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Learning from texts : extending and revising knowledge

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C H A P T E R

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Refutation Texts Enhance Transfer of Knowledge

Under revision

Katinka Beker, Martin Van Boekel, Paul van den Broek and Panayiota Kendeou

Abstract

In this study we determined whether refutation texts facilitate transfer of revised knowledge to new situations. In Experiment 1, students read refutation, transfer, and non-refutation narrative-informational texts. Transfer texts were always preceded by refutation texts. Although the refutation and transfer texts had different story contexts, the transfer text required activation of the same belief that was refuted and explained in the refutation text. The non-refutation text targeted a different belief and served as a control. Each text contained a target sentence that was consistent with the correct belief and reading times of these sentences were measured. If transfer of the revised knowledge is facilitated by reading refutation texts, then reading times in the transfer texts should be faster than in the non-refutation texts. In Experiment 2, students also read similar non-refutation, transfer, and refutation texts, but this time transfer texts were preceded by non-refutation texts. The transfer text required activation of the same belief that was mentioned in the non-refutation text. The refutation text targeted a different belief and served as a control. It was expected that non-refutation texts fail to revise knowledge and thus transfer of revised knowledge. In both experiments, a transfer problem test was also administered after reading the texts to assess transfer in a more explicit way. The results demonstrate that refutation texts are more effective in facilitating revision and transfer of revised knowledge than non-refutation texts. These results add to the growing body of evidence for the applicability of using refutation texts in revising misconceptions.

Introduction

One of the greatest challenges faced by educators is changing previously acquired, incorrect knowledge (Chi, Slotta, & De Leeuw, 1994; Guzzetti et al., 1993; Vosniadou & Brewer, 1992). Incorrect knowledge can arise when students encounter misinformation, for example when multiple internet sources mention the same incorrect information (Ecker, Swire, & Lewandowsky, 2014; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). Other times, incorrect knowledge can arise when students use prior knowledge or personal experiences in an inappropriate way to comprehend new phenomena in the world, for example by overgeneralizing. In some instances, incorrect knowledge can have negative effects on health, and may even put individuals in danger. For example, consider an individual who thinks that lightning never strikes the same place twice. During a thunderstorm this individual may hide underneath a tree that was struck by lightning in the past, because the incorrect knowledge leads to the assumption that this tree is a safe place to seek shelter. This is potentially harmful as the opposite is in fact true: Lightning can strike the same place multiple times.

What makes having incorrect knowledge even more undesirable is the fact that it is often resistant to change (Carey, 2009; Chi, 2005; Novak, 1988; Vosniadou & Brewer, 1992). Many attempts have been made to design methods for changing incorrect knowledge. To be successful, these methods need to influence all aspects of the learning process: The correct knowledge needs to be permanently encoded in memory *and* it needs to be retrieved in relevant situations. Several methods are effective in achieving the first step in learning, such as the use of refutation texts – texts that explicitly refute and explain incorrect knowledge (Guzzetti et al., 1993; Hynd, Alvermann, & Qian, 1997; Hynd, McWhorter, Phares, & Suttles, 1994; Kendeou et al., 2014; Mason & Gava, 2007). It is not known, however, whether these methods are effective in accomplishing the second step in learning, ensuring retrieval in subsequent learning situations (i.e., *transfer*). Such transfer is a main goal in educational settings (Bransford et al., 2000). In the present study, we investigate whether refutation texts enhance transfer of acquired knowledge to new situations. We focus on the revision of one specific type of incorrect knowledge, namely *incorrect beliefs*. Following Chi (2013), an incorrect belief is the lowest level of misconceived knowledge and is defined as factual knowledge that can be represented by a single idea unit.

Refutation texts are characterized by three features: 1) An explicit statement of an incorrect belief, 2) An explicit refutation of this incorrect belief (Guzzetti, 2000), and 3) An explanation of the correct belief (Kendeou et al., 2013; Kendeou et al., 2014). Refutation texts have been found to facilitate the process

of knowledge revision and, consequently, to improve the resulting mental representation of the situation described in the text (Kendeou & van den Broek, 2005, 2007). With regard to the process, research has shown that readers processed statements of the correct belief faster in refutation than in non-refutation texts (Kendeou & van den Broek, 2007; Kendeou et al., 2014; Rapp & Kendeou, 2007; van den Broek & Kendeou, 2008). Furthermore, think-aloud results show that readers engage in more change processes when reading refutation texts than when reading non-refutation texts (Kendeou & van den Broek, 2007; van den Broek & Kendeou, 2008). With regard to the resulting mental representation, knowledge revision is reflected in memory measures administered directly after reading (Braasch, Goldman, & Wiley, 2013; Diakidoy et al., 2003; Kendeou & van den Broek, 2007; van den Broek & Kendeou, 2008), weeks later (Hynd et al., 1994), and even months later (Hynd et al., 1997; Kendeou et al., 2014; Mason & Gava, 2007).

To understand why refutation texts are so effective in changing incorrect beliefs it is important to understand the underlying mechanisms that result in knowledge revision. Research in reading comprehension has provided valuable insights into the cognitive mechanisms involved in updating and revising mental representations during reading (McNamara & Magliano, 2009). Several of these principles are incorporated in the Knowledge Revision Components Framework (KReC) (Kendeou & O'Brien, 2014). An example from the current study will be used to illustrate the principles of the KReC framework. The KReC framework starts with the assumption (principle 1) that once information is encoded into long-term memory it cannot be erased and it always has the potential of being reactivated, although it can decay or interference mechanisms can decrease its activation (Gillund & Shiffrin, 1984; Hintzman, 1986; Kintsch, 1988; Ratcliff, 1978; Ratcliff & McKoon, 1988). So when a reader holds the incorrect belief that 'seasons are caused by the distance between the Earth and the Sun' the encoding principle proposes that this belief cannot be just erased. The second principle is the assumption of passive activation, which proposes that every cue that relates the incorrect belief passively activates related background information and prior knowledge. This means that any information that is related to the current contents of working memory has the potential to become activated regardless of whether it facilitates or interferes with learning and/or comprehension (Gerrig & McKoon, 1998; McKoon et al., 1996; Myers & O'Brien, 1998; O'Brien, 1995). In the context of KReC, knowledge revision occurs when there is a shift in dominance of the information in the mental representation from the previously encoded incorrect belief (e.g. 'the distance towards the Sun causes seasons') to the more recently encoded correct belief (e.g. 'the tilt causes seasons'), and this process is guided by three principles:

Co-activation (principle 3), integration (principle 4) and competing activation (principle 5). Co-activation of the incorrect and correct belief is crucial because it is necessary for the integration (principle 4) of the incorrect and correct beliefs in a single mental representation (Kendeou, Muis, & Fulton, 2011; Kendeou et al., 2013; Kendeou & van den Broek, 2007; Kendeou et al., 2014; O'Brien, Cook, & Gueraud, 2010; O'Brien, Rizzella, Albrecht, & Halleran, 1998; van den Broek & Kendeou, 2008). In a refutation text, this is accomplished by presenting the correct belief immediately after the incorrect belief with an explicit refutation. Then, at a later point in the text (and in subsequent retrieval instances), both beliefs can be simultaneously reactivated because they are part of the same mental representation (Kendeou & O'Brien, 2014). For example, a cue such as '*the tilt of the Earth causes the seasons'* can activate both the incorrect and the correct belief when they are integrated into the same mental representation. This can lead to interference if the two are mutually exclusive. Therefore, for knowledge revision to be successful, the correct belief needs to be dominant in the integrated network of information (principle 5). Activation needs to be drawn away from the incorrect belief, thereby decreasing the disruption caused by the incorrect belief. In refutation texts this is accomplished by building an elaborate network of causal explanations (Kendeou et al., 2014). Causal information inherently provides a rich network of information, which combined with revised information provides additional competition for reactivation, making it more likely that the revised knowledge will return in active memory (Kendeou et al., 2013).

In this description of the knowledge revision process it is assumed that if integration succeeds, subsequent encounters with the topic will activate both the previously encoded incorrect belief and the newly acquired correct belief, and the correct belief will 'dominate' because of its supporting interconnected causal network. Memory, however, is also context-dependent (e.g. Godden & Baddeley, 1975). This may result in activation of the incorrect belief in contexts that strongly cue the incorrect belief, even when the correct belief is more dominant in the integrated network. An analogy can be drawn to research demonstrating that the subordinate rather than the dominant meaning of ambiguous words is activated when the context strongly biases towards the subordinate meaning (Colbert-Getz & Cook, 2013; Wiley & Rayner, 2000). These ambiguous words share features in the mental representation (e.g. orthography, phonology), but they also have different features (e.g. the meaning). Each meaning is connected to a different (semantic) context. Similarly, incorrect beliefs and correct beliefs are part of the same mental representation, but they have different features, and these features may be tied to different contexts. For knowledge revision to be successful, the correct belief needs to be retrieved and applied in novel contexts. Refutation texts have been shown to be effective in revising knowledge

when assessed in similar contexts, but it is not clear whether they also facilitate transfer of revised knowledge to different contexts.

Transfer has been defined in various ways (Shuell, 1986). In the current study, transfer is defined as the process by which newly encoded information is used in a different situation (Barnett & Ceci, 2002; Day & Goldstone, 2012; Shuell, 1986). We examined spontaneous transfer of revised knowledge from one narrative-informational text to a contextually distant narrative text that involves different story characters, activities, and setting (Table 5.1). In Experiment 1, we examined whether readers with incorrect beliefs showed transfer of knowledge that was revised by reading refutation texts. In Experiment 2, we examined whether readers with incorrect beliefs *failed* to show transfer when the correct knowledge was mentioned in a non-refutation text. In both experiments, we obtained on-line (i.e., reading times), as well as off-line (i.e., transfer problem test scores) evidence.

Experiment 1

The objective of Experiment 1 was to determine whether readers transfer knowledge that was revised by means of a refutation text to new situations (i.e. a new text). The reading times of target sentences that present correct information were compared for readers that read refutation texts, transfer texts and non-refutation texts. Prior research has shown that information that is inconsistent with prior beliefs is processed slower than information that is consistent with or unrelated to prior beliefs (Albrecht & O'Brien, 1993). Based on this finding, we expect that correct information will be processed slower by readers with incorrect beliefs regarding that topic than by readers who have revised their incorrect belief.

The design and procedure employed in this experiment were similar to those used in previous studies that examined knowledge revision using refutation texts (Kendeou et al., 2014). Participants read narrative-informational texts that were presented in refutation, transfer, or non-refutation conditions. Specifically, in each refutation text, an incorrect belief (e.g., 'the distance between the Earth and the Sun causes the seasons') was presented and refuted with a supporting explanation of the correct idea (e.g., 'the tilt of the Earth causes the seasons'). In each transfer text, the same correct belief as in the refutation text was required for comprehension, however, the transfer text did not involve a refutation or explanation, and included different story characters, activities, and setting relative to the refutation text. This was done to decrease the similarities between the refutation and transfer texts and make actual transfer more challenging. In each non-refutation text, a different incorrect belief (e.g., 'meteors that land on Earth are hot') did not mention the incorrect belief, nor explain the correct belief, but instead described neutral information. All texts in each condition contained a target sentence that was consistent with the correct belief and was the focal point for comparison across conditions.

The first hypothesis concerned replication of the advantage of refutation texts over non-refutation texts on knowledge revision. More specifically, the expectation was that processing the target sentence (with the correct information) during reading would be faster for refutation texts compared to non-refutation texts because refutation texts lead to knowledge revision and non-refutation texts do not. The second hypothesis and main focus of this study concerned transfer of revised knowledge from refutation texts to new contexts. If readers transfer the revised knowledge to a different context (i.e. the transfer text), then a target sentence that is consistent with the correct belief in the transfer text should also be read faster than a target sentence in a non-refutation text.

In addition, participants were asked to answer transfer questions on a test after reading all texts. If reading refutation texts leads to knowledge revision and transfer of that knowledge, then test scores should be higher for items that participants read in the refutation and transfer texts compared to items that participants read in the non-refutation texts.

Method

Participants

A total of 38 University of Minnesota undergraduate students enrolled in introductory psychology courses participated in the current study. Participants received partial course credit for their participation. Of the 38 participants, 22 were female and 16 were male, with an age range of 18-31 years (M = 19.58, SD = 2.24). The sample size was supported by a power analysis using R-statistics software and the Pwr package for general linear models ($n \geq 26$), with the power level set at .90, the alpha level at .05, the number of conditions at 3, and the effect size at .54, the latter being based on a similar study (Kendeou et al., 2014).

Design

There was one within-subjects factor, Text Type. Participants read refutation texts, transfer texts, and non-refutation texts, 6 of each type, which were always presented in the same order. The transfer text followed directly after the refutation text and involved the same belief, but with different contextual details. The non-refutation text involved a different belief and was included as a

baseline condition to which results of the other two conditions were compared against. See Figure 5.1 for an example of the three conditions. The variables used to measure the transfer of revised knowledge were the reading times on the target sentences and accuracy on the transfer problem test questions. The target sentences across conditions were not exactly the same, but the sentence length was controlled as much as possible (the sentences were always between 37 and 43 characters). To capture any potential delayed effects, the reading time of the sentence following the target sentences was also measured (i.e., spillover effect).

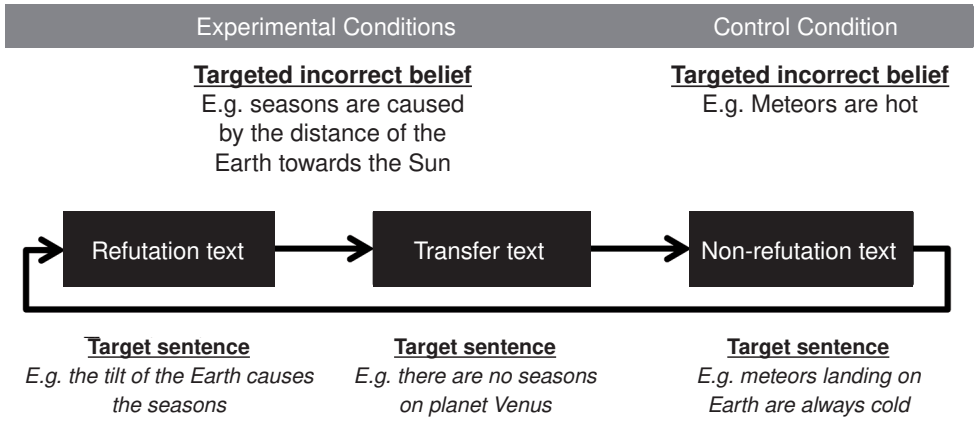

Figure 5.1 Demonstration of the order in which the texts in different conditions were presented in Experiment 1. Each participant went through six of these loops (18 texts in total).

Materials

Texts. The materials consisted of 18 narrative-informational texts (Duke, 2000), of which 12 (6 refutation and 6 non-refutation texts) were used in previous studies (Kendeou et al., 2014; Van Boekel, Lassonde, O'Brien, & Kendeou, 2016) and 6 (transfer texts) were constructed for the purposes of this study. Previous research has indicated that the incorrect beliefs targeted in these texts are common in the population from which our sample was drawn (Van Boekel et al., 2016). All texts began with seven introductory sentences totaling 100 words, which served to establish the storyline. This was followed by one of three elaboration sections equated in word length (133 words): refutation, transfer, and non-refutation. (a) The refutation section explicitly stated and refuted the incorrect belief (e.g. in the text about seasons: '*Ryan said that it was because the Earth is closer to the Sun in the summer than in the winter. Mrs. Parker said she read in a textbook that this idea was incorrect.*'), followed by an explanation of the correct belief. (b) The transfer section described information

that cues the revised belief by mentioning one aspect of the revised belief (e.g. in the text that cues the same belief as in the refutation text about seasons: 'tilt' in the sentences: '*Agnes scanned the website and found out that Venus' tilt is 177 degrees. This means it is almost vertical. The website explained that this means that the axis of Venus has no tilt at all.*'). (c) The non-refutation section continued the story line, with no mention of the incorrect or correct belief and instead describing neutral information (e.g. in the text about meteors: '*The conversation quickly turned back to the meteor, they could not believe a meteor had actually landed in their very own town. Jerry decided to run home and get a few books on astronomy. As the news spread, more people began to gather around the meteor.*'). The purpose of the refutation and explanation section was to revise incorrect prior beliefs. The purpose of the transfer section was to activate revised beliefs that were addressed in the refutation texts. The non-refutation section served as a control for the other conditions.

All three sections were followed by a filler section that continued the story-line and backgrounded the previous information (60 words). After the filler section a target sentence was presented in each condition (37-43 characters) that was consistent with the correct belief. The target sentence required the same belief in refutation and transfer texts that were presented successively, but the content of the target sentence in the transfer text was different and required transfer of the information from the refutation text (e.g. in the refutation text about seasons: '*The tilt of the Earth causes the seasons*', and in the transfer text discussing Venus as a planet that has no tilt: '*There are no seasons on planet Venus*'). The target sentence in the non-refutation texts always required a different belief than the one that was described in the preceding refutation and transfer texts (e.g. in the text about meteors: '*Meteors landing on Earth are always cold*'). To determine whether knowledge is revised by reading refutation texts, the reading times on the target sentence is compared between the refutation and non-refutation condition. Unrevised, incorrect knowledge should interfere with reading the correct belief (target sentence), leading to a slow-down. Thus, reduced slow-downs in the refutation condition reflect evidence for revision. To determine whether revised knowledge is transferred, reading times on the target sentence are compared in the transfer and non-refutation text conditions. Reduced slow-downs in the transfer condition reflect evidence for transfer of revised knowledge.

A spillover sentence of similar length as the target sentence was presented following the correct target sentence. All texts concluded with a closing section that wrapped up the storyline (90 words). After each text, a comprehension question was presented that did not address information concerning the belief to ensure readers were paying adequate attention during reading.

The selection of refutation texts from previous studies (Kendeou et al., 2014; Van Boekel et al., 2016) was based on the criterion that the targeted incorrect belief involved a relation between two concepts. For example, the refutation text about seasons describes a relation between the tilt of the Earth and seasons. One aspect of this relation was mentioned in a subsequent transfer text to activate prior knowledge about the revised belief. Specifically, in the transfer text that followed the refutation text about seasons it is stated that Venus has no tilt. This statement serves as a cue to activate the revised belief concerning the relation between the tilt (of the Earth) and the seasons from the refutation text. This cue is expected to enable transfer of revised knowledge ('tilt causes seasons') to the transfer text. With the exception of the cues in the transfer section, the transfer text that directly followed the refutation text was unrelated to the preceding refutation text. The transfer text was constructed to be as different as possible from the refutation text by using different story characters, who were doing different activities and by situating the stories in different settings (see Table 5.1 for the details of each text and Appendix I for example materials).

Table 5.1 *Contextual Differences Between Refutation and Transfer Texts*

Topic	Text character(s)		Activity of text characters		Setting	
	Refutation with explanation text	Transfer text	Refutation with explanation text	Transfer text	Refutation with explanation text	Transfer text
Seasons	Two young brothers	Old ladies	Water skiing	Taking a computer course	At the lake	In a community center
Chameleons	A child	Biology students	Coloring a lizard	Doing a research assignment	At home	In the reptile house
Force	Student	Two friends	Doing a school assignment	Playing a computer game	At home	At a friends' house
Trauma	Two students	A girl	Doing a school assignment	Celebrating a birthday party	Library	At a party
Dyslexia	A comedian	A mother	Reading about dyslexia	Going on vacation	Browsing through journal articles	In the car
Personality	Mothers	A detective	Talking to a friend	Describing a case in a blog	Not specified, informal meeting	The internet

Transfer Problem Test. The test included six questions that were related to the beliefs that were introduced in the refutation texts and six questions that were related to beliefs that were introduced in the non-refutation texts. Note that the beliefs introduced in the refutation texts also pertained to the transfer texts; therefore there were no additional questions that specifically addressed the topic of the transfer texts. The questions were designed to assess transfer by situating a problem that required the revised knowledge in a novel story setting. Participants were required to write down a solution to the problem. The question always consisted of two parts: One part required a short answer and one part required a more elaborate explanation. For example, for the refutation and transfer texts that related to the causes of seasons this question was: "Consider a planet that has extreme seasons. The difference in temperature between summer and winter is large. Explain what could be the cause of this pattern of extreme seasons (this requires a short answer, e.g.: 'the tilt') and how this pattern would influence temperatures in the summer and in the winter". The latter part requires a more elaborate explanation that draws on the revised knowledge that the tilt is responsible for the seasons and the generalization that no tilt means no seasons. The answers were scored on two aspects: Accuracy of the outcome and accuracy of the explanation. Participants were awarded one point for a correct outcome, and zero points for an incorrect outcome. In addition, correct explanations were awarded two points, incomplete or partially correct explanations were awarded one point, and missing or incorrect explanations were awarded zero points. Thus, the possible scores for each test item ranged between 0 and 3 points. The reliability of the scores on the test was good (i.e. Cronbach's alpha is .78). Participants' responses to each question were scored by the first author of this paper. Twenty-five percent of the answers were coded by a second rater to verify consistency (the weighed Kappa was .88).

Procedure

Participants were tested individually in a single session. The participants were informed that they were going to read several texts. The participants were asked to read at their own pace and they were asked to make sure they understood what they were reading. Participants were instructed to place their thumbs on the line-advance key (spacebar) and their index fingers on the 'yes' and 'no' keys (i.e. the 'Z' and 'M' key on the keyboard). Each trial began with the word "READY" in the center of the screen. When participants were ready to read a text, they pressed the line-advance key. Each press of the key erased the current line of text (always consisting of phrases of 7 words) and presented the next line of text. Reading time was measured as the time between key presses, but only the reading times of the target and spillover sentence were analyzed.

Participants were instructed to read at a normal and comfortable reading rate. Following the last line of each text, the cue "QUESTIONS" appeared in the center of the screen for 2000 milliseconds. This was followed by the comprehension question (e.g. 'Were Jack and Ryan going water skiing?') to which participants responded by either pressing the 'yes' or 'no' key. This question was inserted to make sure participants would pay attention to the task. On the trials in which participants' answers were incorrect, the word "ERROR" appeared in the middle of the screen for 750 milliseconds. Before beginning to read the experimental texts, participants read two practice texts to ensure that they were familiarized with and understood the procedure.

Upon completion of the reading task participants completed the 12-item transfer problem test. Finally, participants completed a short demographic form, were asked what they thought that the purpose of the study was and whether they used certain strategies, after which they were debriefed and thanked for their participation in the study.

Results and Discussion

As in previous studies using a similar paradigm (Kendeou et al., 2013; Kendeou et al., 2014; Rapp & Kendeou, 2007), reading times greater than 2.5 SD above the person and item means were discarded. Across all experiments, this resulted in the loss of 1% of the data. On average, participants answered 87% of the comprehension questions correct, suggesting that they were paying attention to the task. To take into account by subject and by item variability we performed each analysis by subjects (F_1) and by items (F_2). Statistics with an alpha level of .05 or lower were considered significant.

Reading times

For the by-subject analysis we conducted a repeated measures ANOVA (F_1) and for the by-item analysis we conducted a one-way ANOVA (F_2) with Text Type as an independent variable (refutation, transfer, and non-refutation) and target sentence reading times as dependent variable. The mean reading times of the target sentences in Experiment 1 are presented in Table 5.2. Text Type significantly affected the reading times of the target sentence by subjects (F_1 (2, 74) = 14.49, $p < .001$, $\eta_p^2 = .28$), but not by items (F_2 (2, 15) = 2.32, $p = .113$, $\eta_p^2 = .24$). Post-hoc analyses demonstrate that the target sentence was read faster when it followed the refutation elaboration than when it followed the non-refutation elaboration ($p < .001$, Cohen's $d = 1.35$). The target sentence also was read faster when it followed the transfer elaboration than when it followed the non-refutation elaboration ($p < .001$, Cohen's $d = .99$). There were no significant differences in reading times for the target sentence when it followed the refutation elaboration than when it followed the transfer elaboration ($p = .45$, Cohen's $d = -.17$). There were no spillover effects.

The reading time results show that reading a target sentence that relies on the correct belief was faster for refutation texts relative to non-refutation texts, supporting the first hypothesis, namely that refutations texts lead to knowledge revision, and replicating previous research findings (Kendeou & van den Broek, 2007; Kendeou et al., 2014). Furthermore, reading a target sentence that relies on the correct belief was also faster for transfer texts relative to non-refutation texts, supporting the second hypothesis, namely that reading refutation texts leads to revised beliefs, which are *maintained* and *transferred* to a different situation.

Table 5.2 *Mean Reading Times of the Target Sentences (in ms) for the Refutation, Transfer and Non-refutation Texts in Experiment 1*

	Target Sentence	
	M	*SE*
Refutation text	1940.90	72.29
Transfer text	1990.27	87.77
Non-refutation text	2247.85	73.10

Transfer Problem Test

For the by-subject analysis we conducted a paired samples t-test (t_1) and for the by-item analysis we conducted an independent samples t-test (t_2) with Text Type as an independent variable (refutation and non-refutation) and accuracy on the transfer problem test scores as the dependent variable. Accuracy on the transfer problem test differed between the refutation and non-refutation conditions by subjects ($t_1(38) = -14.73$, $p < .001$, Cohen's $d = 2.36$) and by items (t_2 (10) = 3.96, $p = .003$, Cohen's $d = 2.63$). The responses to the transfer problem test questions were more accurate in the refutation condition ($M = 13.95$, $SE = .38$) than in the non-refutation condition ($M = 7.44$, $SE = .41$). These results provide further support that refutation texts facilitate transfer of knowledge more than non-refutation texts, as assessed with the transfer problem test.

The results of Experiment 1 showed that the effect of refutation texts was maintained and transferred to different texts. This was reflected by faster reading times of the target sentences that relied on the correct beliefs in the transfer texts relative to the non-refutation texts (and no difference between transfer and refutation texts), as well as in higher test scores on the transfer problem test questions in the refutation condition compared to the non-refutation condition.

These results also raise two important questions. First, will the observed transfer effect in Experiment 1 disappear if transfer texts are preceded by non-refutation texts that target the same beliefs? In Experiment 1, transfer texts were always preceded by refutation texts that targeted the same belief and never by non-refutation texts that targeted the same belief. As a result, it cannot be determined whether there is a lack of transfer when correct beliefs are stated in non-refutation texts (without refutations) that are followed by transfer texts that target the same beliefs. Reading the target sentence in the non-refutation text, which contains the correct belief, may also lead to knowledge revision. However, the more explicit transfer measure (the transfer problem test) showed lower transfer scores for non-refutation texts compared to refutation texts. This suggests that knowledge revision is less likely to be maintained and transferred after reading non-refutation texts compared to refutation texts. But whether this also applies for more implicit transfer of knowledge, is unclear.

Second, are the effects of conditions explained by differences in the target sentences between conditions? The nature of the design in Experiment 1 precluded the possibility of texts appearing in all conditions, and thus target sentences differed between conditions. Although the length of the target sentences was controlled, they were not equal, so the effects of condition may alternatively be explained by characteristics of the different target sentences. For example, it is possible that on average, the specific words used in the target sentences in the refutation condition were more familiar to readers than the words used in the target sentences in the non-refutation condition. Familiarity generally speeds up reading (Rayner & Duffy, 1986), so the differences between conditions may rather be explained by differences in word frequency than by condition effects. To address these two questions and rule out alternative explanations of the obtained results in Experiment 1, we conducted Experiment 2.

Experiment 2

In Experiment 2 we examined whether the transfer effect that was observed in Experiment 1 disappears when reading non-refutation texts instead of refutation texts. It was expected that reading the statement that describes the correct belief (target sentence) in a non-refutation text is not sufficient to maintain or transfer revised knowledge. If non-refutation texts do not lead to knowledge revision and transfer, then reading times of target sentences in transfer texts should be slower than those in refutation texts. This would suggest that refutations and explanations are necessary for transfer of revised knowledge and that it is not sufficient to simply state the correct information. This should also be reflected in the accuracy on items on the transfer problem test, which were expected to be higher in the refutation than in the non-refutation condition.

Furthermore, by using the non-refutation version of beliefs that were targeted in refutation versions in Experiment 1 it could be determined whether the effects in Experiment 1 were due to conditions or due to differences between the target sentences. If the effects are due to conditions, then the transfer effect should disappear. More specifically, the target sentence in the transfer condition should be processed slower than the target sentence in the refutation condition. If the effects are due to differences between the target sentences the transfer effect should remain. More specifically, the processing time of the target sentence in the transfer condition should be similar to the processing time of the target sentence in the refutation condition.

Method

Participants

A total of 29 University of Minnesota undergraduate students enrolled in introductory psychology courses participated in the current study. Participants received partial course credit for their participation. Of the 29 participants, 14 were female and 15 were male, with an age range of 18-26 years (M = 19.79, SD = 1.83).

Design

Participants read non-refutation texts, transfer texts, and refutation texts, 6 of each kind, which were always presented in the same order. The transfer text followed directly after the non-refutation text and involved the same belief, but with different contextual details. The refutation text involved a different belief and was included as a baseline condition to which results of the other two conditions were compared. See Figure 5.2 for an example of the three conditions. The same measures were administered as in Experiment 1.

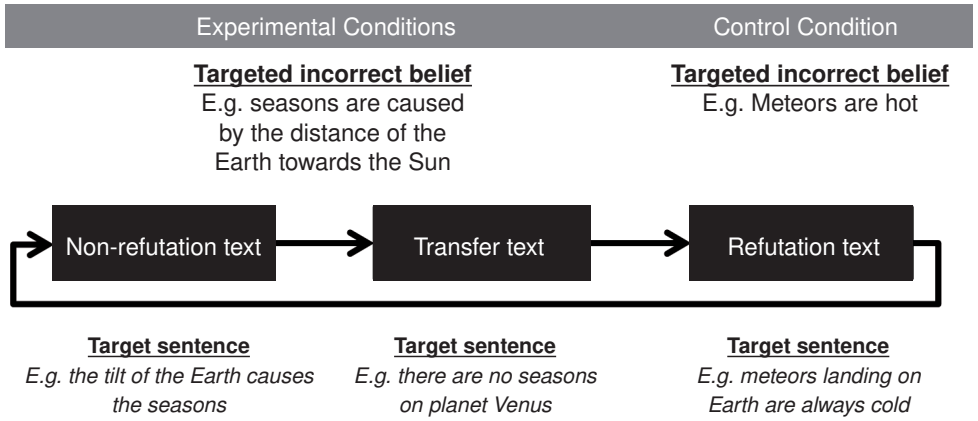

Figure 5.2 Demonstration of the order in which the texts in different conditions were presented in Experiment 2. Each participant went through six of these loops (18 texts in total).

Materials

Texts. The materials consisted of 18 narrative-informational texts (Duke, 2000), of which 12 (6 refutation and 6 non-refutation texts) came from previous studies (Kendeou et al., 2014; Van Boekel et al., 2016) and 6 (transfer texts) were constructed for the purposes of this study (which were the same as in Experiment 1). All texts involved the same story characters, activities, and settings as in Experiment 1. Importantly, however, the topics and beliefs that were described in the refutation texts in Experiment 1 were now described in non-refutation texts, and vice versa. For example, the non-refutation version of the seasons text was used in Experiment 2, whereas in Experiment 1 the refutation version of the seasons text was used. Again, all texts began with seven introductory sentences totaling 100 words, which served to establish the storyline. This was followed by one of three elaboration sections equated in word length (133 words): Non-refutation, transfer and refutation. (a) The non-refutation section continued the story line, with no mention of the incorrect or correct belief and instead describing neutral information (e.g. in the text about seasons: '*She said this was just the sort of thing that the boys should look up in a textbook. The sons agreed that they would look it up after they had finished water skiing.*'). (b) The transfer section described information that cues the correct belief by mentioning one aspect of the correct belief (e.g. in the text that cues the same belief as in the non-refutation text about seasons: '*Agnes scanned the website and found out that Venus' tilt is 177 degrees. This means it is almost vertical. The website explained that this means that the axis of Venus has no tilt at all.*'). (c) The refutation section explicitly stated and refuted the incorrect belief (e.g. in the text about meteors: '*Kate warned everyone not to touch the meteor because it would be hot and they could get burned. Jerry, the professor, said that they shouldn't worry because it actually would not be hot.*'), followed by an explanation of the correct belief. The refutation section served as a control for the other conditions.

All three sections were followed by the same filler section, target sentence, spillover sentence, closing section and comprehension question as in Experiment 1. The target sentence concerned the same belief in non-refutation and transfer texts that were presented successively, but the content of the target sentence in the transfer text was different and required transfer of the information from the non-refutation text (e.g. in the non-refutation text: '*the tilt of the Earth causes the seasons*' and in the transfer text: '*there are no seasons on planet Venus*'). The target sentence in the refutation texts always required a different belief than the one that was described in the preceding non-refutation and transfer texts (e.g. '*meteors landing on Earth are always cold*'). To determine whether non-refutation texts fail to achieve transfer of the correct belief to transfer texts, the reading times on the target sentence is compared between the transfer text and the refutation text. Reduced slow-downs in the refutation condition only and not in the transfer condition is argued to reflect a lack of transfer of revised knowledge.

Transfer Problem Test. The transfer problem test was exactly the same as in Experiment 1 and scored in the same way. The reliability of the scores of the test was good (i.e. Cronbach's alpha is .69). Twenty-five percent of the answers were coded by a second rater to verify consistency (the weighed Kappa was .89).

Procedure

The procedure was the same as in Experiment 1.

Results and Discussion

The same procedure for removing outliers as in Experiment 1 was used in Experiment 2. This resulted in the loss of less than 1% of the data. On average participants answered 88% of the comprehension questions correct, showing they were paying attention to the task.

Reading times

The mean reading times of the target sentences in Experiment 1 are presented in Table 5.3. In the by-subject analysis, Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 9.86$, $p = .007$, therefore

degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .77). Text Type significantly affected the reading times of the target sentence by subjects ($F_1(2, 43) = 11.51$, $p < .001$, $n_p^2 = .29$) but not by items ($F_2(2, 15) = 2.31$, $p = .134$, $n_p^2 = .24$). Post-hoc analyses demonstrate that the target sentence was read faster when it followed the refutation elaboration than when it followed the non-refutation elaboration ($p < .001$, Cohen's d = 1.99), replicating the results of Experiment 1. The target sentence also was read faster when it followed the refutation elaboration than when it followed the transfer text elaboration ($p = .009$, Cohen's $d = .78$). There were no significant differences in reading times for the target sentence when it followed the transfer elaboration than when it followed the non-refutation elaboration ($p = .191$, Cohen's $d = .31$). There were no spillover effects.

The reading time results provide converging evidence for the knowledge revision effect that was demonstrated in Experiment 1. The target sentence, which was always consistent with the correct belief, was read faster in the refutation condition than in the non-refutation and transfer conditions, and refutation and transfer conditions did not differ. These findings suggest that the transfer effect disappears when non-refutation texts precede transfer texts (in contrast to Experiment 1 where refutation texts preceded transfer texts). Experiment 2 also shows that the effects of conditions in Experiment 1 cannot be explained by mere differences between the target sentences across conditions; rather the Text Type condition influenced the results.

Table 5.3 *Mean Reading Times of the Target Sentences (in ms) for the Refutation, Transfer and Non-Refutation Texts in Experiment 2*

	Target Sentence	
	M	*SE*
Non-refutation text	2147.45	95.00
Transfer text	2074.94	102.68
Refutation text	1846.46	93.18

Transfer Problem Test

Accuracy on the transfer problem test differed between the refutation and non-refutation conditions by subjects ($t_1(28) = -2.16$, $p = .04$, Cohen's $d = .41$) but not by items ($t_2(10) = -.44$., $p = .669$, Cohen's $d = .27$) The responses to the transfer problem test questions were more accurate in the refutation ($M = 13.00$, $SD = 2.78$) than in the non-refutation conditions ($M = 11.98$, $SD = 3.21$). These results provide further support that refutation texts facilitate transfer of knowledge more than non-refutation texts, as assessed with transfer problem test questions.

General Discussion

Prior research has shown that refutation texts are effective in revising incorrect beliefs as measured immediately after reading the texts (Kendeou & van den Broek, 2007; Kendeou et al., 2014; Rapp & Kendeou, 2007; van den Broek & Kendeou, 2008) and after a delay when explicitly asked to retrieve the information (Braasch, Goldman, et al., 2013; Diakidoy et al., 2003; Hynd et al., 1997; Hynd et al., 1994; Kendeou & van den Broek, 2007; Kendeou et al., 2014; Mason & Gava, 2007; van den Broek & Kendeou, 2008). The results of both experiments in the current study replicate these earlier findings: Refutation texts were more effective in producing knowledge revision than non-refutation texts. But more importantly, the current study also extends previous work by providing evidence for spontaneous transfer of revised knowledge from a refutation text to a new text. Specifically, revised knowledge was spontaneously activated during reading a subsequent transfer text. Furthermore, participants demonstrated application of revised knowledge from refutation texts to new situations when asked to solve transfer problem questions.

The first experiment showed that the disruption caused by incorrect prior knowledge was reduced when knowledge was revised by means of refutation texts, and this effect was maintained and transferred to new texts that required the revised knowledge for comprehension. The second experiment showed that the disruption caused by incorrect prior knowledge was still apparent when knowledge was not successfully revised by means of non-refutation texts. Although the difference in target sentence reading time is described as reflecting a reduced slow-down in the refutation condition (Kendeou & van den Broek, 2007; Kendeou et al., 2014; Rapp & Kendeou, 2007; van den Broek & Kendeou, 2008), due to the absence of a neutral baseline it could also be described as an increased speed-up. However, previous studies that did include a neutral baseline in the context of processing inconsistencies suggest that such reading time differences are more likely to reflect reduced interference than facilitation (e.g. Albrecht & O'Brien, 1993).

Transfer was also gauged by a second, more explicit measure of transfer, namely open-ended transfer problem test questions. In each experiment, accuracy on the transfer problem test questions was higher in the refutation condition than in the non-refutation condition. This suggests that there was more transfer as a result of reading refutation texts than non-refutation texts, and provides converging evidence for the effectiveness of refutation texts in facilitating transfer.

The results of the current study are consistent with several models of discourse comprehension. First, several models of discourse comprehension state that information from previous read texts and background knowledge is

available to the reader over the course of reading (Albrecht & O'Brien, 1993; Kintsch, 1988; O'Brien et al., 1998; van den Broek, Risden, et al., 1996; van den Broek et al., 1999). Indeed, in the current study information from a prior text (the refutation text) was available during reading of the transfer text. Second, several models describe the process of making information in working memory available as passive and nonstrategic (Albrecht & O'Brien, 1993; Kendeou & O'Brien, 2014; O'Brien et al., 1998; van den Broek, Risden, et al., 1996; van den Broek et al., 1999). In the current study, participants were not explicitly instructed to make connections between the refutation and transfer texts. They also did not report any awareness of the connection between the texts when asked whether they used specific strategies (after completion of the experiment). Thus, although we cannot rule out the possibility of strategic activation, it seems that the information from the refutation text became active in a passive, nonstrategic way. Third, models of discourse comprehension posit that reading processes affect the resulting mental representation (Kintsch, 1988; van den Broek, Risden, et al., 1996). According to these models, differences in processing should be reflected in differences in the mental representation. Indeed, differences between the refutation and non-refutation conditions were reflected in both process measures and measures of the mental representation.

Various mechanisms may be responsible for the abovementioned effects, and at least some of these can be understood in the context of the Knowledge Revision Components framework (Kendeou & O'Brien, 2014). According to the KReC framework, mental representations are constructed and modified through mechanisms of change, which include co-activation, integration and competing activation (principles 3 to 5). Applying this framework to the current experiments, stating the refuted incorrect belief and the correct belief in close proximity in the text may have resulted in co-activation and, through integration, in incorporation into the evolving mental text representation (Kendeou & O'Brien, 2014; van den Broek & Kendeou, 2008). Furthermore, explanation of the correct information in the refutation texts may have strengthened the position of the correct information in the respective mental representations, by making it more central and dominant (Kendeou & O'Brien, 2014; van den Broek, Risden, et al., 1996; van den Broek et al., 1999). As a result, during later retrieval this highly interconnected network may have drawn activation away from the competing incorrect belief (Kendeou & O'Brien, 2014).

In this study, we contrasted two conditions that differ on two aspects: The presence of a refutation and the presence of an explanation. The reason for this was because a combination of refutation and explanation was more effective in bringing about (immediate) knowledge revision than each component on its own (i.e., refutation only, explanation only) in previous studies (Kendeou et al., 2014). Following the same rationale, this combination was argued to be also the most effective in accomplishing *transfer* of revised knowledge, because transfer is dependent on how well knowledge is revised. In addition, in line with the KReC framework, both refutations and explanations seem to be required for transfer: The refutation part may induce co-activation and integration (principle 3 and 4), and the explanation part may cause dominance in the mental representation (principle 5). However, by not including a condition with a refutation only or an explanation only, the question remains whether either the refutation or the explanation alone could have produced similar effects. Future studies should address this issue and help gain more insights into the necessary components of refutation texts.

The design of the current study was based on the assumption that the majority of the participants held the twelve common incorrect beliefs that were targeted in this study. This assumption seems reasonable as it is supported by the results of a pilot study (Van Boekel et al., 2016) and several other studies that targeted the same misconceptions in a similar population (Broughton et al., 2010; Kendeou et al., 2014; Lilienfeld, Lynn, Ruscio, & Beyerstein, 2010; M. Stein, Larrabee, & Barman, 2008). Yet, the possibility that some participants may have held the correct belief cannot be ruled out completely. For example, the item analyses did not hold up across these experiments ($.113 < p < .670$) and, this may be in part to variability in prior misconceptions and/or small item numbers (i.e. low power). It is more likely that participants held most of the incorrect beliefs because (a) there were significant differences in reading times between the refutation and non-refutation condition, and (b) performance on the transfer problem test was not near ceiling. Instead, in both experiments and on both measures there were clear and consistent differences between the two conditions. Future studies, however, should consider the possibility that different misconceptions may differ in their prevalence and strength and, hence, may be differentially susceptible to refutation effects.

In the current experiments, the to-be-revised knowledge was conceived at the individual belief level (Chi, 2008, 2013), and thus was quite simple. It is possible that reading a refutation text may not be sufficient for revising other types of misconceptions that are more complex and conceived at higher knowledge levels, such as the mental model or ontological categories. Theoretical frameworks such as the Knowledge Revision Components framework highlight the fact that the strength of the mental representation of the incorrect belief is of crucial importance in the revision process. The stronger the mental representation of the incorrect belief, the more difficult it will be for the newly encoded correct belief to 'win over' (re)activation, and thus retrieval at subsequent instances. In addition, the links that mental representations have to

certain contexts are likely to play an important role. It is possible that even when the correct information dominates the mental representation, certain information is exclusively linked to the incorrect belief and not to the correct belief. This may result in reactivation of the incorrect belief in those contexts that are exclusively linked to the incorrect belief. Context-dependency of mental representations is especially relevant in the context of transfer (Barnett & Ceci, 2002; Spencer & Weisberg, 1986). The more the context to which information needs to be applied differs from the context in which information was learned, the more difficult it will be for learners to establish links between those situations. That is why it is important to gradually increase the contextual distance between learning and application contexts. In the current experiments, the learning context (the refutation and non-refutation texts) and the application context (the transfer text and the transfer problem test questions) were relatively similar (even though the narratives were quite different). Therefore, the transfer effects that were observed in this study may be classified as *near* transfer (i.e. transfer to a similar situation) following Barnett and Ceci's criteria (2002). By changing dimensions of the context, such as the place, time etc., future research could determine whether refutation texts are effective for facilitating far transfer (i.e. transfer to a different situation) as well. For example, in one recent study, the temporal distance between the context in which knowledge was revised and the context to which revised knowledge had to be applied was increased to one month. This study was the first to show that the effect of refutation texts was retained during this relatively long time interval (Kendeou et al., 2014). Although this result suggests that the effects of refutation texts are relatively long-lasting, more contextual dimensions than time need to be changed to see whether the effects generalize to different situations.

In conclusion, incorrect knowledge is common among students in education. Incorrect knowledge can seriously harm students, so it is important to identify methods that facilitate knowledge revision. Refutation texts are becoming more popular as a method to revise knowledge, because their effectiveness has been demonstrated in several studies (Braasch, Goldman, et al., 2013; Diakidoy et al., 2003; Kendeou & van den Broek, 2007; Kendeou et al., 2014; van den Broek & Kendeou, 2008). Refutation texts presumably facilitate knowledge revision because they scaffold knowledge revision *processes,* such as those suggested by the KReC framework (Kendeou & O'Brien, 2014). The current study adds to this line of work by showing that refutation texts also facilitate one other aspect of learning, the transfer of revised knowledge to different contexts.