Comprehension of Science Texts: Effects of Domain-Specific Knowledge and Language Proficiency

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This thesis is dedicated to

my father, ChuanRen Zhou and
my mother, Zhangfa Chen

献给父亲周传仁,母亲陈璋发

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Abstract

This study focused on the comprehension and cognitive processing of texts in biology by 36 graduate science students for whom Chinese was their first (L1) and English their second language (L2). The students in the study were from two disciplines: one in biology, and the other in engineering. These groups were subdivided into less proficient L2 (i.e., low-intermediate to intermediate) and more proficient L2 group (i.e., high-intermediate to high). From the perspective of a stratified model, the study examined L1 and L2 comprehension of general biology texts. Specifically, it investigated the effects of readers' domain-specific knowledge and language proficiency on various levels of discourse processing. It also examined two methodological issues: the effects of language of recall on processing of semantic and syntactic information from the L2 texts and the validity of using self-rating of text difficulty or content familiarity to index background knowledge.

Domain-specific knowledge was found to affect every aspect of comprehension of semantic information that was assessed in the study for both the L1 and the L2 texts. It also affected efficiency of processing for the L2 texts. Language proficiency, on the other hand, consistently affected lower-level processing. However, it appeared to have few concomitant effects on processing of semantic information. These results were consistent with predictions from stratified models of discourse comprehension in which processing of syntactic and semantic information are viewed as being both multilevel and modular. The results of the study also suggest the importance of investigating background knowledge in content-specific terms. Although the science students generally were comparable both in their knowledge of science text structures and in their patterns of comprehension of different types of semantic information, this comparability did not result in comparable comprehension. Rather, comprehension depended heavily on domain-specific knowledge.

With reference to linguistic distance, the results of this study suggest that caution is needed in applying conclusions drawn from studies of speakers of languages of the same Indo-European family to speakers of languages of greater linguistic distance such as Chinese and English. The lack of production effects observed in this study may be due to differential processing of syntactic information as well as differential processing strategies that many readers reported to have used with different language conditions. Finally, the general discrepancy between perceived text difficulty vs. comprehension and efficiency of processing as assessed by the objective measures suggests caution in using self-rating of text difficulty or content familiarity to index background knowledge.

Résumé

Cette étude a porté sur la compréhension et sur le traitement cognitif de textes de biologie par 36 étudiants diplômés pour qui le chinois était leur langue première (L1) et l'anglais était leur langue seconde (L2). Les étudiants de cette étude provenainent de deux disciplines: la biologie et l'ingénierie. Chacun de ces groupes était subdivisé en deux groupes, les moins compétents L2 (i.e., niveau faible-intermédiaire à intermédiaire) et les plus compétents L2 (i.e., niveau élevé-intermédiaire jusqu'à haut). Dans le cadre d'un modèle stratifié, l'étude a examiné la compréhension de textes généraux en biologie par L1 et L2. Plus précisément, elle analysait les effets de la connaissance d'un domaine spécifique et ceux de la connaissance de la langue sur différents niveaux du traitement du discours. L'étude a également examiné deux questions méthodologiques, d'une part, les effets de la langue de rappel sur le traitement des informations syntaxiques et sémantiques dans les textes L2 et, d'autre part, la validité des jugements émis pour les sujets par évaluer leurs connaissances préalables.

Les résultats ont montré que la connaissance d'un domaine spécifique affecte tous les aspects de la compréhension d'informations sémantiques qui ont été évalués dans l'étude, à la fois pour les textes L1 et L2. Celle-ci affecte également du traitement pour les textes L2. La connaissance de la langue, en revanche affecte de manièré importante les traitements effectués par les processus de bas-niveau. Cependant il semblerait, qu'elle ait peu d'effet en parallèle sur le traitement des informations sémantiques. Ces résultats sont compatibles avec les prédictions des modèles stratifiés concernant la compréhention du discours dans lesquels les traitements des informations sémantiques et syntaxiques sont considérés comme s'effectuant à la fois sur plusieurs niveaux et de façon modulaire. Les résultats de l'étude suggèrent aussi l'intérêt qu'il y a effectuer des recherches sur les connaissances préalables en termes de contenu spécifique. Bien que les étudiants en sciences étaient généralement à la fois comparables dans leur connaissance de la structure des textes scientifiques et dans leurs patrons de compréhension de différents types d'informations sémantiques, cette similarité n'a pas donné lieu à une compréhension comparable. Au contraire, la compréhension reposait fortement sur la connaissance spécifique du domaine.

En ce qui concerne la distance linguistique, les résultats de cette étude suggèrent qu'il faut être prudent lorsque l'on veut généraliser des conclusions résultant d'études réalisées avec des lecteurs de langues provenant de la même famille Indo-Européenc à des lecteurs parlant des langues qui manifestent une plus grande disparité linguistique, comme par exemple le chinois et l'anglais. L'absence d'effets de production observé dans cette étude peut être dû au traitement différentiel des informations syntaxiques ainsi qu'à des stratégies de traitement différentiel que beaucoup étudiants ont rapporté avoir utilisés dans des conditions de langues différentes. Enfin, l'absence de correspondance générale entre la difficulté perçue des textes et la compréhension et l'efficacité des traitements évaluées par des mesures objectives, suggèrent qu'il faut être prudent l'orsque l'on utilise les jugements des sujets pour évaluer leurs connaissances préalables.

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Chapter One

Introduction

Reading constitutes a major part of schooling, especially at the university level where acquisition of knowledge is dependent upon written texts. For university students, a key source of new knowledge in domains of science, for example, is often in the form of textbooks, reference books, periodical articles and lab manuals. Through reading the texts, the readers are expected to either develop or review concepts on their own. Unfortunately, many readers have difficulty in understanding and acquiring knowledge effectively and efficiently from texts. This problem is often more pronounced for bilinguals reading in their weaker language. Bilingual students have often been found to read second language (L2) texts considerably more slowly and with less understanding than texts written in their first language (L1) and, as compared to native speakers. Consequently, many bilingual students experience difficulty with academic curriculum content. For instance, high correlation has been found between language skills and problem solving (Krulik, 1980) and grade point average (Mestre, 1981). Thus, one is confronted with the need to determine the cause(s) of comprehension difficulties for L2 texts in such populations of students.

Although to some researchers, especially many in the L2 area, comprehension difficulties are due mainly to linguistic deficiency, successful text comprehension has come to be viewed as dependent not only on speedy and accurate processing at the lexical and syntactic levels, but also on the conceptual and semantic model of the text that the reader builds (e.g., van Dijk & Kintsch, 1983; Frederiksen & Donin, 1991; Stanovich, 1986). The reader's model is based in part on specific aspects of the text and in part on the knowledge that the individual already possesses concerning the topic, the situation, etc. Thus, to investigate bilingual comprehension processes, one has to determine how readers' prior knowledge in a particular domain and their language proficiency affect comprehension processes at multiple levels for authentic texts such as science texts typically found in textbooks.

Assuming the process of comprehension to be both multilevel and modular, current theories of discourse comprehension such as stratified models of discourse (e.g., Frederiksen & Donin, 1991) suggest the need to simultaneously examine processing at the lexical and syntactic levels, and at semantic and higher conceptual levels. These models also make it apparent that multiple levels are crucial to L2 discourse comprehension (Donin & Silva, 1993). Stratified models may also be used as a basis for making hypotheses about the causes of comprehension difficulties and L1-L2 differences in comprehension. Only when reading processes are better understood, can one make inferences about how a text is processed and what the causes of reading difficulties are. Such knowledge will not only help to improve language instruction and diagnosis of reading problems but it is also crucial for developing texts to be better comprehended by both non-native and native speakers.

As discussed in the next chapter, until very recently, advances in theories of discourse comprehension have not been weli reflected in L2 research. In addition, many cross-language studies have been methodologically flawed. One source of difficulty in either interpreting or generalizing results found in cross-language studies is related to "linguistic distance." Most North American bilingual research has focused on languages that are members of the same Indo-European family, such as Spanish and English or French and English. A question arises as to whether conclusions based on these studies are applicable to individuals speaking languages of greater linguistic distance such as Chinese and English. Comprehension processes, including the comprehension-production gap observed in studies of speakers of languages from the same Indo-European family, may not be the same for people with very different linguistic backgrounds. Another methodological concern is related to the validity of comprehension studies that used self-rating of text difficulty or familiarity to index knowledge in a content area. Unless self-rating of text difficulty or content familiarity was consistent with objective measures of either content knowledge or performance on comprehension tasks, the interpretability of these studies remains in question.

Despite the theoretical and methodological limitations that are often found in much of the current cross-language research on comprehension and cognitive processing of texts, cross-language research has the potential to provide insight not only into second-language comprehension but also into comprehension processing in general. An advantage of cross-language discourse comprehension studies is that by comparing bilinguals' comprehension of texts written in their first to those in their second language, important information can be gained about the ways in which the added linguistic demands affect comprehension processes. Since such comparisons can be made within subjects, one could examine possible effects of linguistic knowledge without being burdened by various kinds of "undesired" reader variability resulting from using between-subject designs. This, in turn, can lead to greater knowledge about the intricate relationships between higher conceptual knowledge and processing and linguistic knowledge and processing as they contribute to comprehension in the unilingual as well as the bilingual situation.

The present study was intended to contribute to a better understanding of the cognitive processes involved in bilingual comprehension of science texts in Chinese and English. The study examined L1 and L2 comprehension of native Chinese speakers from the perspective of a stratified model. Specifically, it examined the effects of graduate science students' domain-specific knowledge and their language proficiency on multiple levels of discourse processing. It also studied two methodological issues: the importance of linguistic distance between first and second language and the validity of self-rating of text difficulty or content familiarity.

Chapter Two

Literature Review

Developments in Reading Comprehension Research

Until the early 1980s, L2 research focused almost exclusively on lexical and syntactic processing (Larsen-Freeman, 1980). Much work in the area today still bears the influence of the generative transformational-grammar paradigm which focuses on phonological, morphological, lexical, syntactic and semantic structures of isolated, context- and text-independent sentences. While identifying sentence-level linguistic processing skills is necessary to the understanding of comprehension processes, one has to realize that it is important to examine the consequences of deficiencies in such lower-level processing on the conceptual and semantic processes that are required to understand a text as a whole. Without an understanding of how lower-level processing affects conceptual and semantic processing, one cannot understand the cognitive principles underlying most of the reported L2 reading difficulties, or the potential effects of differences in syntactic structures across languages (i.e., from L1 to L2) on L2 text comprehension. More importantly, studying the decoding of isolated words or the processing of the syntactic structures of isolated sentences does not satisfy the goal of understanding the cognitive processes required for comprehension or acquisition of information from connected texts.

A classic study by Sachs (1967) demonstrated that native speakers' recognition memory for the semantic features of utterances was superior to their recognition memory for the syntax. In addition, unlike what syntax-centered theory would predict, syntactic simplicity, under certain circumstances, may decrease text cohesion and thus impede comprehension. For example, an early study by Pearson (1974) showed that children recalled more complex texts better than simplified ones. Their enhanced comprehension may have been due to the fact that the richer semantic information in the more complex texts was more likely to be picked up by the readers, thus enabling them to relate this information to their knowledge about the text content. Such prior conceptual knowledge, in turn, would enable them to better allocate their limited processing resources during reading.

The limitation in understanding reading comprehension that is imposed by an approach that examines words and sentences in isolation, however, had not been brought to researchers' attention until the 1970s. Since then, linguists, psychologists, computer scientists, sociologists and others have looked beyond the traditional sentence boundary to explore the area of discourse comprehension --- a new integrated discipline which situates processes of linguistic analysis within rich and authentic contexts of discourse structures and conceptual knowledge.

First Language Processing

Semantic Models of Discourse Comprehension

Current semantic models in discourse comprehension have been influenced by the development of case grammar in linguistics (Fillmore, 1968; 1971) and the concept of semantic networks in artificial intelligence (e.g., Quillian, 1968; Simmons, 1973). As an alternative to the then prevailing psycholinguistic models that were influenced by syntactic theories (e.g., the generative grammar of Chomsky, 1957) which assumed that syntactic representation was central to language understanding, cognitive models of the semantic structure of information were developed in the 1970s (Anderson & Bower, 1973; Frederiksen, 1975; Kintsch, 1974; Meyer, 1975; Norman & Rumelhart, 1975; Schank, 1975). These models assumed that propositions are the basic semantic units of language processing.

A proposition, as the smallest unit of knowledge that can stand as a separate assertion (i.e., it can be either true or false), represents only the literal meaning, not the surface form, of a sentence. For example, suppose a reader recalls "remove the lymphocyte cells from the mouse." This sentence would be represented in two propositions:[1]

PROPOSITION(EVENT(PROP.NUMBER (1.1) ACT (remove) OBJECT.RELATION (1.2) SOURCE.RELATION(SOURCE (OBJECT (mouse DETERMINER (Definite NUMBER Singular))))) TRUTH.VALUE (Positive)))

PROPOSITION(STATE(PROP.NUMBER (1.2) STATE.OBJECT (OBJECT(cell DETERMINER (Definite NUMBER Plural)))) ATTRIBUTE.RELATION.STATE(ATTRIBUTE.STATE (lymphocyte)) TRUTH.VALUE (Positive)))

Suppose another reader's recall is "the lymphocyte cells will be removed from the mouse." This would be represented in the same way as the two propositions listed above, except for the tense slot. Although these two sentences vary in their expressions, it is assumed that the psychological result is similar: two propositions are stored in the readers' memory, with no tense in one case (since it is embedded in a requestive frame) and a future tense in the other. The examples given here also show that a single sentence may be stored in the memory in the forms of multiple propositions. Propositions, on the other hand, may be expressed by different sentence forms. For example, the propositions

PROPOSITION(STATE(PROP.NUMBER (1.1) STATE.OBJECT (OBJECT(baby DETERMINER (Definite NUMBER Singular)))) ATTRIBUTE.RELATION.STATE(ATTRIBUTE.STATE (lovely)) TRUTH.VALUE (Positive)))

PROPOSITION(STATE(PROP.NUMBER (1.2)

---

[1]The model and methodology used here as well as in the later chapters were developed by Frederiksen and his collegues (Frederiksen, 1975; 1986; Frederiksen & Donin, 1991; Frederiksen & Stemmer, 1993).

STATE.OBJECT (OBJECT(baby DETERMINER (Definite NUMBER Singular)))) ATTRIBUTE.RELATION.STATE(ATTRIBUTE.STATE (happy)) TRUTH.VALUE (Positive)))
can be expressed as the following four sentences:

1) The baby is lovely and happy ;

2) The baby is happy and lovely;

3) The baby is lovely;

4) The baby is happy.

They may also form part of a sentence such as "The lovely, happy baby ..." Thus, the propositional representation is clearly distinct from surface forms. This separation of semantic representation from syntactic form allows one to represent meaning independently from particular linguistic forms that express that meaning. It also allows one to explore how meaning is derived, often on the basis of propositions encoded in connected discourse. Another consequence of the independence of propositions from surface forms is that propositional analysis can provide a powerful tool for analyzing comprehension. Propositional analysis can be used to solve the problem of comparability of texts not only within a language but also across languages. Effects of lexical and syntactic differences can be studied when the analysis of propositional information is used to equate the text content. This is because, in propositional analysis, what matters is what semantic content is represented by the surface forms rather than the surface forms themselves. Over the years the psychological validity of propositions has been well established. Although it has been repeatedly shown that syntactic complexity determines comprehension, it has also been observed that comprehension is related to semantic features of the text such as propositional complexity (Kintsch & Keenan, 1973; Renaud & Frederiksen, 1988; Frederiksen & Donin, 1991).

Among semantic theories of propositional representation, some were intended particularly for psychological research on discourse comprehension. Representative of semantic theories for psychological research on discourse comprehension are Kintsch's (1974) and Frederiksen's (1975) systems. Both systems are text-based and both presuppose general text-processing abilities, such as interpreting the propositional content of sentences and making inferences (e.g., involving anaphora, pronominal references and cohesion of a text), that are applicable to all texts. However, in Kintsch's system (1974) a proposition, which is defined in terms of one predicate and one or more arguments, is related to other proposition(s) according to its text-base. Frederiksen (1975), on the other hand, defines a proposition in terms of a unitary semantic network, i.e., the smallest identifiable meaning unit which is related by logical, dependency and algebraic and other relations to other proposition(s) within a semantic network. Although these two systems are both applicable to a wide range of texts, Kintsch's system has been criticized for its lack of specificity and precision (Lachman & Lachman, 1979; Tierney & Mosenthal, 1980).

The problems associated with specificity and precision are not seen in Frederiksen's propositional system which defines propositions by means of a context-free grammar. On the contrary, Frederiksen's system is considered more detailed and comprehensive (Beaugrande, 1980), and consequently is very useful in specifying variables to be examined through measure(s) of comprehension. Such detail is particularly relevant to situations in which it is important to diagnose difficulties in understanding texts, especially in a second language where one has to examine not only the general understanding of the text, but also specific aspects of processing (e.g., drawing anaphoric relations) which have been found to affect comprehension (Clark, 1977; Keenan, Baillet & Brown, 1984; McKoon & Ratcliff, 1980; Ortony & Anderson, 1977). The system also enables researchers to closely examine a reader's precision in representing certain types of propositions and propositional relations, such as states and relations, which are often required in understanding science texts.

Although text-based theories of comprehension have successfully specified propositional representations as well as inferential operations, they alone do not explain why a reader's recall of a text may contain particular types of inferences but not others (e.g., Anderson & Ortony, 1975) and how unfamiliar, complex and novel semantic structures can be understood (Frederiksen & Donin, 1991). It seems evident that in comprehending text, people are not only engaged in text-based processing but they are also guided by context-based sources of information. Comprehension, based on the role of various text structures and the comprehender's prior knowledge structures, is now widely viewed as a constructive process (e.g., Bartlett, 1932; di Sibio, 1982; Spiro, 1980). In other words, instead of passively storing and later retrieving information from a given text, incoming information is actively interpreted in the context of the reader's existing knowledge. The classic work of Bransford and Johnson (1972) demonstrated that a vague opaquely written text, which in isolation seemed meaningless, became comprehensible and easily recalled when an explanatory picture or a title preceded it. Other researchers have also provided evidence of the impact of background knowledge on comprehension. For instance, developmental studies (e.g., Chi, 1978; 1981) have shown that children, who possess relevant prior knowledge, can outperform adults when the latter are lacking pertinent background knowledge.

Schank and Abelson (1977) postulated that in order to behave in and interpret certain stereotypical situations efficiently and effectively, people have to acquire and utilize some common relevant existing knowledge for sequences of events. They called these knowledge structures "scripts". Other parallel theories of processing in which high-level conceptual structures are constructed by using semantic information from various external sources and prior knowledge existing in memory include frame (Minsky, 1975) and schema theories (Rumelhart, 1975; Rumelhart & Ortony, 1977). These models of knowledge structures, although they have their own distinct characteristics, are presently used interchangeably, that is, they are all used to explain how people use their existing knowledge in the process of comprehending new information.

Levels of Processing

Early cognitive theories had a strong tendency to describe text comprehension processing as a series of discrete stages, that is, either as primarily "bottom-up" (Geyer, 1970, Gough, 1972; LaBerge & Samuels, 1974) or "top-down" (Goodman, 1967; 1973; Hochberg, 1970; Neisser, 1976; Smith, 1973). According to the "bottom-up" approach, text comprehension starts with graphic input and progresses through a series of successively higher-order processing stages until meaning is derived. The "top-down" approach, on the other hand, considers comprehension as driven mainly by readers' prior knowledge which generates meaning hypotheses based on contextual information. It is now well established that these two approaches either fail to account for many empirical results in the reading literature, as in the case of the bottom-up models (Danks, 1978); or they are excessively vague in their conceptualization, as in the case of top-down models (Mitchell & Green, 1978; Frederiksen, 1989). Thus some researchers have been led to believe that comprehension proceeds in both a top-down and a bottom-up manner and that comprehension is an interactive rather than a serial process (e.g., Adams & Collins, 1977; Lesgold & Perfetti, 1978; McClelland & Rumelhart, 1981). More recently, theories of discourse comprehension, such as the stratified model of discourse comprehension, view the comprehension process as both multilevel and modular (e.g., Frederiksen & Donin, 1991). The component processes of a stratified model as specified by Frederiksen and Donin (1991), which emphasize multiple semantic representations and processing operations associated with them, are as follows:

(1) Processing of natural language structures in terms of morpho-lexical processing and syntactic analysis;

(2) Processing of propositional meanings in terms of semantic interpretation, micro-propositional inferences and contextual inferences;
(3) Conceptual processing in terms of integration of propositions, frame generation and inference and, frame integration.

According to this model, processing at the various levels occurs in parallel. However, representation at higher levels of the system may be generated from those produced at the levels immediately below it. Specifically, the representation at lower levels influences those at the higher levels by means of the data they output. In addition, higher conceptual level processing may also affect processing at the local semantic levels and subsequently may affect processing at the local syntactic levels. Although they differ in many aspects, especially in their postulation of the relationships between various component processes, stratified models, interactive models and serial processing models of discourse comprehension share a common feature: they all include component processes for both semantic and syntactic information. Some of the controversy about the relationships among various component processes, therefore, may be resolved if one simultaneously examines processing at semantic and syntactic levels (Frederiksen & Stemmer, 1993). In this case one should utilize models that do not limit themselves to any particular level(s) of processing and are flexible enough to capture readers' influence. Stratified models are one example of this kind of model. With a stratified model of discourse comprehension one can simultaneously examine processing at the lexical and syntactic levels, local semantic levels and higher conceptual levels, all of which are crucial particularly to L2 text comprehension.

Second vs. First Language Processing

It is clear that in the past 20 years, reading comprehension research has shifted towards emphasizing the central role of semantic representation. Within various frameworks of discourse comprehension, thousands of L1 studies have been conducted and our understanding of cognitive processes underlying unilingual comprehension has been considerably furthered. However, cross-language comprehension research with a cognitive perspective is only a recent development in a field in which awareness of L1 reading comprehension models is minimal. A review of L2 research from 1974 to 1988 (Bernhardt, 1991) has shown that, except for Goodman's (1967) and Smith's (1973) psycholinguistic models, models frequently used in L1 research such as those of Kintsch (1974), Frederiksen (1975) and Norman and Rumelhart (1977), have generally been ignored by North American L2 researchers. Nevertheless there are still a limited number of examples of L2 studies that have approached the problem of cross-language discourse comprehension from a cognitive rather than the older psycholinguistic perspective. The following is a review of the studies that are directly relevant to the issues of cross-language discourse comprehension in terms of multiple levels of processing, the use of domain-specific knowledge, and L2 proficiency.

Processing of Semantic and Syntactic Information

Since the 1980s a limited number of L2 discourse comprehension studies have examined both the effects of L2 proficiency and background knowledge on comprehension. Carrell (1983), for example, compared the effects of background knowledge on L2 readers and native speakers' comprehension of Bransford and Johnson's (1973) *Washing Clothes* and *Balloon Serenade* texts. Focusing on the effect of knowledge of baseball games and levels of L2 proficiency, Levine and Haus (1985) assessed readers' comprehension of a report of a baseball game using a 12-item multiple choice test. Although these two studies used different comprehension measures, both focused only on global comprehension of semantic information as measured either by overall recall of semantic information or comprehension scores based on answers to the multiple choice questions. Consequently, they do not provide us with knowledge of how specific textual information is processed and how such processing is affected by various levels of knowledge in the second language and knowledge in the content area.

In L1 comprehension research, however, it has been well established that a good understanding of cognitive processes underlying comprehension requires an examination of comprehension not only globally, but also through specific variables identified by theories of discourse comprehension as differentiating and determining specific components of comprehension. Research in the first language has repeatedly shown that textual variables, such as hierarchical organization of text propositions, are among the most significant variables that predict comprehension and comprehension processes (Clements, 1978; Meyer, 1975; Renaud & Frederiksen, 1988). A cross-language study on simultaneous translation also suggested that comprehension and comprehension processes are determined not only by the organization of text propositions but also by type of text information, i.e., narrative vs. procedural texts (Dillinger, 1989). In addition, global measures of comprehension of semantic information do not reveal how linguistic knowledge and prior knowledge affect processing of surface features of text such as processing of specific syntactic forms or processing of sentences with varied degrees of clausal complexity.

On the other hand, some bilingual comprehension studies that focused on effects of L2 proficiency have demonstrated that at lower processing levels, patterns of less proficient L2 readers are different from those of native speakers and more proficient L2 readers. For example, a study by Hatch, Polin and Part (1974) showed that in performing tasks of canceling letters in a text while reading it for comprehension, native speakers paid considerably more attention to such content words as noun, verbs, adjectives and adverbs, while less proficient L2 readers did not seem to have processed the functional and content words differently. Consistent results were also observed by Cziko (1980) in his study of oral reading errors. Cziko found that less proficient L2 readers were more attentive to graphic information and that the ability to utilize contextual information in reading

L2 texts was also dependent on readers' L2 proficiency. What seems apparent from these studies is that readers with limited L2 proficiency tend to exert an excessive amount of cognitive effort in recognizing words and applying appropriate syntactic rules. The control of processing, unfortunately, requires more time for process activation, thus often impeding the ability to perform simultaneously other tasks that also require a capacity investment. These L2 reading strategies may result in difficulties in integrating contextual information which is crucial for deriving meaning from texts (McLaughlin, Rossman & McLeod, 1986).

Unfortunately most L2 language studies, as mentioned before, tend to focus on the phonological, morphological, syntactic and semantic structure of isolated, context- and text-independent sentences. As a result, not much is known about the effects of conceptual knowledge and knowledge of the language on comprehension of syntactic and semantic information in context. In addition, although there has been empirical evidence of various effects of structural differences (e.g., Juffs, 1990; Kilborn, & Ito, 1989; Suchman, 1982; Takashima, 1989; Zobl, 1982), very few studies have investigated syntactic units other than morphological, lexical and phonological units in these studies. Thus questions arise as to whether and how sentence-level structural differences, such as voice and tense, affect comprehension. For instance, Chinese, unlike English, is a tenseless language. Although it also uses both active and passive voice, the passive voice in Chinese is much less frequently used than that in English (for examples see Appendix A). Until the effects of these kinds of structural differences are investigated, we do not know if and how such differences affect L2 comprehension.

Domain-Specific Knowledge and Language Proficiency

Most cross-language research on text-level phenomena has tended to focus on culture-specific aspects of text content. For example, Johnson (1982) demonstrated that familiarity with Halloween had a greater impact on English-second-language readers' comprehension of a *Halloween* text than did the pre-teaching of vocabulary. Other cross-cultural studies also shed light on how familiarity or unfamiliarity with particular culture-specific knowledge may facilitate or hinder readers' understanding of highly culture-specific texts such as texts about weddings (Steffensen, Joag-Dev & Anderson, 1979), funerals (Pritchard, 1990), American folklore (Johnson, 1981) and foreign literature (Gatbonton & Tucker, 1971; Kujoory, 1978). While some difficulties may be attributable to cultural as well as to other types of knowledge in narratives, such as those contained in Bransford and Johnson's (1972) *Washing Clothes* and *Balloon Serenade* texts, many others are not, or at least are much less so. For instance, background knowledge applicable to the understanding of science texts such as specific knowledge in biology, engineering or physics, to a great extent, is *not* culture-specific, nor does it depend much on knowledge in other task domains than that in the areas of science. While students in biology, for example, may well understand texts on Halloween, and Romeo and Juliet's romance, they may still find a text on nuclear power much less comprehensible. On the other hand, the same students, who presumably have some knowledge in the area of biology, would understand a text on monoclonal antibodies better than would either engineering or physics students, even if their overall levels of language proficiency were equivalent and even if their cultural as well as other kinds of knowledge in other task domains were comparable.

Successful comprehension of texts in a particular content area appears to be closely related to relevant and available domain-specific knowledge. For example, comprehension in a specific domain may involve the implicit use of that domain's principles which direct selective attention to domain-relevant information, i.e., to search, identify and provide clues as to how to interpret domain-relevant information (Gelman & Greeno, 1989). If this is true, then a better understanding of bilingual discourse comprehension processes involved in reading science texts requires an examination of the manner in which specific content knowledge is used. Although there has been a tradition in studies of problem solving expertise to investigate the impact of domain-specific knowledge (e.g., Chase & Simon, 1973; Chi, 1978; 1981; Chi, Feltovich & Glaser, 1981; Hayes-Roth, Waterman & Lenet, 1983; Newwell & Simon, 1972; Voss, Tyler & Yengo, 1983), discourse comprehension studies, especially cross-language comprehension studies with very few exceptions (Alderson & Urquhart, 1988; Donin & Silva, 1993; Goldman & Duran, 1988; Mohammed & Swales, 1984) have tended to focus on either cultural knowledge or particular types of knowledge such as ordering in a restaurant and washing clothes.

Some researchers have argued for general language ability that cuts across different domains based on the assumption that various task domains often make use of the same restricted processes such as language processing (Perfetti, 1989). The relevant issue here is not whether or not comprehension requires only linguistic knowledge, but rather whether linguistic knowledge or domain-specific knowledge alone is enough to guarantee successful comprehension. Perfetti (1989), for example, has presented empirical evidence suggesting that, in terms of L1 comprehension of conceptual information from football texts, a reader could compensate for lack of domain-specific knowledge with linguistic knowledge and compensate for lack of linguistic knowledge with domain-specific knowledge. However, he also found that at lower processing levels, as assessed by a reading-time measure, what differentiated processing was the readers' language proficiency rather than their knowledge in the content area.

Although cross-language studies have tended to focus on linguistic knowledge, a very limited number of studies on bilingual discourse comprehension have examined relationships between linguistic knowledge and conceptual knowledge. Among the few studies that did investigate the two variables (Alderson & Urquhart, 1988; Goldman & Duran, 1988; Goldman, Reyes & Varnhagen, 1984; Hammadou, 1991; Levine & Haus, 1985; Mohammed & Swales, 1984), inconsistent results were found. For example, Hammadou (1991) reported that French-English and Italian-English bilinguals' recall of English texts on various topics appeared to be related to their L2 proficiency rather than their own familiarity rating of the texts. In contrast, Levine and Haus (1985) observed that Spanish-L2 readers' performance on the multiple-choice comprehension test on a baseball game text was related more to content knowledge than to L2 proficiency. However, one should notice that these studies have explored only high level processing, that is, processing of the semantic information, and that some of these studies may have methodological limitations related to the use of inadequate comprehension measures, linguistic distance, the use of between-subject designs and inadequate matching of the testing texts (which will be discussed in the next section).

The ability to acquire information from text also depends on the way in which the text content is organized as well as readers' expectations of how it is organized (e.g., Carrell, 1984, Kintsch & Yarbrough, 1982; Meyer, Brandt & Bluth, 1980; Goldman & Varnhagen, 1983; Mandler, 1984; Meyer & Freedle, 1984; Richgels, McGee, Lomax & Sheard, 1987; Roy, 1991; Urquart, 1984). It is well established, that in the repertoire of readers' schemata, background knowledge in a content area and experience with text organization are the two major factors that act together to determine comprehension (van Dijk, & Kintsch, 1983); and that awareness of L2 rhetorical structures is related to comprehension of L2 texts (Carrell, 1984; Urquhart, 1984). Nevertheless, discourse comprehension studies in general have tended to examine separately the effects of prior knowledge and text structures and to investigate one variable while leaving the other uncontrolled. One of the very few exceptions is a recent study of L1 comprehension by Yochum (1991) who examined children's knowledge of cities in their home state and in another state and their comprehension of texts with attribution and comparison structures. The results of her study suggest that the effects of prior knowledge and text structure were independent of each other and were functions of task and a reader's general reading ability.

Some Methodological Issues

Many cross-language discourse comprehension studies are characterized by the use of research designs in which there was very little control over the text structure or in which readers were grouped according to their ethnic background without regard for their level of L2 proficiency. As a result, we still do not know whether or not effects of cultural and other types of knowledge operate differently across various types of rhetorical structures and across various levels of L2 proficiency. In addition, since many of the current cross-language discourse comprehension studies have some of the methodological characteristics discussed below, these and other L2 discourse comprehension data can only be partially understood.

Comprehension Measures

Post-Input Tasks and Real-Time Measures

Part of the difficulty in understanding cross-language discourse comprehension data is due to the complexity of language comprehension itself. A second source of difficulty arises from the use of inadequate comprehension measures, such as multiple-choice questions or cloze tests that have serious theoretical and methodological limitations. Although these measures are often statistically reliable, especially in terms of scoring, the test scores offer little specific information about readers' comprehension processes. Such information is essential to understanding cognitive processes in reading. Another serious problem is that the measuring instruments may serve as additional cues for readers and consequently make the comprehension tasks less authentic and more difficult to interpret.

To avoid these problems, many researchers in cross-language discourse comprehension have begun to employ post-input tasks such as free-recall which usually reflect the organization imposed by readers. In analyzing recall data, semantic models of discourse comprehension have often been used to compare readers' recall protocols with semantic representations of the texts. With a detailed analysis of both recall and inference of semantic information, one can assess the semantic information people acquire from a text and relationships between semantic information acquired from a text and semantic information from the knowledge domain from which the text is derived. Inferences about the underlying processes can then be made accordingly. In addition, recall measures also assure that no new information is introduced by the assessment task that could bias or lead the readers in their cognitive representations. The task thus helps to provide a general picture of the amount and type of information that has been retained and the reorganization that readers have imposed on the text. However, in analyzing recall data, there has been a tendency to examine only the overall recall through a count of percentage recall of propositions for a whole passage. Consequently, what has been missed is detailed information about specific processing, such as processing for specific types of semantic or conceptual information. Another problem in analyzing recall data is that some researchers tend to use "idea units," a measure which is not only loose in its psychological interpretation, but also poorly defined and thus prone to subjectivity.

In addition, in analyzing recall data, one should be aware that readers' recall protocols may include information that reflects only part of their memory representations. To alleviate this problem, one could use recall measures in conjunction with some real-time measures such as on-line reading time which could help to capture the temporal organization of various component processes involved in processing text and the manner in which they interact. The assumption in using reading-time measures is that the cognitive load associated with underlying processing fluctuates with time and that different factors contribute to these fluctuations. Reading time is sensitive to variables such as familiarity of words, phrases, syntactic constraints, as well as to such semantic features as propositional density (Kintsch & Keenan, 1973; Renaud & Frederiksen, 1988; Ratcliff & McKoon, 1978; Roy, 1991). Sentence reading-time (Graesser, 1981; Graesser, Hoffman & Clark, 1980; Kieras, 1981; Haviland & Clark, 1974; Miller & Mckean, 1964) is one of the major on-line measures which is presumed to provide a measure of the comprehension process. Reading time is often defined as an interval between key presses. That is, a reader is asked to press a key either when he feels that he has understood or when he has finished reading a sentence. Although on-line reading-time measures have succeeded in providing important information, especially about the efficiency of processing, L2 discourse comprehension studies generally have not used both recall and reading-time measures in the same study.

Self-Reported Data

Self-reported data have also been used as comprehension measures. Such measures, however, may be constrained by the reader's ability to articulate clearly, accurately or reliably (Markman, 1979). In addition, some researchers have found self-reported data of how and what has been processed often show little correspondence with what readers in fact do both among young readers (e.g., Paris & Meyers, 1981) and among college students (Phifer & Glover, 1982). However, other researchers have shown agreement between perceived reading difficulty and measured comprehension (Miller & Yochum, 1991) and, between sensitivity of perceived reading proficiency and task variability (Davey, 1987). A L2 study by Barnett (1988) also suggests that reading comprehension, actual strategy use and perceived strategy use are related among university-level readers of French as a foreign language. A problem common to many of these studies is that the researchers have either shied away from relatively more objective measures of comprehension and comprehension processes or tended to limit themselves to use only post-input measures and have rarely examined comprehension processes on-line.

Comprehension and Production

Another difficulty in interpreting L2 discourse comprehension studies arises from the gap between comprehension and production. It has long been recognized that people may understand more than what they produce under recall conditions in their second language. The difference between comprehension and production seems to be more pronounced for bilinguals reading in their weaker language (Flynn, 1986). But such differences have seldom been examined or counterbalanced in cross-language discourse comprehension studies before the mid-1980s. Indeed, many researchers have used L2 production to access L2 comprehension (e.g., Alderson & Urquhart, 1988; Carrell, 1983; Connor, 1984; Waters & Wolf, 1986). Recently, the validity of many of the earlier studies that used target language recall has been brought into question by researchers who have shown that people appear to recall more and display more high-level processing when recall is in their native language rather than in their second language (Donin & Silva, 1993; Lee, 1986). However, one should note that research that explored the relationship between comprehension and production has focused on Western European languages such as Spanish and English (Lee, 1986) and French and English (Donin & Silva, 1993). The assumption that readers can recall more in their first than in their second language may not apply to a language which is at a greater linguistic distance from the target language such as Chinese and English. In such a case, recall of a L2 text in the native language may not have the same facilitative effect as suggested by Lee (1986).

Linguistic Distance

This brings us to a further difficulty in interpreting L2 discourse comprehension studies. Most North American bilingual research, with the exception of some studies of the effects of cultural knowledge, has focused on languages that are members of the same Indo-Europèan family. A question arises as to whether conclusions based on these studies are applicable to individuals speaking languages of greater linguistic distance. English, French and Spanish, for example, share quite a few common features in terms of orthography, phonetics and lexicon (Table 1). Although considerable variation does exist among these languages, the differences between any two language families are much greater than the differences within any language family. For example, languages in the Indo-European family differ significantly from Chinese, a language of the Sino-Tibetan language family, not only in terms of the writing system and the lexicons (Chen, 1991; Halliday, 1993), but also in terms of various sentence structures (Chen, 1991; Chu, 1982). While verbs in languages from the Indo-European family conjugate for tense, languages in the Sino-Tibetan family are tenseless; Indo-European languages have relatively more embedded clauses and use more passive voice than do those in the Sino-Tibetan family.

Table 1

Some Major Similarities within and Differences between Language Families

	Indo-European Family	**Sino-Tibetan Family**
Orthography	Alphabetic writing	Idiographic writing
Phonology	Meaning and sound correspondence	Meaning and sound correspondence
	Some speech sound sequence constraints	Some speech sound sequence constraints
Lexicon	Article	Measure words
	Inflection	No inflection
	etc.	etc.
Examples	**English French Spanish**	**Mandarin**
A	flowers fleurs flores [flaus] [flɔ:r] [flɔres]	花 [hua:]
B	three trois tres [θri:] [trwa] [tres]	三 [san]
C	come venir venir [kʌm] [vəni:r] [venir]	来 [lai]

Enormous differences also exist in phonology, not only in terms of how a word with the same meaning is pronounced, but also in terms of the existence or lack of existence of certain speech sounds and phonological sequence constraints. For example, languages in the Indo-European family generally allow more than one phonetic consonant in initial position (e.g., [fl-] and [tr-]); most languages in the Sino-Tibetan family, on the other hand, allow only one phonetic consonant in initial position (see Table 1 for examples).

The Use of Between-Subject Designs

The problem associated with linguistic distance is compounded by the use of between-subject designs in which L2 readers, regardless of their linguistic background and other characteristics, are either categorized into one group, i.e., the non-native speakers, or grouped by their L2 proficiency. In these cases, it is difficult to determine whether the results of the studies were confounded with linguistic distance or other variability in readers such as their knowledge of rhetorical structures, educational experience, academic focus, or cultural and other types of prior knowledge.

Comparability of Test Texts

Difficulty in interpreting L2 research has also been related to the lack of comparability of texts used both within and between various studies. There has been a tendency in research on L2 comprehension to disregard the importance of text characteristics. As pointed out by Bernhardt (1991), most

L2 studies have only reported comprehension scores without providing information about the actual texts used. When the testing materials were described, often the texts either were not matched or they were matched only in terms of certain syntactic features. Although matching texts syntactically usually leads to less ambiguous interpretation of the studies than leaving texts completely unmatched, one has to be aware that semantic features such as number, density and types of propositions, conceptual frame structures and topic familiarity are particularly important predictors of discourse comprehension (e.g., Kintsch & Keenan, 1973; Renaud & Frederiksen, 1988).

Chapter Three

Rationale

The review of the literature on discourse comprehension research has led to a number of conclusions. First, semantic and conceptual processing are important components of not only unilingual but also bilingual discourse comprehension. Secondly, a good understanding of discourse comprehension requires an investigation of comprehension processes at both local lexical and syntactic levels, and at higher conceptual and semantic levels. Thirdly, comprehension of texts in science domains may require domain-specific knowledge rather than cultural or other types of knowledge required in other task domains. Effective text comprehension in these areas also requires knowledge of relevant text structure as well as the more general knowledge of the written language's regularity.

Therefore, a better understanding of discourse comprehension of science texts, both within and across languages, requires an examination of (a) how specific types of science texts are processed at multiple levels and (b) the interactions that occur between various levels of processing. With such an examination one could, for example, investigate at various processing levels (a) the effects of higher-level conceptual knowledge such as differences in domain-specific content knowledge and (b) the effects of lower-level language processing such as differences in knowledge of syntactic structures or efficiency of sentence processing. As discussed in the previous chapter, stratified models that view discourse comprehension as both multilevel and modular provide a guide for such an investigation.

What is apparent from the literature review pertinent to these issues is the paucity of empirical studies and the inconsistency of results, especially in cross-language research. Among the relevant cross-language studies, many have both theoretical and methodological limitations resulting from the use of inadequate measure(s) or the inadequate use of valid comprehension measure(s). In addition, the issues of comprehension-production gap, linguistic distance, reader variability, the use of between-subject designs and the lack of comparability of test texts also have contributed to difficulties either in interpreting or in generalizing the research results. Some of these problems, however, could be addressed by: (a) focusing on readers who are from a greater linguistic distance from that of the target language and who are as comparable as possible in aspects other than those under examination; (b) employing post-input tasks such as free-recall in conjunction with on-line measures such as reading-time; (c) focusing not only on a single general index of comprehension but also on variables identified by models of comprehension as being able to account for and predict differential representation and processing; d) and by using semantic analysis techniques (e.g., Frederiksen, 1975; 1986; Frederiksen & Donin, 1991; Kintsch, 1974; van Dijk & Kintsch, 1983) so as to match not only syntactic but also semantic aspects of texts both within and between languages. Also, in order to examine how the added linguistic demands affect the L2 discourse comprehension, within-subject designs comparing the L1 and the L2 comprehension and L2 comprehension with different recall conditions need to be employed.

The objective of the present study was to investigate the cognitive processes involved in bilingual discourse comprehension. The study focused on the content area of general biology and on Chinese first- and English second-language graduate science students. From the perspective of a stratified model, it examined the effects of domain-specific content knowledge and language proficiency on various levels of text processing. It also examined the effects of language and text structure on multi-level processing. In addition, the study investigated two methodological issues: the effects of language of recall and the validity of using self-rating of text difficulty or content familiarity. To investigate the effects of language of recall, the study examined both semantic and syntactic processing and reading strategies reported to have been used. In order to examine the validity of using self-rating to index knowledge in the content area, the study examined relationships between perceived text difficulty and measured comprehension, and efficiency of processing.

A. Comprehension of Semantic Information and Efficiency of Processing of the L1 and the L2 Texts

The first part of the study focuses on multilevel processing. It addresses the issue of comprehension of semantic information, as assessed by overall recall of propositional information and recall of specific types of propositional information, and efficiency of processing, as assessed by reading time. It examines *between-groups* effects of **(a) background knowledge** and **(b) L2 proficiency**, and *within-groups* effects of **(c) language condition, (d) text structure** and **(e) propositional type**. It also examines interactions among these variables. Specifically, the first part of the study addresses the following questions:

(A-a1) Does domain-specific knowledge affect readers' general comprehension of semantic information?
(A-a2) Does domain-specific knowledge affect readers' comprehension of specific types of semantic information?
(A-a3) Does domain-specific knowledge affect readers' efficiency of processing?

(A-b1) Does L2 proficiency affect readers' general comprehension of semantic information?
(A-b2) Does L2 proficiency affect readers' comprehension of specific types of semantic information?
(A-b3) Does L2 proficiency affect readers' efficiency of processing?

(A-c1) Does language condition, i.e., language of presentation (L1 texts vs. L2 texts) and language of production (L2 texts with L1 recall vs. L2 texts with L1 recall) affect readers' general comprehension of semantic information?

(A-c2) Does language condition affect readers' comprehension of specific types of semantic information?
(A-c3) Does language condition affect readers' efficiency of processing?

(A-d1) Does text structure affect readers' general comprehension of semantic information?
(A-d2) Does text structure affect readers' efficiency of processing?

(A-e) Do different types of semantic information affect readers' comprehension?

B. Effects of Language of Recall on Processing of Semantic and Syntactic Information from the L2 Texts

Since different languages of recall may induce different types of surface-level processing, language of recall may affect processing of not only semantic but also syntactic information. The second part of the study, thus, examines *within-groups* effects of **(f) language of recall** on processing of semantic and syntactic information from the L2 texts and relationships among language of recall, background knowledge and L2 proficiency. In the syntactic analyses, the study focuses on an aspect of syntax in which Chinese and English differ significantly: the voice forms. The study also explores self-reported reading strategies used with different languages of recall. The second set of research questions are as follows:

(B-f1) Does language of recall affect readers' general comprehension of semantic information from the L2 texts?

(B-f2) Does language of recall affect readers' processing of syntactic information from the L2 texts?

Prediction

From the perspective of a stratified model of discourse comprehension (Frederiksen & Donin, 1991), two predictions relevant to the first two parts of the study were made as follows:

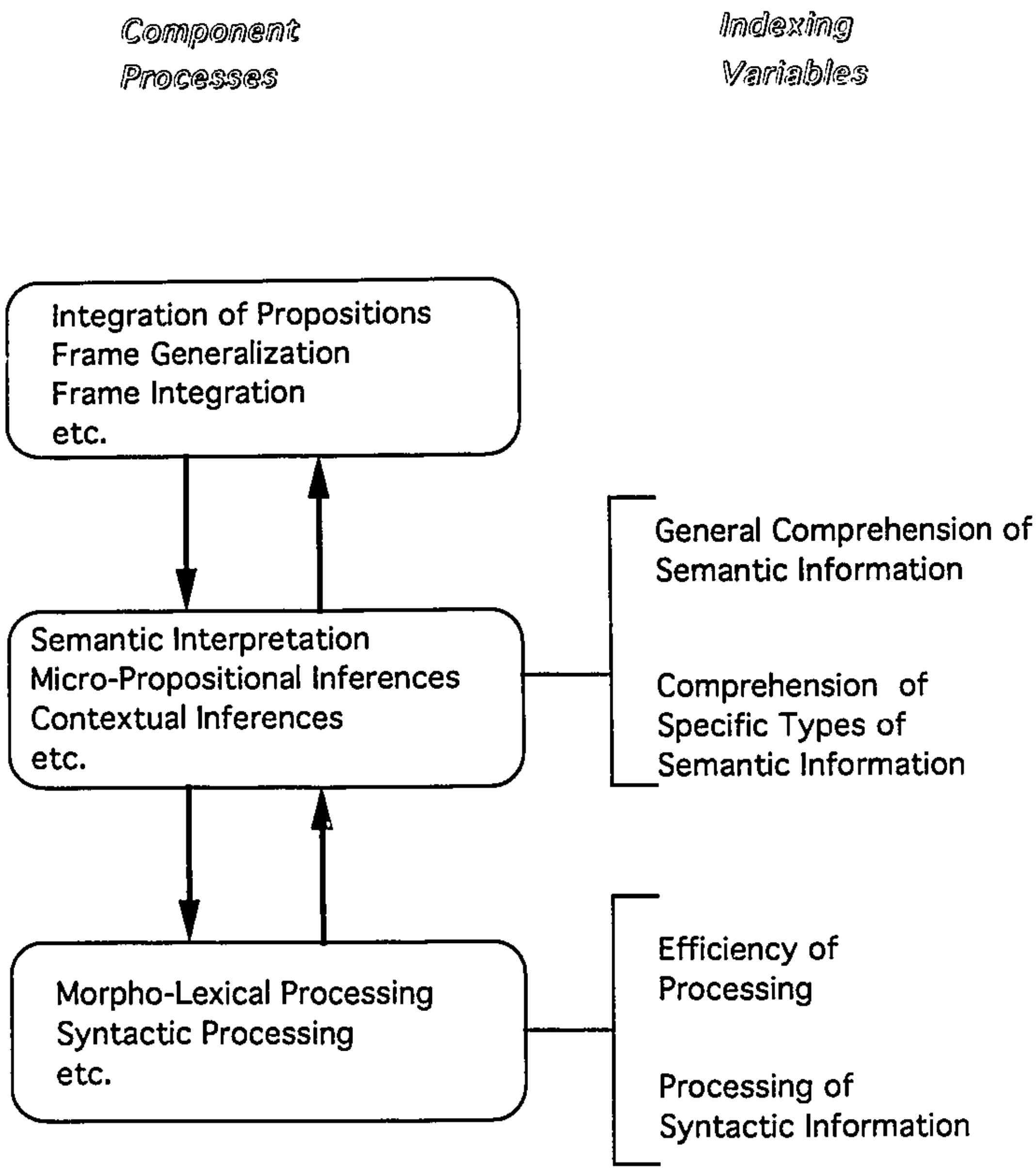
Prediction A. Prior conceptual knowledge (i) exerts strong effects on processing at the higher conceptual and semantic levels and (ii) has limited effects on processing at the local lexical and syntactic levels;
Prediction B. Language proficiency (i) exerts strong effects on processing at the local lexical and syntactic levels and (ii) has limited effects on processing at the higher conceptual and semantic levels.

Figure 1 summarizes the component processes in a stratified model with the four dependent variables investigated in the present study. While the first part of the study examines general comprehension of semantic information, comprehension of specific types of semantic information and efficiency of processing of both the L1 and the L2 texts, the second part of the study focuses on general comprehension of semantic information and processing of syntactic information from the L2 texts.

C. Perceived Text Difficulty

In order to investigate the validity of using self-rating of text difficulty or content familiarity to index background knowledge, the present study includes another set of analyses which explores *within groups*: relationships between readers' (g) **perceived text difficulty** and measured comprehension of semantic information, and efficiency of processing and, interactions

Figure 1
Component Processes of Text Comprehension and Its Indexing Variables Examined



The stratified model was adapted from Frederiksen and Donin (1991) among perceived text difficulty, background knowledge and L2 proficiency. In addition, the study examines attribution of text difficulty. The two specific research questions investigated in this part of the study are as follows:

(C-g1) Is there any relationship between perceived text difficulty and measured comprehension of semantic information?

(C-g2) Is there any relationship between perceived text difficulty and measured efficiency of processing?

Methodological Approach

To investigate these research questions, Chinese and English bilinguals, i.e., speakers of two languages with great linguistic distance, were studied. As mentioned earlier, the content area that this study focused on was general biology which is both content-specific and relatively culture-free. The subjects consisted of students who were Chinese graduate students in the areas of either engineering or biology. While these students were comparable in their L1 proficiency, cultural, and educational background and knowledge of rhetorical structures of science texts, they differed significantly in their knowledge of the content area of general biology, and in L2 proficiency.

The study used detailed propositional analysis and semi-structured interview techniques. Comprehension and comprehension processes were assessed by both recall and on-line reading-time measures. Although the on-line recall task did not represent a typical situation of college science reading (i.e., in terms of reading from the computer screen and providing on-line interpretation), the texts used in testing were authentic enough to ensure that they were representative of the type of procedural texts often found in textbooks, lab manuals and study guides. This type of texts is usually encountered by the readers in their lives as graduate students. Also, a previous study (Renaud & Frederiksen, 1988) demonstrated that an on-line recall task did not affect off-line recall or sentence reading-time data. The present study also included interview data. The purpose of including interview data was to obtain information about strategic processing and about the issue of validity of using self-rating of text difficulty or content familiarity to index background knowledge.

For the purposes of data analyses, the study used mixed between- and within-subject designs in addition to a between-subject design. The mixed between- and within-subject designs allowed for an examination of how added linguistic demands affect the same readers' comprehension and comprehension processes for texts written in their first vs. their second language. It also allowed for examination of the effects of language of recall, text structure, propositional type and perceived text difficulty. In addition, the mixed designs controlled for the so called "undesired" reader variability which often has confounded the results of various studies. In order to facilitate both between- and within-language comparisons, the texts used in the study were specifically matched, both between- and within-language in terms not only of important syntactic but also semantic features. These will be described in detail in Chapter 4.

Chapter Four

Method

Subjects

Forty Chinese (Mandarin) first- and English second-language graduate science students enrolled at McGill or Concordia University in Montreal participated in the study. Four of these students were subsequently excluded from data analyses: three students did not follow the instructions and one did not meet the grouping criterion for prior conceptual knowledge (see description of the materials). Subjects for the data analyses thus consisted of 36 students. Among them, eighteen were biology students and eighteen were engineering students. Since the testing texts were all in the areas of general biology (as typically used by undergraduate biology programs for their first-year students), the biology graduate students formed a high background-knowledge group while the engineering graduate students formed a low background-knowledge group. Based on their scores on the Michigan Test of English Language Proficiency, the students in each of the knowledge group were further divided into a more proficient L2 (i.e., from high-intermediate to high) and less proficient L2 group (i.e., from low-intermediate to intermediate).

These students were all educated in mainland China prior to their coming to Canada for their graduate studies. Thus, they shared, to a great extent, the same cultural and educational experiences. Due to the fact that these students had all passed entrance examinations in mainland China (including examinations of their Chinese reading proficiency) which admitted less than 2% from the cohort population to various undergraduate programs, they could be presumed to be proficient readers of Chinese. More importantly, with at least four years' formal post secondary education in science, these students were also comparable in their experience with the rhetorical structures used in science texts which are characterized by the use of definition, procedure, description and so forth. While both biology and engineering students would be expected to be comparable in their knowledge of the rhetorical structures of scientific texts, and in their general Chinese reading proficiency and their cultural background, the disciplines of biology and engineering are sufficiently different to ensure that one group of readers would not have the specific subject-matter knowledge of biology that the other group was expected to have.

Materials

Based on several English textbooks on general biology (Barrett, Abramoff, Kumaran & Millington, 1986; Campbell, 1987; Curtis, & Barnes, 1985) currently used in many first-year undergraduate biology programs in North American universities and a Chinese textbook on general biology for first-year undergraduates (Liu & Jiang, 1978), three predominantly procedural texts in general biology were constructed each in both English and Chinese (see Appendix A). Each text consisted of two paragraphs: the first paragraph included a general description of the usage of a biotechnique (i.e., monoclonal antibody or karyotype or radioactive tracer), the second paragraph was a step-wise description of the particular biotechnique (i.e., the procedure explaining how to either produce monoclonal antibodies, prepare a karyotype, or use a radioactive tracer). Anyone who has advanced into graduate study in biology would be expected to have at least general knowledge of these three biotechniques. On the other hand, the author generally does not expect graduate engineering students to be familiar with any of these topics. The interview data confirmed that while all the biology students reported having prior knowledge about these topics, all the engineering students except one (who was excluded from data analyses) reported having no prior knowledge about any of these topics.

To facilitate between- as well as within-language comparisons, the texts were matched for their semantic complexity in terms of number of propositions and propositional types using Frederiksen's (1975; 1986) propositional analysis system. The propositions were further categorized into three types: events and systems consisting of either an action or a process plus any case and identifying information; states consisting of objects and their identifying information; and relations consisting of all relational propositions such as those with algebraic, dependency, propositional and binary relations as their head elements (See Appendix B for the coding scheme of each text which was based on propositional analysis of the text). The texts were also matched for their conceptual complexity in terms of number of technical terms in biology based on the judgment of two experts who held PhDs in biology. In addition, pairs of texts were also matched semantically across languages so that the same semantic analysis applied to both the English and Chinese version of any given text. Table 2 summarizes the semantic matching. Among the three texts, the total number of propositions, mean density of propositions per sentence, frequencies of the three proposition types, as well as total number of technical terms were either nearly identical or identical.

The texts were also matched for their syntactic complexity in terms of number of sentences, clauses and embeddings per sentence using Winograd's (1983) clausal analysis system. Table 3 presents a profile of syntactic features that were matched. The number of sentences, clauses, embeddings and patterns of embedding were either exactly the same or nearly identical both between- and within-languages. Here one should notice that although the Chinese language generally does not use as many

Table 2

Summary of Semantic Features of Test Texts

	Karyotype		Monoclonal Antibody		Radioactive Tracer	
	English	Chinese	English	Chinese	English	Chinese
Total Propositions	61	61	61	61	63	63
Mean Propositional Density/Sentence	4.69	4.69	4.69	4.69	4.85	4.85
Total Events & Systems	23	23	24	24	31	31
Total States	29	29	28	28	23	23
Total Relations	9	9	9	9	9	9
Total Technical Terms	15	15	13	13	14	14

Table 3
Summary of Syntactic Features of Test Texts

	Karyotype		Monoclonal Antibody		Radioactive Tracer	
	English	Chinese	English	Chinese	English	Chinese
Total Sentences	13	13	13	13	13	13
Total Clauses	25	24	25	25	25	24
Clause density	1.92	1.85	1.92	1.92	1.92	1.85
Embedded Clauses	21	20	21	21	21	20
Clause(s) per Sentence						
1	4	4	4	4	4	4
2	7	7	7	7	7	7
3	1	2	1	1	1	2
4	1	0	1	1	1	0
Voice						
Active	4	12	3	9	4	12
Passive	9	1	10	4	9	1
Tense						
Present	7		9		7	
Future	6		4		6	
Total Words	195	297	194	296	188	285

embedded clauses, exceptions do exist especially in science texts which may be due to the fact that modern sciences were originally developed in Western countries and then introduced to China mainly through translation of English texts. As shown in Table 3, although the number of words, voice and tense were very close among the three texts within each language, there were significant differences between languages. Such differences were of particular interest as it may help to reveal possible effects of the structural differences between the two languages on comprehension. In terms of number of words, the discrepancy between languages is due to the fact that in English what defines a word is the meaning rather than its pronunciation, while in Chinese a word is a smaller unit. A Chinese word is more a phonemic than a semantic unit which must be monosyllabic. In addition, while English verbs are marked for tense, Chinese uses an adverb or an adverbial clause or order to mark time. Finally, although both languages have both active and passive voice, the passive voice is used much less often in Chinese. In order to maintain the authenticity of texts and to examine possible effects of structural differences, number of words, past and present tense and passive and active voice were left unmatched between languages. However, these features were closely matched within each language so as to facilitate within-language comparisons.

Procedure

The Explanation of the Purpose and the Procedure

Participants were informed in a note explaining in Chinese the purpose and the procedure of the study prior to their coming to the experimental session. To ensure that readers understood the purpose and procedure for the study, they were asked to read the same note again at the beginning of the experimental session. Only a few readers asked specific questions about the procedure. These questions were answered orally by the experimenter (i.e., the author).

The Reading Session

Readers were tested individually with the aid of, Word Streamer, an interactive computer program (Hoover & Goodger, 1990). Sentences of the text (without title) were presented one at a time on the computer screen. Readers were instructed (in Chinese) to read at their normal reading speed and press the space-bar to continue. They were asked to tell in their own words as much as they could about what they had just read in four places within each passage during reading (i.e., on-line recall) and to give detailed recall for the whole passage at the end of each text (i.e., retrospective recall). The first on-line recall prompt was at the end of the descriptive paragraph. Readers were then asked to recall at three places within the procedural paragraph where natural conceptual breaks occurred (see Appendix C for the presentation condition for each test text). Each reader read three matched biology texts, two in English (one with English and the other with Chinese recall), and one in Chinese (with Chinese recall). To control for content familiarity effects and order effects between and within language, the text and language presentation orders were counterbalanced. Readers' sentence reading time was recorded automatically by Word Streamer.

To ensure that readers understood the instructions and to familiarize them with both the computer and the recall conditions, each reader read two practice texts in English, one with English recall and the other with Chinese recall. Then they read the three test texts. Each reading session took about 35 minutes.

The Interview

Immediately after the reading session, each reader was interviewed on a one-to-one basis by the experimenter. Each interview was tape-recorded and lasted about five to ten minutes. The interviews were conducted in Mandarin with the exception of one reader from Shanghai who insisted on communicating with the experimenter in their native Shanghainese[2] (i.e., the Wu language used in Shanghai and some other regions of China). The interviews were semi-structured.

The interviewer began with the statement, "You have read three texts. The first one was X (the experimenter added a short title to the first

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[2] Although there are more than 80 different spoken languages in China, Mandarin is the official language, language of education and written language of more than 94% of the educated Chinese.

text, i.e., either 'karyotype,' 'monoclonal antibody' or 'radioactive tracer'), the second one was Y (a short title of the second text), and the third one was Z (a short title of the third text)." The titles of the texts were stated in the language in which the texts were presented. Then the interviewer paused to let the reader reflect on the texts that s/he had read. If the reader asked about what had been read, the interviewer would provide a longer title to the text (i.e., 'how to prepare a karyotype' or 'how to produce a monoclonal antibody' or 'how to use a radioactive tracer'). Then the interviewer asked, "Of these three texts which one did you feel most comfortable with, in other words, which one did you find easiest?" Although it was intended to probe information about perceived familiarity with the text content, the question itself was indirect. The purpose of using an indirect rather than a direct question was to avoid biasing the responses because the author believed that content familiarity may or may not be a factor perceived to affect discourse comprehension. However, if the reader did not address the question from a content familiarity perspective, the interviewer would restate the question suggesting that the reader comment on the content by asking, "From a content perspective, which one do you think is the easiest?" Readers were probed for elaboration of their responses.

A second set of questions was designed to gather information about reading strategies believed to have been used in each of the language of recall condition for the L2 texts. The interviewer said, "In recalling the three texts, you had three language conditions. One was Chinese-Chinese, one was English-Chinese and the other was English-English." After pausing for a while to let the reader reflect, the interviewer continued: "Which recall condition did you prefer?" If the reader listed Chinese-Chinese as their preferred condition, the question was then restated as, "Compare the English-English to the English-Chinese recall condition, which one did you prefer?" If a preference (i.e., between English-English and English-Chinese) was given, the experimenter would ask the reader to explain why one condition was preferred over the other.

The Second Language Proficiency Test

After the interview, each reader took a five to ten minute break. Then the Michigan Test of English Proficiency was administered. The Michigan test is a popular commercial test of English language proficiency published by the English Language Institute of the University of Michigan (1977). The test has usually been used to "estimate whether a student whose native language is not English is able to pursue academic study in an English college or university, and how much study he might be able to undertake at his present level of proficiency in English." It contains subtests of grammatical usage, vocabulary and reading comprehension. The present study used the overall score as a general index of the reader's English language proficiency.

Analytic Procedures

Semantic Analyses

For the semantic analyses, the recall protocols of both the English and Chinese texts were transcribed and segmented into the shortest possible sentences, i.e., a main clause plus embedded clauses. Evaluation of readers' comprehension was made by matching the segments from readers' on-line recall data for a given text to the propositions, i.e., the logical and semantic structures expressed in the presented text. For each text a coding sheet was developed listing each concept-relation-concept triple for each proposition for each sentence (Appendix B). A concept was coded as recalled if the concept in the reader's protocol was semantically equivalent, i.e., identical or synonymous, to that in the presented text. An example of part of a coded protocol is given in Appendix D. Dependent measures were constructed by calculating the percent of information recalled per proposition.

Coding Reliability

The recall protocols were all coded by the experimenter. To check the consistency of the coding, nine protocols (three for each text) were double coded fourteen months later by the same experimenter. Reliability percentages were obtained by dividing the number of agreements between each coding by the total number of concepts and relations presented in either the first or the second coding, depending on which had more slots coded. The intra-rater reliability was found to be 92%. In addition, the nine protocols were also coded by another graduate student who was familiar with the coding system. The original agreements between the two coders was 78%. The two coders then checked each other's coding to resolve differences which resulted from not following the coding rules established prior to coding. After resolving these differences, the inter-rater reliability was 90%.

Syntactic Analyses

Evaluation of readers' processing of syntactic information was made by comparing readers' recall data to the active and passive voice of the texts presented. A voice was marked as a recall if it was identical in the reader's protocol to that in the text. For the two sentences with double predicates (i.e., in the Karyotype text), the voice form was coded on the first predicate. Voice was also coded for change, i.e., from active to passive voice, from passive to active voice, from active to any ambiguous voice forms (i.e., any inconsistency in the verb form such as: be + root, auxiliary such as 'will' + past participle, modal + past participle, modal + noun) and from passive to any ambiguous voice forms. The last two categories of change were not included in data analysis due to the fact that the Chinese language does not inflect, and thus it is impossible to make this comparison between the two languages of recall, i.e., the English-Chinese vs. the English-English conditions.

The Interview Data

The interview protocols were also transcribed. Readers' perceived text difficulty was tallied. The information about their elaboration on language of recall conditions for the L2 texts and text difficulty was organized into three thematic clusters: (a) reading strategies used in the Chinese recall (b) reading strategies used in the English recall and (c) attribution of text difficulty. Readers' responses were then checked against these coding sheets.

Designs

For the statistical analyses, this study employed mixed between- and within-subject designs in all three sets of data analyses (reported respectively in Section A, B and C in the Results and Discussion Chapter). In addition, a between-subject design was included in the first set of data analyses. The between-subject factors in both the mixed between- and within-subject designs and in the between-subject design were **(a) background knowledge** and **(b) L2 proficiency.** There were two levels of background knowledge: high (consisting of biology students) and low (consisting of engineering students); and two levels of L2 proficiency: more (high-intermediate to high) and less (low-intermediate to intermediate).

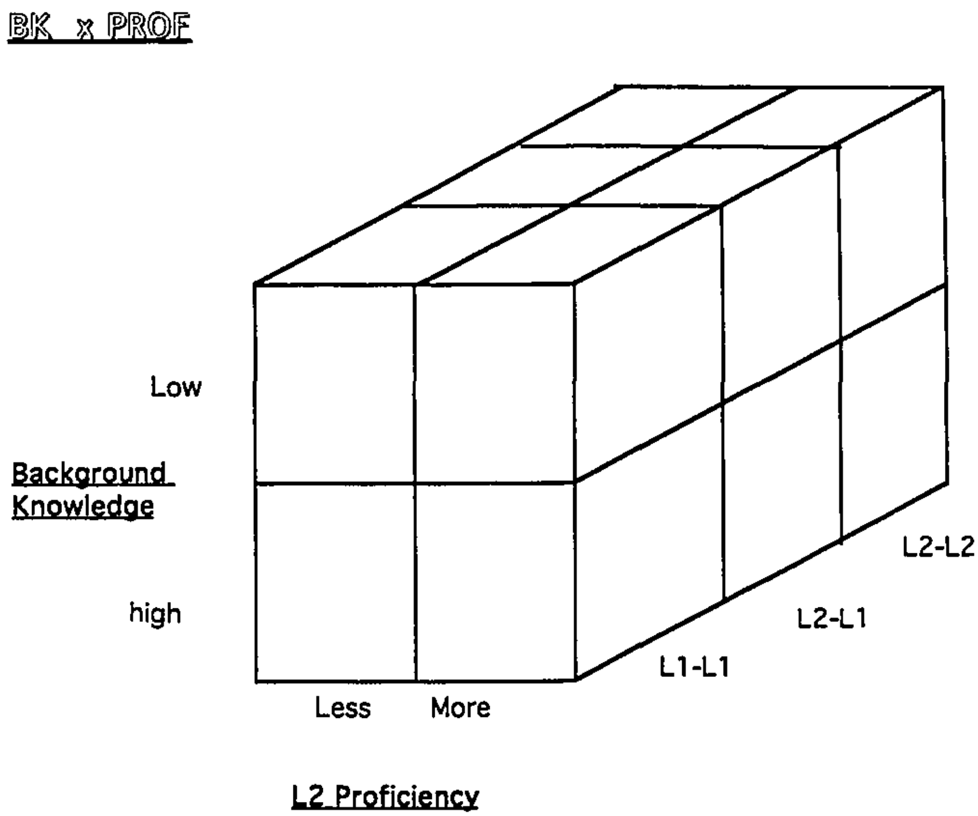
In the first set of analyses (reported in Section A in the Results and Discussion Chapter), the multivariate repeated measure analyses of variance (MANOVAs) in the *between-subject design* examined effects of **(a) background knowledge** and **(b) L2 proficiency**, relating to research questions (p.36) A-a, and A-b1, A-a2 and a-b2, A-a3 and A-b3, and interactions between the two variables. Figure 2 illustrates the design.

The pre-planned within-subject contrasts in the first set of data analyses were **(c) language condition** (i.e., L1 presentation with L1 recall vs. L2 presentation with L1 recall vs. L2 presentation with L2 recall) **(d) text structure** (i.e., descriptive vs. procedural paragraphs) and **(e) propositional type** (i.e., events and systems vs. states vs. relations). The within-subject factors were different for analyses of particular aspects of data pertaining to specific research questions. Therefore, specific within-subject factors were investigated in separate multivariate repeated measure analyses of variance (MANOVAs). Figure 3 lays out, respectively, the specific *mixed between- and within-subject designs* for analyzing data pertaining to research questions on language condition (see p.36 for research questions A-c1, A-c2 and A-c3), text structure (see p.37 for research questions A-d1 and A-d2) and propositional type (see p.37 for research question A-e), as well as interactions among the within- and the between-subject factors.

The second set of analyses (reported in Section B in the Results and Discussion Chapter) investigated research questions B-f1 and B-f2 (p.37). A *mixed within- and between-subject design* was employed for this set of analyses. Univariate analyses of variance (ANOVAs) was conducted. The pre-planned within-subject contrasts in the analyses were **(f) language of recall** for the L2 texts (i.e., L2 texts with L1 recall vs. L2 texts with L2 recall). This set of analyses also examined interactions among language of recall, background knowledge and L2 proficiency. Figure 4 illustrates the design used for this set of data analyses.

The third set of analyses (reported in Section C in the Results and Discussion Chapter) addressed research questions C-g1 and C-g2 (p.40). Similar to the second set of analyses, a *mixed between- and within-subject design* was also employed for the univariate analyses of variance (ANOVAs). The pre-planned within-subject contrasts were **(g) perceived text difficulty** (i.e., texts perceived to be relatively easy vs. texts perceived to be more difficult). This set of analyses also investigated interactions among perceived text difficulty, background knowledge and L2 proficiency. Figure 5 illustrates the design used for analyzing the last set of data.

Figure 2
Between-Subject Design for Analyzing Data: Comprehension of Semantic Information and Efficiency of Processing under *Three Language Conditions



L1-L1: first language presentation with first language recall;
L2-L1: second language presentation with first language recall;
L2-L2: second language presentation with second language recall.

Figure 3
Mixed Between- and Within-Subject Designs for Analyzing Data: Comprehension of Semantic Information and Efficiency of Processing under Three Language Conditions

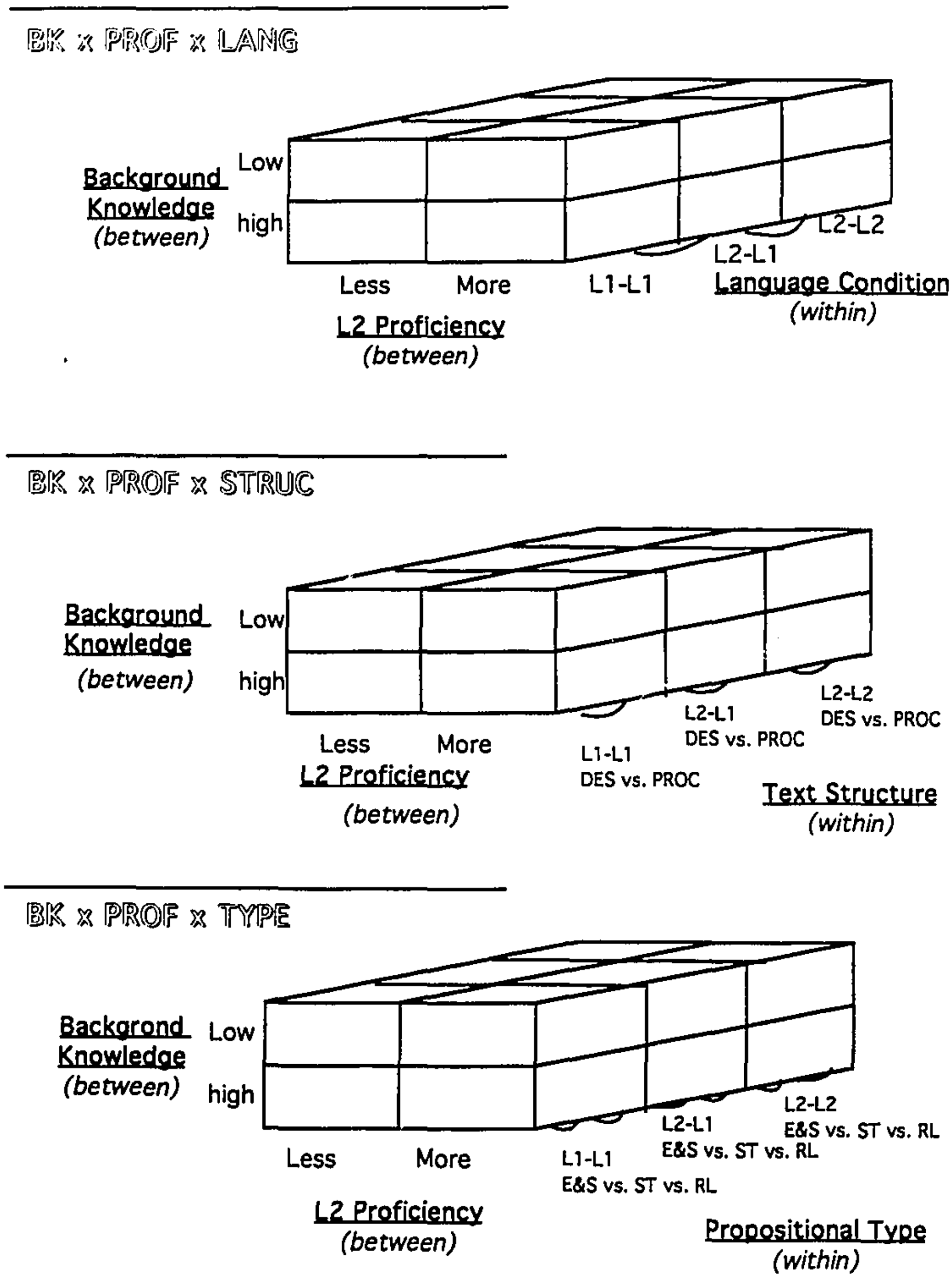


Figure 4
Mixed Between- and Within-Subject Design for Analyzing Data: Processing of Semantic and Syntactic Information from the L2 Texts

BK x PROF x LR

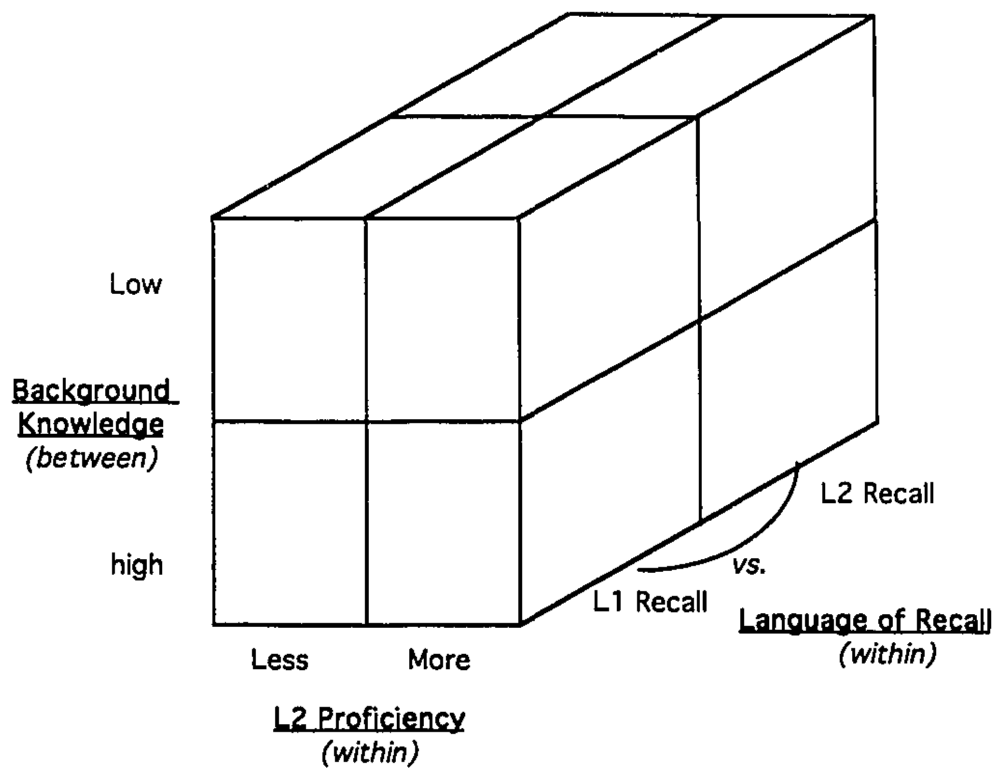
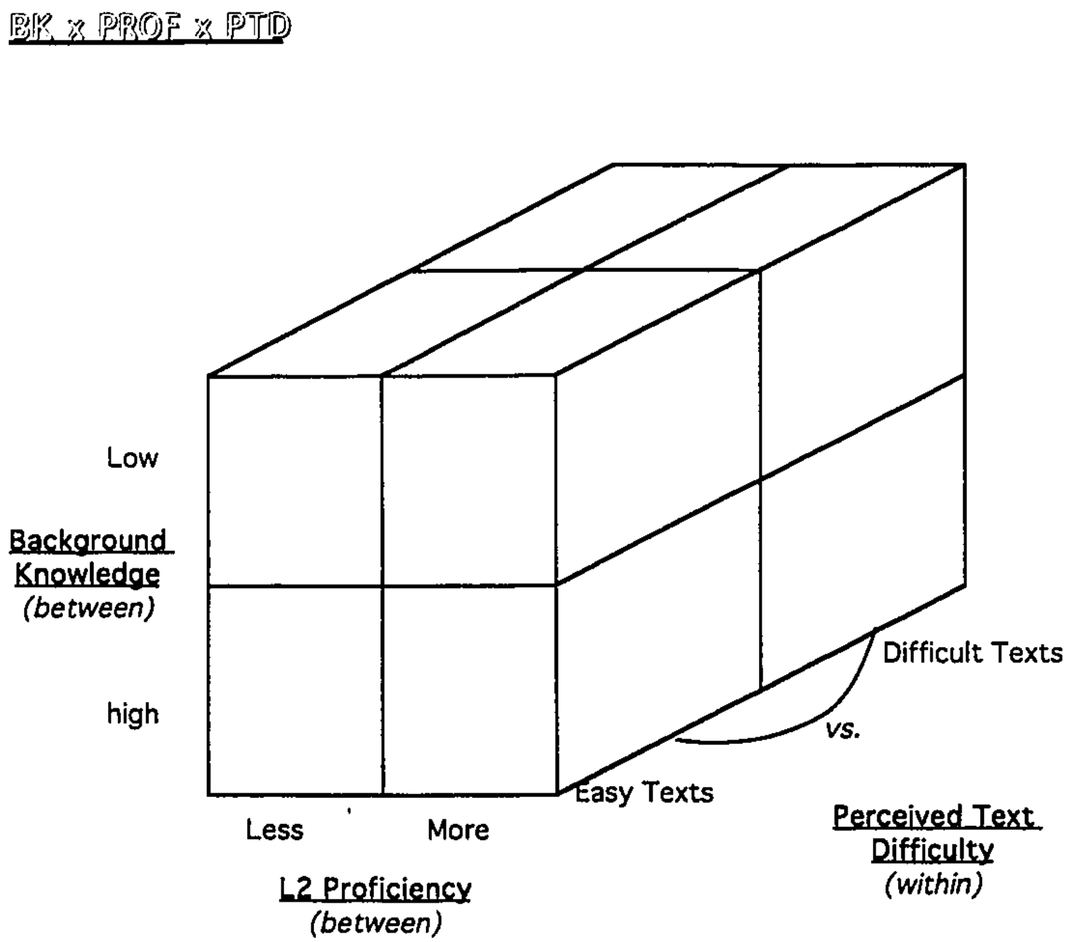


Figure 5
Mixed Between- and Within-Subject Design for Analyzing Data: Perceived Text Difficulty



Chapter Five

Results and Discussion

The results obtained in this research are presented in .three separate sections, each dealing with a distinct issue. Each section also includes a discussion of the results. The first section, *Comprehension of Semantic Information and Efficiency of Processing of the L1 and the L2 Texts,* explores the effects of domain-specific knowledge and language proficiency from the perspective of a stratified model. Focusing on research questions A-a1 to A-e (p.36-37), Section A presents results and discussion pertaining to comprehension of both general and specific semantic information and efficiency of processing. Section B, *Effects of Language of Recall on Processing of Semantic and Syntactic Information from the L2 Texts,* reports the findings related to processing of semantic information, processing of syntactic information and reading strategies reported to have been used in different languages of recall. Analyses in this section examine questions B-f1 and B-f2 (p.37). Section C, *Perceived Text Difficulty,* addresses questions C-g1 and C-g2 (p.40) which investigate relationships between perceived text difficulty and measured comprehension of semantic information, and efficiency of processing. It also explores the attribution of text difficulty.

Before carrying out each of these individual analyses, the English proficiency scores on the Michigan Test of English Proficiency were obtained and used to group the readers. Table 4 presents the distribution of scores for readers with both high and low background knowledge in biology. Based on the English proficiency scores, each of the background knowledge group was subdivided into a less (low-intermediate to intermediate) and a more proficient L2 group (high-intermediate and high). The less proficient L2 group included those who scored at or below 79 (Also see Table 4 for norms and interpretations of test scores). The more proficient L2 group included those who scored above 79. The group mean of the English proficiency scores for the high background-knowledge group (73.33) was lower than that for the low background-knowledge group (77.00). However, this difference was not significant ($t=-1.44$, $df=34$, $p<0.16$). While the number of less vs. more proficient L2 readers was the same among the low background-knowledge readers, the high background-knowledge group divided into a less proficient L2 group with 14 readers and a more proficient L2 group with 4 readers. Because of the unequal cell frequencies, alternative orders were used to test the significance of the effects of between-subject factors to avoid bias in estimates of effects due to pooling over unequal groups of readers (Finn & Bock, 1984).

Table 4

Scores of the Michigan Test of English Language Proficiency with *Norm and Interpretation Information

Score	Norm & Interpretation	Number of Readers with High Background Knowledge	Number of Readers with Low Background Knowledge	L2 Proficiency Group
64	Not proficient enough to take any academic work	0	2	Less Proficient
65-79	May take up to 1/2 the normal academic load	14	7	
80-84	May take up to 3/4 the normal academic load	2	6	More Proficient
85-95	Proficient enough to carry a full-time academic program	2	3	

*The norms and the interpretations given by the English Language Institute (1977).

A. Comprehension of Semantic Information and Efficiency of Processing of the L1 and the L2 Texts

The analyses presented here examine *between-subjects* effects of **(a) background knowledge** (high and low) and **(b) L2 proficiency** (more and less). They investigate *within-subjects* effects of **(c) language condition** (L1 presentation with L1 recall vs. L2 presentation with L1 recall vs. L2 presentation with L2 recall), **(d) text structure** (descriptive vs. procedural) and **(e) propositional type** (events and systems vs. states vs. relations). It also examines interactions among these variables. Both a between-subject design and mixed between- and within-subject designs (see p.57-58) were used for analyzing data pertaining to research questions listed in Chapter 2 (p.36-37). The dependent measures for the between-subject analyses were (i) general comprehension of semantic information, as assessed by percent recall of propositional information for the entire texts and for the individual paragraphs, (ii) comprehension of specific types of semantic information, as assessed by percent recall of the events and systems, the states and the relations for the entire texts and, (iii) efficiency of processing, as assessed by mean reading time (in seconds per proposition) for the entire texts and for the individual paragraphs. In the mixed between- and within-subject analyses, the dependent measures for analyzing effects of language condition were differences in (i) general comprehension of semantic information for the entire texts, (ii) comprehension of specific types of semantic information for the entire texts and, (iii) efficiency of processing.

The dependent measures for text structure were differences in general comprehension of semantic information, and differences in efficiency of processing. The dependent measure for analyzing effects of propositional type was the difference in comprehension of semantic information for the entire texts. Table 5 summarizes all the variables investigated in this section, with specific designs, related research questions and dependent measures.

A1. Recall of Propositional Information

Recall of Propositional Information for the Entire Texts

The group mean proportions of recall of propositional information for the entire texts with each condition of language of presentation and language of recall [i.e., Chinese-Chinese (CC), English-Chinese (EC) and English-English (EE)] are summarized in Figure 6. A series of MANOVAs with preplanned univariate contrasts were conducted to determine if there were any significant main effects and interactions. The results presented are all from multivariate tests, unless otherwise specified. Table 6 presents multivariate analyses of effects of background knowledge (BK) and L2 proficiency (PROF) on percent recall of propositional information for the entire texts and, effects of language (LANG) on differences in percent recall of propositional information for the entire texts.

Strong effects of background knowledge on recall of propositional information were observed [$F(3,30)=7.77$, $p<0.001$]. Specifically, univariate analyses of the individual variables showed that readers with high background knowledge recalled more than those with low background knowledge from the Chinese texts with Chinese recall (CC) [CC: Univariate

Table 5

Variables, Designs, Research Questions and Dependent Measures for Analyses of Comprehension of Semantic Information and Efficiency of Processing of the L1 and the L2 Texts

A. Between-Subject Analyses

Variable	Design *(p.58)*	Research Question *(p.36)*	Dependent Measure
Background Knowledge	BK x PROF	A-a1	Percent recall of propositional information for (i) the entire texts, (ii) the descriptive and (iii) the procedural paragraphs;
		A-a2	Percent recall of propositional information for (i) the events & systems, (ii) the states and (iii) the relations;
		A-a3	Mean reading time (in seconds per proposition) for (i) the entire texts, (ii) the descriptive and (iii) the procedural paragraphs.
L2 Proficiency	BK x PROF	A-b1	
		A-b2	the same as above
		A-b3	

Table Continues

Table 5 *(Continued)*

B. Mixed Between- and Within-Subject Analyses

Variable	Design *(p.59)*	Research Question *(36-37)*	Dependent Measure
Language Condition	BK x PROF x LANG	A-c1	Differences in percent recall of propositional information for the entire texts written in Chinese with Chinese recall vs. those written in English with Chinese recall vs. those written in English with English recall;
		A-c2	Differences in percent recall of the (i) events & systems (ii) the states and (iii) the relations for the entire texts written in Chinese with Chinese recall vs. those written in English with Chinese recall vs. those written in English with English recall;
		A-c3	Differences in mean reading time (in seconds per proposition) for the entire texts written in Chinese with Chinese recall vs. those written in English with Chinese recall vs. those written in English with English recall.
Text Structure	BK x PROFx STRUC	A-d1	Differences in percent recall of propositional information for the descriptive vs. the procedural paragraphs;
		A-d2	Differences in mean reading time (in seconds per proposition) for the descriptive vs. the procedural paragraphs.
Propositional Type	BK x PROF x TYPE	A-e	Differences in percent recall of the events & systems vs. the states vs. the relations for the entire texts.

Figure 6
Recall for the Entire Texts (under Three Language Conditions) by Background Knowledge (BK) and L2 Proficiency

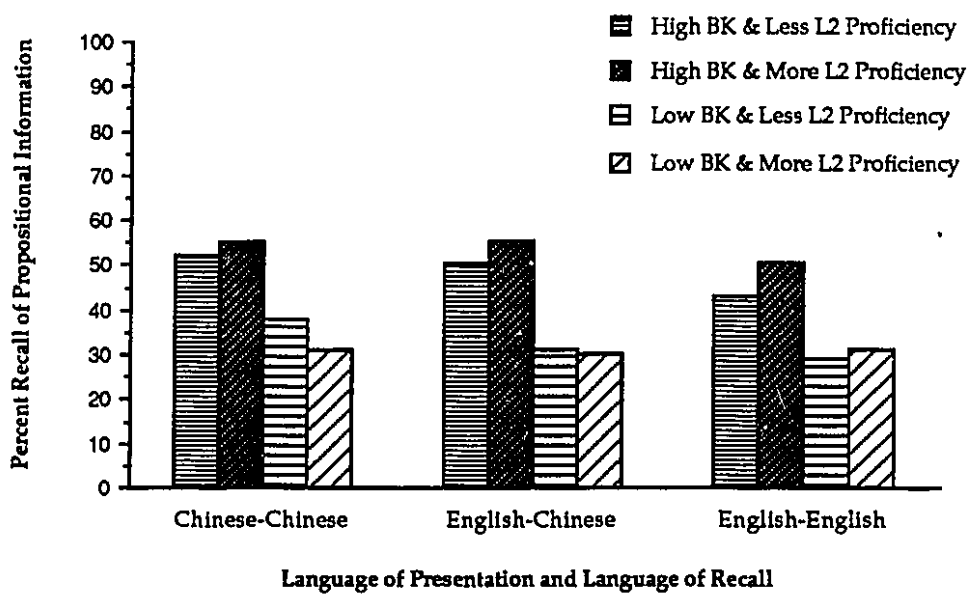


Table 6

MANOVAs of Recall of Propositional Information for the Entire Texts under Three Language Conditions

A. Between-Subject Analyses

Source	*df*	*F*	*p*
Between-Subject Factors			
Background Knowledge [BK]	3,30	7.77	0.0006***
L2 Proficiency [PROF]	3,30	0.51	0.6802
BK*PROF	3,30	0.33	0.8068

B. Mixed Between- and Within-Subject Analyses

Source	*df*	*F*	*p*
Within-Subject Factor			
Language [LANG]	2,31	2.56	0.0936
Interaction bt. the Between- & Within-Subject Factors			
BK*LANG	2,31	0.59	0.5611
PROF*LANG	2,31	0.79	0.4647
BK*PROF*LANG	2,31	0.14	0.8710

$F(1,32)=12.64$, $p<0.001$], the English texts with Chinese recall condition (EC) [EC: Univariate $F(1,32)=22.94$, $p<0.0001$], and the English texts with English recall condition (EE): [EE: Univariate $F(1,32)=7.95$, $p<0.01$]. There were, however, no significant effects of L2 language proficiency on recall of propositional information. Nor were there any significant interactions between background knowledge and L2 proficiency.

To determine the effects of specific language conditions, analyses of contrasts that compared mean proportions of recall of propositional information among the three language conditions were conducted. Multivariate analyses suggested no significant language effect. There were no interactions of these contrasts with background knowledge, or L2 proficiency. There were no triple interactions among language condition, background knowledge and L2 proficiency.

Recall of Propositional Information for the Individual Paragraphs

Figure 7 summarizes the group mean proportions of recall of propositional information for the descriptive (DES) and procedural paragraphs (PROC) with each condition of language of presentation and language of recall. Table 7 presents the multivariate analyses of effects of background knowledge (BK), L2 proficiency (PROF) and text structure (STRUC) on recall of propositional information from individual paragraphs. Strong effects of background knowledge were observed again on recall of propositional information from both the descriptive paragraphs [$F(3,30)=6.63$, $p<0.01$] and procedural paragraphs [$F(3,30)=6.40$, $p<0.01$].

Figure 7
Recall for the Two Individual Paragraphs (under Three Language Conditions) by Background Knowledge (BK) and L2 Proficiency

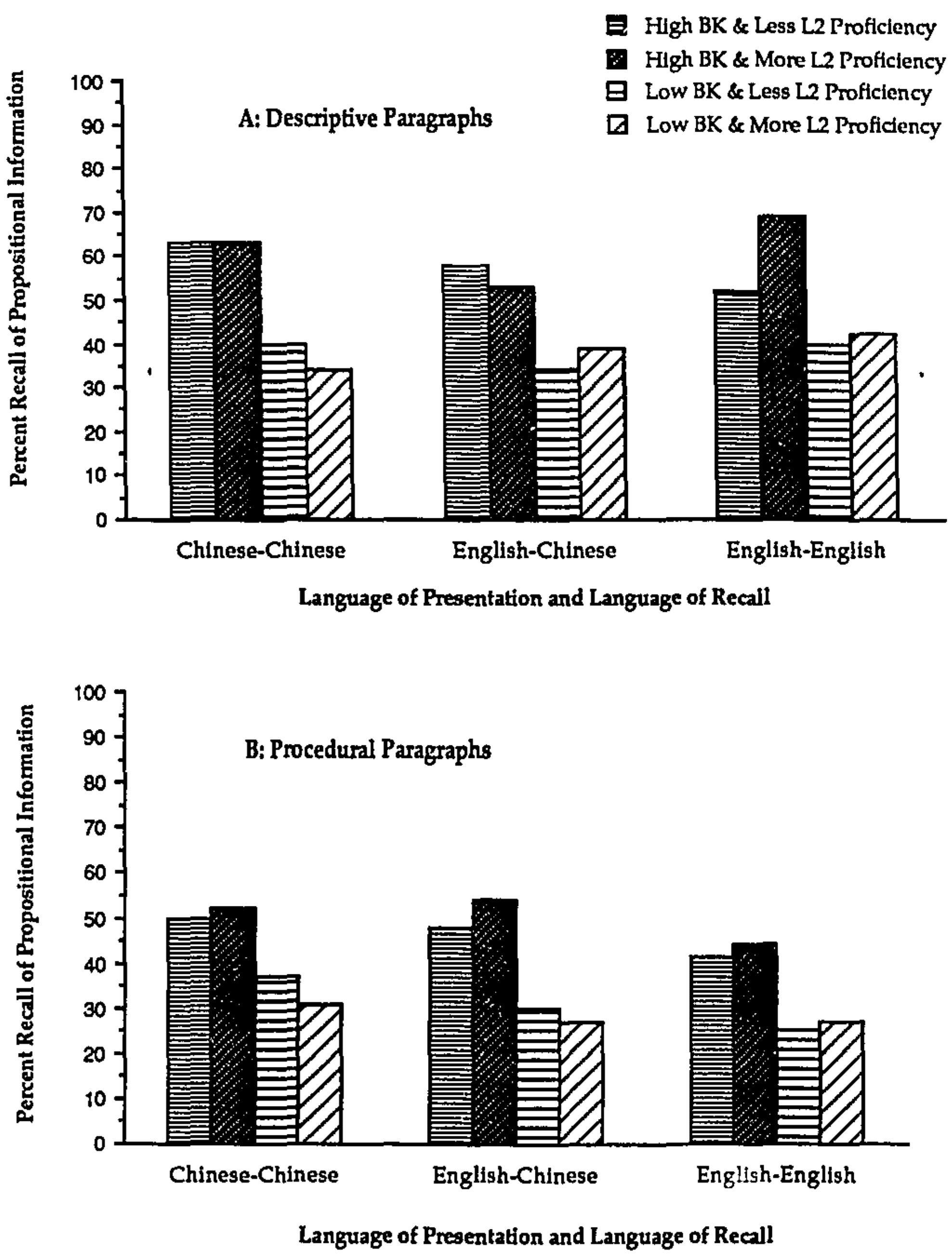


Table 7
MANOVAs of Recall of Propositional Information for the Two Individual Paragraphs under Three Language Conditions

A. Between-Subject Analyses

Source	*df*	*F*	*p*
Background Knowledge [BK]			
Descriptive Paragraph [DES]	3,30	6.63	0.0015**
Procedural Paragraph [PROC]	3,30	6.40	0.0018**
L2 Proficiency [PROF]			
DES	3,30	0.62	0.6090
PROC	3,30	0.21	0.8894
BK*PROF			
DES	3,30	1.04	0.3903
PROC	3,30	0.47	0.7029

B. Mixed Between- and Within-Subject Analyses

Source	*df*	*F*	*p*
Within-Subject Factors			
Text Structure [STRUC]	3,30	16.56	0.0001****
Interaction bt. the Between-Within-Subject Factor			
BK*STRUC	3,30	1.34	0.2788
PROF*STRUC	3,30	0.46	0.7138
BK*PROF*STRUC	3,30	1.68	0.1930

Univariate analyses revealed that readers with high background knowledge recalled more than those with low background knowledge from the Chinese texts for both the descriptive paragraphs [Univariate $F(1,32)=14.95$, $p<0.001$] and the procedural paragraphs [Univariate $F(1,32)=8.72$, $p<0.01$]. The high knowledge readers also recalled more from the English texts for the descriptive paragraphs [English-Chinese: Univariate $F(1,32)=14.21$, $p<0.001$; English-English: Univariate $F(1,32)=5.29$, $p<0.05$] and the procedural paragraphs [English-Chinese: Univariate $F(1,32)=19.36$, $p<0.001$; English-English: Univariate $F(1,32)=7.60$, $p<0.01$]. There were, again no significant effects of L2 language proficiency on recall of propositional information from the individual paragraphs. Nor were there any significant interactions between background knowledge and L2 proficiency.

To determine whether there was any text structure effect, analyses that compared the mean proportions of recall of propositional information for the two paragraph structures were conducted. A text structure effect was observed: there was more recall of the descriptive than the procedural paragraphs [DES-PROC: $F(3,30)=16.56$, $p<0.001$]. Specifically, the readers tended to recall more from the descriptive paragraphs from both the Chinese texts [DES-PROC(CC): Univariate $F(1,32)=10.84$, $p<0.01$] and the English texts with both Chinese recall [DES-PROC(EC) Univariate $F(1,32)=11.31$, $p<0.01$] and English recall conditions [DES-PROC(EE): Univariate $F(1,32)=32.17$, $p<0.0001$]. The text structure effect, however, interacted with neither background knowledge nor L2 proficiency. There was no triple interaction between text structure, background knowledge and L2 proficiency.

A2. Recall of Specific Types of Propositional Information

Having examined general comprehension of semantic (propositional) information, the next step was to determine (1) whether background knowledge (BK) and L2 proficiency (PROF) affected comprehension of specific types of propositional information, i.e., events and systems (E&S), states (ST) and relations (RL) (2) whether there were any effects of propositional type (TYPE), and (3) whether there were any effects of language (LANG) on comprehension of each specific type of propositional information. Interactions among these variables were also examined. The group mean proportions of recall of the three types of propositions for the entire texts within each language condition are presented in Figure 8.

Consistent with the results found in the analyses of recall of propositional information for the entire texts and the individual paragraphs, background knowledge also exerted a strong impact on the recall of all three propositional types (See Table 8). Specifically, readers with high background knowledge recalled more than those with low background knowledge for the events and systems [$F(3,30)=4.81$, $p<0.01$], the states [$F(3,30)=10.51$, $p<0.0001$] and the relations [$F(3,30)=3.77$, $p<0.05$]. Univariate analyses showed that the high knowledge readers recalled more than the low knowledge readers from the Chinese texts for the three propositional types [E&S: Univariate $F(1,32)=8.30$, $p<0.01$; ST: Univariate $F(1,32)=13.94$,

Figure 8
Recall of the Three Types of Propositional Information (under Three Language Conditions) by Background Knowledge (BK) and L2 Proficiency

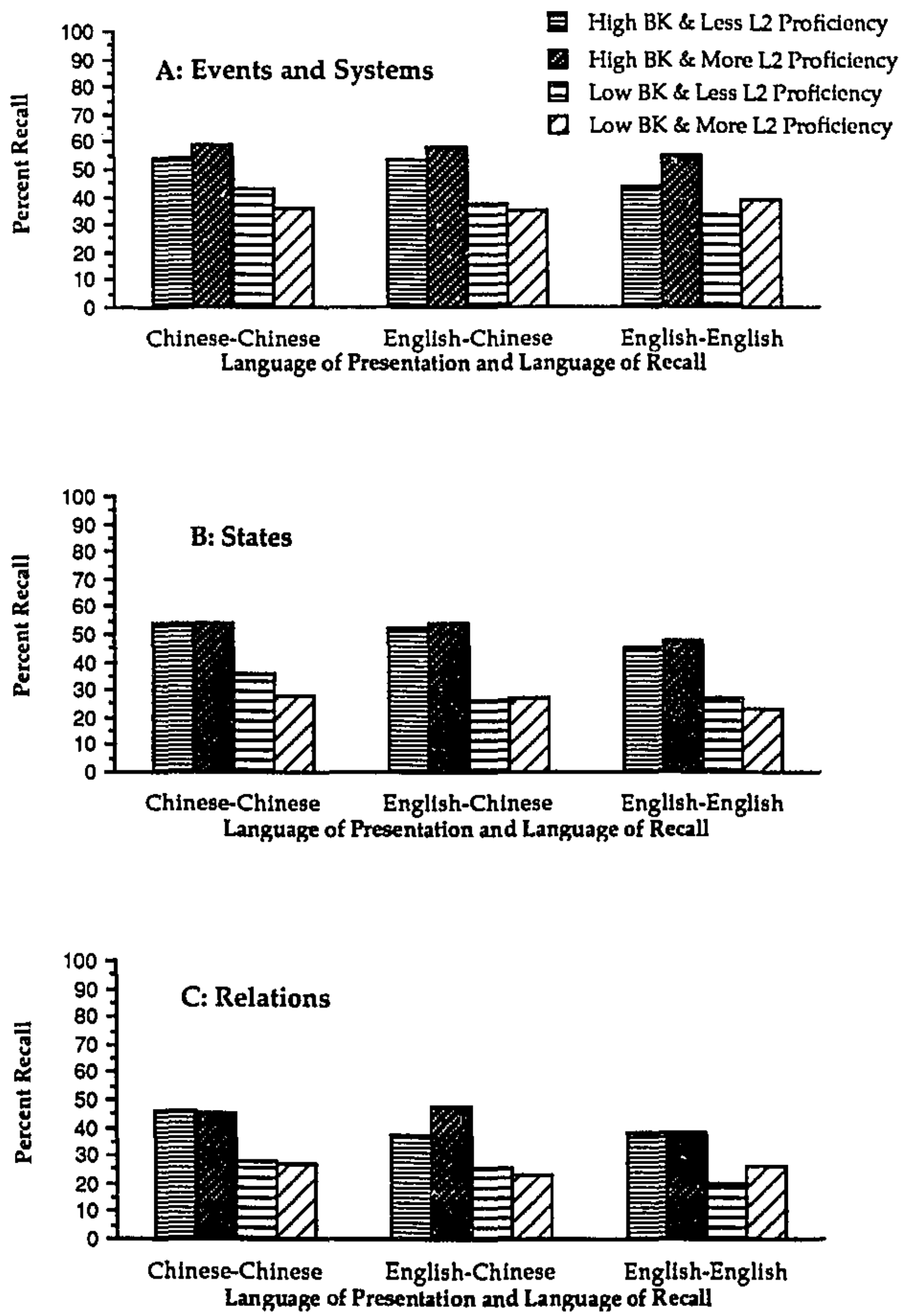


Table 8

MANOVAs of Recall of the Three Types of Propositional Information under Three Language Conditions

A. Between-Subject Analyses

Source	*df*	*F*	*p*
Between-Subject Factors			
Background Knowledge [BK]			
Event & System [E&S]	3,30	4.81	0.0076**
States [ST]	3,30	10.51	0.0001****
Relations [RL]	3,30	3.77	0.0210*
L2 Proficiency [PROF]			
E&S	3,30	0.78	0.5164
ST	3,30	0.35	0.7908
RL	3,30	0.22	0.8808
BK*PROF			
E&S	3,30	0.43	0.7367
ST	3,30	0.23	0.8718
RL	3,30	0.50	0.6874

Table Continues

Table 8 *(Continued)*

B. Mixed Between- and Within-Subject Analyses

Source	*df*	*F*	*p*
Within-Subject Factors			
Propositional Type [TYPE]	6,27	15.85	0.0001****
Language [LANG]			
E&S	2,31	2.06	0.1445
ST	2,31	3.46	0.0440*
RL	2,31	1.53	0.2331
Interaction bt. the Between-Within-Subject Factors			
BK*TYPE	6,27	2.95	0.0242*
PROF*TYPE	6,27	2.06	0.0915
BK*PROF*TYPE	6,27	0.63	0.7079
BK*LANG			
E&S	2,31	0.49	0.6200
ST	2,31	0.78	0.4692
RL	2,31	0.03	0.9687
PROF*LANG			
E&S	2,31	1.18	0.3199
ST	2,31	0.49	0.6180
RL	2,31	0.24	0.7961
BK*PROF*LANG			
E&S	2,31	0.20	0.8216
ST	2,31	0.22	0.8025
RL	2,31	0.70	0.5042

p<0.001; RL: Univariate F(1,32)=6.65, p<0.05]. They also recalled more from the English texts with both Chinese recall [E&S: Univariate F(1,32)=14.32, p<0.001; ST: Univariate F(1,32)=29.12, p<0.01; RL: Univariate F(1,32)=7.26, p<0.01] and English recall [E&S: Univariate F(1,32)=4.20, p<0.05; ST: Univariate F(1,32)=12.19, p<0.01; RL: Univariate F(1,32)=6.65, p<0.05].

Also similar to the results found in overall recall of propositional information, there were no effects of L2 proficiency on recall of specific types of propositional information. Nor was there any significant interaction between background knowledge and English proficiency.

Within-subject comparisons of recall for the three types of propositional information showed differential processing of particular types of propositional information [F(6,27)=15.85, p<0.0001]. Specifically, among the three propositional types, events and system were recalled more than states [E&S-ST(CC): Univariate F(1,32)=4.81, p<0.05; E&S-ST(EC): Univariate F(1,32)=8.25, p<0.01; ES-ST(EE): Univariate F(1.32)=22.16, p<0.0001] while relations were recalled less than states [ST-RL(CC): Univariate F(1,32)=6.72, p<0.01; ST-RL(EC): Univariate F(1,32)=11.90, p<0.01; ST-RL(EE): Univariate F(1,32)=4.84, p<0.05]. These effects also interacted with background knowledge [BK*TYPE: F(6,27)=2.95, p<0.05]. Univariate analyses revealed that the interaction was located in the differential recall of the events and system vs. states where the tendency to recall more events and systems than states was stronger in the low background-knowledge than in the high background-knowledge group [BK*TYPE E&S-ST(EC): Univariate F(1,32)=4.95, p<0.05; BK*TYPE E&S-ST(EE): Univariate F(1,32)=8.44, p<0.01].

The effects of propositional type, however, did not interact with English proficiency. There was no triple interaction among propositional type, background knowledge and L2 proficiency.

Analyses of language condition for each propositional type showed a significant effect of language condition on readers' recall of states [$F(2,32)=3.46$, $p<0.05$]. Univariate analyses revealed this effect was attributable to the differential processing of states for the Chinese vs. for the English texts with English recall. Readers tended to recall more states from texts written in Chinese than from English texts with English recall [ST(CC-EE): Univariate $F(1,32)=3.89$, $p<0.01$]. The effect of language of presentation, however, did not interact with either background knowledge or L2 proficiency.

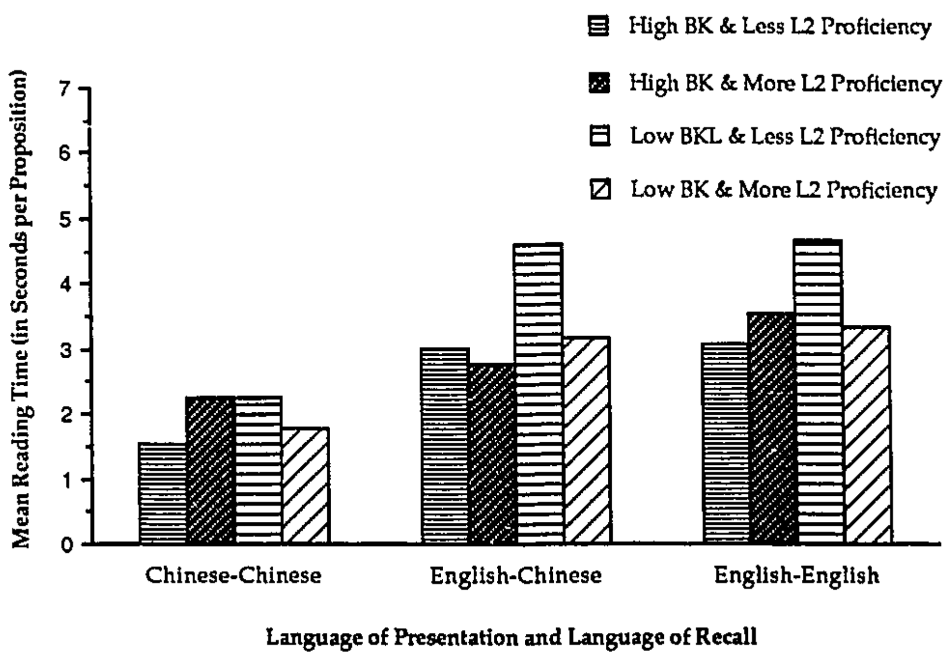
A3. Reading Time

While the analyses of comprehension of propositional information helped to illustrate what information may have been comprehended, they did not indicate how processing efforts were allocated and what relationships are between such efforts and background knowledge, L2 proficiency, language condition and text structure. To address these issues, reading time was examined.

Reading Time for the Entire Texts

Figure 9 summarizes the reading-time results in terms of mean reading time (in seconds per proposition) for the entire texts under each language condition. This section presents the results of analyses of effects of

Figure 9
Passage Reading Time (under Three Language Conditions) by Background Knowledge (BK) and L2 Proficiency



background knowledge (BK) and L2 proficiency (PROF) on reading time, and effects of language condition (LANG) on reading time for the entire texts. Multivariate analyses (Table 9) showed that background knowledge affected reading time [$F(3,30)=6.17$, $p<0.01$]. Univariate analyses revealed that readers with high background knowledge read faster than those with low background knowledge for the English texts with both Chinese recall [Univariate $F(1,32)=12.66$, $p<0.001$] and English recall [Univariate $F(1,32)=4.38$, $p<0.05$]. However, background knowledge had no significant effect on the reading time for the Chinese texts.

Unlike the results for recall of propositional information, English proficiency was found to affect reading time for the entire texts [$F(3,30)=5.50$, $p<0.01$]. Univariate analyses revealed that readers with greater English proficiency tended to read faster than those with less proficiency the English texts with Chinese recall [Univariate $F(1,32)=7.24$, $p<0.01$]. The L2 proficiency effect, however, did not interact with background knowledge. Since the patterns of reading time within each prior knowledge group appeared to be different, separate group analyses were conducted to further examine the effects of English proficiency. It appeared as if the English proficiency effects observed in the pooled group analyses were attributable principally to the low knowledge readers. Specifically, readers with low background knowledge and with greater English proficiency read faster than those with less proficiency for the English texts with Chinese recall

Table 9

MANOVAs of Reading Time for the Entire Texts under Three Language Conditions

A. Between-Subject Analyses

Source	*df*	*F*	*p*
Between-Subject Factors			
Background Knowledge [BK]	3,30	6.17	0.0022**
L2 proficiency [PROF]	3,30	5.50	0.0040**
BK*PROF	3,30	1.26	0.3065

B. Mixed Between- and Within-Subject Analyses

Source	*df*	*F*	*p*
Within-Subject Factor			
Language [LANG]	2,31	108.19	0.0001****
Interaction bt. the Between- & Within-Subject Factors			
BK*LANG	2,31	7.74	0.0019**
PROF*LANG	2,31	8.07	0.0016**
BK*PROF*LANG	2,31	0.35	0.7112

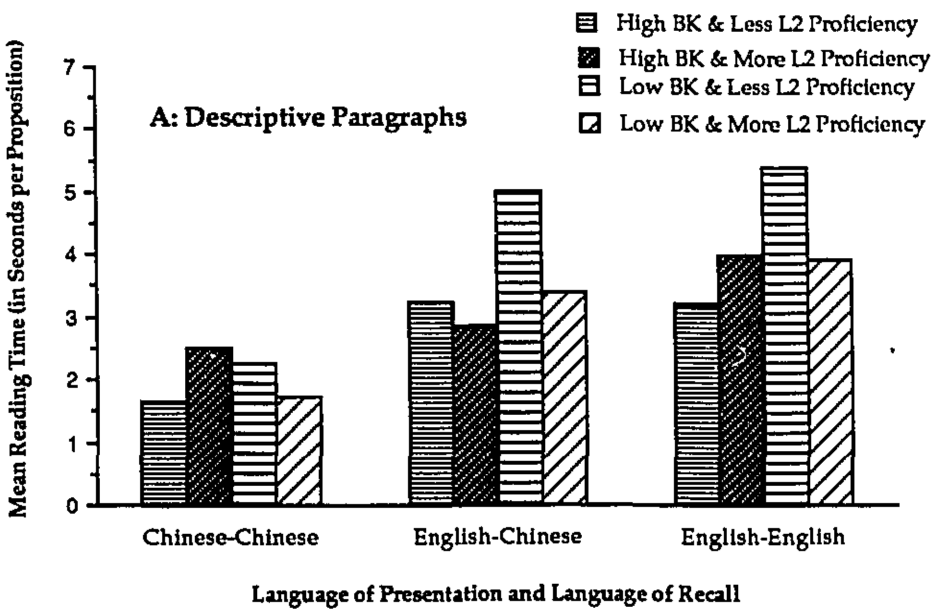
[Univariate $F(1,16)=9.43$, $p<0.01$]. Analyses within the high background-knowledge group, on the other hand, showed no significant effects of English proficiency.

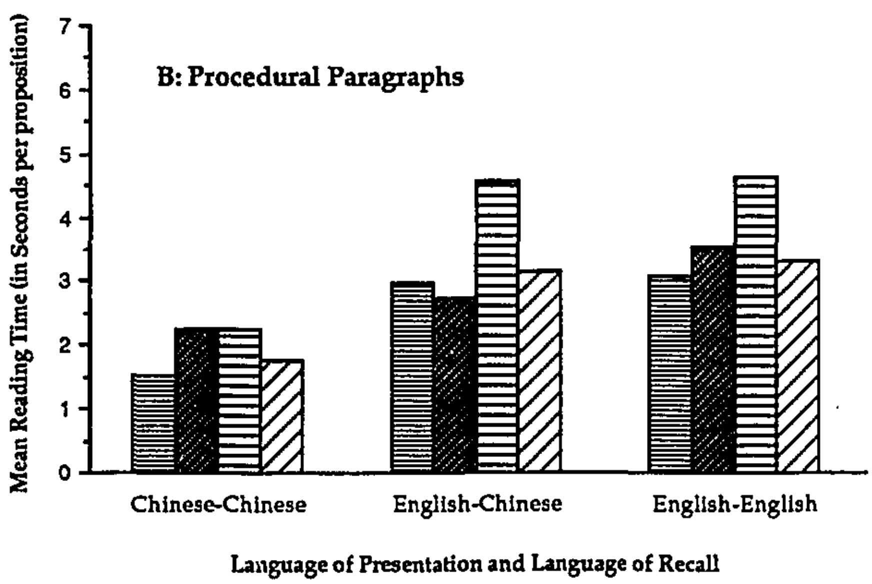
Within-subject analyses of contrasts that compared reading time in different language conditions showed strong language effects on reading time [$F(2,31)=108.19$, $p<0.0001$]. Univariate analyses revealed that it was the language of presentation rather than language of production that explained these differences, i.e., reading time for the Chinese text was faster not only than that for the English texts with the Chinese recall [(CC-EC): $F(1,32)=212.83$, $p<0.0001$] but also than the English texts with English recall [(CC-EE): $F(1,32)= 97.25$, $p<0.0001$]. Language effects interacted with both background knowledge [$F(2,31)=7.74$, $p<0.01$] and English proficiency [$F(2,31)=8.07$, $p<0.01$]. Univariate analyses suggested that the interactions also resided in the language of presentation, i.e., Chinese texts were read significantly faster than English texts with Chinese recall [BK*LANG(CC-EC): $F(1,32)=15.96$, $p<0.001$; PROF*LANG(CC-EC): $F(2,32)=16.41$, $p<0.001$]. Although the language effect appeared to be smaller among readers with specific background knowledge in biology and among readers with high level of L2 proficiency, there were no significant triple interactions among language condition, background knowledge and English proficiency.

Reading Time for the Individual Paragraphs

Figure 10 summarizes the reading-time results for the individual paragraphs. The following analyses examined effects of background knowledge (BK) and L2 proficiency (PROF) on reading time for individual

Figure 10
Paragraph Reading Time (under Three Language Conditions) by Background Knowledge (BK) and L2 Proficiency





paragraphs and effects of text structure (STRUC) on reading time for the individual paragraphs. It was observed that background knowledge affected the reading time for the procedural paragraphs [$F(3,30)=5.90$, $p<0.01$] (See Table 10). Univariate analyses revealed that readers with high background knowledge read faster than those with low background knowledge for the English procedural paragraphs with both Chinese recall [Univariate $F(1,32)=12.56$, $p<0.001$] and English recall [Univariate $F(1,32)=4.86$, $p<0.05$] and for the English descriptive paragraphs with Chinese recall [Univariate $F(1,32)=6.47$, $p<0.05$]. However, background knowledge had no significant effect on the reading time for the Chinese paragraphs and the English descriptive paragraphs in the English recall condition.

English proficiency was found to affect reading time for the procedural paragraphs [$F(3,30)=5.41$, $p<0.01$]. Univariate analyses revealed that readers with greater English proficiency tended to read faster than those with less proficiency the English procedural paragraphs with Chinese recall [Univariate $F(1,32)=6.94$, $p<0.01$]. Univariate analysis also revealed an effect of English proficiency for the English descriptive paragraphs with Chinese recall [Univariate $F(1,32)=4.10$, $p<0.01$]. Separate analyses of L2 proficiency effects within each conceptual knowledge group indicated again that the English proficiency effects observed in the pooled group analyses may be attributable principally to the low background-knowledge group. English proficiency affected low knowledge readers' reading time of the English descriptive paragraphs with Chinese recall [Univariate $F(1,16)=4.78$, $p<0.05$] and the English procedural paragraphs with English recall [Univariate

Table 10
MANOVAs of Reading Time for the Two Individual Paragraphs under Three Language Conditions

A. Between-Subject Analyses

Source	*df*	*F*	*p*
Between-Subject Factors			
Background Knowledge [BK]			
Descriptive parag. [DES]	3,30	2.17	0.1124
Procedural parag. [PROC]	3,30	5.90	0.0028**
L2 proficiency [PROF]			
DES	3,30	1.34	0.2804
PROC	3,30	5.41	0.0043**
BK*PROF			
DES	3,30	0.97	0.4189
PROC	3,30	1.43	0.2537

B. Mixed Between- and Within-Subject Analyses

Source	*df*	*F*	*p*
Within-Subject Factors			
Text Structure [STRUC]	3,30	1.49	0.2380
Interaction bt. the Between- & Within-Subject Factor			
BK*STRUC	3,30	0.31	0.8156
PROF*STRUC	3,30	0.07	0.9773
BK*PROF*STRUC	3,30	0.13	0.9399

$F(1,16)=4.83$, $p<0.05$]. Analyses within the high knowledge group again showed no significant effects of English proficiency.

Finally, analyses of contrasts between the reading time for the descriptive vs. that for the procedural paragraphs showed no significant effect of type of text structure. Neither were there any significant interactions between text structure, background knowledge and English proficiency.

A4. Summary of the Results of Comprehension of Semantic Information and Efficiency of Processing of the L1 and the L2 Texts

The following summarizes the results obtained from the analyses of the two between-subject factors, the three within-subject factors and the interactions involving both the between- and the within-subject factors.

1) Background Knowledge: Background knowledge greatly facilitated recall of propositional information from the entire texts, from individual paragraphs and for all the specific types of propositional information from both the Chinese and the English texts. It also significantly decreased reading time for the entire English texts and the English procedural paragraphs. Background knowledge, however, did not affect reading time for the entire Chinese texts. Neither did it affect reading time for the Chinese paragraphs and the English descriptive paragraphs with English recall.

2) L2 proficiency: More proficient L2 readers in **the low knowledge group** tended to read faster the entire English-language texts, the English descriptive paragraphs with Chinese recall, and the English procedural

paragraphs with English recall. No differences were found for the high knowledge groups' reading time. Nor was English proficiency found to affect overall recall of propositional information or recall of specific types of propositional information for readers in both the high and the low knowledge groups.

3) Text structure: The readers tended to exhibit more recall of propositional information from the descriptive than from the procedural paragraphs. Their reading time for the descriptive paragraphs did not differ from that for the procedural paragraphs.

4) Propositional type: The readers tended to recall events and systems most and relational information least.

5) Language Condition: The effects of language condition were seen in the reading time and in the recall of the states. These effects were attributable to the language of presentation (i.e., readers tended to read faster the entire texts and have more recall of states written in Chinese than those written in English).

6) Interactions: In terms of reading time, language of presentation interacted not only with background knowledge, but also with English proficiency. An interaction also occurred between the differential processing of events and systems and states and background knowledge. There were, however, no other interactions.

A5. Discussion of the Results of Comprehension of Semantic Information and Efficiency of Processing of the L1 and the L2 Texts

In general, these results are consistent with stratified theories of discourse comprehension (e.g., Frederiksen & Donin, 1991) where comprehension processes are viewed as being both multilevel and modular. The effects of background knowledge, as exhibited in the present study, were so strong that they affected every aspect of comprehension at the higher conceptual and semantic levels that were assessed in the present study. Knowledge of biology differentiated recall of propositional information for the entire texts, for the descriptive and procedural paragraphs, and for various types of propositional information of texts written in both the first and second language. Although prior knowledge also affected processing at the local lexical and syntactic levels, as seen in the faster reading time, it did not affect efficiency of processing for the L1 texts. Thus, *prediction A*: Prior conceptual knowledge (i) exerts strong positive effects on comprehension at the higher conceptual and semantic levels and (ii) has some limited effects on processing at the local lexical and the syntactic levels, was verified.

On the other hand, language proficiency appears to have affected processing at the local lexical and syntactic levels. As exhibited in the present study, the readers tended to read the L1 texts faster than the L2 texts. This processing difference seems to have originated from the fact that readers might have greater linguistic knowledge and/or efficiency of lexical and syntactic processing in their first than their second language. It seems that automaticity (LaBerge & Samuels, 1974), in which processing of the orthographic, lexical and syntactic information is effortless, is more likely to be reached when one is reading in one's first language. More direct evidence of effects of language proficiency on lower-level processing came from low knowledge readers' reading time for the L2 texts. Among this group of readers, the more proficient L2 readers tended to read faster than the less proficient ones for the L2 texts. However, as far as processing at the higher conceptual and semantic levels was concerned, the effects of language proficiency were very limited. When comprehension of different types of semantic information was examined, language proficiency only benefited recall of states. However, recall of events and systems and relational information as well as recall of propositional information for the entire texts was not affected by language proficiency. These results were consistent with *predictions B*: language proficiency (ii) exerts strong effects on processing at the local lexical and syntactic levels and (ii) has some limited effects on processing at the higher conceptual and semantic levels.

Many discourse comprehension researchers, especially those in the L2 area, have tended to assume that lack of linguistic skills in some way would either result in bottom-up processing or would short-circuit comprehension processes, thus making it difficult for L2 readers to utilize higher conceptual knowledge (e.g., Clarke, 1980; Cziko, 1980). The results of this study suggest that such assumptions may be simplistic. With respect to comprehension of semantic information, conceptual knowledge may not only play a much more important role than linguistic skills, but it may also exert much stronger compensatory effects than many researchers have believed. It seems clear that lack of domain-specific knowledge will result in less comprehension. A less obvious implication suggested by this study is that lack of linguistic skills does not necessarily cause difficult processing at the higher conceptual and semantic levels. For the high knowledge readers with less L2 proficiency, their relevant conceptual schemes seemed to have compensated for their deficiency in the language. The compensatory mechanism (e.g., Stanovich, 1986; Wolf, 1987) was such that their comprehension seemed to be relatively unaffected by their language deficiency. Insufficient linguistic knowledge was more likely to result in laborious processing when there were no relevant conceptual schemes to rely upon. Furthermore, for those readers lacking relevant conceptual schemes, increased processing time did not result in enhanced comprehension, i.e., regardless of the extra processing efforts the low knowledge readers exerted, their comprehension for the semantic information was still much less than that of the high knowledge readers. These results suggest that domain-specific knowledge is a must for successful comprehension and that deficiency in language becomes a problem primarily when one does not have adequate domain-specific knowledge to override it.

These results not only implicate the importance of preexisting knowledge structures (e.g., Bartlett, 1932; Rumelhart & Ortony, 1977) but also point out the need to study how a specific type of preexisting knowledge structure affects comprehension and comprehension processes. Both the high and low knowledge groups exhibited the same patterns for the differential recall of information from the descriptive and procedural paragraphs and the same patterns of reading time for the descriptive and the procedural paragraphs (i.e., they tended to recall more from descriptive than procedural paragraphs and, their reading time for the two types of paragraphs did not differ). They also exhibited the same pattern of differential recall of specific types of propositional information (i.e., they tended to recall events and systems most and relations least). Thus, we are led to believe that, in this context, science students generally are comparable in their knowledge of both science text structure and in their patterns of comprehension of different types of information. Nevertheless, such comparability did not result in comparable comprehension which, as exhibited in the present study, depends heavily on domain-specific knowledge. Prior knowledge differentiated every aspect of comprehension at higher conceptual and semantic levels that was assessed in the present study. In addition, although both the high and the low knowledge readers recalled more events and systems than states, states appeared to be more challenging to the low knowledge readers. This may be due to the fact that comprehension of states in these texts required more domain-specific knowledge than did that of the events and systems. Analyses of the test texts confirmed that while the events and systems expressed concepts that generally were not domain-specific, the majority of the biology terminology was expressed by states. It appears that comprehension in a specific domain depends on, just as Gelman and Greeno (1989) have hypothesized, the use of that domain's principles which may have directed the readers' selective attention to search, identify and provide clues as how to interpret domain-relevant information from the input texts. Since domain-specific knowledge is a must for successful comprehension, and since deficiency in language becomes a problem primarily when one does not have any appropriate conceptual knowledge to override it, it is desirable for classroom instruction to be sensitive to knowledge in a particular content area. In helping readers to acquire and utilize conceptual knowledge, curriculum and instruction could, for example, be designed to connect new information to the concepts and principles that readers already have.

Finally, unlike the results found by Lee (1986) and Donin and Silva (1993), the present study found no significant difference between L1 and L2 production. Since the task of recalling a L2 text in one's first language requires a reader to access two language codes, the inconsistency of this study with the results of the other studies may be due to the great linguistic distance between Chinese and English. As discussed earlier in Chapter 2, languages in the same language family tend to share many features in terms of orthography, phonetics, lexicons and sentence structures, while languages from different language families differ greatly across these linguistic features. Thus it may be easier for the speakers of languages in the same language family to shift back and forth from one language to another. Such facility may, in turn, allow the bilinguals to benefit from using their native language which may facilitate their processing and/or expressing of information in their first language. This may explain why in reading

English texts both Spanish and French first language readers tend to recall more in their native than their L2 language. Although the Chinese-English readers may also find it easier to express what they have comprehended in their L1 language, they may at the same time be hindered by trying to resolve enormous linguistic differences between the two languages. In other words, while the L1 recall condition may facilitate certain aspects of cognitive processing for the Chinese-English readers, it may at the same time increase the memory demands as the reader tries to find equivalence between the two languages. The effects of language of recall will be explored furthere in the next section.

B. Effects of Language of Recall on Processing of Semantic and Syntactic Information from the L2 Texts

This section focuses on effects of language of recall on processing of both semantic and syntactic information from the L2 texts. It addresses research questions B-f1 and B-f2 (p.37). A mixed between- and within-subject design (p.60) was employed. It investigates, *within-subjects*, effects of language of recall (LR), and the interactions among language of recall, background knowledge (BK) and L2 proficiency (PROF). In addition, this section examines self-reported reading strategies used in different languages of recall. The dependent measures were as follows:

(i) differences in percent recall of propositional information in the L1 (i.e., Chinese) vs. the L2 (i.e., English) recall condition;
(ii) differences in percent recall of (a) active and (b) passive voice in the L1 (i.e., Chinese) vs. the L2 (i.e., English) recall condition;
(iii) differences in mean number of change of the voice forms in the L1 (i.e., Chinese) vs. the L2 (i.e., English) recall.

B1. Processing of Semantic Information

The analysis conducted here was designed to determine whether there were any production effects, i.e., if the readers recalled more propositional information in the L1 (EC) than the L2 (EE) recall condition. Figure 11 summarizes the mean proportion of propositional recall for the entire English texts in both the Chinese and English recall conditions. A univariate analysis (Table 11) that compared contrasts between the two recall conditions showed no production effect. Nor were there any significant

Figure 11
Recall for the Entire English Texts by Background Knowledge (BK) and L2 Proficiency

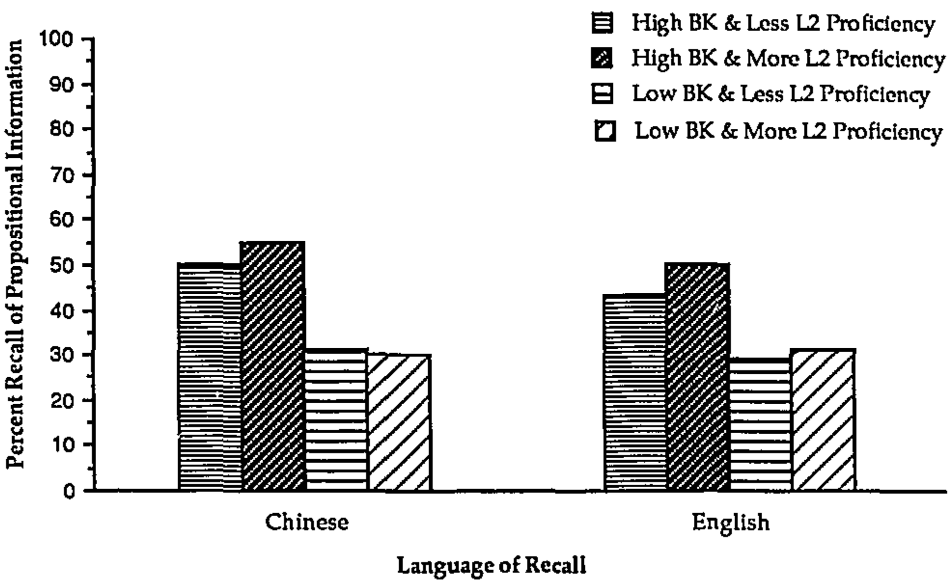


Table 11

ANOVAs of Effects of Language of Recall on Recall of Propositional Information from the English Texts

Source	*df*	*F*	*p*
Within-Subject Factor			
Language of Recall: EC-EE (LR)	1,32	2.03	0.1637
Interaction bt. the Between- & Within-Subject Factors			
Background Knowledge(BK)*LR	1,32	1.03	0.3176
L2 Proficiency(PROF)*LR	1,32	0.51	0.4382
BK*PROF*LR	1,32	0.03	0.8676

interactions between language of production, background knowledge and L2 proficiency.

B2. Processing of Syntactic Information

To investigate effects of language of recall on processing of L2 syntactic information from the L2 texts, differential recall and change of the voice forms in the L1 (EC) vs. the L2 recall condition (EE) were examined. Figure 12 summarizes the mean proportions of recall of active voice (AV) and passive voice (PV) for each group of readers. In order to determine whether recall of the voice forms was affected by the language of recall condition, ANOVA tests that compared contrasts of mean proportion of recall of (1) active voice in the L1 recall vs. that in the L2 recall condition and (2) passive voice in the L1 recall vs. that in the L2 recall condition were conducted (Table 12). The readers were found to have recalled more active voice in the L1 than in that the L2 recall condition [Active(EC-EE): $F(1,32)=4.26$, $p<0.05$] and recalled less passive voice in the L1 than in the L2 recall [Passive(EC-EE): $F(1,32)=4.81$, $p<0.04$]. These effects, however, did not interact with background knowledge and L2 proficiency.

The analysis of syntactic processing also included an examination of change of voice. Figure 13 summarizes average number of changes from passive to active voice. One should note that this figure does not show any changes that the readers made from the active voice to the passive voice. The reason for this is that **none** of the readers made even a single change from active to passive voice in both the Chinese and the English recall

Figure 12
Recall of the English Voice Forms by Background Knowledge (BK) and L2 Proficiency

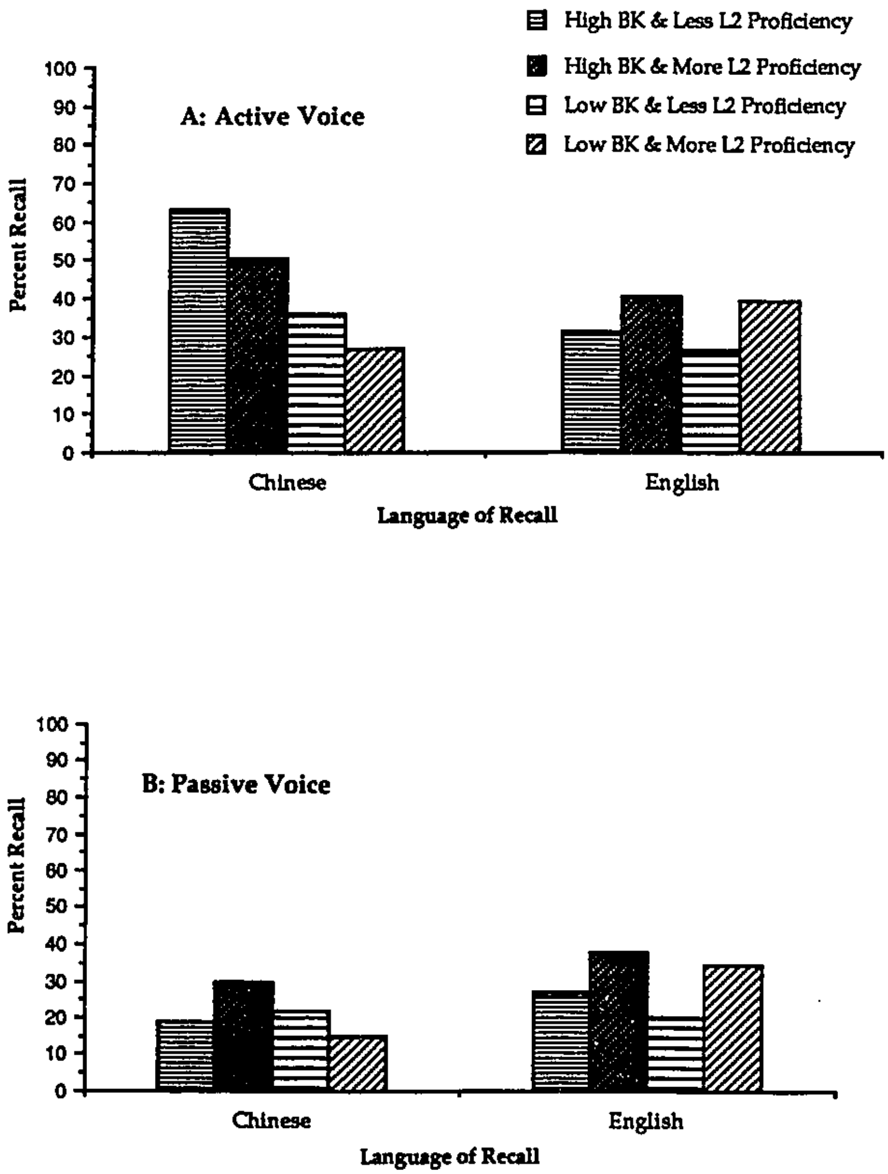
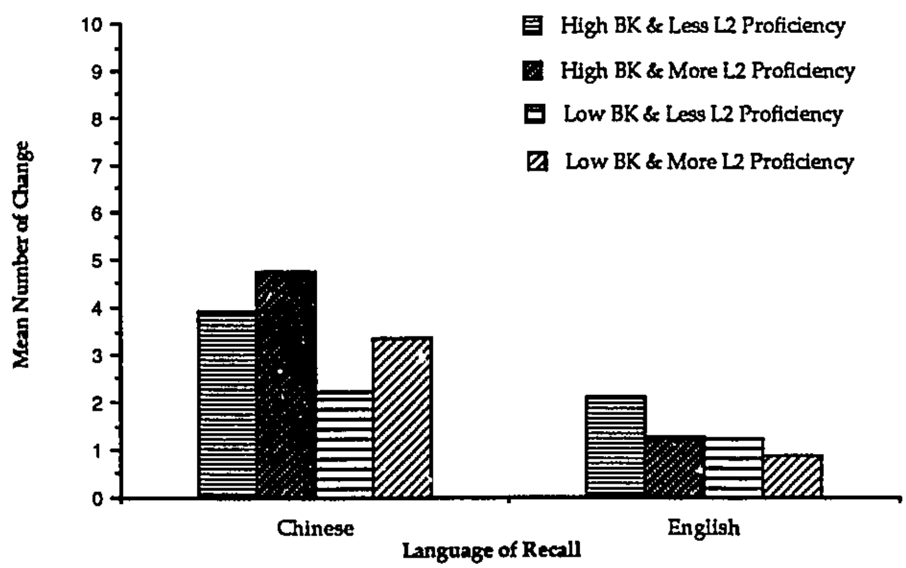


Table 12

ANOVAs of Effects of Language of Recall on Recall of the Voice Forms from the English Texts

Source	*df*	*F*	*p*
Within-Subject Factors			
Language of Recall: EC-EE (LR)			
Active Voice (AV)	1,32	4.26	0.0473*
Passive Voice (PV)	1,32	4.81	0.0358*
Interaction bt. the Between- & Within-Subject Factors			
Background Knowledge (BK)*LR			
BK*AV	1,32	2.81	0.1035
BK*PV	1,32	0.17	0.6875
L2 Proficiency (PROF)*LR			
PROF*AV	1,32	2.54	0.1208
PROF*PV	1,32	2.41	0.1308
BK*PROF*AV	1,32	0.00	0.9682
BK*PROF*PV	1,32	1.68	0.2039

Figure 13
Change of the English Voice Forms (from Passive to Active) by Background Knowledge (BK) and L2 Proficiency



conditions. In sharp contrast to the zero change from active to passive voice was that more than 89% of the readers made various numbers of changes from passive to active voice in the L1 recall and, that more than 38% of the readers made various numbers of change from passive to active voice in the L2 recall condition. Furthermore, ANOVA tests (Table 13) that compared contrasts of mean number of changes in the L1 vs. that in the L2 recall condition revealed that more changes from passive to active voice were made in the Chinese than in the English recall [Passive to Active (EC-EE): $F(1,32)=30.09$, $p<0.0001$]. These effects, again, did not interact with background knowledge and English proficiency.

B3. Self-Reported Use of Reading Strategies

The interview data revealed that the readers may have processed the texts in the L2 recall condition differently from that in the L1 recall condition. With the L2 recall condition, 42% of the readers reported that they had employed a surface-level processing strategy, characterized by verbatim recall. A typical example was found in this reader's report:[3]

> "You can recall a word without knowing what it is. You know what it is. If it's a noun, you put it into a place where it belongs (Reader Code: BL20)."

On the other hand, 29% of the readers reported that the L1 language recall condition facilitated their thinking processes or/and their expressions.

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[3] All the quotes were the author's translation from the original Chinese.

Table 13

ANOVAs of Effects of Language of Recall on Change of the Voice Forms (from Passive to Active) from the English Texts

Source	*df*	*F*	*p*
Within-Subject Factors			
Language of Recall: EC-EE (LR)	1,32	30.09	0.0001****
Interaction bt. the Between- & Within-Subject Factors			
Background Knowledge (BK)*LR	1,32	1.51	0.2278
L2 Proficiency (PROF)*LR	1,32	3.81	0.0599
BK*PROF*LR	1,32	0.02	0.9016

A high background-knowledge reader explained (Reader Code: BL05):

> "If it's in Chinese, I can express myself freely. ... As long as I understand, I can elaborate easily. Besides, I have knowledge in the field. So, as soon as I look at the title [Note: In the reading-session, no title was provided. Here the reader may refer to the theme], I can just make up [an answer]."

This view was also shared by those who had much less prior knowledge in the content area. Some readers stated that they tended to store the content of the L2 texts in their first language.

> "[Even] when I recalled in English, it seems that I have turned it into Chinese first... In order to remember them, I used the simplest Chinese structure, ... [i.e. first] turned it into simplest Chinese, and then translated it back into English."

While this processing style may facilitate some aspects of comprehension, it seems that it was not without a price, as was realized by many readers. With the L1 recall condition many readers found themselves involved in translation in which they often had to struggle with finding the equivalent sentence structures, lexicons and so on between languages. The following are two typical examples.

> "If [the recall condition] is English-Chinese, translation processes often take place in your mind. [While translating], you may forget a lot of key words. So the meaning becomes incomplete. When you try to think how to translate a word within a short lapse, it becomes difficult for you to remember the content that follows (Reader Code BL01)."

> "[to recall in English] I can copy the word, I don't have to organize them in Chinese..... If I have to reorganize the English clauses in Chinese, like 'which' and some phrases, [I] would be under [time] pressure. It's only a very short lapse, but [time] is limited. That would interfere with my understanding of the content (Reader Code EL27)."

B4. Discussion of the Results of Language of Recall

The results in this part of the study suggest differential effects of linguistic knowledge on different levels of processing. Linguistic knowledge was found to have little effect on semantic-level processing, as seen in the recall of propositional information; however, it strongly influenced syntactic-level processing. It was in their first language that the readers were more likely to change the less frequently used voice form to the more frequently used voice form (i.e., change the passive to the active voice). The effects of the L1 structures were so strong that **none** of the 36 readers made a single change from the active to the passive voice. But more than 38% of these readers made various numbers of changes from the passive to the active voice in both the Chinese and the English recall conditions. In addition, it was in readers' first language that they were more likely to relatively over-produce the voice form which is more frequently used in their first language (i.e., the active voice) and to avoid the voice form which is much less frequently used in their first language (i.e., the passive voice). These results, again, are consistent with stratified theories of discourse comprehension (e.g., Frederiksen & Donin, 1991). They confirmed *hypothesis B*, that is, linguistic knowledge (ii) exerts strong effects on processing at the local lexical and syntactic levels and (ii) has some limited effects on processing at the higher conceptual and semantic levels. These results could also be explained by Selinker's interlanguage theory (1969; 1972) which assumes transfer effects from L1 on production of a target language. As has been repeatedly shown in the field of L2 acquisition, a language learner's model of L2 tends to be a function of both his second and first language. Production or acquisition of a second language seems to depend on both similarity and differences of the syntactic structures between the individual's first and second language (Kilborn & Ito, 1989; Suchman, 1982; Takashima, 1989; Zobl, 1982). The present study provides empirical evidence showing that L2 production of the Chinese-English bilingual graduate students was affected by the syntactic structure of their first language. These readers' production of their second language was characterized by avoidance of the less frequently used syntactic form in their first language and by over-production of the more frequently used syntactic form in their first language.

On the other hand, the findings in this and in the previous section suggest caution in applying conclusions drawn from comprehension-production studies of languages from one language family to that of others. Although production effects have been consistently observed in studies of speakers of languages from Indo-European language family such as French-English (Donin & Silva, 1993) and Spanish-English (Lee, 1986), the present study did not support these conclusions. For these Chinese-English bilinguals, there were no significant production effects. The readers did not recall more propositional information in the L1 than in the L2 recall condition.

However, readers' processing of syntactic information as discussed above did seem to reflect the language recall conditions. The interview data also revealed that language of recall not only affected processing of syntactic information, it also induced different processing strategies. While in the L2 recall condition, the readers may have involved themselves in surface-level processing, such as verbatim recall, many readers reported that the L1 recall condition tended to elicit extra processing, especially translation, and was thus more demanding. Since the task of recalling a L2 text in one's first language required a reader to access two language codes, the discrepancy of this study to that of the others may be related to the linguistic distance between readers' first and second languages.

The translation processes, in particular, may be less demanding to the speakers of languages in the same language family, such as Spanish-English and French-English, than to the bilinguals speaking languages of different language family, such as Chinese-English. This is because English, French and Spanish tend to share many features in terms of orthography, phonetics, lexicons and sentence structures while languages in different language families differ greatly in these linguistic features. Thus, it may be easier for the speakers of languages in the same language family to shift back and forth from one language to another. However, to bilinguals speaking two languages of different language families, the great linguistic distance may demand more processing. Finding lexical and syntactic equivalence between languages which are structurally so different may overload working memory. Consequently, it may interfere with readers' processing and retention of semantic information and remove any potential advantages of the L1 over the L2 recall.

An important implication of this study is that one should be cautious in generalizing conclusions drawn from studies of languages of relatively less linguistic distance to those of greater linguistic distance from a target language. In particular, conclusions drawn from studies of languages of the same Indo-European family may not apply to speakers of languages of greater linguistic distance. To further explore relationships between linguistic distance and patterns of comprehension and production, future studies should compare directly bilinguals whose first languages are of different linguistic distances from a target L2 language.

C. Perceived Text Difficulty

In the interview readers were also asked to identify which text they felt most comfortable with and to elaborate on their responses (see Chapter 4 for details). This section addresses research questions C-g1 and C-g2 (p.40). A mixed between- and within-subject design (p. 61) was used to examine *within-subjects* relationships between **perceived text difficulty** (PTD) and measured comprehension and efficiency of processing, and interactions among perceived text difficulty, background knowledge (BK) and L2 proficiency (PROF). This section also explores attribution of text difficulty. The two dependent measures were as follows:

(i) differences in percent recall of propositional information from the text(s) reported to be the easiest vs. those reported to be more difficult;

(ii) differences in mean reading time (in seconds per proposition) for the text(s) reported to be the easiest vs. those reported to be more difficult.

C1. Results of Perceived Text Difficulty

Thirty of the thirty-six readers identified text(s) that they felt most at ease with. Among them two high background-knowledge readers and one low background-knowledge reader listed two instead of one text as the texts they felt most comfortable with. Six readers were excluded from the data analyses because they reported no differences with respect to the texts: four in the high background-knowledge and two in the low background-knowledge group. The analyses in this section thus included thirty readers.

In the following analyses, averaged scores of the two more difficult texts were used. For those who reported two texts as being "easiest" rather than one, averaged scores for the easy texts were computed. Figure 14 summarizes the mean proportion of recall of propositional information by background knowledge and English proficiency for the texts perceived to be relatively easy and the texts perceived to be more difficult.

To determine if perceived text difficulty (PTD) was related to measured comprehension and if such relationships interact with background knowledge (BK) and English proficiency (PROF), ANOVA tests were conducted. The tests compared contrasts of recall of propositional information from the relatively "easy" vs. that of the more "difficult" texts. The results (Table 14) showed no significant difference between recall of the texts perceived to be relative easy and recall of the texts perceived to be more difficult. There were no significant interactions among perceived text difficulty, background knowledge and English proficiency.

With respect to reading time (Figure 15), ANOVA tests that compared contrasts of reading time for the relatively "easy" vs. the more "difficult" texts showed no significant effects (Table 15). However, separate group analyses within each knowledge group revealed that high background-knowledge readers [$F(1,12)=7.16$, $p<0.02$] read the texts they believed to be easiest more quickly than those they believed to be more difficult. This effect, however, was not observed in the low background-knowledge group.

Figure 14
Relationships between Perceived Text Difficulty and Recall for the Entire Texts by Background Knowledge (BK) and L2 Proficiency

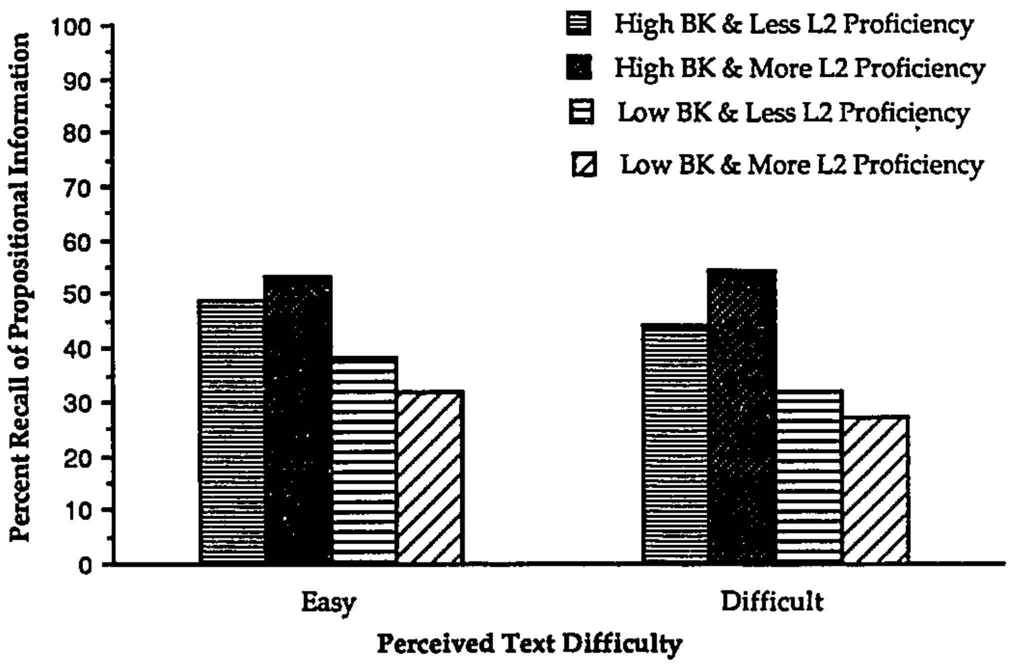


Table 14

ANOVAs of Recall of Propositional Information from the Texts Perceived to be Relatively Easy vs. Texts Perceived to be More Difficult

Source	*df*	*F*	*p*
Within-Subject Factor			
Perceived Text Difficulty (PTD): "Easy" vs. "Difficult" Texts	1,26	3.33	0.0796
Interaction bt. the between- & Within-Subject Factors			
Background knowledge (BK)*PTD	1,26	0.38	0.5427
L2 Proficiency (PROF)*PTD	1,26	0.37	0.5506
BK*PROP*PTD	1,26	0.40	0.5354

Figure 15
Relationships between Perceived Text Difficulty and Passage Reading Time by Background Knowledge (BK) and L2 Proficiency

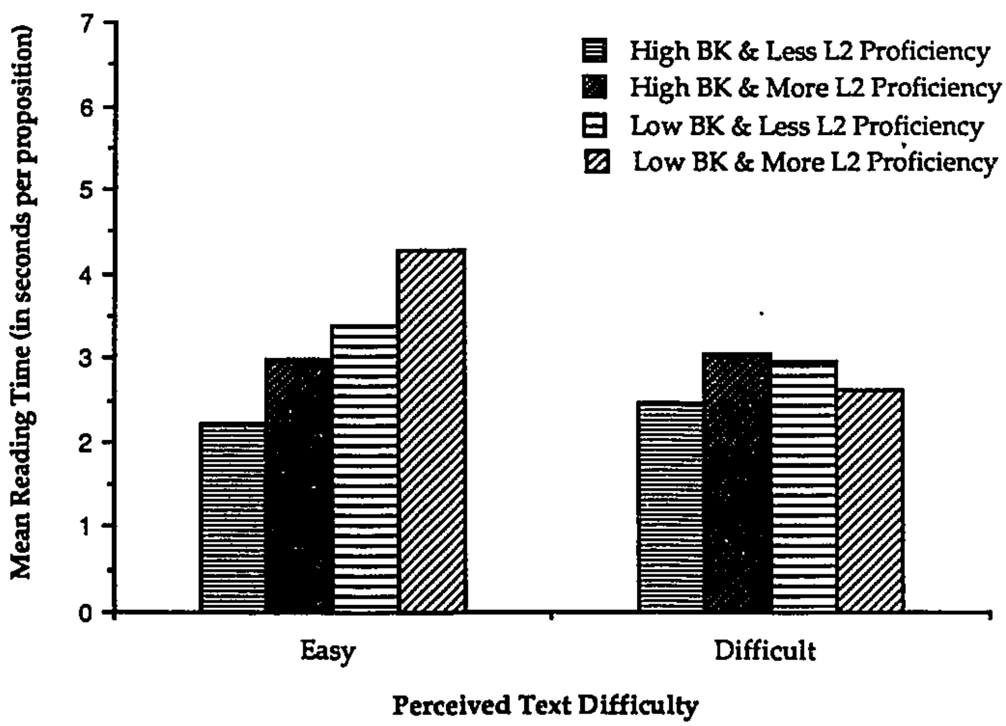


Table 15

ANOVAs of Reading Time for the Texts Perceived to be Relatively Easy vs. Texts Perceived to be More Difficult

Source	*df*	*F*	*p*
Within-Subject Factor			
Perceived Text Difficulty (PTD) "Easy" vs. "Difficult" Texts	1,26	3.75	0.0637
Interaction bt. the Between- & Within-Subject Factors			
Background Knowledge (BK)*PTD	1,26	0.26	0.6133
L2 Proficiency (PROF)*PTD	1,26	2.38	0.1354
BK*PROP*PTD	1,26	0.98	0.3322

Differences between the high and the low knowledge groups were also observed in readers' attribution of the cause of easiness or difficulty of the texts. As categorized in Table 16, the high background-knowledge readers tended to relate text difficulty to content familiarity (i.e., their domain-specific knowledge). Eleven out of the fourteen high background-knowledge readers attributed text difficulty to familiarity with either the topic or vocabulary used in the texts. For example, one of the high background-knowledge readers (Reader code: BL06) explained as to why the monoclonal antibody text seemed to be the easiest:

> "I have read about the topic. ... The vocabulary is comfortable [for me]. I also know the principles it covers. ... [The other two texts] were all uncomfortable to me. [Because I] haven't learnt and read much about them."

On the other hand, almost all the low background-knowledge readers associated text difficulty with features of text structure such as sequencing and logic, or task condition such as language of recall and language of presentation. The response that one reader (Reader code: EL23) provided is typical of this group of readers:

> "I think it spells out the main ideas at very beginning. It [first] describes the functions of antibody, then describes how it's produced. So, [I] can grasp the key ideas at once. ... [Between the two more difficult texts], the one written in Chinese was OK. Because it was in Chinese, it's more comprehensible."

Although this reader also thought the text about monoclonal antibody was the easiest, what this reader attributed the easiness to was

Table 16
*Reported Reasons for Judging Text the Easiest

Reported Reasons	High Background-Knowledge Readers (N=14)	Low Background-Knowledge Readers (N=16)
Familiar with the topic, vocabulary	11	0
Fewer technical terms	0	2
Text well written	1	9
Text in their first language	2	2
Recall condition	0	2
Understand better	0	2
Interesting	0	1
Easier	0	1

*All the readers gave one reason, except two in the low background-knowledge group (one gave two reasons and the other gave three reasons) clearly very different from that reported by the high background-knowledge reader.

C2. Discussion of the Results of Perceived Text Difficulty

The findings in this section suggest that, to some extent, the relevant knowledge that readers already have in the content area is related to their judgment about text difficulty. Perceived text difficulty was found to be related to efficiency of processing for those who had prior conceptual knowledge in biology areas. Such a relationship, however, was not observed for those who had little knowledge in the content areas. In addition, readers' attribution of causes of text difficulty also indicates that, to some extent, understanding of text difficulty depends on the content knowledge that the readers have. A significant difference between the two knowledge groups in their attribution of text difficulty was that the high background-knowledge readers tended to focus on content familiarity while those in the low background-knowledge group were more likely to emphasize text structure as well as language of recall and presentation. While it is reasonable to expect that familiarity of a particular topic facilitates reading, it is not likely, in the present study, that text structure contributed to variation in text difficulty. Contrary to what was perceived by the low knowledge readers, text structure was in fact balanced across the three test texts: the three texts all began with a short paragraph describing the usage or the function of a biotechnique, followed by a procedural paragraph which was a step-wise description of a biotechnique. The texts were also matched on important semantic and syntactic features and conceptual complexity. In addition, in order to control for content familiarity and order effects, the language of presentation order and language of recall conditions were counterbalanced (see the Section on the Materials in Chapter 2).

One may expect, that for those who had little content knowledge, ranking text difficulty is almost an impossible task. That is, all three texts used in this study should appear equally difficult to these readers. However, when the low background-knowledge readers were asked to rank text difficulty or content familiarity (as in the cases of this and many other comprehension studies), they tended to provide, rather than refuse to give, a rank. In the present study only two out of eighteen low knowledge readers reported no differences with respect to perceived text difficulty. To make the situation even worse, without exploring attribution of causes of text difficulty or content familiarity (as in the cases of some comprehension studies), it is very difficult for one to be alert to the fact that for the low knowledge readers ranking content difficulty or familiarity tends to be an impossible, if not a "coercive," task. These results thus raise a question about the validity of the practice in comprehension studies in which self-rating of text difficulty or content familiarity have been used to index what readers know about the content area, i.e., their background knowledge.

Although intuitively one might expect graduate science students with fairly high L2 proficiency to have a good knowledge of the level of difficulty of the texts they read, the findings in this part of the study showed that this may not be the case. Perceived text difficulty was not related to measured comprehension for either the high or the low knowledge readers. It also did not relate to the low knowledge readers' efficiency of processing. Furthermore, there appeared to be no relationship between perceived text difficulty and L2 proficiency. Due to the small sample size, these null findings, however, need to be interpreted with caution. To clarify the findings, further research needs to consider a larger sample size. If results continue to show, as this study does, that perceived text difficulty or content familiarity does not relate to comprehension, then one should definitely not use self-ratings of text difficulty or content familiarity to index readers' background knowledge.

Chapter Six

Conclusions

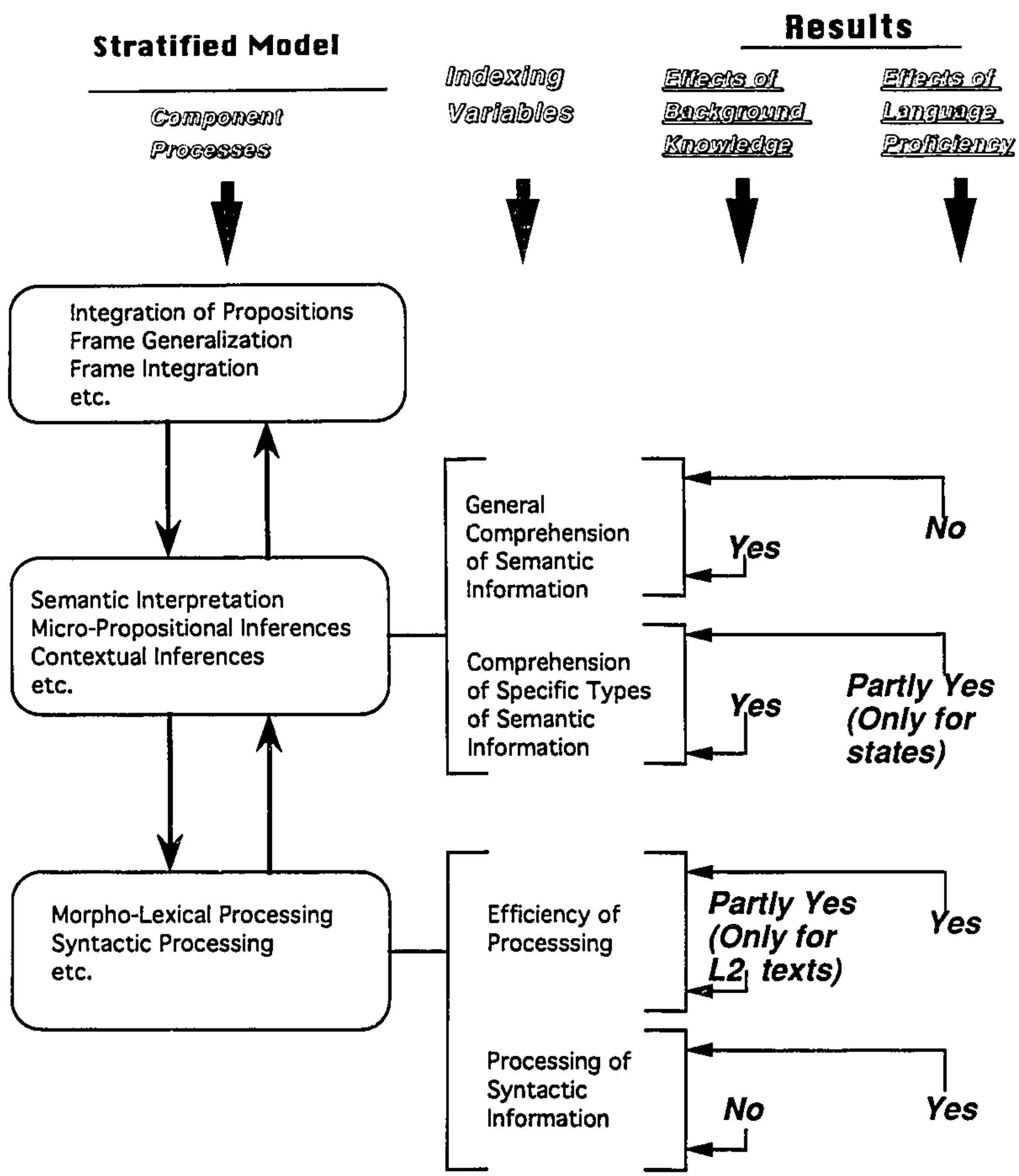
This research investigated the effects of domain-specific knowledge and language proficiency on various levels of discourse processing. It also addressed the issue of language of recall and the validity of using self-rating of text difficulty or content familiarity to index content knowledge. The following are some general conclusions.

Summary of the Results

Discourse Comprehension: Multilevel and Modular Processes

Figure 16 summarizes the results of the present study as they relate to the theoretical component processes of text comprehension. While domain-specific knowledge greatly facilitated processing of semantic information, its effects on lower-level processing were limited. On the other hand, language proficiency affected lower-level processing without showing much of concomitant effects at higher processing levels. The differential effects of the linguistic and conceptual knowledge were clearly consistent with stratified

Figure 16
Effects of Background Knowledge and Language Proficiency on Text Comprehension



The stratified model was adapted from Frederiksen and Donin (1991) theories of discourse comprehension (e.g., Frederiksen & Donin, 1991) where the comprehension processes are viewed as both multilevel and modular. Although many L2 discourse comprehension researchers tend to assume that lack of linguistic skills in some way will either result in bottom-up processing or will short-circuit comprehension, the results of the present study suggest that these assumptions may be too simplistic. Insufficient linguistic knowledge was more likely to result in laborious processing when there were no relevant conceptual schemes to rely upon. In the cases in which one had good conceptual knowledge but only limited linguistic knowledge, the relevant conceptual schemes may have been used to "bypass" syntactic processing. In addition, the study highlights the importance of studying background knowledge in content-specific terms: it was specific knowledge in the content area that differentiated the science students' comprehension.

Generalizing Findings From Studies of Languages from One Language Family: Be Aware of Linguistic Distance

The results of this study also suggest caution in applying conclusions drawn from studies of languages from one language family to that of others. Although studies from the Indo-European family such as French-English (Donin & Silva, 1993) and Spanish-English (Lee, 1986) have shown consistent production effects, the present study does not replicate these findings. Since the task of recalling a L2 text in one's first language required a reader to access two language codes, the discrepancy of this study from that of the others may be related to different linguistic distance between readers' first and second languages. The lack of the production effect observed in this study may be related to the differential processing of the syntactic information and the use of the differential processing strategies with different languages of recall.

Are Self-Ratings Reliable Indexes of Content Knowledge?

Finally, the study raised a question about the practice of using self-rating of text difficulty or content familiarity to index what readers know about the content area. The general discrepancy between perceived text difficulty and measured comprehension and efficiency of processing as assessed by the objective measures suggests that recall and reading-time measures are much more valid indicators of text comprehension and comprehension processes. Yet, the relevant knowledge that the readers already had in the content area appeared to be related to readers' judgment of some aspects of text difficulty, as observed in the higher conceptual knowledge readers' efficiency of processing as well as their attribution of text difficulty.

Limitation of the Study

As one of the first studies that has examined both the effects of domain-specific knowledge and language proficiency on various levels of discourse comprehension and in particular that compared multiple aspects of discourse comprehension of texts written in languages of great linguistic distance, this study has left many aspects of discourse comprehension unexplored. The unexplored issues include processing of semantic information at levels higher than at the local propositional level as well as processing of syntactic information other than voice, and strategy use. The small cell size of the group with high background knowledge and more L2 proficiency (n = 4) imposed limitations on the analyses that compared the more proficient to the less proficient L2 readers within the high knowledge group. Until this cell size is increased, one needs to be tentative in interpreting L2 proficiency effects or lack of L2 proficiency effects on various aspects of discourse comprehension for those who have high conceptual knowledge.

Fortunately, the small cell size of the high background-knowledge and more proficient group did not affect any results drawn from the analyses for the low background-knowledge group. This was because within the low background-knowledge group, there were reasonable numbers of readers in both the more proficient and the less proficient groups, i.e., nine in each group. Thus, one can be more confident about the findings for the low conceptual knowledge readers regarding the effects of their L2 proficiency. The sample size limitation also does not seem to have confounded conclusions about the conceptual knowledge effects. In studying the effects of conceptual knowledge and language proficiency, one usually is interested mainly in knowing whether having one kind of knowledge would compensate for the deficiency caused by lacking the other kind of knowledge. In this case, what is more interesting is the comprehension processes of three sub-groups: 1) the low background-knowledge and less proficient L2 group, 2) the low background-knowledge and more proficient L2 group and, 3) the high background-knowledge and less proficient L2 group. In other words, one needs to determine whether the second group outperforms the first and the third group. Fortunately, the cell size for the three groups were all reasonable ($n_1 = 9$, $n_2 = 9$, $n_3 = 14$). In addition, throughout the analyses it was found that there were no significant interactions between background knowledge and L2 proficiency.

Pedagogical Implications

The present study suggests the need to emphasize domain-specific knowledge and to use such objective measures as recall and reading-time to assess discourse comprehension. Since domain-specific knowledge is a must for successful comprehension and, since deficiency in language becomes a problem primarily when one does not have any appropriate conceptual knowledge to override it, it is desirable for classroom instruction to be sensitive to knowledge in a particular content area. In helping readers to acquire and utilize conceptual knowledge, curriculum and instruction could, for example, be designed to connect new information to the concepts and principles that the readers already have.

On the other hand, teachers should be aware that readers even as "sophisticated" as those at the graduate level, including those who have sufficient conceptual knowledge and L2 proficiency, may still need help to assess their own comprehension. Since the ability to judge whether one has understood what one has read is related to comprehension (Baker & Brown, 1984; Markman, 1981), one should help readers better evaluate their comprehension and comprehension difficulties in particular. To adequately capture readers' comprehension and comprehension difficulties in particular, one should use multiple measures of comprehension. By pointing out the discrepancy (i) between what has been comprehended and what is perceived to have been comprehended and, (ii) between how texts have been processed and how they are perceived to have been processed, one may help readers to reallocate their limited processing resources and adjust their reading strategies accordingly. With the ability to better evaluate one's current level of understanding, one is more likely to economize limited processing resources, to anticipate reading difficulties and to adopt strategies such as compensatory strategies accordingly (Paris & Meyer, 1981).

Implications for Future Research

As mentioned earlier, in order to determine how L2 proficiency affects comprehension processes for those who have conceptual knowledge, future research needs to increase the sample size, especially for the group with high conceptual knowledge and high L2 proficiency. The null findings observed in the analyses of perceived text difficulty also need to be clarified in further research with larger sample size. To explore further the effects of domain-specific knowledge and language proficiency on bilingual discourse comprehension, future research needs to be extended to content areas other than biology. It also needs to examine other aspects of comprehension such as the number and type of inferences drawn from the presented semantic information and comprehension at "higher" conceptual levels such as that at the "frame" level. While this study examined processing of sentence-level syntactic information, it has not investigated processing of such syntactic structures as tense, inflection of verbs and nouns, and the use of articles. An examination of the effects of these structural differences on comprehension and comprehension processes could provide more information about syntactic processing and the relationship between processing at this level and at other levels. The extent of the influence of L1 structures could also be explored further if one were to examine other language group(s) or compare readers with first languages at various linguistic distances from a target language. In order to determine whether linguistic distance affects the effectiveness of reading strategies and hence determines the existence of production effects, one could also compare reading strategies used by readers with different linguistic differences from that of a target language. Finally, while in the present study reading strategies were assessed through self-reported data, future research needs to employ multiple data collection techniques such as think-aloud and observation to investigate further reading strategies and the reliability of self-reported strategy use. It should investigate further the extent to which these reading strategies affect processing at local lexical, syntactic and higher conceptual levels.

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Appendixes

Appendix A

Test Texts

Text 1 (English)

A karyotype is a graphic representation of the chromosomes of an organism. It is often used to identify genetic defects involving abnormalities in the chromosomes.

The first step in preparing a human karyotype is to add colchicine to a test tube that contains white cells. Mitosis of the white cells is thus arrested at metaphase, when the chromosomes are in a state of maximum condensation. Each metaphase chromosome consists of two sister chromatids. In order to swell the metaphase cells, some hypotonic solution will be added to the test tube. After settling out the white cells, one drop of the cell suspension will be spread on a microscope slide. To reveal their band patterns, the chromosomes will also be stained. On the basis of their appearance, these chromosomes can be distinguished from one another under a microscope. The metaphase chromosomes can then be photographed and enlarged. For a normal karyotype of a male somatic cell, the picture will show forty-six chromosomes, including twenty-two homologous pairs. Finally, the chromosomes will be cut out of the enlarged picture and lined up with one another in matching pairs. The homologous pairs will be placed before the sex chromosomes.

Text 1 (Chinese)

染色体组型为有机体染色体的图像表示. 它常被用来鉴定源于染色体异常的遗传缺陷.

制作人体染色体组型的第一个步骤是把秋水仙素加入存有白细胞的试管中. 这样, 白细胞的有丝分裂便会在染色体处于最高密度时的中期中止. 中期染色体由二个姐妹染色单体所组成. 为使中期细胞膨胀, 我们应在试管中加入低渗溶液. 待白细胞沉淀下去后, 在显微镜玻片上点一滴细胞悬液. 此外, 我们还将给染色体着色, 以显示其带型. 根据染色体的外型, 我们能够在显微镜下把它们一一区别开来. 然后, 再把这些中期染色体拍摄下来, 并将图片放大. 正常男性体细胞染色体组型图片上有四十六条染色体, 其中包括二十二个同源对. 最后, 我们把染色体从放大了的图片上剪下来, 并将其一一配对排列. 同源对子应放在性染色体之前.

Text 2 (English)

Monoclonal antibodies are often described as "magic bullets" because they go directly to a target cell when antibodies are injected in an individual. If attached to anti-cancer drugs, some antibodies can be used to kill tumor cells without damaging healthy cells. The following is a basic procedure for producing monoclonal antibodies.

First, a mouse is injected with an antigen. In a few days, spleen lymphocyte cells that produce antibodies are removed from the mouse. These lymphocyte cells will be fused with mouse myeloma cells. Myeloma cells are a type of cancer cells that can proliferate indefinitely in culture. As a result of the fusion, hybridoma cells, which have the capabilities of both their parent cancer cells and lymphocyte cells, are produced. However, from the numerous hybridoma cells, only those that produce a particular type of antibody will be selected. These cells will usually be grown in a culture dish containing as many as ninety wells. Eventually, all the cells in the culture dish will produce the same antibody molecules. The hybridoma cell line can be used to produce indefinite quantities of the specific monoclonal antibody. These cells can also be stored in liquid nitrogen.

Text 2 (Chinese)

在注入个体 时，单克隆抗体直接作用于靶细胞，所以这 些 抗体常 被 称为 "神弹"．一旦与抗癌药物并用，某些抗体可以被用来杀死肿瘤细胞，但又不损伤健康细胞．以下是生产单克隆抗体的基本程序．

首先，将抗原注入鼠体．几天以后再从鼠体中取出生成抗体的脾淋巴细胞．这些淋巴细胞将被融合于鼠骨髓瘤细胞．骨髓瘤细胞是一种能在培养基中无限增殖的癌细胞．融合后，具有其亲代癌细胞和淋巴细胞功能的杂种细胞便产生了．然而，在众多杂种细胞中，我们仅选用那些能生成一类特殊抗体的细胞．这些细胞一般被放在一个内有多达九十来个孔的培养皿内培养．培养皿里所有的细胞最终均将产生出相同的抗体分子．因此，我们 能用这个杂种细胞系来大量生产这种单克隆抗体．我们还可以把这些细胞储存在液态氮中．

Text 3 (English)

Radioactive isotopes are often used by biologists to follow metabolic processes. The following is a typical experiment. The purpose of conducting an experiment of this kind is to determine how temperature affects the rate of DNA replication of mammalian cells.

First, samples of the dividing cells are cultured in a growth medium. The medium typically contains glucose, amino acids and other ingredients used by the cells to make new DNA. One of these ingredients is labeled with a radioactive isotope of hydrogen, called tritium. Tritium will be used to trace the incorporation process of the ingredient into newly synthesized DNA. Meanwhile, each culture dish will be stored separately at a specific temperature. In about five to twelve days, the cells grown at the various temperatures will be killed. Their DNA will be precipitated onto pieces of filter paper. These papers will in turn be placed in vials containing scintillation fluid. The fluid emits flashes whenever certain chemical substances in it are excited by radiation from the tracer. Finally, the frequency of flashes, which is directly proportional to the amount of radioactive material in the samples, will be recorded.

Text 3 (Chinese)

生物学家常用放射性同位素来监测代谢过程.以下是个典型的实验.进行这类实验的目的是为了了解温度是怎样影响哺乳动物细胞DNA复制速率的.

首先,在生长培养基中培养分裂细胞的样本.这些培养基往往含有葡萄糖,胺基酸以及其它可被细胞用来合成新DNA的组份.我们将其中某一个组份用叫作氚的氢放射性同位素标定.氚将被用来追踪那一组份被整合到新合成DNA中的过程.与此同时,把各个培养皿分别放在特定的温度下.约在五至十二天后,再把不同温度下培养出来的 细胞杀死.把它们的DNA沉淀在过滤纸上.然后,将滤纸浸入存有闪烁液的容器中.一旦溶液里某些化学物质受到示踪物的辐射刺激,液体便会发出闪光.最后,我们记录下与样本中放射性物质含量成正比的闪光频率.

Appendix B

Coding Schemes for Propositional Analyses

Coding Scheme for Propositional Analysis of Text 1

/: Difference between the two languages. The English concept was placed before the slash, the Chinese concept was placed after the slash. Recall of propositional information was weighted by the total number of concept slots of the language of presentation.

Sentence	Proposition	
1	1.1	IDENTITY.RELATION
1	1.1	Identity
1	1.1	Arg: karyotype, 1.2
1	1.1	Tense: present
1	1.1	Truth.Value: pos
1	1.2	STATE
1	1.2	State.Object: representation
1	1.2	State.Ident(Att): graphic
1	1.2	State.Ident(Theme): 1.3
1	1.2	Truth.value: pos
1	1.3	STATE
1	1.3	State.Object: organism
1	1.3	State.Ident(Prt): chromosome
1	1.3	Truth.value: pos
2	2.1	EVENT
2	2.1	Act: use
2	2.1	Rf.Object: it (karyotype or 1.2)
2	2.1	Rf.Goal: 2.2
2	2.1	Aspect: iter *often*
2	2.1	Tense: present
2	2.1	Truth.Value: pos
2	2.2	EVENT
2	2.2	Act: identify
2	2.2	Rf.process: 2.3
2	2.2	Truth.Value: pos

2	2.3 SYSTEM
2	2.3 Process: defect
2	2.3 Process.Ident(Att): genetic
2	2.3 Aspect: iter *s*
2	2.3 Truth.Value: pos
2	2.4 STATE
2	2.4 State.Object: 2.3
2	2.4 State.Ident(Cat): *involve* 2.5
2	2.4 Truth.value: pos
2	2.5 SYSTEM
2	2.5 Process: abnormality
2	2.5 Process.Ident(Loc): chromosome
2	2.5 Aspect: iter *s*
2	2.5 Truth.Value: pos
3	3.1 IDENTITY.RELATION
3	3.1 Identity
3	3.1 Arg: 3.2, 3.5
3	3.1 Tense: present
3	3.1 Truth.Value: pos
3	3.2 SYSTEM
3	3.2 Process: step
3	3.2 Process.Ident(Att): first
3	3.2 Process.Ident(Theme): 3.3
3	3.2 Truth.Value: pos
3	3.3 EVENT
3	3.3 Act: prepare
3	3.3 Rf.Object: 3.4
3	3.3 Truth.Value: pos
3	3.4 STATE
3	3.4 State.Object: karyotype
3	3.4 State.Ident(Att): human
3	3.4 Truth.value: pos
3	3.5 EVENT
3	3.5 Act: add
3	3.5 Rf.Object: colchicine
3	3.5 Act.Ident(Loc): 3.6
3	3.5 Truth.Value: pos

3	3.6	STATE
3	3.6	State.Object: test tube
3	3.6	State.Ident(Att): 3.7
3	3.6	Truth.Value: pos
3	3.7	SYSTEM
3	3.7	Process: contain
3	3.7	Pf.Patient: that (/test tube)
3	3.7	Pf.Rel.Object: 3.8
3	3.7	Tense: present
3	3.7	Truth.Value: pos
3	3.8	STATE
3	3.8	State.Object: cell
3	3.8	State.Ident(Prt): white
3	3.8	Truth.Value: pos
4	4.1	ALGEBRAIC.RELATION
4	4.1	Equiv(Temp): when
4	4.1	Arg: 4.2, 4.4
4	4.1	Truth.Value: pos
4	4.2	SYSTEM
4	4.2	Process: mitosis
4	4.2	Pf.Rel.Object: 4.3
4	4.2	Process.Ident(Temp): metaphase
4	4.2	Aspect: cess *arrest*
4	4.2	Tense: present
4	4.2	Truth.Value: pos
4	4.3	STATE
4	4.3	State.Object: cell
4	4.3	State.Ident(Prt): white
4	4.3	Truth.Value: pos
4	4.4	STATE
4	4.4	State.Object: chromosome
4	4.4	State.Ident(Att): *in state* 4.5
4	4.4	Tense: present
4	4.4	Truth.Value: pos

4	4.5	SYSTEM
4	4.5	Process: condensation
4	4.5	Process.Ident(Att): maximum
4	4.5	Truth.Value: pos
5	5.1	STATE
5	5.1	State.Object: 5.2
5	5.1	State.Ident(Prt): *consist* 5.3
5	5.1	Tense: present
5	5.1	Truth.Value: pos
5	5.2	STATE
5	5.2	State.Object: chromosome
5	5.2	State.Ident(Att): metaphase
5	5.2	Deg: each/ empty
5	5.2	Truth.Value: pos
5	5.3	State.Object: chromatid
5	5.3	Num.Real: 2
5	5.3	State.Ident(Att): sister
5	5.3	Truth.Value: pos
6	6.1	EVENT
6	6.1	Act: add
6	6.1	Rf.Agent: empty /we
6	6.1	Rf.Object: 6.2
6	6.1	Rf.Goal: 6.3
6	6.1	Act.Ident(Loc): test tube
6	6.1	Modality: empty/ root *should*
6	6.1	Tense: future
6	6.1	Truth.Value: pos
6	6.2	STATE
6	6.2	State.Object: solution
6	6.2	State.Ident(Att): hypotonic
6	6.2	Deg: some /empty
6	6.2	Truth.Value: pos
6	6.3	EVENT
6	6.3	Act: swell
6	6.3	Rf.Object: 6.4
6	6.3	Truth.Value: pos

6	6.4 STATE
6	6.4 State.Object: cell
6	6.4 State.Ident(Att): metaphase
6	6.4 Truth.Value: pos
7	7.1 ALGEBRAIC.RELATION
7	7.1 Order(Temp): after
7	7.1 Arg: 7.2, 7.4
7	7.1 Truth.Value: pos
7	7.2 EVENT
7	7.2 Act: settle out
7	7.2 Rf.Object: 7.3
7	7.2 Truth.Value: pos
7	7.3 STATE
7	7.3 State.Object: cell
7	7.3 State.Ident(PRT): white
7	7.3 Truth.Value: pos
7	7.4 EVENT
7	7.4 Act: spread
7	7.4 Rf.Object: 7.5
7	7.4 Act.Ident(Loc): 7.6
7	7.4 Tense: future
7	7.4 Truth.Value: pos
7	7.5 STATE
7	7.5 State.Object: suspension
7	7.5 State.Ident(Att): cell
7	7.5 Deg: one drop
7	7.5 Truth.Value: pos
7	7.6 STATE
7	7.6 State.Object: slide
7	7.6 State.Ident(Att): microscope
7	7.6 Truth.Value: pos

8 8.1 EVENT
8 8.1 Act: stain
8 8.1 Rf.Agent: empty /we
8 8.1 Rf.Object: chromosome
8 8.1 Rf.Goal: 8.2
8 8.1 Act.Ident(Att): also
8 8.1 Tense: future
8 8.1 Truth.Value: pos

8 8.2 EVENT
8 8.2 Act: reveal
8 8.2 Rf.Object: 8.3
8 8.2 Truth.value: pos

8 8.3 STATE
8 8.3 State.Object: their (chromosome)
8 8.3 State.Ident(Att): 8.4
8 8.3 Truth.Value: pos

8 8.4 STATE
8 8.4 State.Object: pattern
8 8.4 State.Ident(Att): band
8 8.4 Truth.Value: pos

9 9.1 BINARY.DEPENDENCY.RELATION
9 9.1 Binary.Dependency(Cond):*on basis*
9 9.1 Arg: 9.2, 9.3
9 9.1 Truth.Value: pos

9 9.2 STATE
9 9.2 State.Object: their (/chromosome)
9 9.2 State.Ident(Att): appearance
9 9.2 Truth.Value: pos

9 9.3 EVENT
9 9.3 Act: distinguish
9 9.3 Rf.Agent: empty /we
9 9.3 Rf.Object: chromosome (/they)
9 9.3 Rf.Instr: *under* microscope
9 9.3 Aspect: iter *from one another*
9 9.3 Modality: can
9 9.3 Tense: present
9 9.3 Truth.Value: pos

10	10.1	ALGEBRAIC.RELATION
10	10.1	Order(Temp): then
10	10.1	Arg: 9.3, (10.2, 10.3)
10	10.1	Truth.Value: pos
10	10.2	EVENT
10	10.2	Act: photograph
10	10.2	Rf.Object: 10.4
10	10.2	Modality: can /empty
10	10.2	Tense: present
10	10.3	EVENT
10	10.3	Act: enlarge
10	10.3	Rf.Object: 10.4 (/picture)
10	10.3	Modality: can /empty
10	10.3	Tense: present
10	10.3	Truth.Value: pos
10	10.4	STATE
10	10.4	State.Object: chromosome
10	10.4	State.Ident(Att): metaphase
10	10.4	Truth.value: pos
11	11.1	BINARY.DEPENDENCY.RELATION
11	11.1	Binary.Dependency(Cond):
11	11.1	Arg: 11.2, 11.4
11	11.1	Truth.value: pos
11	11.2	STATE
11	11.2	State.Object: karyotype
11	11.2	State.Ident(Att): normal
11	11.2	State.Ident(Theme): 11.3
11	11.2	Truth.value: pos
11	11.3	STATE
11	11.3	State.Object: cell
11	11.3	State.Ident(Att): somatic
11	11.3	State.Ident(Att): male
11	11.3	Truth.value: pos

11	11.4 SYSTEM
11	11.4 Process: show
11	11.4 Pf.Patient: picture
11	11.4 Process.Ident(theme): 11.5
11	11.4 Tense: future
11	11.4 Truth.Value: pos
11	11.5 STATE
11	11.5 State.Object: chromosome
11	11.5 Num.real: 46
11	11.5 State.Ident(Prt): *include* 11.6
11	11.5 Truth.Value: pos
11	11.6 STATE
11	11.6 State.Object: pair
11	11.6 Num.Real: 22
11	11.6 State.Ident(Att): homologous
11	11.6 Truth.Value: pos
12	12.1 ALGEBRAIC.RELATION
12	12.1 Order(Temp): finally
12	12.1 Arg: empty, (12.2,12.5)
12	12.1 Truth.Value: pos
12	12.2 EVENT
12	12.2 Act: cut
12	12.2 Rf.Agent: empty /we
12	12.2 Rf.Object: chromosome
12	12.2 Rf.result: 12.3
12	12.2 Tense: future
12	12.2 Truth.Value: pos
13	12.3 STATE
12	12.3 State.Object: the chromosomes
12	12.3 State.Ident(Loc): *out of* 12.4
12	12.3 Truth.Value: pos
12	12.4 STATE
12	12.4 State.Object: picture
12	12.4 State.Ident(Att): enlarged
12	12.4 Truth.Value: pos

12	12.5	EVENT
12	12.5	Act: line up
12	12.5	Rf.Agent: empty
12	12.5	Rf.Object: the chromosomes (/they)
12	12.5	Act.Ident(Att): *with* one another
12	12.5	Act.Ident(Att): 12.6
12	12.5	Tense: future
12	12.5	Truth.Value: pos
12	12.6	STATE
12	12.6	State.Object: pair
12	12.6	State.Ident(Att): matching
12	12.6	Truth.Value: pos
13	13.1	EVENT
13	13.1	ACT: place
13	13.1	Rf.Object: 13.2
13	13.1	Rf.Object: 13.3
13	13.1	Modality: empty /root *should*
13	13.1	Tense: future
13	13.1	Truth.Value: pos
13	13.2	STATE
13	13.2	State.Object: pair
13	13.2	State.Ident(Att): homologous
13	13.2	State.Ident(Loc): 13.4
13	13.2	Truth.value: pos
13	13.3	STATE
13	13.3	State.Object: chromosome
13	13.3	State.Ident(Att): sex
13	13.3	State.Ident(Loc): 13.4
13	13.3	Truth.value: pos
13	13.4	ALGEBRAIC.RELATION
13	13.4	Order(Loc): *before*
13	13.4	Arg: 13.2, 13.3
13	13.4	Truth.value: pos

Coding Scheme for Propositional Analysis of Text 2

Sentence	Proposition	
1	1.1	BINARY.DEPENDENCY.RELATIONS
1	1.1	Binary.Dependency(Cause):*because*
1	1.1	Arg: 1.4, 1.7
1	1.1	Truth.value: pos
1	1.2	ALGEBRAIC.RELATIONS
1	1.2	Order(Temp): when
1	1.2	Arg: 1.3, 1.4
1	1.2	Truth.Value: pos
1	1.3	EVENT
1	1.3	Act: inject
1	1.3	Rf.Object: antibody /empty
1	1.3	Rf.Recepient: individual
1	1.3	Tense: present
1	1.3	Truth.Value: pos
1	1.4	EVENT
1	1.4	Act: go
1	1.4	Rf.Agent: they (/1.5)
1	1.4	Act.Ident(Att): directly
1	1.4	Act.Ident(Loc): 1.6
1	1.4	Tense: present
1	1.4	Truth.Value: pos
1	1.5	STATE
1	1.5	State.Object: antibody
1	1.5	State.Ident(Att): monoclonal
1	1.5	Truth.value: pos
1	1.6	STATE
1	1.6	State.Object: cell
1	1.6	State.Ident(Att): target
1	1.6	Truth.value: pos

1	1.7	EVENT
1	1.7	Act: describe
1	1.7	Rf.Agent: empty
1	1.7	Rf.Object: 1.5/ antibody
1	1.7	Rf.Rel.Theme: 1.8
1	1.7	Aspect: iter *often*
1	1.7	Tense: present
1	1.7	Truth.Value: pos
1	1.8	STATE
1	1.8	State.Object: bullet
1	1.8	State.Ident(Att): magic
1	1.8	Truth.value: pos
2	2.1	BINARY.DEPENDENCY.RELATIONS
2	2.1	Binary.Dependency(If): *if*
2	2.1	Arg: 2.2, 2.4
2	2.1	Truth.value: pos
2	2.2	EVENT
2	2.2	Act: attach (/combine)
2	2.2	Act.Ident(Loc): 2.3 /Rf. Object: 2.3
2	2.2	Truth.Value: pos
2	2.3	STATE
2	2.3	State.Object: drug
2	2.3	State.Ident(Att): anti-cancer
2	2.3	Truth.value: pos
2	2.4	EVENT
2	2.4	Act: use
2	2.4	Rf.Agent: empty
2	2.4	Rf.Object: 2.5 (or 1.5 or 1.8)
2	2.4	Rf.Goal: 2.6
2	2.4	Modality: can
2	2.4	Tense: present
2	2.4	Truth.Value: pos

2	2.5 STATE
2	2.5 State.Object: antibody
2	2.5 Deg: some
2	2.5 State.Ident(Att): monoclonal
2	2.5 Truth.value: pos
2	2.6 EVENT
2	2.6 Act: kill
2	2.6 Rf.Object: 2.7
2	2.6 Rf.Act: 2.8
2	2.6 Truth.Value: pos
2	2.7 STATE
2	2.7 State.Object: cell
2	2.7 State.Ident(Cat): tumor
2	2.7 Truth.value: pos
2	2.8 EVENT
2	2.8 Act: damage
2	2.8 Rf.Object: 2.9
2	2.8 Truth.Value: neg
2	2.9 STATE
2	2.9 State.Object: cell
2	2.9 State.Ident(Att): healthy
2	2.9 Truth.value: pos
3	3.1 IDENTITY
3	3.1 Identity
3	3.1 Arg: following, 3.2
3	3.1 Tense: present
3	3.1 Truth.Value: pos
3	3.2 SYSTEM
3	3.2 Process: procedure
3	3.2 Rf.Goal/Rf.Theme: 3.3
3	3.2 Process.Ident(Att): basic
3	3.2 Truth.Value: pos
3	3.3 SYSTEM
3	3.3 Process: produce
3	3.3 Pf.Result: 3.4
3	3.3 Truth.Value: pos

3	3.4 STATE
3	3.4 State.Object: antibody
3	3.4 State.Ident(Att): monoclonal
3	3.4 Truth.value: pos
4	4.1 ALGEBRAIC.RELATIONS
4	4.1 Order(Temp): first
4	4.1 Arg: 4.2, empty
4	4.1 Truth.Value: pos
4	4.2 EVENT
4	4.2 Act: inject
4	4.2 Rf.Recipient: mouse
4	4.2 Rf.Object: antigen
4	4.2 Tense: present
4	4.2 Truth.Value: pos
5	5.1 FUNCTIONS
5	5.1 Diff(Temp): in
5	5.1 Arg: 4.2, 5.2
5	5.1 Measure: a few
5	5.1 Unit: day
5	5.1 Truth.Value: pos
5	5.2 EVENT
5	5.2 Act: remove
5	5.2 Rf.Object: 5.3
5	5.2 Rf.Source: mouse
5	5.2 Tense: present
5	5.2 Truth.Value: pos
5	5.3 STATE
5	5.3 State.Object: cell
5	5.3 State.Ident(Cat): lymphocyte
5	5.3 State.Ident(Att): spleen
5	5.3 State.Ident(Att): 5.4
5	5.3 Truth.Value: pos
5	5.4 EVENT
5	5.4 Act: produce
5	5.4 Rf.Agent: that (/5.3)
5	5.4 Rf.Result: antibody
5	5.4 Tense: present
5	5.4 Truth.Value: pos

6	6.1	EVENT
6	6.1	Act: fuse
6	6.1	Rf.Object: 6.2
6	6.1	Rf.Object 6.3
6	6.1	Tense: future
6	6.1	Truth.Value: pos
6	6.2	STATE
6	6.2	State.Object: cell
6	6.2	State.Ident(Cat): lymphocyte
6	6.2	Truth.Value: pos
6	6.3	STATE
6	6.3	State.Object: cell
6	6.3	State.Ident(Cat): myeloma
6	6.3	State.Ident(Att): mouse
6	6.3	Truth.Value: pos
7	7.1	IDENTITY
7	7.1	Identity
7	7.1	Identity.Arg: 7.2, (7.3, 7.4)
7	7.1	Tense: present
7	7.1	Truth.Value: pos
7	7.2	STATE
7	7.2	State.Object: cell
7	7.2	State.Ident(Cat): myeloma
7	7.2	Truth.Value: pos
7	7.3	STATE
7	7.3	State.Object: cell
7	7.3	State.Ident(Cat): cancer
7	7.3	State.Ident(Cat): type
7	7.3	Empty /Num.Real: one
7	7.3	State.Ident(Att): 7.4
7	7.3	Truth.Value: pos

7	7.4	SYSTEM
7	7.4	Process: proliferate
7	7.4	Pf.Patient: that (/7.3 or 7.2)
7	7.4	Process.Ident(Dur): indefinitely
7	7.4	Process.Ident(Loc): culture
7	7.4	Modality: can
7	7.4	Tense: present
7	7.4	Truth.Value: pos
8	8.1	BINARY.DEPENDENCY.RELATIONS
8	8.1	Binary.Dependency(Cause): *result*
8	8.1	Arg: (fusion 6.1), 8.2
8	8.1	Truth.value: pos
8	8.2	EVENT
8	8.2	Act: produce
8	8.2	Rf.result: 8.3
8	8.2	Tense: present
8	8.2	Truth.Value: pos
8	8.3	STATE
8	8.3	State.Object: cell
8	8.3	State.Ident(Cat): hybridoma /hybrid
8	8.3	State.Ident(Att): 8.4
8	8.3	Truth.value: pos
8	8.4	STATE
8	8.4	State.Object: which (/8.3)
8	8.4	State.Ident(Att): *have* 8.5
8	8.4	Tense: present
8	8.4	Truth.Value: pos
8	8.5	STATE
8	8.5	State.Object: 8.7, 8.8 *both*
8	8.5	State.Ident(Att): capability
8	8.5	Truth.Value: pos
8	8.6	SYSTEM
8	8.6	Process: *poss* their
8	8.6	Pf.Rel.Object: 8.7
8	8.6	Pf.Rel.OBJ: 8.8
8	8.6	Truth.Value: pos

8	8.7 STATE
8	8.7 State.Object: cell
8	8.7 State.Ident(Cat): cancer
8	8.7 State.Ident(Att): parent
8	8.7 Truth.Value: pos
8	8.8 STATE
8	8.8 State.Object: cell
8	8.8 State.Ident(Cat): lymphocyte
8	8.8 State.Ident(Att): parent
8	8.8 Truth.Value: pos
9	9.1 EVENT
9	9.1 Act: select
9	9.1 Rf.Agent: empty /we
9	9.1 Rf.Object: 9.3
9	9.1 Rf.Source: 9.2
9	9.1 Aspect: qual *only*
9	9.1 Tense: future
9	9.1 Truth.Value: pos
9	9.2 STATE
9	9.2 State.Object: cell
9	9.2 State.Ident(Cat): hybridoma /hybrid
9	9.2 State.Ident(Deg): numerous
9	9.2 Truth.Value: pos
9	9.3 STATE
9	9.3 State.Object: those (/cell)
9	9.3 State.Ident(Att): 9.4
9	9.3 Truth.Value: pos
9	9.4 EVENT
9	9.4 Act: produce
9	9.4 Rf.Agent: that (/cell)
9	9.4 Rf.Result: 9.5
9	9.4 Modality: empty /can
9	9.4 Tense: present
9	9.4 Truth.Value: pos

9 9.5 STATE
9 9.5 State.Object: antibody
9 9.5 State.Ident(Cat): type
9 9.5 Num: sing /Num.Real: one
9 9.5 Deg: particular /Empty
9 9.5 Empty/Ident(Att): specific
9 9.5 Truth.Value: pos

10 10.1 EVENT
10 10.1 Act: grow /put
10 10.1 Rf.Object: cell
10 10.1 Rf.Goal: empty /grow
10 10.1 Act.Ident(Loc): 10.2
10 10.1 Modality: qual *usually*
10 10.1 Tense: future
10 10.1 Truth.Value: pos

10 10.2 STATE
10 10.2 State.Object: dish
10 10.2 Num: sing /Num.Real: one
10 10.2 State.Ident(Att): culture
10 10.2 State.Ident(Att): 10.3
10 10.2 Truth.value: pos

10 10.3 SYSTEM
10 10.3 Process: contain
10 10.3 Pf.Patient: 10.2
10 10.3 Pf.Rel.Object: well
10 10.3 Num.Real: 90
10 10.3 Deg: as many as (/about)
10 10.3 Truth.value: pos

11 11.1 ALGEBRAIC.RELATIONS
11 11.1 Order(Temp): eventually
11 11.1 Arg: empty, 11.2
11 11.1 Truth.Value: pos

11 11.2 EVENT
11 11.2 Act: produce
11 11.2 Rf.Agent: 11.3
11 11.2 Rf.Result: 11.5
11 11.2 Tense: future
11 11.2 Truth.Value: pos

11	11.3	STATE
11	11.3	State.Object: cell
11	11.3	State.Ident(Loc): 11.4
11	11.3	Deg: all
11	11.3	Truth.value: pos
11	11.4	STATE
11	11.4	State.Object: dish
11	11.4	State.Ident(Att): culture
11	11.4	Truth.value: pos
11	11.5	STATE
11	11.5	State.Object: molecule
11	11.5	State.Ident(Att): antibody
11	11.5	State.Ident(Att): same
11	11.5	Truth.value: pos
12	12.1	EVENT
12	12.1	Act: use
12	12.1	Rf.Agent: empty /we
12	12.1	Rf.Object: 12.2
12	12.1	Rf.Goal: 12.3
12	12.1	Modality: can
12	12.1	Tense: present
12	12.1	Truth.Value: pos
12	12.2	STATE
12	12.2	State.Object: line
12	12.2	State.Ident(Att): cell
12	12.2	State.Ident(Att): hybridoma /hybrid
12	12.2	Truth.Value: pos
12	12.3	EVENT
12	12.3	Act: produce
12	12.3	Rf.result: 12.4
12	12.3	Act.Ident(Att): indefinite quantity
12	12.3	Truth.Value: pos
12	12.4	STATE
12	12.4	State.Object: antibody
12	12.4	State.Ident(Att): monoclonal
12	12.4	State.Ident(Att): specific/Empty
12	12.4	Empty/(Cat):kind
12	12.4	Truth.Value: pos

13	13.1	EVENT
13	13.1	Act: store
13	13.1	Rf.Agent: empty /we
13	13.1	Rf.Object: cell
13	13.1	Act.Ident(Att): also
13	13.1	Act.Ident(Loc): 13.2
13	13.1	Modality: can
13	13.1	Tense: present
13	13.1	Truth.Value: pos
13	13.2	STATE
13	13.2	State.Object: nitrogen
13	13.2	State.Ident(Att): liquid
13	13.2	Truth.value: pos

Coding Scheme for Propositional Analysis of Text 3

Sentence	Proposition	
1	1.1	EVENT
1	1.1	Act: use
1	1.1	Rf.Agent: biologist
1	1.1	Rf.Object: 1.2
1	1.1	Rf.Goal: 1.3
1	1.1	Aspect: iter *often*
1	1.1	Tense: present
1	1.1	Truth.Value: pos
1	1.2	STATE
1	1.2	State.Object: isotope
1	1.2	State.Ident(Att): radioactive
1	1.2	Truth.value: pos
1	1.3	SYSTEM
1	1.3	Process: follow
1	1.3	Pf.Process: 1.4
1	1.3	Truth.Value: pos
1	1.4	SYSTEM
1	1.4	Process: process
1	1.4	Process.Ident(Att): metabolic
1	1.4	Aspect: iter *es*
1	1.4	Truth.Value: pos
2	2.1	IDENTITY
2	2.1	Identity
2	2.1	Arg: following, 2.2
2	2.1	Tense: present
2	2.1	Truth.Value: pos
2	2.2	SYSTEM
2	2.2	Process: experiment
2	2.2	Num.Real: one
2	2.2	Process.Ident(Att): typical
2	2.2	Truth.Value: pos

3	3.1	EVENT
3	3.1	Act: conduct
3	3.1	Rf.Goal: *purpose* 3.3
3	3.1	Rf.Rel.Process: 3.2
3	3.1	Truth.Value: pos
3	3.2	SYSTEM
3	3.2	Process: experiment
3	3.2	Process.Ident(Cat): kind
3	3.2	Truth.Value: pos
3	3.3	EVENT
3	3.3	Act: determine
3	3.3	Act.Ident(Theme): 3.4
3	3.3	Truth.Value: pos
3	3.4	EVENT
3	3.4	Act: affect
3	3.4	Rf.Source: temperature
3	3.4	Rf.Rel.Act: 3.5
3	3.4	Act.Ident(Att): how
3	3.4	Tense: present
3	3.4	Truth.Value: pos
3	3.5	EVENT
3	3.5	Act: replication
3	3.5	Rf.Object: 3.6
3	3.5	Act.Ident(Att): rate
3	3.5	Truth.Value: pos
3	3.6	STATE
3	3.6	State.Object: 3.7
3	3.6	State.Ident(Prt): DNA
3	3.6	Truth.value: pos
3	3.7	STATE
3	3.7	State.Object: cell
3	3.7	State.Ident(Att): mammalian
3	3.7	Truth.value: pos

4	4.1	ALGEBRAIC.RELATIONS
4	4.1	Order(Temp): first
4	4.1	Arg: 4.2, empty
4	4.1	Truth.Value: pos
4	4.2	EVENT
4	4.2	Act: culture
4	4.2	Rf.Object: 4.3
4	4.2	Act.Ident(Loc): 4.5
4	4.2	Tense: present
4	4.2	Truth.Value: pos
4	4.3	STATE
4	4.3	State.Object: cell
4	4.3	State.Ident(Prt): sample
4	4.3	State.Ident(Att): 4.4
4	4.3	Truth.value: pos
4	4.4	SYSTEM
4	4.4	Process: divide
4	4.4	Pf.Patient: cell
4	4.4	Aspect: cont *ing* /empty
4	4.4	Truth.Value: pos
4	4.5	STATE
4	4.5	State.Object: medium
4	4.5	State.Ident(Att): growth
4	4.5	Truth.Value: pos
5	5.1	STATE
5	5.1	State.Object: medium
5	5.1	State.Ident(Prt): *contain* glucose
5	5.1	State.Ident(Prt): amino acid
5	5.1	State.Ident(Prt): 5.2
5	5.1	Modality: qual *typically*
5	5.1	Tense: present
5	5.1	Truth.Value: pos
5	5.2	STATE
5	5.2	State.Object: ingredient
5	5.2	State.Ident(Att): 5.3
5	5.2	State.Ident(Cat): other
5	5.2	Truth.Value: pos

5	5.3 EVENT
5	5.3 Act: use
5	5.3 Rf.Agent: cell
5	5.3 Rf.Object: other ingredients
5	5.3 Rf.Goal: 5.4
5	5.3 Modality: empty /can
5	5.3 Truth.Value: pos
5	5.4 EVENT
5	5.4 Act: make
5	5.4 Rf.result: 5.5
5	5.4 Truth.Value: pos
5	5.5 STATE
5	5.5 State.Object: DNA
5	5.5 State.Ident(Att): new
5	5.5 Truth.value: pos
6	6.1 EVENT
6	6.1 Act: label
6	6.1 Rf.Agent: empty /we
6	6.1 Rf.Object: 6.2
6	6.1 Rf.Instr: 6.3
6	6.1 Tense: present
6	6.1 Truth.Value: pos
6	6.2 STATE
6	6.2 State.Object: ingredient
6	6.2 State.Ident(Prt): one
6	6.2 Truth.value: pos
6	6.3 STATE
6	6.3 State.Object: 6.4
6	6.3 State.Ident(Prt): hydrogen
6	6.3 Truth.value: pos
6	6.4 STATE
6	6.4 State.Object: isotope
6	6.4 State.Ident(Att): radioactive
6	6.4 Truth.value: pos

6	6.5	ALGEBRAIC.RELATIONS
6	6.5	Equiv(OBJ): *call*
6	6.5	Arg: 6.3, tritium
6	6.5	Truth.Value: pos
7	7.1	EVENT
7	7.1	Act: use
7	7.1	Rf.Instr: tritium
7	7.1	Rf.Goal: 7.2
7	7.1	Tense: future
7	7.1	Truth.Value: pos
7	7.2	EVENT
7	7.2	Act: trace
7	7.2	Rf.Process: 7.3
7	7.2	Truth.Value: pos
7	7.3	SYSTEM
7	7.3	Process: process
7	7.3	Pf.Process.Rel: incorporation
7	7.3	Pf.Rel.Object: 7.4
7	7.3	Truth.Value: pos
7	7.4	STATE
7	7.4	State.Object: ingredient
7	7.4	Num.Real: one
7	7.4	State.Ident(Loc): 7.5
7	7.4	Truth.value: pos
7	7.5	STATE
7	7.5	State.Object: DNA
7	7.5	State.Ident(Att): 7.6
7	7.5	Truth.value: pos
7	7.6	EVENT
7	7.6	Act: synthesize
7	7.6	Rf.Result: (DNA)
7	7.6	Act.Ident(Att): newly
7	7.6	Truth.Value: pos

8	8.1	ALGEBRAIC.RELATIONS
8	8.1	Equiv(Temp): meanwhile
8	8.1	Arg: 6.1, 8.2
8	8.1	Truth.Value: pos
8	8.2	EVENT
8	8.2	Act: store
8	8.2	Rf.Object: 8.3
8	8.2	Act.Ident(Att): separately
8	8.2	Act.Ident(Att): 8.4
8	8.2	Tense: future
8	8.2	Truth.Value: pos
8	8.3	STATE
8	8.3	State.Object: dish
8	8.3	State.Ident(Att): culture
8	8.3	Deg: each
8	8.3	Truth.value: pos
8	8.4	SYSTEM
8	8.4	Process: temperature
8	8.4	Process.Ident(Att): specific
8	8.4	Truth.Value: pos
9	9.1	FUNCTION
9	9.1	Diff(Temp): in
9	9.1	Arg: (4.2,6.1,8.2),9.2
9	9.1	Measure: about 5 to 12
9	9.1	Unit: day
9	9.1	Truth.Value: pos
9	9.2	EVENT
9	9.2	Act: kill
9	9.2	Rf.Object: 9.3
9	9.2	Tense: future
9	9.2	Truth.Value: pos
9	9.3	STATE
9	9.3	State.Object: cell
9	9.3	State.Ident(Att): 9.4
9	9.3	Truth.Value: pos

9	9.4	EVENT
9	9.4	Act: grow
9	9.4	Rf.Object: the cells
9	9.4	Act.Ident(Att): 9.5
9	9.4	Truth.Value: pos
9	9.5	SYSTEM
9	9.5	Process: temperature
9	9.5	Process.Ident(Att): various
9	9.5	Truth.Value: pos
10	10.1	EVENT
10	10.1	Act: precipitate
10	10.1	Rf.Object: 10.2
10	10.1	Rf.Result: 10.3
10	10.1	Tense: future
10	10.1	Truth.Value: pos
10	10.2	STATE
10	10.2	State.Object: their (cell)
10	10.2	State.Ident(Prt): DNA
10	10.2	Truth.value: pos
10	10.3	STATE
10	10.3	State.Object: 10.2
10	10.3	State.Ident(Loc): 10.4
10	10.3	Truth.value: pos
10	10.4	STATE
10	10.4	State.Object: paper
10	10.4	Deg: pieces
10	10.4	State.Ident(Att): filter
10	10.4	Truth.value: pos
11	11.1	ALGEBRAIC.RELATIONS
11	11.1	Order(Temp): in turn
11	11.1	Arg: 10.1, 11.2
11	11.1	Truth.Value: pos

11	11.2	EVENT
11	11.2	Act: place
11	11.2	Rf.Object: paper
11	11.2	Rf.Result: 11.3
11	11.2	Tense: future
11	11.2	Truth.Value: pos
11	11.3	STATE
11	11.3	State.Object: these papers
11	11.3	State.Ident(Loc): 11.4
11	11.3	Truth.value: pos
11	11.4	STATE
11	11.4	State.Object: vial
11	11.4	State.Ident(Att): 11.5
11	11.4	Truth.value: pos
11	11.5	SYSTEM
11	11.5	Process: contain
11	11.5	Pf.Patient: (vials)
11	11.5	Pf.Rel.Object: 11.6
11	11.5	Truth.Value: pos
11	11.6	STATE
11	11.6	State.Object: fluid
11	11.6	State.Ident(Att): scintillation
11	11.6	Truth.value: pos
12	12.1	BINARY.DEPENDENCY.RELATIONS
12	12.1	Dependency(Cond): *whenever*
12	12.1	Arg: 12.2, 12.5
12	12.1	Truth.Value: pos
12	12.2	EVENT
12	12.2	Act: excite
12	12.2	Rf.Source: 12.4
12	12.2	Rf.Object: 12.3
12	12.2	Tense: present
12	12.2	Truth.Value: pos

12	12.3	STATE
12	12.3	State.Object: substance
12	12.3	State.Ident(Att): chemical
12	12.3	State.Ident(Cat): certain
12	12.3	State.Ident(Loc): it (/fluid)
12	12.3	Truth.value: pos
12	12.4	SYSTEM
12	12.4	Process: radiation
12	12.4	Process.Ident(Loc): tracer
12	12.4	Truth.Value: pos
12	12.5	EVENT
12	12.5	Act: emit
12	12.5	Rf.Source: fluid
12	12.5	Rf.Process: flash
12	12.5	Aspect: iter *es*
12	12.5	Tense: present
12	12.5	Truth.Value: pos
13	13.1	ALGEBRAIC.RELATIONS
13	13.1	Order(Temp): finally
13	13.1	Arg: empty, 13.2
13	13.1	Truth.Value: pos
13	13.2	EVENT
13	13.2	Act: record
13	13.2	Rf.Agent: empty /we
13	13.2	Rf.Act: 13.3
13	13.2	Tense: future
13	13.2	Truth.Value: pos
13	13.3	EVENT
13	13.3	Act: flash
13	13.3	Act.Ident(Att): frequency
13	13.3	Aspect: iter *es*
13	13.3	Truth.Value: pos

13	13.4	PROPOSITIONAL.RELATIONS
13	13.4	Prop.Head(Att): *directly* proportional
13	13.4	Arg: (13.3, which), 13.5
13	13.4	Tense: present
13	13.4	Truth.Value: pos
13	13.5	STATE
13	13.5	State.Object: material
13	13.5	State.Ident(Att): radioactive
13	13.5	State.Ident(Att): amount

Appendix C

Presentation of Test Texts

Presentation of Text 1

[ ]: Instruction;

#: End of a sentence mark, which did not appear on the computer screen in the actual presentation. In the reading session, the readers saw one sentence at a time. When they finished reading a sentence, they pressed the space-bar to continue.

[Please read the following passage
with your normal reading speed.]
#
A karyotype is a graphic representation
of the chromosomes of an organism.
#
It is often used to identify genetic defects
involving abnormalities in the chromosomes.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
The first step in preparing a human
karyotype is to add colchicine to a
test tube that contains white cells.
#
Mitosis of the white cells is thus arrested
at metaphase, when the chromosomes
are in a state of maximum condensation.
#
Each metaphase chromosome
consists of two sister chromatids.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#

[Please press the SPACEBAR again.]
#
In order to swell the metaphase cells, some
hypotonic solution will be added to the test tube.
#
After settling out the white cells,
one drop of the cell suspension will
be spread on a microscope slide.
#
To reveal their band patterns, the
chromosomes will also be stained.
#
On the basis of their appearance, these
chromosomes can be distinguished from
one another under a microscope.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
The metaphase chromosomes can then
be photographed and enlarged.
#
For a normal karyotype of a male somatic cell,
the picture will show forty-six chromosomes,
including twenty-two homologous pairs.
#
Finally, the chromosomes will be cut
out of the enlarged picture and lined up
with one another in matching pairs.
#
The homologous pairs will be placed
before the sex chromosomes.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Could you please tell us in your own words,
as much as you can, what you have read in
the entire passage.]

Presentation of Text 2

[Please read the following passage
with your normal reading speed.]
#
Monoclonal antibodies are often
described as "magic bullets" because
they go directly to a target cell when
antibodies are injected in an individual.
#
If attached to anti-cancer drugs, some
antibodies can be used to kill tumor
cells without damaging healthy cells.
#
The following is a basic procedure for
producing monoclonal antibodies.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
First, a mouse is injected with an antigen.
#
In a few days, spleen lymphocyte
cells that produce antibodies are
removed from the mouse.
#
These lymphocyte cells will be
fused with mouse myeloma cells.
#
Myeloma cells are a type of cancer cells
that can proliferate indefinitely in culture.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
As a result of the fusion, hybridoma cells, which
have the capabilities of both their parent cancer

cells and lymphocyte cells, are produced.
#
However, from the numerous hybridoma
cells, only those that produce a particular
type of antibody will be selected.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
These cells will usually be grown in a culture
dish containing as many as ninety wells.
#
Eventually, all the cells in the culture dish
will produce the same antibody molecules.
#
The hybridoma cell line can be used
to produce indefinite quantities of
the specific monoclonal antibody.
#
These cells can also be stored in liquid nitrogen.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Could you please tell us in your own words,
as much as you can, what you have read in
the entire passage.]

Presentation of Text 3

[Please read the following passage
with your normal reading speed.]
#
Radioactive isotopes are often used by
biologists to follow metabolic processes.
#
The following is a typical experiment.
#
The purpose of conducting an experiment of this
kind is to determine how temperature affects
the rate of DNA replication of mammalian cells.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
First, samples of the dividing cells
are cultured in a growth medium.
#
The medium typically contains glucose,
amino acids and other ingredients
used by the cells to make new DNA.
#
One of these ingredients is labeled with a
radioactive isotope of hydrogen, called tritium.
#
Tritium will be used to trace the
incorporation process of the ingredient
into newly synthesized DNA.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
Meanwhile, each culture dish will be stored
separately at a specific temperature.

#
In about five to twelve days,
the cells grown at the various
temperatures will be killed.
#
Their DNA will be precipitated
onto pieces of filter paper.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Please press the SPACEBAR again.]
#
These papers will in turn be placed
in vials containing scintillation fluid.
#
The fluid emits flashes whenever
certain chemical substances in it are
excited by radiation from the tracer.
#
Finally, the frequency of flashes,
which is directly proportional to
the amount of radioactive material
in the samples, will be recorded.
#
[Now please tell us in your own words,
as much as you can, what you have just read.]
#
[Could you please tell us in your own words,
as much as you can, what you have read in
the entire passage.]

Appendix D

Part of a Coded Protocol

Student: 11511;
Text 2; Order: 2;
Time of Recall: On-line;
Language of Presentation: English;
Language of Recall: English.

1. Monoclonal [bio-, antibody, is a:, (4") ma-, umm is a:,] antibody it has been [s-] term as a magic [umm] bullet because it can [umm] go straight to target [umm] certain cells.

Seg	Prop		Recall	Inference
1	1.1	BINARY.DEPENDENCY.RELATIONS		
1	1.1	Binary.Dependency(Cause):*becaus*	1	
1	1.1	Dependency.Argument: 1.4, 1.7	1	
1	1.1	Truth.value: positive	1	
1	1.2	ALGEBRAIC.RELATIONS		
1	1.2	Order: when		
1	1.2	Variables(Temporal): 1.3, 1.4		
1	1.2	Truth.Value: positive		
1	1.3	EVENT		
1	1.3	Act: inject		
1	1.3	Rf.Object: antibody		
1	1.3	Rf.Recepient: individual		
1	1.3	Tense: present		
1	1.3	Truth.Value: positive		

1	1.4	EVENT		**CSGOAL: target 1.6*
1	1.4	Act: go		
1	1.4	Rf.Agent: they	*1: it<1.5>*	
1	1.4	Act.Ident(Attribute): directly	*1: straight*	
1	1.4	Act.Ident(Locative): 1.6		
1	1.4	Tense: present	*1*	
1	1.4	Truth.Value: positive	*1*	**MOD: can*
1	1.5	STATE		
1	1.5	State.Object: antibody	*1*	
1	1.5	State.Ident(Attribute): monoclonal	*1*	
1	1.5	Truth.value: positive	*1*	
1	1.6	STATE		**OBJCAT: certain*
1	1.6	State.Object: cell	*1*	
1	1.6	State.Ident(Attribute): target		
1	1.6	Truth.value: positive	*1*	
1	1.7	EVENT		
1	1.7	Act: describe	*1: term*	
1	1.7	Rf.Object: 1.5	*1: it; 1.5*	
1	1.7	Rf.Theme: 1.8	*1*	
1	1.7	Aspect: iterative *often*	*1: been*	
1	1.7	Tense: present	*1*	
1	1.7	Truth.Value: positive	*1*	
1	1.8	STATE		
1	1.8	State.Object: bullet	*1*	
1	1.8	State.Ident(Attribute): magic	*1*	
1	1.8	Truth.value: positive	*1*	

Seg=Segment
Prop=Proposition
Rf=Resultive frame
Ident=Identifying relation
CSGOAL=Case: Goal
MOD=Modality
OBJCAT=Object: Category

Proposition	% Recall
1.1	100
1.4	83
1.5	100
1.6	67
1.7	100
1.8	100