Text Structure Affects the Patterns of Processing During Reading: An Eye Movement Study

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Abstract. The present study was aimed at examining the interplay of text structure and reading patterns on the cognitive processing during the reading of an expository science text. We also investigated whether the refutation text effect in enhancing a deeper comprehension is particularly relevant for readers who are non-strategic processors. Participants read either a refutation or a non-refutation text while their patterns of reading processing were monitored by means of an eye-tracking methodology. Following, learning performance was assessed. Findings revealed two reading patterns of an expository text: linear and strategic readers. Linear readers in the refutation condition were facilitated to strategically reread the relevant information, the scientific concepts. Furthermore, these readers achieved a deeper comprehension of scientific concepts than linear readers in the non-refutation condition. These findings add new evidence of the crucial role of refutation text in organizing the reading behavior and promoting a deeper learning, particularly among non-strategic readers.

Keywords: Refutation text effect; reading patterns; eye movements; conceptual learning.

Introduction

Research on conceptual change has documented that, especially in science domains, deep conceptual learning from text implies knowledge revision. Students often hold alternative conceptions about scientific phenomena, particularly resistant to change (Vosniadou, 1994). As such a knowledge restructuring is difficult to achieve, conceptual change has been described as a strategic and intentional process (Sinatra & Pintrich, 2003). Scholars from the field of text comprehension have pointed out that a particular text structure, the refutation, promotes knowledge revision (Hynd, 2003). A refutation text acknowledges students' inaccurate ideas, directly refutes them, and introduces scientific conceptions as viable alternatives. Recently, it has been proposed that text structure affects learning from text by influencing cognitive processing during reading (van den Broek & Kendeou, 2008). To describe this processing, eye movements have been demonstrated as particularly useful as they can capture the "global text processing", a kind of processing of text segments implied in knowledge restructuring (Hyönä, Radach, & Deubel, 2003).

With respect to the on-line processing during the reading of an expository text, Hyönä, Lorch, and Kaakinen (2002) identified different reading patterns on the basis of eye movement behavior. Two of them were of particular interest: linear readers and topic structure processors. Specifically, topic structure processors engaged more in backtracking the parts of the text introducing the relevant information. In a following investigation, Hyönä and Nurminen (2006) pointed out that longer rereading fixations reflect a kind of processing that can be defined as strategic.

To extend current research, the aim of the present study was to examine whether different reading patterns process the information differently according to the reading condition (refutation and non-refutation). In addition, we investigated whether the refutation text effect in enhancing a deeper comprehension is more evident for a particular kind of readers, the linear. Two main hypotheses have guided our study: 1. Refutation text would actively organize the reading processing of linear readers, making them more strategic on the relevant information, that is, the scientific concepts; 2. Linear readers of the refutation text would learn more from text than linear readers of the non-refutation text.

Method

Fifty-one (22 male and 29 female) undergraduates (age: M = 23.9, SD = 3.1) from the University of Padova (Italy) served as participants in the experiment. Half of them read a refutation and half a non-

refutation text about the phenomenon of tides after their prior conceptions were assessed by means of five questions: two multiple-choice questions about Newton's universal gravitational law and three open-ended questions about the phenomenon of tides. Both texts embedded the same number of sentences (14), words (298), and characters (1527) and were presented on one screen only. Participants' eye movements were monitored by means of a Tobii T120 eye-tracker. Three eye movement indices were computed (Hyönä *et al.*, 2003): *first-pass fixation time*, reflecting the early processing of a text segment; *look-back fixation time*, revealing the strategic behavior during reading; *look-from fixation time*, reflecting the simultaneous processing of different text segments. After reading each text, students' verbal working memory was assessed. Finally, to directly assess the change in their conceptions, participants answered the same text-based questions they were given before the reading task.

Results

Two *t*-tests were first performed to ensure the equivalence for prior-knowledge and verbal working memory of the participants in the two reading conditions (refutation and non-refutation). They revealed no statistically significant differences: prior-knowledge, $t(49) = .170$, $p = .866$; verbal working memory, $t(49) = .966$, $p = .339$. Thus, prior-knowledge and verbal working memory were not considered in the subsequent analyses.

Reading Patterns

We performed a cluster analysis (Ward's method) to categorize readers on the basis of three segment-level eye fixation measures: first-pass fixation time, look-back fixation time, and look-from fixation time, all having the parts identical in the two text versions, the scientific concepts, as the target regions. Two reading patterns emerged from the cluster analysis, which closely match the descriptions provided by Hyönä *et al.* (2002), that is, linear readers (N = 20, 39%) and topic structure processors (N = 31, 61%). In particular, topic structure processors made significantly longer look-back fixations than linear readers, $t(44.067) = -10.541$, $p < .001$, as well as longer looks-from, $t(47.622) = -7.700$, $p < .001$. Thus, following Hyönä and Nurminen (2006), the former were referred to as strategic readers.

Reading Patterns and Text Structure

To examine whether the two clusters devoted the fixation time differently as a function of the reading condition, ANCOVAs were performed separately for each eye movement measure, with text (refutation and non-refutation) and reading patterns (linear and strategic) as between-subject variables (reading time as a covariate). For the first-pass fixation time, results showed a significant text x reading pattern interaction, $F(1, 46) = 4.533$, $p = .039$, $n^2_p = .09$. Specifically, linear readers of the non-refutation text made longer first-pass fixations on the scientific concepts than refutation text readers of the same group. Furthermore, for the look-back fixation time, findings revealed a main effect of text, $F(1, 46) = 7.639$, $p = .008$, $n^2_p = .14$, and of reading pattern, $F(1, 46) = 7.870$, $p = .007$, $n^2_p = .15$. Readers of the refutation text as well as strategic readers backtracked for a longer time the scientific segments than readers of the non-refutation text and linear readers, respectively. These main effects were qualified by a text x reading pattern interaction, $F(1, 46) = 6.809$, $p = .012$, $n^2_p = .13$ (Figure 1). Linear readers who read the refutation text showed a more strategic behavior on the scientific concepts than linear readers in the non-refutation text condition.

Conceptual Learning

Finally, in order to test whether the effectiveness of refutation text in promoting a deeper conceptual learning varied according to the reading pattern (linear and strategic), a 2 (text) x 2 (pre-posttest) mixed-factor design was performed separately for each reading pattern. Results revealed that, among

the linear readers, participants who read the refutation text learned more from text than non-refutation text readers, outperforming them at posttest, $F(1, 17) = 6.617$, $p = .020$, $n^2_p = .28$ (Figure 2).
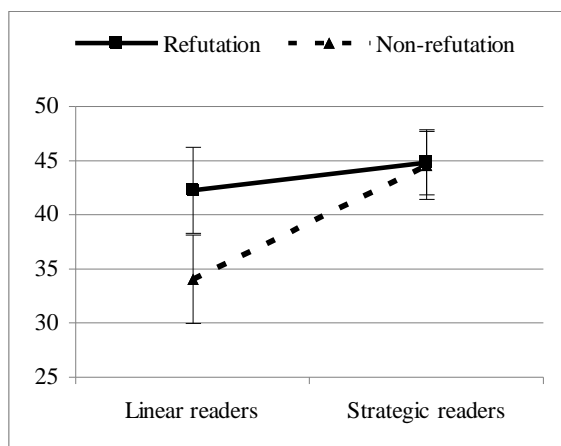

Figure 1. Look-back fixation time (in sec) of linear and strategic readers by text.
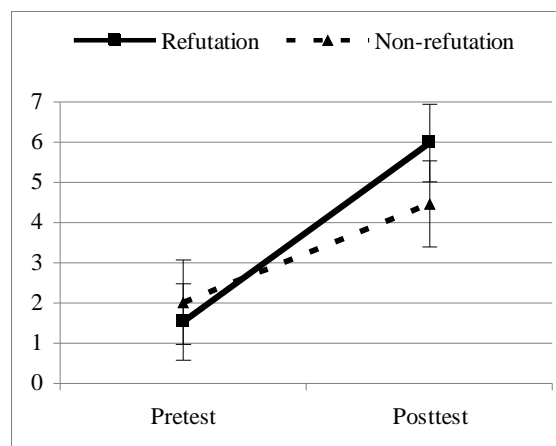

Figure 2. Scores of linear readers at pre- and posttest by text.

Discussion

The aim of this study was to document whether reading patterns of an expository text are affected differently according to the text structure. In addition, we tested whether a refutation text enhances deeper comprehension for a particular group, the non-strategic readers. Cluster analysis revealed two reading patterns, linear readers and topic structure processors, closely similar to those identified by Hyönä and colleagues (Hyönä *et al*., 2002). Specifically, topic structure processors were referred to as strategic readers (Hyönä & Nurminen, 2006). Refutation text actively organized the reading behavior of the linear readers, supporting them to strategically focus on the relevant information, that is, the scientific concepts. Moreover, linear readers particularly benefited from the reading of a refutation text. Among the former, readers who were given the refutation text achieved a deeper conceptual learning than those in the non-refutation condition.

In sum, evidence is provided for the hypothesis that refutation text effect acts differently according to the patterns of reading processing, being particularly relevant for students who are not strategic processors.

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