Effect of Text Cohesion on Comprehension of Biology Texts

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Abstract

This study explored the effect of text cohesion on reading comprehension of challenging science texts among students with little topic-relevant knowledge. Introductory level psychology students, considered to have a low level of knowledge on the topic, read high and low cohesion versions of biology texts. After reading the texts, their comprehension of the texts was assessed with text-based or inference-based open-ended comprehension questions. The results showed that participants benefited from high cohesion texts. The benefit was observed only for text-based questions, and the positive effect was marginally larger for skilled compared to unskilled readers. This study provides a better understanding of how text cohesion affects one's comprehension of science texts.

Introduction

Numerous studies have demonstrated a positive effect of text revision on comprehension (e.g., Beck, McKeown, Sinatra, & Loxterman, 1991; McNamara & Kintsch, 1996) of both narrative and expository texts (see Britton, Gulgoz, & Glynn, 1993 for review). However, the research indicates that the effect of text revisions on reading comprehension differs depending on the reader's characteristics, the characteristics of the text, the nature of the text revisions, and the ways in which the effect of text revision is assessed.

For example, McNamara and her colleagues (McNamara, Kintsch, Songer, Kintsch, 1996; McNamara & Kintsch, 1996) have shown that the effect of text revision, in particular increased text cohesion, depends on the reader's prior level of knowledge in the text domain. Following the Construction Integration Model (Kintsch, 1988) of reading comprehension, McNamara and her colleagues revised texts by increasing argument overlap, adding connectives, and adding background information. These text revisions alleviate readers' heavy reliance on their prior knowledge when constructing a coherent mental model of the overall text meaning based on text-based information. The results of a series of studies conducted by these authors have consistently indicated that: 1) low domain knowledge readers benefit from reading higher cohesion texts; 2) reading higher cohesion texts produces a detrimental effect for high domain knowledge readers' comprehension, in particular when the measure taps into deep level understanding of the text (e.g., inference questions, card sorting task). One interpretation of this reversed effect of cohesion is that the redundancy between the high level of prior knowledge and added cohesion in the text led these readers to process the text passively (McKoon & Ratcliff, 1992). As a result, high knowledge readers who read high cohesion texts fail to attain the deep level of understanding of the text which high knowledge readers reading a low cohesion text attain.

The effect of text revision on comprehension appears to be influenced by other individual differences. For example, Voss and Silfies (1996) showed that more-skilled readers learned more than less-skilled readers when reading history texts that were expanded to make causal relations more explicit. The level of prior knowledge did not affect learning from expanded texts in this study. Thus, skilled readers were better at taking advantage of added information that increased text cohesion. Yet, another study has shown that both less and more-skilled readers equally benefited from reading texts that have been improved in terms of causal cohesion (Linderholm, Everson, van den Broek, Mischinski, Crittenden, & Samuels, 2000). Interestingly, this study also indicated that the positive effect of text revision was specific to more difficult texts regardless of readers' skills. This text was judged to be more difficult based on the presence of causal organization, goal structure, and referential connections. This finding suggests that when the original text has good referential and causal organization, a further revision does not improve readers' comprehension, indicating the importance of matching the text and reader characteristics in reading comprehension.

Overall, these studies indicate that providing extra scaffolding to readers by adding referential and/or causal cohesion to texts helps readers better understand the textbook when the original text is challenging. The degrees of this benefit differ depending on the readers' skills to take advantage of the extra scaffoldings of increased cohesion. However, the added scaffolding has only a little or sometimes even a negative influence on comprehension when the original text is not challenging to the readers, suggesting that how text cohesion affects comprehension differs depending on the reader's familiarity with the text content.

The current study addresses a question concerning text difficulty by focusing on the effect of text revision when the text content is highly unfamiliar to the reader. Does added

cohesion help when readers are faced with an extremely unfamiliar topic? This is not a trivial issue. In classroom situations, students are often faced with highly unfamiliar concepts in their textbooks. Although a course may be designed such that each complex topic builds upon an earlier, less difficult topic, many students are forced to move on to the difficult topics without gaining sufficient understanding of the earlier content matter which serves as background knowledge. Thus, it is important to understand whether increasing text cohesion benefits the comprehension of readers who are faced with unfamiliar materials.

Present study

We explored two specific questions in this study: 1) whether and to what extent increasing text cohesion benefits a reader's comprehension of extremely unfamiliar domains; and 2) whether having a higher level of reading skill helps in taking advantage of the increased cohesion even when the text content is extremely unfamiliar. In examining these questions, we followed the McNamara (2001) study, in which psychology students read a high or low cohesion version of a challenging biology text. The results of this study showed a benefit of increased cohesion in low knowledge readers' ability to answer text-based questions, but not inference-based questions. Furthermore, the detrimental effect of increased cohesion among high knowledge readers was observed only for their performance of text-based questions. Thus, we expect to find the benefit of increased cohesion only in questions about basic level concepts when the text content is extremely unfamiliar to readers. In order to examine whether the effect of text revision is specific to basic level understanding of the texts, we included three types of comprehension questions: text-based, local inference, and global inference questions. Having these three types of questions makes it possible to effectively examine the effect of text revision on different levels of understanding.

Several specific details of the study deserve attention. First, following McNamara (2001), we used biology texts instead of social science or history texts (e.g., Voss & Silfies, 1996, Linderholm et al., 2000) because social science and history texts often describe relatively familiar individual concepts and events (e.g., war situation, conflict between groups, politics) in a novel context. Thus, using a social science text may not afford examining reading comprehension of unfamiliar concepts.

Second, we manipulated text cohesion as a within-subjects variable. A within-subjects manipulation of text cohesion allowed us to examine the interaction of reading skill and text cohesion more precisely by eliminating confounds between the effects of other individual differences on comprehension. No past study has examined the effects of text cohesion using a within-subjects manipulation of cohesion.

Method

Participants and Design

The sample consisted of 108 undergraduate students recruited from the psychology department at the University of Memphis. The 2 x 3 experimental design included text cohesion (low and high) and type of question (textbase, near bridging, and far/global bridging) as within-subjects variables. Participants' prior knowledge and reading skill were assessed to create quasi-experimental independent variables.

Materials

Two texts were taken from high-school biology textbooks and modified to produce low- and high-cohesion texts. One text described a plant's response to an external stimulus (plant text), and the other described internal distribution of heat in animals (heat text).

Manipulations to increase cohesion included: 1) replacing ambiguous pronouns with nouns; 2) adding descriptive elaborations which link unfamiliar concept with familiar concepts; 3) adding connectives to specify the relationships between sentences or ideas; 4) replacing or inserting words to increase the conceptual overlap between adjacent sentences; 5) adding topic headers; and 6) adding thematic sentences that serve to link each paragraph to the rest of the text and overall topic. These manipulations were aimed at increasing what others have called referential (Britton & Gulgoz, 1996) and causal (e.g., Voss & Silfies, 1996) cohesion. We did not restrict the text revision to a specific type of cohesion (e.g., causal) because the focus of this study is not on the type of cohesion manipulation, but the effect of overall text cohesion on comprehension of highly unfamiliar materials. As indicated in Table 1, text revision increased the text length by approximately 50%. However, the increase in the text length is common in past text revision studies (e.g., Beck et al, 1991; Voss & Silfies, 1996).

Care was taken to ensure that the difficulty level of the plant and the heat texts were approximately the same, and the degrees of cohesion manipulation between high and low cohesion versions of the two texts were equivalent by monitoring several text features that are known to be indicative of text cohesion and associated with text difficulty. These features include argument and stem overlap between sentences, LSA cosine between sentences, and word frequency (Graesser, McNamara, Lowerse, & Cai, 2004). Monitoring of these text features was achieved using the Coh-Metrix tool (Graesser et al., 2004). The primary features of high and low cohesion versions of the plant and heat texts are reported in Table 1.

Table 1: Text features of high and low cohesion plant and heat texts.

	Heat text		Plant text	
Cohesion	Low	High	Low	High
Argument overlap adjacent	.571	.823	.568	.816
Stem overlap adjacent	.714	.901	.795	.899
LSA all sentences	.290	.332	.310	.345
Flesh-Kincaid grade level	10.03	12.00	9.12	10.30
Word Frequency (0-6)	0.768	0.823	0.659	0.669
Number of words	604	968	633	991

As described earlier, the primary aim of this study was to examine the effect of cohesion on students reading comprehension of unfamiliar materials. The word frequency indexes for the texts confirm that the texts included highly unfamiliar words. Word frequency was calculated based on the average of the lowest frequency content word in each sentence. We used this measure instead of an overall content word frequency, because the difficulty of a sentence is often determined by the most unfamiliar word in the sentence. The word frequency measures confirm that the plant and heat texts are lower in word frequency than the Voss and Silfies (1996) texts (1.02/1.06 for original) and the Linderholm et al. (2000) texts (1.12/1.04 for original).

There were 12 comprehension questions for each text, of which 4 were text-based, 4 were near or local bridging, and 4 were far or global bridging questions. A question was classified as text-based when the answer to the question did not require any prior knowledge or text-based inferences but could be answered based on information explicitly stated within the text. A question was classified as a local bridging question when the answer to the question required an integration of information located within 5 or 6 clauses across multiple sentences. Far or global bridging questions are similar to local bridging questions, but involved the integration of information located across larger distances, more than 5 or 6 clauses apart.

Four types of individual difference measures were collected: general reading comprehension ability, general world knowledge, biology knowledge, and domain-specific knowledge on the topic of the text. General reading comprehension ability was measured using the Nelson-Denny (Brown, Fishco, & Hanna, 1993) reading comprehension ability test. The Nelson-Denny reading comprehension test is a standardized reading comprehension test for college level students. General world knowledge was assessed with 19 multiple-choice questions on historical facts, authors of well known books, paintings, etc. Biology knowledge was assessed with 21 multiple-choice questions on anatomy, reproduction, genetics, etc. Domain specific knowledge questions on plants and the distribution of heat was measured with a total of 16 open-ended questions on the knowledge of plant biology (eight questions) and animal circulatory system (eight questions). These questions were concerned with information relevant to understanding the texts but not provided in the texts.

Procedure

Participants were first administered the prior knowledge test, which included the general world knowledge and biology questions, followed by the Nelson-Denny reading skills assessment. Each test (i.e., prior knowledge and Nelson Denny) was restricted to 15 minutes. The participants then read the texts and answered the questions, which were presented in a booklet. Participants read both texts, one high cohesion and one low cohesion, and then answered comprehension questions for both texts, in the order of text presentation. The order of the texts and the order of the cohesion level were counterbalanced. Reading times for each text were obtained through a self-report measure. Once the subjects finished reading, they were not allowed to return to the text to answer the questions. The subjects were not allowed to return to the previous section of questions after they moved to the next set of questions. Domain specific prior knowledge questions were then presented in the order of the text presentation. Neither type of question was limited by time, but working time was recorded by a self-report measure. Participants' responses to the open-ended questions were scored independently and then compared by two raters. Inter-rater reliability was greater than 95%.

Results

Participants' domain knowledge

Participants' scores on the domain specific knowledge measures establish that participants' domain knowledge was very low. Average proportion correct was .22 (*SD* =.14) on heat-related questions and .27 (*SD* = .21) on plant-related questions, with 99% of participants scoring below .5 for heat-related questions, and 91% of participants scoring below .5 for plant-related questions. A paired-samples t-test indicated that participants performed significantly better on plant than heat questions, $t(107) = 3.09$, $p < .01$. However, the performance on these two tests were highly correlated $r = .594$, $p < .001$. As these data indicate, participants' knowledge related to plant and heat distribution in animals was limited. We further divided the participants into higher and lower domain knowledge groups based on the combined score of heat- and plant-related question in order to isolate extremely low domain knowledge participants.

Table 2 describes the two groups (lower and higher domain specific knowledge) in terms of the other individual difference scores (e.g., general world knowledge, general biology knowledge, etc.).

Table 2. Lower and higher domain knowledge participants' profile

	Lower domain knowledge group (N = 53)	Higher domain knowledge group (N =53)
Plant-related knowledge	.10 (.11)	.44 (.13)
Heat-related knowledge	.13 (.11)	.31 (.11)
General biology knowledge	.41 (.13)	.46 (.14)
General world knowledge	.41 (.14)	.51 (.15)
Nelson-Denny reading ability	.52 (.18)	.64 (.18)

Note: Standard deviations are in parentheses

A series of one-way ANOVAs indicated that higher and lower domain knowledge participants differ in terms of all the above measures at $p < .05$. In the subsequent analyses, we analyzed data from all the participants. We then performed analyses only with lower domain knowledge students' performance to examine how text cohesion particularly affects this group of participants.

Comprehension question performance

We first analyzed whether the pairing of text and cohesion, and the order in which texts were read (for counter-balancing) influenced comprehension performance. A 2 (text) x 2 (cohesion) x 2 (text order) ANOVA on overall comprehension scores indicated no effect of cohesion, text, order, or interaction among them. Table 3 below indicates the participants' performance (proportion of correct answer to comprehension questions) as the function of cohesion, domain specific knowledge, and question type. A 2 (knowledge) x 2 (cohesion) x 3 (question type) ANOVA indicated main effects of knowledge, $F(1, 106) = 31.656$, $MSE = 7.509$, $p < .001$, question type, $F(2, 105) = 46.820$, $MSE = 0.506$, $p < .01$, and an interaction between knowledge and question type, $F(2, 105) = 6.212$, $MSE = .506$, $p < .01$. No other effects, including the effect of cohesion, reached statistical significance.

The analysis indicates that cohesion did not affect overall performance. However, as discussed in the introduction, the benefit of cohesion was expected to be observed for performance on questions probing for basic level concepts. Hence, we performed a separate analysis for the effect of cohesion by including only the text-based and local inference questions. A 2 (question type) x 2 (cohesion) x 2 (domain knowledge) ANOVA indicated main effects of question type, $F(1, 106) = 10.68$, $MSE = .038$, $p < .01$, domain knowledge, $F(1, 106) = 30.01$, $MSE = .149$, $p <001$, and an interaction between cohesion and question type, $F(1,106)\_= 4.004$, $MSE = .036$, $p < .05$. The interaction

Table 3: Performance on comprehension questions as the function of domain knowledge, cohesion, and the type of question.

		Lower Domain Knowledge (N = 53)	Higher Domain Knowledge (N = 55)	Mean
Low Coh	Text	.18 (.21)	.38 (.27)	.28
	Local	.13 (.21)	.37 (.26)	.25
	Global	.07 (.14)	.20 (.19)	.14
High Coh	Text	.25 (.26)	.40 (.29)	.33
	Local	.12 (.18)	.34 (.33)	.23
	Global	.12 (.13)	.20 (.15)	.17

between question type and cohesion indicates that participants scored significantly higher on the text-based questions than local inference questions when reading a high cohesion text, $t(107) = 3.406$, $p < .01$. In contrast, there was no difference between text-based and local inference questions for the low cohesion text $t(107) = 1.024$ ns. Additionally, for text-based questions, there was a marginal benefit of high cohesion, $t(107) = 1.84$, $p=.06$. It is also evident from Table 3, that lower knowledge participants showed significant gains on text-based questions, $t(52) = 2.163$, $p = .035$, whereas the higher domain knowledge participants showed negligible gains.

We further examined whether the benefit of reading a high cohesion text was more apparent for skilled readers. The conflicting findings between Voss and Silfies (1996) and Linderholm et al. (2001) studies indicate that interactions of reading skill and cohesion may depend further on text difficulty. Specifically, more-skilled compared to less-skilled readers may show benefits of increased cohesion only when the text is sufficiently challenging. Thus, we examine here whether skilled readers show larger benefits of cohesion when the text is highly unfamiliar. We performed a 2 (reading skill) x 2 (cohesion) ANOVA on text-based questions. We did not include local and global inferential questions because the earlier analysis confirmed no effect of cohesion in these measures. Table 4 shows participants' performance on text-based questions as a function of cohesion and reading skill.

This analysis indicated, in addition to a marginal effect of cohesion which has been already reported, a main effect of reading skill, $F(1, 106) = 23.474$, $MSE = .0925$, $p < .01$. The interaction between reading skill and cohesion was not significant, $F(1, 106) = 1.04$. Nonetheless, separate tests were performed for skilled and less skilled readers to pursue the question of whether the effect of cohesion differs between skilled and less skilled readers. These analyses showed that the difference in comprehension performance for low and high cohesion texts was marginal for skilled readers, $t(49) = 1.882$, $p = .06$ (but reliable according to a one-tailed t-test), whereas the difference was not significant for the less skilled readers, $t(57) < 1.0$.

Table 4: Performance on text-based questions as the function of reading skill and text cohesion.

	Less Skilled readers (N = 58)	Skilled readers (N= 50)
Low cohesion	.20 (.21)	.37 (.29)
High cohesion	.22 (.23)	.45 (.29)

Discussion

There are two main findings. The experiment indicated that revising texts, by increasing referential and explanatory cohesion, helps students understand biology texts even when the text content is highly unfamiliar to them. However, the benefit of cohesion was quite small and limited to questions that requested information explicitly provided within individual sentences in the text. Thus, in this case, the cohesion did not help the low knowledge students understand the relations between ideas – it only helped them understand individual ideas in the text. This result, as found by McNamara (2001), is likely a function of the text difficulty. That is, the text was too challenging for the readers to develop a coherent situation model of the text content. Interestingly, however, the benefit of the increased cohesion was observed only for students with an extremely low level of domain knowledge; we did not observe an effect of cohesion with higher domain knowledge participants. This is in line with previous research (i.e., that cohesion does not benefit high knowledge students), but frankly, is not what we were expecting because the prior domain knowledge of the participants was relatively low overall.

Second, the results indicated that skilled readers benefit more than less-skilled readers from increased cohesion. This finding, in the light of others' work (e.g., Linderholm et al., 2000; Voss & Silfies, 1996), seems to indicate that text difficulty moderates how reading skill interacts with cohesion. As discussed, whereas Voss and Silfies (1996) found larger benefit of cohesion for skilled readers, Linderholm et al., (2000) reported no difference in benefit of cohesion between skilled and less skilled readers. Given the marginally larger benefit of cohesion for skilled as opposed to less skilled readers with unfamiliar texts observed in this study, it is likely that whether readers benefit from increased cohesion, and whether the benefit is larger for skilled readers depends on the overall difficulty of the text. Although different studies are not directly comparable, one important message that this study provides in the light of others' findings (e.g., Linderholm et al., 2000; McNamara et al 1996) is that when the text is too easy or too difficult, the effect of cohesion, and also the interaction between reading skill and cohesion declines, or sometimes, entirely disappears.

Why do skilled readers enjoy larger benefits of cohesion when the text is challenging? This may have occurred because the skilled readers have a larger vocabulary, because they are better able to parse the sentences, or perhaps because they are more strategic, active readers (McNamara & O'Reilly, in press). Unfortunately, we were not able to collect measures to discriminate between the specific abilities contributed by reading skill. Nonetheless, the effect of cohesion observed in this study appears to reflect the notion that skilled readers are better able to take advantage of added argument overlap, connectives, and background information, in their attempt to understand and learn new information from the unfamiliar texts.

Overall, this paper contributes to reading comprehension literature, in particular text revision research, by highlighting the importance of matching text difficulty and reader's ability, specifically the level of domain knowledge. In this study, we focused on a particular kind of text difficulty, namely topic unfamiliarity, operationalized as low content word frequency of the text. The findings here, along with previous studies, suggest that cohesion manipulations affect readers' comprehension of and learning from the text at their level of zone of proximal development (Vygotsky, 1978) determined by the reader's familiarity with the text content, and not necessarily at a specific level of understanding as reported by McNamara et al. (1996). In this case, the zone of proximal development was the basic level understanding of the text content because readers' familiarity with the content was low. Thus, under some circumstances, the understanding and learning of unfamiliar individual concepts rather than the global text meaning may be the area of comprehension that readers can improve by using reading related skills to take advantage of increased text cohesion. A challenge for future research is to reliably identify readers' zone of proximal development, and how that depends on their aptitudes, the text difficulty, and the demands of the comprehension task.

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