Using Students' Background Knowledge for Enhancing Computer Network Text Understanding

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The present study explores effects of background knowledge on learning from high- and low-coherence texts in the domain of Informatics. We were driven theoretically by Kintsch's construction-integration model of text comprehension. The sample in this study was comprised of fifty-nine 1st semester students of the Department of Informatics and Telecommunications, University of Athens. We examined students' comprehension using four versions of a text. The first version has maximum local and global coherence, the second maximum local and minimum global coherence, the third minimum local and global coherence and the fourth minimum local and maximum global coherence. Participants' comprehension was examined through free-recall measure and text – based questions, problem- solving questions, and a sorting task. We found that readers with low knowledge background performed better with a coherent text, whereas readers with high background knowledge performed better after reading the low-coherence text. We support that this happens because low-coherence texts force readers of high background knowledge to engage in compensatory processing to infer unstated relations in the text.

Keywords
Background knowledge, Computer networks, Local/global coherence, Text understanding.

1. Introduction

People learn a great deal from texts: storybooks, textbooks, newspapers, or manuals. However, the process of learning from texts is complex and yet not completely understood [1]. People are often able to reproduce a text quite well but are unable to use information contained within for other purposes. Factors that help people to reproduce a text have been studied [2, 3, 4]. The literature indicates that the more a reader knows about the domain of a text, the more likely the reader will comprehend and learn from the text [2, 5, 6, 7]. It has also been demonstrated that readers with greater background knowledge employ more effective reading strategies [8,9] and express more interest in the reading material [10,11].

Text comprehension can also be improved by rewriting poorly written texts in order to make them more coherent and to provide the reader with all the information needed for reading comprehension [2, 3, 12, 13, 14]. Text coherence refers to the extent to which a reader is able to understand the relations between ideas in a text. This is generally dependent on whether these relations are explicit in the text. The general approach to increasing text coherence is to add surface-level indicators of relations between ideas in the text. Such modifications range from adding low-level information, such as identifying anaphoric

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referents, synonymous terms, or connective ties, to supplying background information left unstated in the text. However, increasing text coherence is not necessarily the best condition for learning. Making readers participate more actively in the comprehension process can help memory and learning. In many research domains it has been shown that learning can be improved by making the learner's task more difficult [4, 15, 16, 17]. Therefore, the findings for facilitating the reading and comprehension process are contradictory.

McNamara et al. [2] has approached the previous contradictory findings in terms of Kintsch's model of text comprehension [18,19]. This model assumes that there are at least two levels of text understanding, textbase understanding and situational understanding, and consequently, that memory of a text is not the same as learning from the text [20]. Because a good text base understanding relies on a coherent and well – structured representation of the text, facilitating the reading process by presenting a coherent and well-structured text, it should indeed improve textbase understanding. In contrast, a good situation model relies on different processes, primarily on the active use of long term-memory, or world knowledge, during reading. Links between the textbase and world knowledge must be activated in the reader's mental representation of the text. Therefore, requiring readers to make their own bridging inferences, while reading a low-coherence text, should produce a deeper, situational understanding of the text, provided that readers have sufficient background knowledge to do so. If motivated readers encounter a gap in the text, an attempt will be made to fill in this gap. Doing so requires accessing information from the readers' world knowledge, which in turn results in the text information being integrated with long- term memory. This gap-filling process can only be successful if readers have the necessary background knowledge. Therefore, for a good situational understanding, a single text cannot be optimal for every reader: low–knowledge readers should benefit more from an easier, coherent text, whereas high-knowledge readers should be allowed to do their own inference with harder, less coherent texts.

Beyer [12] used a computer manual as his learning material. He revised the original manual by making its macrostructure explicit by means of titles and subheadings and by improving the comprehensibility of the instructions contained in the manual with illustrative examples. The revised text proved to be significantly better than the original version, but the improvement was restricted to problem-solving tasks. A more systematic approach to filling in the local coherence gaps in a text was employed by Britton and Gulgoz [3], who used a history text as their learning material that described the U.S. air war in Vietnam. A third research has been reported by McNamara et al. [2]. They examined students' comprehension of one of four versions of a biology text, orthogonally varying local and global coherence. They found that readers who know little about the domain of the text benefit from a coherent text, whereas high-knowledge readers benefit from a minimally coherent text. Beck et al. [13], working with fourth- and fifth-grade students who studied a text about the American Revolutionary War, significantly improved performance on open-ended questions and recall by adding explanatory coherence to the text, especially emphasizing causal relations.

In this line of research we explored effects of background knowledge on learning from high- and low- coherence text in the domain of Informatics. This paper is organized as follows: We start by presenting the theoretical framework (Kintsch's construction-integration model [19]). Next, the methods applied in the present study are detailed. Subsequently, the results are presented and discussed. This paper concludes with suggestions for improving the currently used Informatics texts and with our plans for future research.

1.1 The construction – integration model

The construction – integration model was an extension of earlier models of comprehension [18, 21], primarily specifying computationally the role of prior knowledge during the

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comprehension process. This framework has been applied successfully to numerous aspects of text and discourse comprehension [22, 23, 24] as well as more complex domains such as expert-novice differences in problem-solving tasks [19, 25, 26]. (Within the construction-integration framework, processing occurs in two stages. In the first stage, construction, concepts from the text as well as syntax, semantic, and world knowledge are activated without taking into account global constraints to produce a network of activated concepts. In the second stage, integration, activation flows through the network of activated concepts according to connectionist principles of constraint satisfaction. Concepts that are compatible with the overall context mutually enhance the activation of one another, while concepts that are not compatible with the context lose activation. Thus, comprehension arises from an interaction and fusion between the text information and knowledge activated by the comprehender. We refer to the final product of this construction and integration process as the reader's mental representation of the text.

The levels of understanding that are most relevant for our purposes are the text base and situation model. The text base consists of those elements and relations that are directly derived from the text itself. The text base is what would be obtained if the text is to be translated into a propositional network and then integrate this network cycle-by-cycle but without adding anything that is not directly cued by the text. In general, this procedure results in an incoherent network. The reader must add nodes and establish links between nodes from his own world knowledge and experience (e.g., schemas), in order to make the structure coherent, to complete it, to interpret it in terms of the reader's prior knowledge and to integrate it with prior knowledge. The situation description that a comprehender constructs on the basis of a text as well as prior knowledge and experience is called the situation model. Thus, the text base comprises those nodes and links in the mental representation of the text that have direct correspondences in the text itself. The situation model includes the text base, but also nodes and links that have been added on the basis of world knowledge.

Analogous to the distinction between text-base and situation model is the distinction between the micro and macro – structure of the text. Micro-structure refers to local text properties, macro-structure to the global organization of text. Micro-structure is generally cued by the text via explicit indicators of relations between concepts and ideas in the text (e.g. connectives, argument overlap and pronominal reference). Micro-structure can also be constructed on the basis of the comprehender's knowledge when there are details or relations left unstated in the text. A text's macro-structure can be cued directly in the text via topic headers and sentences.

In the general case, the situation model that a reader generates from a text is a mixture of text-derived (the text base) and knowledge – derived elements. If the reader has no relevant background knowledge or does not employ it in understanding a text, the text representation will be dominated by the text base [27]. On the other hand, if rich relevant background knowledge is available and the text itself is poorly written and disorganized, the reader's knowledge elaborations may come to dominate the mental representation of the text and a good situation model may be obtained at the expense of the text base [28].

This paper reports on a study aiming to investigate how students' learning is enhanced while reading Computer Network texts with different coherence, in relation to the students' background knowledge. Based on previous studies [1, 2, 3, 4] we hypothesized that students with adequate background knowledge may learn better when they have to provide coherence themselves, rather than reading a fully coherent text at both local and global levels in this domain. We expect such readers to use their knowledge to generate the information that is missing from the text and, in doing so, to construct a more complete model of the situation it describes. This active processing advantage would manifest itself most clearly on tasks that depend on the construction of a situation model and less on tasks that assess memory for the text itself. Therefore, we used tasks that are differentially sensitive to text-base and situation – model constructions.

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Considering the levels of understanding are not separate structures, and since, because the situation model involves both the textbase and long – term memory, a comprehension measure cannot exclusively tap into one level of understanding. Nevertheless, some measures are more indicative of text memory (e.g., recognition, text-based questions and reproductive recall) whereas other measures are more sensitive to learning (e.g., bridging inference questions, recall elaborations, problem – solving tasks and keyword sorting tasks).

2. The Present Study

Measures, we use in our study, are free recall, text- based and situation model questions. Free recall is a measure of memory for the text itself, a text-base measure, particularly when the task presented to the reader is simply to recall the text. Text-based questions require only a single sentence from the text in order to be answered; thus, understanding the relation between two sentences or the text in whole is not necessary. Situation-model measures include problem-solving questions, bridging-inference questions, elaborative-inference questions, as well as the sorting task. Problem – solving questions require applying information from the text to a novel situation and hence depend on situational understanding. Bridging-inference questions require linking information from two or more sentences in the text to answer the question. Inferring the unstated relation between sentences is also a process that relies on the situation model. Elaborative-inference questions require linking textual and outside knowledge information, which requires some, but not necessarily a very deep, situational understanding. Finally, the sorting task measures the reader's understanding of the relation between concepts presented in the text, which reflects, at least in part, the situation model [1].

2.1 Participants

Our research was conducted with the participation of fifty-nine 1st semester students of the Department of Informatics and Telecommunications at the National and Kapodistrian University of Athens. Fifteen participants were randomly assigned to one of four groups concerning 4 different text versions.

2.2 Materials

Texts

The experimental texts were based mainly on an introductory chapter concerning "Local Computer Network Topologies" [29, 30]. We chose this original topic assuming it would be fairly unfamiliar to most of the students and would also reveal a wide variation in their background knowledge. By varying the coherence of the original text, according to rules described below, we obtained four texts with the same content but different in coherence, which was orthogonally manipulated at the local and global levels, by adding or deleting linguistic coherence signals. This process resulted in four text versions: (a) a maximally coherent text at both the local level and the macrolevel (LG), (b) a text maximally coherent at the local level and minimally coherent at the macrolevel (Lg), (c) a text minimally coherent at the local level and maximally coherent at the macrolevel (l G), and (d) a minimally coherent text at both the local level and the macrolevel (lg). The number of words in the LG, Lg, l G, and lg texts are 1866, 1777, 1374 and 1294, respectively. Thus, 483 words were added to increase local coherence and 89 words to increase coherence at the macrolevel. The following three types of rules were used to maximize local coherence [2]:

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1. Replacing pronouns with noun phrases when the referent was potentially ambiguous (e.g. In the phrase: *"Having determined the next destination of a packet, the network layer appends this address to it as an intermediate address and hands it to the link layer.",* we replace *"it"* with *"the packet".*)
2. Adding descriptive elaborations that link unfamiliar concepts with familiar ones (e.g., "*The network topology determines the way in which the nodes are connected*", is elaborated to: "*The network topology determines the way in which the nodes are connected, which means, the data paths and consequently the possible ways of interconnecting any two network nodes*").
3. Adding sentence connectives (i.e. however, therefore, because, so that) to specify the relation between sentences or ideas.

In the global macrocoherence versions of the text (l G and LG), macro propositions were signaled explicitly by various linguistic means (i.e., macro signals):

1. Adding topic headers (e.g., Bus Topology, Access control methods in the Medium) and
2. Adding macro propositions serving to link each paragraph to the rest of the text and the overall topic (e.g., "Subsequently, the main topologies referring to wired local networks, and their main advantages and disadvantages, will be examined in more detail") [2].

Prior- Knowledge Questions

Participants were given a knowledge-assessment test consisting of 16 questions (e.g. *"Why do we use communication networks?", "Which conditions should be filled in order for a group of computers to constitute a network?", "What is the role of the computer network administrator?", "Describe the procedure of sending a message (e-mail)"…).*

Text Recall

The four text versions were propositionalized according to the principles specified in van Dijk and Kintsch [18]. There were 13 micropropositions about the topic which concern packets and the procedure of sending a message in Bus Topology common to all texts. Participants were asked to remember from this topic as many micropropositions as they could.

Post-test Questions (Assessment Questions)

Participants answered 4 questions concerning the content of the text classified into 2 different types:

1. Text-based questions: The necessary information to answer the question contained within a single sentence of the minimally coherent lg text (e.g., *"What is a local computer network"?)*
2. Problem-solving questions: Linking information from separate sentences within the text and applying this information to a novel situation is required (e.g., *"Let us assume a bus network with 1-persistent CSMA. What is the process that a node follows in order to send a packet? What happens: (1) if the medium of transmission is occupied? (2) if the medium of transmission is free?")*

Sorting Task

Participants were given fourteen concepts and are asked to categorize them into 3 groups. There were 2 non-text and 12 key-word concepts from the text. Five of them related to "Categories of Transmission medium", 5 to "Wired Topologies" and 2 to "Rules-protocols that determine the transfer of information". Our motivation for selecting these concepts was to provide a group of concepts for which there were not only several rational sorting principles, but also clearly discernible, text-driven sorting principles.

2.3 Procedure

The order of the experimental tasks was as follows: (a) sorting task (pre-reading test), (b) prior-knowledge questions, (c) text reading, (d) text recall, (e) post-test questions, (f) text reading, (g) text recall, (h) post-test questions, and (i) sorting task (post-reading test). Reading and task completion times were recorded. The session lasted approximately 1.5 hr.

3. Results

3.1 Prior-Knowledge Questionnaire

According to the correct answers in the questionnaire, participants classified as "high" or "low". The classification was made based on a median split procedure. There was a total of 16 possible points on the knowledge test, 1 point for each correct piece of information supplied. The questions were scored for percentage correct. The results are presented in Table 1.

Table 1. Prior-knowledge questionnaire – Scores

	LG	Lg	lg	lG
All participants in each group	53.9%	63.5%	48.1%	45.8%

As we can see, there were significant differences among the participants assigned to the four different texts ($F=3.35$, $p<0.05$.). The Bonferroni test showed a significant mean score difference between subgroups Lg and lG. The scores for high-knowledge (N=27) and low-knowledge (N=31) participants were $M_H=68.2\%$ and $M_L=39.6\%$ respectively. These scores differed statistically (t_test, $p<0.001$). Within both subgroups ("High" and "Low"), there were no statistically significant differences among the participants assigned to the four different text conditions in terms of proportion correct (ANOVA). The difference in knowledge between the high and low-knowledge participants could partly be due to the fact that participants have a different background in the subject due to past schooling.

3.2 Reading rates

Participants recorded the time required to read the text. The results are presented in Table 2.

Table 2. Reading Rates

	LG	Lg	lg	lG
All participants in each group	126 words/min	98 words/ min	100 words/min	116 words/min

As we can see from the tablet the absence of an explicit macrostructure in a text apparently slowed participants down and the factor global coherence was statistically significant (t test, $p<0.05$).

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On the other hand, high and low-knowledge participants read the texts at about the same rate, 116 and 105 words per minute respectively. However, there was a significant interaction between global coherence and knowledge, (t test, $p<0.05$) reflecting the finding that low-knowledge participants read the text more quickly when macro signals were present (M=120 words per min) than when absent (M=89 words per min). The same applies for the high – knowledge participants (125 and 109 words respectively), however the difference in this case was not statistically significant.

3.3 Text Recall

The four text versions were propositionalized according to the principles specified in van Dijk and Kintsch [18]. There were 13 micropropositions about the topic which concern packets and the procedure of sending a message in Bus Topology common to all texts. Participants were asked to remember from this topic as many micropropositions as they could. Participants recalled the text twice, once after the first reading and again after reading the text a second time. The two results for each participant were pooled and scored collectively. ANOVAs by participants and by items were performed on proportional recall including the factors local coherence, global coherence, knowledge, and proposition type (microproposition). The results are presented in Table 3.

Table 3. Text Recall-Scores

	LG	**Lg**	**lg**	**lG**
All participants in each group	42.6%	37%	29%	33.2%
High knowledge	41.4%	44.1%	40.3%	40.5%
Low knowledge	38.3%	36.3%	31.1%	34.9%

Participants reproduced texts well enough. Percentage of text propositions recalled, were: (M_{LG} = 42.6%, M_{Lg} = 37%, M_{lg} = 29.5% and M_{lG}= 33.2%). Apparently the least coherent text, lg, was recalled worst. These differences were not statistically significant (t test). For high–knowledge participants, coherence at either the local or global levels made very little difference (M_{LG} = 41.4 %, M_{Lg} = 44.1%, M_{lg} = 40.3% and M_{lG}= 40.5%). These differences were not statistically significant (t test). Apparently, they were able to construct a good text base with or without the help of explicit linguistic signals. In contrast to the high-knowledge participants, low-knowledge participants seemed to form a better text base with a text that had coherence added at one level or another (Lg and lG) or at both levels (LG). (M_{LG} = 38.3%, M_{Lg} = 36.3%, M_{lg} = 31.1% and M_{lG} = 34.9%). These differences were not statistically significant (t-test).

3.4 Post-test Questions (Assessment Questions)

Participants answered 4 questions after each of the two readings of the text. The results are presented in Table 4.

Table 4. Proportion of correct responses on the assessment reading questions for the four text conditions in relation to knowledge and question type.

	LG	**Lg**	**lg**	**lG**
High knowledge				
Text based	0.81	0.69	0.70	0.67
Problem Solving	0.66	0.85	0.90	0.81
Low knowledge				

Text based	0.69	0.58	0.44	0.61
Problem Solving	0.41	0.38	0.27	0.39

The questions were scored for percentage correct. As there was no difference between the scores for the first and second assessment reading tests, these scores were combined for each participant. ANOVAs, both by participants and items, were performed on the assessment reading question percentage-correct scores, with the factors of local coherence, global coherence, knowledge, and question type (text based, problem solving). The main effects of local and global coherence were unreliable according to both the by-participants and by-items analyses. An effect of knowledge by participants was observed. High – knowledge participants scored better on the assessment questions than did low-knowledge participants.

Percentage of text-based questions answered correctly (M=.65), and problem – solving questions, (M=.59). Participants who had read texts with an explicit macrostructure answered text-based questions more correctly (M=.70) than participants who read low global – coherence texts (M=.60), whereas global coherence did not affect performance on the problem solving questions: low global coherence, M=.60, high global coherence M=.57. No other factors reliably interacted with question type. As it can be seen from the table, high-knowledge participants performed better on the questions with the lg text whereas low-knowledge participants appeared to perform worse on the questions with the lg text.

Of great interest was the interaction between knowledge and text coherence between the maximally (LG) and minimally (lg) coherent texts for each of the two question types. Low-knowledge participants performed better with the coherent text. This result is consistent with previous findings [2]. High-knowledge participants performed better on problem – solving questions with the lg text and better on the text-based questions with the LG text. This occurs because the text with coherence gaps would force the high-knowledge readers to engage in active processing, leading to a better situation model of the text information and, furthermore, that answering the problem-solving questions relied on this situation model.

3.5 Sorting

The results of this analysis are shown in table 5. High-knowledge participants had better scores in the sorting post-reading test task with the minimally coherent text (lg), whereas low-knowledge participants had better scores in the sorting post-reading test task with the maximally coherent text. Results were in the expected direction, confirming our hypothesis, i.e. that low-knowledge participants would change their sorting patterns more towards the text structure after reading the LG text, whereas the high-knowledge participants would change more with the lg text.

Table 5. Sorting – Task Scores

	LG	**Lg**	**lg**	**lG**
High knowledge				
Pre-reading test	0.69	0.65	0.61	0.68
Post-reading test	0.80	0.75	0.90	0.79
Low knowledge				
Pre-reading test	0.45	0.39	0.49	0.55
Post-reading test	0.67	0.50	0.81	0.73

4. Conclusions

Our study, conducted in the Informatics domain, gave results that are in accordance to those from similar studies in other learning domains [2]. We concluded that readers with little knowledge in the domain of Computer Networks, benefit from a coherent text, whereas high-knowledge readers benefit from a minimally coherent text. Texts containing too much information that the reader already knows are boring to read and, indeed, confusing (e.g., legal and insurance documents that leave nothing to be taken for granted). Hence, too much coherence and explication may not necessarily be a good thing. Therefore our results are in accordance with McNamara's results from the domain of biology [2].

With respect to educational applications, our findings suggest constructing several versions of a text in order to adapt to varying levels of knowledge among the readers. Our future plans include the development of an authoring tool capable of supporting authors while constructing texts of different coherence in the domain of Informatics, accompanied by questions or tasks designed to access a student's comprehension on line. An instructional Informatics text could then be presented at the level of coherence that is adapted to the student's current level of understanding. In this way, students will be forced to use their background knowledge while reading and more students will have the opportunity to achieve better learning results in learning from Informatics texts than reading a single textbook in informatics targeted at an average reader.

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