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Refutations in science texts lead to hypercorrection of misconceptions held with high confidence

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ABSTRACT

Misconceptions about science are often not corrected during study when they are held with high confidence. However, when corrective feedback co-activates a misconception together with the correct conception, this feedback may surprise the learner and draw attention, especially when the misconceptions are held with high confidence. Therefore, high-confidence misconceptions might be more likely to be corrected than low-confidence misconceptions. The present study investigates whether this hypercorrection effect occurs when students read science texts. Effects of two text formats were compared: Standard texts that presented factual information, and refutation texts that explicitly addressed misconceptions and refuted them before presenting factual information. Eighth grade adolescents ($N = 114$) took a pre-reading test that included 16 common misconceptions about science concepts, rated their confidence in correctness of their response to the pre-reading questions, read 16 texts about the science concepts, and finally took a post-test which included both true/false and open-ended test questions. Analyses of post-test responses show that reading refutation texts causes hypercorrection: Learners more often corrected high-confidence misconceptions after reading refutation texts than after reading standard texts, whereas low-confidence misconceptions did not benefit from reading refutation texts. These outcomes suggest that people are more surprised when they find out a confidently held misconception is incorrect, which may encourage them to pay more attention to the feedback and the refutation. Moreover, correction of high-confidence misconceptions was more apparent on the true/false test responses than on the open-ended test, suggesting that additional interventions may be needed to improve learners' accommodation of the correct information.

1. Introduction

Adolescents in secondary education are increasingly expected to engage in self-regulated learning in many subjects, and science is no exception (Alvermann, 2002). Self-regulated learning of science texts can be challenging, especially when learners are required to understand novel concepts presented in the texts (Otero, Leon, & Graesser, 2002; Sinatra & Broughton, 2011). For instance, learners have difficulty understanding concepts explained in texts, such as airflow (Braasch, Goldman, & Wiley, 2013), motion (McCloskey, 1983), or the nature of light (Mason, Gava, & Boldrin, 2008). Furthermore, learners often cannot accurately monitor whether they correctly understand the information presented in studied texts (Thiede, Griffin, Wiley, & Redford, 2009). When monitoring of text learning is inaccurate, self-regulated learning is not likely to be well adapted to the current level of understanding. Because learners cannot strategically decide which passages are not yet well learned, they may stop studying prematurely (Metcalfe & Finn, 2008; Rawson & Dunlosky, 2013; Son & Metcalfe, 2000; Thiede, Anderson, & Therriault, 2003).

According to Piaget (1964), learning is a transformative process that requires modification of existing cognitive schemata through assimilation and accommodation. When a science text contains information that extends or deepens existing knowledge, learners need to assimilate the novel information into their existing cognitive schema. Alternatively, when the new information is not compatible

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with learners' cognitive schema, and conflicts with the information in their knowledge base, this means that they need to change the organization of their cognitive schema by accommodating the novel information (Kendeou & O'Brien, 2014; Piaget, 1964).

One major obstacle to learning from science texts is learners' misconceptions, which are often based on naive ideas about concepts that differ from the accepted scientific facts. For instance, Schneps (1989) reported that many university students hold the misconception that seasonal changes are caused by fluctuations in the distance between the Earth and the Sun. Instead, seasonal changes are caused by the tilted position of the Earth. Such misconceptions about scientific concepts are prevalent and resistant to change, and can therefore hinder accommodation of accurate knowledge (Alvermann & Hynd, 1989; Braasch et al., 2013; Hammer, 1996; Kendeou & van den Broek, 2005).

1.1. Confidence and hypercorrection of misconceptions

Schneps (1989) found that students were very confident in their misconceptions, suggesting that these are firmly established. The relation between confidence in misconceptions and correction of misconceptions seems to be complex. On the one hand, high confidence in prior knowledge negatively impacts learners' success in accommodating contrasting information (Pintrich, Marx, & Boyle, 1993). Misconceptions that learners state with high confidence are resistant to change (Dole & Sinatra, 1998; Ecker, Lewandowsky, & Tang, 2010). Presumably, high-confidence misconceptions are harder to correct than the ones that are held with lower confidence, because high-confidence misconceptions are more strongly represented in memory (Ecker, Lewandowsky, Swire, & Chang, 2011). On the other hand, unless learners are given feedback, correction of misconceptions is unlikely (Metcalfe, Butterfield, Habeck, & Stern, 2012); and contrary to intuition, feedback may help most when learners are highly confident in a misconception (Butterfield & Metcalfe, 2001; Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014). In particular, when learners receive explicit feedback that they hold a misconception, the misconceptions that are held with high confidence are more likely to be corrected than misconceptions that are held with less confidence, a finding called the *hypercorrection effect* (Butterfield & Metcalfe, 2001).

In prior research on hypercorrection, participants answered general information questions such as: What is the name of the river that runs through Rome? After giving an answer, they rated their confidence in the response. When they answered questions incorrectly, they received feedback immediately in the form of the correct answer (Butterfield & Metcalfe, 2001; Metcalfe & Finn, 2012). On a subsequent test, it appeared that high-confidence errors were more often corrected than low-confidence errors. Presumably, when people confidently make an incorrect response, the correcting feedback surprises them and draws attention to the feedback (e.g., Butler, Fazio, & Marsh, 2011; Metcalfe et al., 2012). People are more surprised when feedback contradicts their high-confidence misconceptions than their low-confidence ones, so they might pay extra attention to the correct information, which in turn leads to the hypercorrection effect (Butterfield & Metcalfe, 2006; Metcalfe & Finn, 2011, 2012).

1.2. Correcting misconceptions with refutation texts

Whether the hypercorrection effect will also occur when reading texts about science concepts, instead of learning short answers to general information questions (which were the materials used in prior research), is not yet known. When reading science texts, simply giving feedback that an answer is not correct is usually insufficient for conceptual change to occur (for a review, refer to Guzzetti, Snyder, Glass, & Gamas, 1993). In most educational science text books, standard text formats are used that emphasize and explain currently accepted scientific explanations of concepts (Tippett, 2010). When reading standard texts, learners might have difficulties with noticing the discrepancy between their misconceptions and the provided explanation for the correct conception. Therefore, standard text formats may not be effective for correcting misconceptions, because explanations in the studied text do not undermine the perceived truth of learners' science misconceptions (Braasch et al., 2013; Diakidoy, Kendeou, & Ioannides, 2003).

When studying science texts, providing explicit refutations of misconceptions seems to increase the likelihood of correction (Guzzetti et al., 1993). To correct misconceptions, learners need to co-activate these together with the correct concepts to become aware that the two conflict with each other (van den Broek & Kendeou, 2008). A special text format, called a refutation text, has been designed to support such co-activation. *Refutation texts* always contain two components in addition to a standard text: The statement of the misconception and explicit refutation of this misconception (Braasch et al., 2013; Tippett, 2010). When explicitly refuting the misconception and co-activating it with the correct concept, the inconsistency between a learner's misconceptions and the contrasting information is likely to lead to an experience of cognitive dissonance (Guzzetti et al., 1993). Because reading refutation texts increases awareness of conflicts between a learner's prior beliefs and new information, this text format helps the learner to correct misconceptions.

With this study, we aim to address the question: Does reading refutation texts also lead to hypercorrection for high-confidence misconceptions? When high-confidence misconceptions are activated and then refuted in the text, learners might be surprised and more fully attend to the correct conception than when it is presented using standard texts (Broughton, Sinatra, & Reynolds, 2010). Hence, a hypercorrection effect might occur when learners read refutation texts on topics for which they hold high-confidence misconceptions. This study investigates both the processes of 'outdating', which is negating the misconception, and 'updating', which is accommodating the correct alternative in the memory representation (Kendeou, Smith, & O'Brien, 2013). Moreover, it is important to investigate whether hypercorrection (if it occurs) would remain after some delay. In educational settings, learners are typically not tested immediately after studying texts but after a delay, and hence they need to retain the studied information in long-term memory. However, almost all research on hypercorrection has used a delay of only a few minutes between the presentation of feedback and the final test, although outcomes from two studies suggest that the hypercorrection effect persists after one week (Butler et al., 2011; Butterfield & Mangels, 2003). We investigated whether reading refutation texts, containing explicit feedback about how their misconceptions are incorrect, has beneficial effects on adolescents' correction (i.e., outdating and updating) of high-confidence science misconceptions on a delayed test.

Accordingly, the main purpose of this study was to test the refutation-causes-hypercorrection (RCH) hypothesis, which predicts that reading refutation texts leads to enhanced correction of high-confidence misconceptions in comparison to reading standard texts; for correction of low-confidence misconceptions reading refutation texts is hypothesized to have less of an effect (Hypothesis 1). Moreover, consistent with Sanchez and Garcia-Rodicio (2013), we expected that reading refutation texts would specifically focus learners on correction of misconceptions, so that text format would not affect learning of details (Hypothesis 2). In the present study, we investigated eighth graders' correction of misconceptions. Half of the learners studied refutation texts and the other half studied standard texts. A post-test administered one week after studying the science texts assessed whether learners outdated their misconceptions and were able to update their misconceptions with the