape recorded. It will be scheduled according to mutual convenience.

The procedure is not a test of my ability to understand the text, my reading speed, or reading level. Its purpose is to study the reading comprehension process. The results of the study will be used to understand in more depth the tasks faced by teachers of English as a Second Language, and it is hoped, to improve the quality of their teaching.

There is no known risk to me in this procedure. Because I will be reading more slowly than usual, there may be slight discomfort or confusion at the beginning. A small pilot study showed that other participants soon adjusted to the procedure and from it gained some interesting new knowledge of their reading comprehension processes. I will also benefit by making a contribution to Applied Linguistics.

My questionnaire and the tape recording of my interview will be identified only by number, so that my specific contribution is kept strictly confidential. I may choose not to be in the study or decide to drop out of it at any time without prejudice to my relations with SJSU. If I have questions about the study I may call Carolyn Baker at (415) 653-6360. If I have complaints, I may call Denise Murray, Ph.D. at (408) 924-4443. For questions or complaints about research subjects' rights, or in the event of a research-related injury, I may contact Serena Stanford, Ph.D., Associate

Academic Vice President for Graduate Studies and Research, at (408) 924-2480. A copy of this consent form has been given to me to keep.

My signature indicates I have read the above information and decided to participate.

_____ _____

Date Signature of Participant

_____

Signature of Investigator

Identification No. _____

Reading Research Questionnaire

What was your undergraduate major? _____

In what fields have you done graduate work? _____

_____

Did you change majors or fields at any time? _____

Please briefly explain why you changed: _____

_____

What is your occupation or occupational goal now? _____

What is your specialty? _____

What do you read for pleasure? _____

Please read the following statements and check the box that best describes your first reaction to them

1 The value of theory is its application to practice.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

2 Many important decisions about Star Wars systems depend on information that does not yet exist.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

3. I enjoy sharing information with researchers outside my field.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

4. I don't enjoy reading technical publications.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

5. Most of my friends are scientists.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

6. Popularization of science (e.g. Carl Sagan) is good for society.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

7 I like to write/edit/review technical material.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

8. Creating new life forms (e.g. gene splicing) will upset the balance of nature and we will never be able to recover it.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

9 Ambiguity is not my cup of tea.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

10. Scientific knowledge will bring about a better world
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

11. I'm more interested in myths than mechanisms.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

12. Scientists are good conversationalists.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

13. The scientific method is the only valid research methodology
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

14. I think of myself as an empiricist.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

15. Nothing new has ever been invented.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

16. Scientific discovery (e.g the ring and moon system of Jupiter is continually evolving) is more important than technological innovation (e.g new way to recycle aluminum)
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

17 Scientists are not more rational than other people.
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

18 In the search for truth, the subconscious is indispensible
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree

19 Research into language learning is confused because it considers too many variables
☐ strongly agree ☐ agree ☐ undecided ☐ disagree ☐ strongly disagree