The Role of Inhibition in Conceptual Learning from Refutation and Standard Expository Texts

Publisher:
Springer

Published version:
DOI: 10.1007/s10763-017-9874-7

Metadata of the article that will be visualized in OnlineFirst

1	Article Title	**The Role of Inhibition in Conceptual Learning from Refutation and Standard Expository Texts**	
2	Article Sub- Title		
3	Article Copyright - Year	**Ministry of Science and Technology, Taiwan 2017 (This will be the copyright line in the final PDF)**	
4	Journal Name	International Journal of Science and Mathematics Education	
5	Corresponding Author	Family Name	**Mason**
6		Particle	
7		Given Name	**Lucia**
8		Suffix	
9		Organization	University of Padua
10		Division	Department of Developmental Psychology and Socialization
11		Address	Via Venezia 8, Padua 35131
12		e-mail	lucia.mason@unipd.it
13	Author	Family Name	**Zaccoletti**
14		Particle	
15		Given Name	**Sonia**
16		Suffix	
17		Organization	University of Padua
18		Division	Department of Developmental Psychology and Socialization
19		Address	Via Venezia 8, Padua 35131
20		e-mail	
21	Author	Family Name	**Carretti**
22		Particle	
23		Given Name	**Barbara**
24		Suffix	
25		Organization	University of Padua
26		Division	Department of General Psychology
27		Address	Via Venezia 8, Padua 35131
28		e-mail	
29	Author	Family Name	**Scrimin**

30		Particle	
31		Given Name	**Sara**
32		Suffix	
33		Organization	University of Padua
34		Division	Department of Developmental Psychology and Socialization
35		Address	Via Venezia 8, Padua 35131
36		e-mail	
37	Author	Family Name	**Diakidoy**
38		Particle	
39		Given Name	**Irene-Anna N.**
40		Suffix	
41		Organization	University of Cyprus
42		Division	Department of Psychology
43		Address	Nicosia 1678
44		e-mail	

45		Received	23 October 2017
46	Schedule	Revised	
47		Accepted	17 December 2017

48	Abstract	Text is the primary tool to learn disciplinary knowledge in school. Text-based learning is shaped by a complex interplay between the text and reader characteristics. This study examined the role of text structure and inhibition in conceptual learning about energy. Inhibition implies the ability to block dominant but inappropriate responses automatically activated. Eighty-five fourth and fifth graders were randomly assigned to the condition of standard expository text, or the condition of refutation text in a pre-test, post-test, and delayed post-test design. Findings revealed that students progressed from pre- to post-test and maintained the gained knowledge at delayed post-test regardless of text read. Moreover, only for refutation-text readers inhibition, as measured by response times, uniquely predicted conceptual learning at delayed post-test over and above reading comprehension, prior knowledge, and short-term conceptual learning. The study deepens our understanding of the refutation text effect by revealing its association with the ability to activate inhibitory control and suggesting a previously unexplored benefit of the refutation text for learning science concepts.

49	Keywords separated by ' - '	Conceptual change - Expository text - Inhibition - Refutation text - Science learning
50	Foot note information	The online version of this article (https://doi.org/10.1007/s10763-017-9874-7) contains supplementary material, which is available to authorized users.

Electronic supplementary material

ESM 1
(DOCX 14 kb)

Int J of Sci and Math Educ
https://doi.org/10.1007/s10763-017-9874-7

The Role of Inhibition in Conceptual Learning from Refutation and Standard Expository Texts

Lucia Mason[1] **· Sonia Zaccoletti**[1] **· Barbara Carretti**[2] **·**
Sara Scrimin[1] **· Irene-Anna N. Diakidoy**[3]

Received: 23 October 2017 / Accepted: 17 December 2017

Abstract Text is the primary tool to learn disciplinary knowledge in school. Text-based learning is shaped by a complex interplay between the text and reader characteristics. This study examined the role of text structure and inhibition in conceptual learning about energy. Inhibition implies the ability to block dominant but inappropriate responses automatically activated. Eighty-five fourth and fifth graders were randomly assigned to the condition of standard expository text, or the condition of refutation text in a pre-test, post-test, and delayed post-test design. Findings revealed that students progressed from pre- to post-test and maintained the gained knowledge at delayed post-test regardless of text read. Moreover, only for refutation-text readers inhibition, as measured by response times, uniquely predicted conceptual learning at delayed post-test over and above reading comprehension, prior knowledge, and short-term conceptual learning. The study deepens our understanding of the refutation text effect by revealing its association with the ability to activate inhibitory control and suggesting a previously unexplored benefit of the refutation text for learning science concepts.

Keywords Conceptual change · Expository text · Inhibition · Refutation text · Science learning

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10763-017-9874-7) contains supplementary material, which is available to authorized users.

✉ Lucia Mason
lucia.mason@unipd.it

Q1

[1] Department of Developmental Psychology and Socialization, University of Padua, Via Venezia 8, 35131 Padua, Italy

[2] Department of General Psychology, University of Padua, Via Venezia 8, 35131 Padua, Italy

[3] Department of Psychology, University of Cyprus, 1678 Nicosia, Cyprus

Text, either printed or digital, is the primary tool to acquire disciplinary knowledge in school. Text-based learning is shaped by a complex interplay between the text and reader characteristics (e.g. McNamara & Kintsch, 1996; Otero, Leon & Graesser, 2002). Learning from science text, in particular, often requires the revision of alternative conceptions—usually defined as misconceptions—about a phenomenon, or conceptual change. For example, the idea that seasonal change is due to the earth being closer to the sun during the summer and further away from the sun in the winter is a common misconception. In this case, conceptual change implies the abandoning of this misconception and revising the knowledge structure to incorporate the scientific conception that seasonal change is due to two features of the earth: Its tilted axis and its elliptical orbit around the sun (Broughton, Sinatra & Reynolds, 2010). It is well known, however, that students have difficulties understanding counterintuitive science concepts. One instructional tool that has been found effective in promoting conceptual change in science domains is a refutation text that explicitly acknowledges potential misconceptions in contrast to scientifically acceptable conceptions (Guzzetti, Snyder, Glass & Gamas, 1993; Sinatra & Broughton, 2011; Tippett, 2010).

However, more recent evidence suggests that after conceptual change has occurred, misconceptions are not replaced and continue to influence problem solving and reasoning (Babai & Amsterdamer, 2008; Shtulman & Valcarcel, 2012). Moreover, neuroscientific studies have documented that, even in experts, inhibitory control mechanisms are involved when task performance requires the use of a scientific conception instead of a naïve one (Brault-Foisy, Potvin, Riopel & Masson, 2015; Masson, Potvin, Riopel & Brault Foisy, 2014). These investigations highlight executive functions as a potentially important factor underlying conceptual learning from text. Therefore, in this study, we related relevant issues of research on refutation text and research on executive functions in order to advance current knowledge on text-based conceptual learning.

Specifically, we focused on the structure of text through which science knowledge is conveyed, refutation vs. standard expository text, and on a specific executive function, inhibition of a dominant but inappropriate response. The novel aspect of the investigation was to examine the contribution of the ability to inhibit prepotent responses to conceptual learning maintained over time and induced by reading a text in the context of the classroom.

Refutation Text and Conceptual Change

Q2

A refutational text structure includes three essential components: The presentation of a potential misconception, its refutation, and the explanation of the scientific conception (Braasch, Goldman & Wiley, 2013). A shared assumption is that a refutation text is more effective than a standard text in supporting the abandonment of alternative but incorrect conceptions in favor of scientific knowledge. Research comparing the effectiveness of a refutation text to that of a standard informational text has generally documented the superiority of the former with college students (Ariasi, Hyönä, Kaakinen & Mason, 2016; Ariasi & Mason, 2011; Broughton et al., 2010; Diakidoy, Mouskounti & Ioannides, 2011; Kendeou & van den Broek, 2007) and elementary (e.g. Diakidoy, Kendeou & Ioannides, 2003; Mason, Gava & Boldrin, 2008; Mikkilä-

Erdmann, 2001), middle (Mason & Gava, 2007), and high school students (Qian & Pan, 2002).

However, a few studies have also shown no effects of refutation text on conceptual change learning when compared to those of standard expository texts (Broughton et al., 2010; Diakidoy, Mouskounti, Fella & Ioannides, 2016; Kendeou & van den Broek, 2007). Nevertheless, the findings, taken together, serve to highlight the overall positive influence of refutation texts.

From an educational perspective, the effectiveness of refutation text has been attributed to increasing students' awareness of their own conceptions in relation to scientific ones (Hynd, 2003). This awareness, which involves the recognition of their own conceptions as limited and scientific ones as correct, is an essential condition for conceptual change. From a cognitive perspective, the co-activation principle, posited by van den Broek and Kendeou (2008), offers the ground for understanding how a refutation text supports conflict detection between prior knowledge and new scientific information. It postulates that, by explicitly presenting misconceptions and scientific conceptions in close proximity to each other, a refutation text induces their co-activation in readers' working memory which, in turn, facilitates the detection of conflicts and efforts to resolve them. In a slightly different vein, Braasch et al. (2013) have argued that refutations in a text function as tags or guideposts that serve to effectively constrain the explanatory power of prior knowledge and the contexts of its use. This account, although compatible with the co-activation principle, does not predict conflict resolution and the replacement of incorrect prior knowledge. This possibility is supported by the findings of Diakidoy et al. (2016), which showed refutation text to reduce not the amount of misconception-related distortions generated in recall but their negative influence on subsequent measures of scientific knowledge acquisition.

Misconceptions and Conceptual Change

Although refutation text research has sought to examine the effectiveness of this text structure in the restructuring or replacement of misconceptions, recent work on conceptual change has challenged the idea that an initial conception no longer exists once conceptual change occurs. For example, Babai and Amsterdamer (2008) found that adolescents' classifications for "atypical" solids and liquids (such as non-rigid solids, powders, and dense liquids) were less accurate indicating the presence of misconceptions. More interesting, however, reaction time results indicated that adolescents who correctly classified these atypical solids and liquids took longer to do so when compared to the time they took to classify more typical solids and liquids. Similarly, other studies have shown experts to experience greater difficulty in verifying the life status of plants than animals (Goldberg & Thompson-Schill, 2009) and to be more likely to accept inaccurate teleological explanations of natural phenomena under restricted time conditions (Kelemen, Rottman & Seston, 2013).

Shtulman and Valcarcel (2012) addressed directly the question of what happens to misconceptions once conceptual change occurs by using a speeded reasoning task. Students, who had taken several math and science courses at college level, were asked to verify as quickly as possible two types of statement, one whose truth value was supported by both a naïve and a scientific perspective about a phenomenon (e.g. "Rocks are composed of matter"), the other whose truth value was supported by only one of the two perspectives (e.g. "Plants turn food into energy"). Participants needed longer time and were less accurate in responding to the latter than the former statements across ten domains of knowledge. Interestingly, students with higher expertise in a particular domain also showed greater cognitive conflict in that domain, as indexed by response latency. The authors posited that naïve theories are *suppressed*, not *supplanted*, by scientific theories (Shtulman & Valcarcel, 2012).

Potvin, Masson, Lafortune and Cyr (2015) investigated different levels of misconception interference and negative priming on response times. The target misconception was "heavy objects sink more than lighter ones", and secondary-school students had to judge which of the two balls of different sizes and materials would have a stronger tendency to sink. Levels of misconception were varied by presenting stimulus pairs where the correct responses ranged from very counter-intuitive to neutral, to very intuitive. Negative priming (interference by previously activated inhibitory mechanisms) was investigated by manipulating the degree to which the immediately preceding task required the inhibition of a dominant intuitive response or not. Findings revealed that the intensity of interference (intuitive, neutral, counter-intuitive correct responses) corresponded to longer response times. Negative priming also emerged, indicating that the activation of inhibitory mechanisms in a previous task facilitates the processing of a subsequent task that also requires the inhibition of a dominant intuitive response.

Overall, reaction time and speeded condition results show that accurate responses in counter-intuitive tasks take longer to produce than responses to intuitive or congruent tasks. These findings suggest the possibility of misconceptions persisting even after knowledge revision has taken place. Possible co-existence of misconceptions with scientific conceptions in memory implicates inhibitory control underlying the production of an accurate response. This implication is reinforced by recent neuroscientific research.

Neuroscientific Research and Conceptual Change

In a set of two studies, Dunbar, Fugelsang and Stein (2007) sought to understand what happens in the brain circuits when students encounter data that are consistent or inconsistent with a preferred theory (effectiveness of drugs against depression) and a science misconception that they may have (bigger balls fall faster than smaller balls). Results indicated different areas of activation as a function of consistency: Data consistent with the preferred theory led to increased activation of the brain areas associated with learning, while data inconsistent with the preferred theory led to increased activation in the areas associated with error detection and conflict monitoring, and with effortful processing and working memory. The fact that inconsistent data did not activate usual learning areas/mechanism indicated that these data are treated as errors and are not easily incorporated into one's existing knowledge structures (Dunbar et al., 2007). Results of the second study indicated that when physics students saw the bigger ball falling faster, there was increased activation in the area associated with error detection. In contrast, the non-physics students perceived the Newtonian (simultaneous) falling as erroneous. Of note is that half of the non-physics students provided correct answers when they saw two balls of different mass falling at the same rate. However, these accurate responses were accompanied by greater activation in the brain areas associated with error detection and response inhibition. Therefore, when conceptual change seems to have occurred, students must still have access to their naïve theories, which they need to inhibit in order to respond accurately.

Further support for this possibility is provided by more recent fMRI data. Masson et al. (2014) have shown that even experts when responding scientifically inhibit a common misconception about electrical circuits ("one wire is sufficient to light a bulb"). More specifically, experts (undergraduate students in physics) and novices (undergraduate students in humanities) were asked to evaluate three types of stimuli regarding electric circuits: Non-scientific (based on the misconception), scientific (based on the scientific conception), and control (based on both). Experts manifested more activation of brain areas associated with inhibition when evaluating the non-scientific, incorrect circuits when compared to novices. In contrast, areas associated with inhibitory control were not activated when the experts evaluated scientifically accurate circuits (Masson et al., 2014). A similar expert-novice study targeting the misconception that "a heavier ball falls faster than a lighter ball" replicated the above results. Experts activated significantly more than novices two brain areas associated with inhibition when they evaluated the non-scientific stimuli (Brault-Foisy et al., 2015).

To summarize, neuroscientific studies seem to indicate that inhibition is involved when a scientific conception is used and a naïve conception is suppressed. This is consistent with the recently proposed, but based primarily on behavioral data, the Knowledge Revision Components (KReC) framework (Kendeou & O'Brien, 2014). In addition to the aforementioned co-activation principle, the framework also includes a competing activation principle postulating that even after knowledge revision, previously acquired but incorrect, information competes with the newly acquired correct information (Kendeou & O'Brien, 2014). If inhibitory control mechanisms are active, an incorrect conception loses the competition with the scientific conception.

Inhibition and Conceptual Change

Although inhibition cannot be considered a unitary mechanism (Dempster, 1991; Friedman & Miyake, 2004; Nigg, 2000), prepotent response inhibition, which refers to the ability to block dominant motor or cognitive responses automatically activated by the presented stimulus, seems particularly relevant in conceptual change learning. The relations between executive functioning, including dominant response inhibition and conceptual change in science have been first investigated in the domain of biology (Zaitchik, Iqbal & Carey, 2014). As hypothesized, the construction of the first explicit theory of biology regarding life, death, and body functions was found to be partly related to differences in executive function of children aged 5 to 7, after controlling for age and verbal IQ. However, the specific contribution of the inhibitory mechanisms to conceptual change was not explored in this study.

Further research focused more closely on the relation between executive functions and conceptual understanding and change (Vosniadou et al., 2015). The authors hypothesized that the ability to inhibit predominant responses and to shift attention plays a role in knowledge construction and restructuring in the domains of science and mathematics. Fourth- and sixth-grade students' understanding across domains was measured with a set of classification and judgment tasks that required the categorization of words/concepts in alternative (initial) or scientific categories and the evaluation of the truth of a series of common-sense and scientific statements. Composite measures of inhibition and shifting taking into account both accuracy and reaction time in modified Stroop-like tasks served as indices of executive functioning. As expected, the results revealed that accuracy and reaction time in executive functioning predicted conceptual understanding and change in the learning of science and mathematics.

In summary, behavioral and fMRI data implicate the positive role of executive functioning in conceptual change (e.g. Zaitchik et al., 2014; Vosniadou et al., 2015) and the need to inhibit prior inaccurate conceptions after its occurrence (e.g. Dunbar et al., 2007; Masson et al., 2014). However, the specific role of the inhibition of dominant but incorrect responses in reading-induced conceptual learning in the naturalistic context of the classroom using ecologically valid instructional materials has not been examined. Of note is that neuroscientific studies have used minimal tasks compared to school-like tasks such as reading and comprehending a complex science text. Therefore, the present study extends current research by exploring the role of inhibition ability in conceptual learning from refutation and standard expository text in the naturalistic context of the classroom.

The Current Study: Questions and Hypotheses

The purpose of the study was to examine the combined role of text structure and inhibition ability in learning about the concept of energy in primary school students. The topic of energy was chosen for two reasons. First, it is included in the Italian science curriculum for the fifth grade, which marks the beginning of formal learning about this abstract scientific concept. Second, young students are more likely to conceptualize energy as a substance possessing material properties (Diakidoy et al., 2003). In fact, we aimed to involve students of primary school considering they would be at the very beginning of learning about energy and, possibly, changing their understanding of it as a substance, allowing us to better examine the contribution of a refutation text.

We focused on one specific executive function, dominant response inhibition, for two main reasons. First, the aforementioned neuroscientific studies have documented that conceptual change is specifically associated with the ability to resist previously acquired and highly automatized knowledge. Second, we reasoned that learning from a refutation text, which explicitly acknowledges misconceptions in contrast to scientific conceptions, would render inhibitory control of the former essential for good performance.

Specifically, the following research questions guided the study:

(1) Does text facilitate primary school students' conceptual learning regardless of text structure?
(2) Is maintained conceptual learning related to learners' ability to inhibit dominant responses? If so, does inhibition ability predict maintained conceptual learning in readers of both standard and refutation text, after controlling for prior knowledge and reading comprehension ability?

For research question 1, we expected all students to learn from text, regardless of text structure (Diakidoy et al., 2011). However, we also hypothesized that those reading the refutation text, which addresses the common misconception, would show greater conceptual learning at post-test than the readers of the standard text and that this advantage would persist over time, as revealed at delayed post-test (hypothesis 1). This hypothesis is justified on the basis of research documenting the effectiveness of refutation text over standard text at different educational levels (Braasch et al., 2013; Danielson, Sinatra & Kendou, 2016; Diakidoy et al., 2003, 2011; Mason et al., 2008).

For research question 2, we expected that response times in tasks that measure inhibition ability to correlate with conceptual learning maintained over time, as revealed at delayed post-test, that is, the measure of more stable and long-term acquired knowledge. The faster the inhibition, the greater the conceptual learning. Of note is that we expected response times for inhibition to predict conceptual learning over time because they are considered fundamental in measuring inhibitory ability, whereas accuracy scores for inhibition can be less indicative of inhibitory control (e.g. Nichelli, Scala, Vago, Riva & Bulgheroni, 2005).

However, for research question 2, we also expected response times for inhibition to predict long-term conceptual learning over and above other individual characteristics for refutation-text readers as opposed to standard expository-text readers (hypothesis 2). This hypothesis is justified by the current literature in cognitive psychology (Shtulman & Valcarcel, 2012; Vosniadou et al., 2015) and science learning (Babai & Amsterdamer, 2008), which implicates the suppression of misconceptions, as opposed to their replacement, and the need to inhibit them for successful performance in scientific tasks. In addition, the hypothesis is justified with reference to the competing activation principle of the Knowledge Revision Components (KReC) framework (Kendeou & O'Brien, 2014), which states that even after knowledge revision, previously acquired but incorrect information competes with the newly acquired correct information. The refutation text activates both the misconception and the scientific conception and clearly distinguishes the former from the latter. Inhibition is, therefore, more involved in refutation than non-refutation text readers to suppress the misconception and to use the scientific conception.

Method

Participants and Design

Initially, 91 students attending fourth and fifth grade in two public primary schools in a north-eastern region of Italy were involved on a voluntary basis with parental consent. Because 6 participants obtained high scores at pre-test, indicating that they did not hold the targeted misconception, we considered the data of 85 students (F = 46, $M_{age} = 10.14$, SD = .46). Of these, 77 were native-born Italians with Italian as their first language and 8 came from families where neither parent spoke Italian as their first language (2 were from Colombia, 2 from China, 2 from Nigeria, 1 from Morocco, and 1 from Brazil). Participants shared a middle-class social background. At the start of the study, participants were randomly assigned to the condition of standard text ($n = 42$), or to the condition of refutation text ($n = 43$) within a pre-test, post-test, and delayed post-test design.

Learning Material

Two versions of the same text on energy were used. The text versions were comparable in length: The refutation version contained 416 words (in Italian) and the standard version 414. The texts differed only in the first paragraph. The first paragraph of the refutation text (124 words) included the refutation segment that explicitly stated the common misconception that energy is like a substance, refuted it, and mentioned the scientific explanation explained in the following paragraphs. The corresponding first paragraph of the standard text (124 words) elicited prior experience with the term energy and mentioned that it refers to an abstract concept used by scientists to indicate changes in the physical word. The topic had not been dealt with in the science classes.

Measures

Pre-, Post-Test, and Delayed Post-Test Conceptual Knowledge About Energy At the three testing times, conceptual knowledge was assessed through an energy test including 22 questions. All of them assessed students' potential misconception about energy as a material entity. More specifically, the test included 6 multiple-choice questions with three options each (e.g. If you describe the rubber of your bike as black, soft, and flexible, you refer to: a. its energy, b. its physical properties, c. its force) and 16 true-false questions (e.g. If we use a very strong microscope, then we see the energy in the gasoline). Five of the true-false questions required students to justify their choice. Sixteen of the questions were transfer questions requiring the application of the scientific knowledge that energy is not a substance. Both types of questions were scored dichotomously with correct responses receiving a score of 1 and incorrect ones receiving a score of 0. Correct responses to questions followed by justification received a score of 1 only if both the choice and the justification were correct. This allowed us to avoid, at least to some extent, the problem of false positive responses. The mean reliability coefficient for the energy test, as measured by Cronbach's alpha, was = .68. It should be noted that although moderate, it is within the acceptable range as argued in the literature regarding the psychometric properties of scales only developed for research purposes (Nunnally, 1978). A total score for each participant at each testing time was computed (score range 0 – 22).

Inhibition Tasks Two tasks were used to measure participants' general ability of inhibitory control.

Animal-Stroop (adapted from Wright, Waterman, Prescott & Murdoch-Eaton, 2003 by Nichelli et al., 2005). The task, based on the classic Stroop paradigm, consisted of a series of animal figures (goose, sheep, cow, and pig) in which the congruency between the head and the body is manipulated. The test included three experimental conditions, each comprising 24 stimuli: (1) Incongruent condition: Each head was replaced by the head of one of the others. (2) Congruent condition: The stimuli were the same as the prototypes presented to the child during the training phase. (3) Control-face condition: The head was composed of caricatures of faces. Participants had to name the animal the body belongs to as quickly as possible. In each experimental condition, the 24 stimuli are presented to the child in a notebook, each page containing 8 stimuli (which are balanced in terms of orientation: 4 facing right and 4 facing left). The different conditions were presented to the participants in fixed order (congruent, incongruent, control-face). The duration of response to stimuli for each page was timed using a stopwatch. In the Stroop tasks, strong responses to stimuli have to be restrained in order to produce a less dominant response.

It should be pointed out that we measured inhibition ability as a general individual difference to examine its contribution to maintained conceptual learning. It implies that the ability to inhibit dominant but inappropriate responses is measured regardless of the topic that students are asked to learn. Moreover, considering the age of our participants and the fact that word decoding could not be completely automatized at that age, we decided to use the animal Stroop task instead of the classic Stroop task with words. Previous studies have demonstrated that the animal Stroop task is well suited to obtain a measure of the ability to inhibit prepotent responses in children with typical and atypical development (e.g. Borella et al., 2010; Borella & de Ribaupierre, 2014). The Q3 choice of the task was therefore not driven by the content of the text but the characteristics of our sample and the purpose of the study.

Total time in seconds taken to respond to all the stimuli within each condition of the animal Stroop task was first computed. However, since the error responses were included in reaction times (RT), as in all clinical versions of this task, the total number of errors per condition was also considered. Then, an interference index, based on the differences between the incongruent and control-face condition (see Nichelli et al., 2005), was calculated on response times and used as the variable of interest. A higher score in the interference index implies greater difficulty in controlling the prepotent response in the incongruent condition, and thus a decreased efficiency of inhibition. As reported in Borella, Carretti & Pelegrina (2010), reliability coefficients were good for RT (incongruent, $r = .92$; control-face, $r = .93$) and acceptable for errors (incongruent, $r = .73$; control-face, $r = .56$).

Of note is that the paper-and-pencil version was preferred because of the setting of the study. Although a limitation of this version is that it does not enable the computation of response times for correct answers only, it has the advantage of added sensitivity in capturing inhibitory deficit when compared to the computerized version. Specifically, in the computerized version of the Stroop test, the items are presented one by one, reducing the interference due to the simultaneous presence of other items, which is typically the case with the paper-and-pencil version of the task (e.g. Ludwig, Borella, Tettamanti & de Ribaupierre, 2010).

Hayling task. This task is the Italian version (Marzocchi, Re & Cornoldi, 2010) of the Junior Hayling test (Shallice et al., 2002). It consisted of 20 sentences in which the final word was missing. In the ten congruent-type sentences, students were asked to complete the sentence with a word that fitted the phrase, so the maximum score was 10. In the ten incongruent-type sentences, students were asked to produce a word that made no sense at all in the context of the sentence. The participants were told that the word had to be completely unrelated to words in the sentence. The two types of sentences (congruent, incongruent) were presented alternatively. Two practice sentences were read to the participants. The accuracy scoring for the incongruent-type sentences was calculated with the standard Hayling procedure, as follows: 0 points if the child said a word unrelated to the sentence, but using a strategy (e.g. producing a name of an object present in the room); 1 point if the child said a word unrelated to the sentence without using a clear strategy; 2 points if the child said a word related to the sentence or to the related answer; 3 points if the child said a word that completed the sentence. Thus, a high score in incongruent-type sentences meant a poor performance (maximum score = 30). Cronbach's alpha reliability for this test was .73. Although the Hayling task yielded only accuracy scores, we considered its combined use with the Stroop task to provide a stronger measure of inhibition.

Reading Comprehension This was measured as a control variable using the MT (Italian) tests for fourth and fifth grades (Cornoldi & Colpo, 2011). These tests require reading an informational text and answering 14 questions. Reliability of these instruments has been reported in the range of .73 to .82 (Cronbach's alpha).

Procedure

Data collection took place in four sessions during class hours. Session 1 lasted 50 – 60 min and involved the group administration of the pre-test questions and reading comprehension test. Session 2 took place 4 or 5 days later and involved the individual administration of the two inhibition tasks for about 10 min. In session 3 that took place 2 weeks after the first, the participants met in groups and read the refutation or standard text at their own pace. Before presenting the material (in print), the experimenter gave the following verbal instructions: "We now ask you to read a text. Read it carefully. We will then ask you some questions about the text." After reading the text, the participants completed a brief filler task. Then, they completed the post-test. Session 3 lasted 40 – 50 min. Because of constraints in the school setting, session 4 took place 2 weeks later and included the group administration of the delayed post-test. This session lasted 10 – 20 min. The topic of energy was not discussed in the science classes between the two post-tests.

Results

Preliminary Analysis

We first performed a MANOVA to ensure that readers across the two reading conditions were equal for inhibitory control. The main effect of condition did not emerge, $F < 1$, revealing that refutation-text readers did not differ from standard-text readers for accuracy and response time in the animal Stroop task, and for accuracy in the Hayling task (see Table 1). We also performed a MANOVA to test the equivalence of the readers across the two conditions for reading comprehension and prior knowledge. The effect of condition did not emerge, Wilks' lambda = .97, $F(2, 82) = 1.04$, $p = .357$, indicating that the readers of the standard text did not differ significantly from readers of the refutation text for the essential ability in learning from text and prior knowledge about the text content (see Table 1).

Research Question 1: Conceptual Learning from Text

To answer the first research question, we conducted a repeated measures ANOVA with condition as the between-subjects factor and conceptual knowledge at the three testing times (pre-test, post-test, and delayed post-test) as the within-subjects factor. This analysis revealed the main effect of testing time, Wilks' lambda = .31, $F(2, 82) = 92.60$, $p < .001$, $\eta^2_p = .69$. Planned comparisons revealed that overall post-test scores were higher than pre-test scores (both $p < .001$) and that the two post-tests did not differ significantly from one another. The interaction term time × condition was not significant, Wilks' lambda = .97, $F(2, 82) = 1.15$, $p = .319$.

These outcomes indicate that in both conditions, the participants learned some scientific knowledge about energy and this knowledge was at least maintained 2 weeks after reading the text (see Table 2).

Research Question 2: Inhibition Ability As Predictor of Conceptual Learning

To answer the second research question, we first carried out partial correlational analyses between the scores for conceptual learning at delayed post-test and the various indices of inhibition ability, controlling for reading comprehension, prior knowledge, and conceptual learning at pre-test. Specifically, the measures of inhibition were the interference indexes computed on accuracy and response time for the animal Stroop task, and the score obtained in incongruent-type sentences for the Hayling task. A significant negative correlation only emerged between the maintained conceptual learning and response times for inhibiting the predominant response in the animal Stroop task ($r = -.32$, $p = .003$). These outcomes indicate that the faster the participants were in inhibiting the wrong response, the better their conceptual learning 2 weeks after reading the text (see Table 3).

Moreover, it should be pointed out that the same analyses for the first post-test indicated no significant correlations between this measure obtained immediately after reading the text and any of the indices of inhibition ability ($p > .05$). Inhibition,

Table 1 Means and standard deviations for reader characteristics as a function of condition

	Standard text ($n = 42$) *M* (SD)	Refutation text ($n = 43$) *M* (SD)
Reading comprehension	9.50 (2.54)	10.23 (2.12)
Inhibition interference time[a]	7.71 (7.58)	9.91 (9.14)
Inhibition interference accuracy[a]	−0.11 (0.70)	−0.13 (0.86)
Inhibition accuracy[b]	10.88 (5.74)	10.48 (5.22)

Control variables are reading comprehension, pre-test, and post-test

[a] Animal Stroop task

[b] Hayling task

Table 2 Means and standard deviations for conceptual learning as a function of condition

	Standard text ($n = 42$) M (SD)	Refutation text ($n = 43$) M (SD)
Pre-test	10.04 (2.57)	10.34 (2.36)
Post-test	13.02 (2.76)	14.04 (1.92)
Delayed post-test	12.59 (2.82)	13.58 (2.49)

therefore, was only associated with conceptual learning over time. Finally, condition did not correlate with any conceptual learning or inhibition indices (all $p < .05$).

Given the findings of the correlation analysis, to answer the second research question, we then carried a hierarchical regression analysis for each text structure separately, using the scores at delayed post-test as the criterion variable. In the first step, we considered reading comprehension, prior knowledge (pre-test), and conceptual learning at post-test as predictors. In the second step, the interference index on response times for inhibition was entered into the regression equation.

For conceptual learning from standard text at delayed post-test, after entering the predictors in the first step, the model was significant, $R^2 = .54$, $F_{change}(3, 38) = 15.08$, $p < .001$. Conceptual learning at post-test ($ß = .50$) was a positive predictor. The addition of interference index on response times in the animal Stroop task did not result in a statistical increase in the explained variance in the second step, $R^2 = .56$, $F_{change}(1, 37) = 1.77$, $p = .194$, with prior knowledge ($ß = .28$) and conceptual learning at post-test ($ß = .51$) the only positive predictors (see Table 4).

For conceptual learning from refutation text at delayed post-test, after entering the predictors in the first step, the model was significant, $R^2 = .36$, F_{change} $(3, 39) = 7.17$, $p = .001$. Only prior knowledge ($ß = .36$) was a positive predictor. The addition of interference index on response times in the Stroop task resulted in a statistical increase in the explained variance in the second step, $R^2 = .44$, $F_{change}(1, 38) = 5.48$, $p = .025$, where the executive function was a negative predictor ($ß = -.29$) and prior knowledge ($ß =$ .37) a positive one. Interestingly, the ability to inhibit wrong responses predicted conceptual learning over time from refutation text only (see Table 4).

Table 3 Partial correlations between delayed post-test and inhibition scores

	1	2	3	4
1. Delayed post-test				
2. Inhibition interference time[a]	− .32**			
3. Inhibition interference accuracy[a]	− 11	.08		
4. Inhibition accuracy[b]	.10	− .25*	.13	

Control variables are reading comprehension, pre-test, and post-test

*$p < .05$; **$p < .01$

[a] Animal Stroop task. Scores were calculated by subtracting the reaction time to control items from the reaction time to incongruent ones to create a difference score. Higher difference scores indicated lower inhibitory control in the animal Stroop task

[b] Hayling task

Discussion

Conceptual learning in science domains is difficult to achieve when students hold misconceptions that hinder the integration of the scientific conceptions to their knowledge base (e.g. Chi, Slotta & de Leeuw, 1994; Vosniadou, 1994). For three decades of research, the replacement of an abandoned misconception with the scientific one has been conceived as the fundamental outcome of successful learning. However, recent behavioral and neuroscientific data indicate that misconceptions are not replaced but suppressed or inhibited, even after conceptual change appears to have occurred (e.g. Babai & Amsterdamer, 2008; Masson et al., 2014).

The current study aimed to extend current research by examining the role of inhibition, as an individual characteristic, in reading-induced conceptual learning in the educational context of the classroom. Reading to acquire subject knowledge is a common school learning activity. In this study, two structures of text about the scientific concept of energy were used with primary school students: A refutation and a standard

Table 4 Results of hierarchical multiple regression analyses for variables predicting conceptual learning at delayed post-test by text

Predictor	ΔR^2	*B*	SE	*ß*	*t*	*p*
Standard text ($n = 42$)						
Model 1	.54**					
Reading comprehension		.09	.13	.08	.728	.471
Pre-test		.28	.15	.26	1.87	.069
Post-test		52	.15	.51	3.43	.001
Model 2	.02					
Reading comprehension		.06	.14	.05	.44	.657
Pre-test		.31	.15	.28	2.05	.047
Post-test		.52	.15	.51	3.49	.001
Inhibition interference time[a]		− .05	.04	− .15	− 1.32	.194
Refutation text ($n = 43$)						
Model 1	36**					
Reading comprehension		.31	.16	.27	1.94	.060
Pre-test		.38	.15	.36	2.55	.015
Post-test		.21	.19	.16	1.12	.266
Model 2	.08*					
Reading comprehension		.23	.16	.20	1.49	.144
Pre-test		.39	.14	.37	2.77	.009
Post-test		.26	.18	.20	1.44	.159
Inhibition interference time[a]		− .07	.03	− .29	− 2.34	.025

*$p < .01$; **$p < .001$

[a] Scores were calculated by subtracting the reaction time to control items from the reaction time to incongruent ones to create a difference score. Higher difference scores indicated lower inhibitory control in the animal Stroop task

expository text. With respect to inhibitory control, the study focused on a specific aspect, dominant response inhibition, as previous findings suggest that the acquisition of new information requires the suppression of automatically activated prior knowledge.

The first research question asked whether reading facilitates primary school students' acquisition of scientific knowledge about the abstract concept of energy. Although the results are in the expected direction, the difference between the two reading conditions was not strong enough to reach statistical significance. Hypothesis 1, therefore, was only partially confirmed as all students progressed conceptually from pre- to post-test and maintained the gained knowledge at delayed post-test regardless of the text read. Although this expected outcome is positive per se as it indicates learning as a result of reading (Diakidoy et al., 2011), it is not aligned with studies documenting the superiority of refutation text in learning about physics concepts in students of primary school (e.g. Diakidoy et al., 2003; Mason et al., 2008). Nevertheless, previous research with young adults has also indicated that refutation text is not always more effective than a typical informational text in producing learning effects (Broughton et al., 2010; Diakidoy et al., 2016; Kendeou & van den Broek, 2007).

In this study, the lack of learning differences between the two groups of readers may be due to a combination of related reasons. A possible explanation is that successful revision of a misconception may depend on several factors, including the adequacy of an alternative explanation, the plausibility of the new scientific information, and readers' commitment to their alternative conception (Dole & Sinatra, 1998; Kendeou & van den Broek, 2007), all of which may have played a role in the current study. It must be noted, however, that the refutation text addressed a single and basic-level misconception about energy, and that both texts were developed to support science learning. The texts were of equal length and both aimed at an understanding of the concept of energy as an abstract one. Although the standard text did not include any refutations, it emphasized the abstractness of the concept and elaborated on its use in explaining changes occurring in the physical world.

The second research question asked whether a general ability inhibition is related to conceptual learning maintained over time and, if so, whether it predicts the latter, after controlling for reading comprehension, prior knowledge, and conceptual learning immediately after reading. One of the three indices of inhibition, the interference index on response times, significantly correlated with scores at the delayed post-test: The shorter the former, the higher the latter.

However, regression analyses for each text structure revealed that the interference index on response times for inhibition was a significantly negative predictor only for the refutation-text readers. Hypothesis 2 was therefore confirmed. These data are aligned, to some extent, with the outcomes of the recent studies showing that misconceptions are not erased even when scientific knowledge has been learned (e.g. Babai & Amsterdamer, 2008; Shtulman & Valcarcel, 2012) and that inhibition is associated with science and mathematics learning (Babai, Eidelman, & Stavy, 2012; Brault-Foisy et al., 2015; Dunbar et al., 2007; Masson et al., 2014; Vosniadou et al., 2014; Zaitchik et al., 2013). Q5 Q6

The implications of this outcome concern both the nature of the refutation text effect and the role of inhibition in science learning. Specifically, it suggests that the nature of the refutation text effect may be associated with increased awareness of the faultiness of a misconception and the need for its suppression in tasks where it could interfere, providing the grounds for inhibition to manifest its influence in subsequent successful performance (e.g. Masson et al., 2014).

Of note is that inhibition ability was only associated with scores at delayed post-test. It means that only in this later phase, inhibitory control is relevant for blocking a misconception. At the immediate post-test, correct responses may depend on the ability to update information and to decrease the activation of no-longer relevant information, that is, on some essential aspects of executive functioning related to comprehension processes (e.g. Palladino, Cornoldi, De Beni & Pazzaglia, 2001). At the delayed post-test, the maintenance of conceptual learning implies the ability to minimize the intrusion of a misconception which may still have a moderate level of activation and compete with the scientific information. These are only speculations as an in-depth analysis of the role of all executive functions is needed to shed more light on the relation between inhibition and conceptual learning.

It should also be noted that the inhibition-related results concern the contribution of response times, not accuracy. Specifically, only the index computed for response times in the Stroop task was a significant predictor of conceptual learning overall and in the refutation text group. In contrast, the index of accuracy in the Stroop or the Hayling task did not correlate with conceptual learning. Response times are considered a more sensitive measure of inhibitory control as error rate is usually low in typical populations (Ludwig et al., 2010).

The relevance of response time for inhibitory control is in line with previous research involving children between 6 and 11 years old (Nichelli et al., 2005). It is also consistent with studies on science and mathematics learning, showing that response times are the indicators of the complexity of the process involved in a task, thus the longer the reaction time, the more complex a reasoning process (e.g. Babai et al., 2012; Potvin et al., 2014). Q7

In the case of the Stroop task, the outcome is also consistent with research showing larger effects with response times in a blocked presentation condition (as employed in the current study) than in an item-by-item presentation format (e.g. Kindt, Bierman & Brosschot, 1996; Salo, Henik & Robertson, 2001). In the case of the Hayling task, the version employed (Marzocchi et al., 2010) did not enable us to measure response times, and this may have limited the sensitivity of the task.

Taken together, the results of the present study indicate that refutation-text readers learn as much as standard-text readers in terms of conceptual content. However, they also learn that their prior knowledge is faulty and it is better to avoid using it. These results are also compatible with those of Diakidoy et al.'s (2016) study that showed that refutation text reading did not result in greater concept learning compared to standard text reading, but the former neutralized the negative effects of misconceptions, that is distortions, on learning. As posited by Braasch et al. (2013), it is more likely that refutation-text readers mentally "tag" their misconception-based prior knowledge as wrong, which in turn facilitates its inhibition. When giving the correct answers, refutation-text readers, therefore, are more likely to activate inhibitory control of the misconception.

In accordance with the competing activation principle of the Knowledge Revision Components framework (Kendeou & O'Brien, 2014) described earlier, inhibition may help to reduce or eliminate interference from incorrect conceptions, thus facilitating the use of the correct ones. Even if the scores for the delayed post-test of refutation-text readers were not significantly different from those of the standard-text readers, they were higher and inhibitory control contributed to them, whereas the latter did not seem to have played the same role for the standard text.

Limitations and Directions for Future Research

Limitations of the present study should be considered when interpreting the results. The number of participants in each reading condition was modest. Larger samples of students will allow more solid outcomes regarding the role of inhibition in text-based science learning. Performance on the post-tests, although superior to that of the pre-test, was not high. However, it should be taken into account that these learning outcomes were the result of reading a single, relatively short text with no other instructional support, such as teacher presentations or group discussions (e.g. Guzzetti et al., 1993). In addition, the delayed post-test took place only 2 weeks after the post-test because of school constraints. In further research, a longer time span between the two post-tests should be used to examine the stability of conceptual learning.

Furthermore, regarding inhibition, the current study focused only on one function: dominant response inhibition. However, other functions may also be involved differently depending on reading comprehension profile and type of task. For example, Borella et al. (2010) showed that poor comprehenders were particularly impaired in a proactive interference measure (i.e. intrusion errors; see also Carretti, Borella, Cornoldi & De Beni, 2009). In contrast, for typically developing children, Borella and de Ribaupierre (2014) found reading comprehension performance to be associated to resistance to distractor interference, but only when text was not available at the time of test. Finally, future research examining online processing would contribute further to our understanding of the role of inhibitory functions on both the processing and the outcomes of learning from refutation and standard text.

Conclusions

Despite these limitations, the study has scientific significance since it extends current research by providing unique evidence of the role that inhibition plays in maintaining conceptual learning from a particular text structure, the refutation. The study deepens, therefore, our understanding of the refutation text effect in science education by revealing its association with the ability to activate inhibitory control.

The study has also educational significance as it suggests a previously unexplored benefit of the refutation text for science learning. By making the conflict between a misconception and the scientific conception explicit, this structure of text also allows readers' inhibition ability to come into play. Inhibition emerges as an important factor in science learning and conceptual change. If an alternative conception is never erased from memory once it has been encoded, then it is important to be inhibited to avoid its negative interference with subsequent learning. Inhibition, therefore, cannot only be promoted by implementing specific interventions, but also by designing appropriate learning materials, like texts, embedding in them the "affordance" of this executive function.

Acknowledgements The authors are very grateful to all the students involved in the study, their parents and teachers, and the school principals.

References

Ariasi, N., Hyönä, J., Kaakinen, J., & Mason, L. (2016). An eye-movement analysis of the refutation effect in reading science text. *Journal of Computer Assisted Learning, 33*, 202–221. https://doi.org/10.1111/jcal.12151.

Ariasi, N., & Mason, L. (2011). Uncovering the effect of text structure in learning from a science text: An eye-tracking study. *Instructional Science, 39*, 581–601. https://doi.org/10.1007/s11251–010–9142–5.

Babai, R., & Amsterdamer, A. (2008). The persistence of solid and liquid naive conceptions: A reaction time study. *Journal of Science Education and Technology, 17*, 553–559. https://doi.org/10.1007/s10956–008–9122–6.

Babai, R., Eidelman, R., & Stavy, R. (2012). Preactivation of inhibitory control mechanisms hinders intuitive reasoning. *International Journal of Science and Mathematics Education, 10*, 763–775. https://doi.org/10.1007/s10763–011–9287–y.

Borella, E., Carretti, C., & Pelegrina, S. L. (2010). The specific role of inhibitory efficacy in good and poor comprehenders. *Journal of Learning Disabilities, 43*, 541–552. https://doi.org/10.1177/0022219410371676.

Borella, E., & de Ribaupierre, A. (2014). The role of working memory, inhibition, and processing speed in text comprehension in children. *Learning and Individual Differences, 34*, 86–92. https://doi.org/10.1016/j.lindif.2014.05.001.

Braasch, J. L. G., Goldman, S. R., & Wiley, J. (2013). The influences of text and reader characteristics on learning from refutations in science texts. *Journal of Educational Psychology, 105*, 561–578. https://doi.org/10.1037/a0032627.

Brault-Foisy, L. M., Potvin, P., Riopel, M., & Masson, S. (2015). Is inhibition involved in overcoming a common physics misconception in mechanics? *Trends in Neuroscience and Education, 4*, 26–36. https://doi.org/10.1016/j.tine.2015.03.001.

Broughton, S. H., Sinatra, G. M., & Reynolds, R. E. (2010). The nature of the refutation text effect: An investigation of attention allocation. *Journal of Educational Research, 103*, 407–423. https://doi.org/10.1080/00220670903383101.

Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences, 19*, 246–251. https://doi.org/10.1016/j.lindif.2008.10.002.

Chi, M. T. H., Slotta, J. D., & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction, 4*, 27–43. https://doi.org/10.1016/0959–4752(94)90017–5.

Cornoldi, C., & Colpo, G. (2011). *Prove di lettura MT2 per la scuola elementare 2 [MT2 tests of reading comprehension for the elementary school]*. Florence: Organizzazioni Speciali.

Danielson, R. W., Sinatra, G. M., & Kendou, P. (2016). Augmenting the refutation text effect with analogies and graphics. *Discourse Processes, 53*, 392–414. https://doi.org/10.1080/0163853X.2016.1166334.

Dempster, F. N. (1991). Inhibitory processes: A neglected dimension of intelligence. *Intelligence, 15*, 157–173. https://doi.org/10.1016/0160–2896(91)90028–C.

Diakidoy, I. N., Kendeou, P., & Ioannides, C. (2003). Reading about energy: The effects of text structure in science learning and conceptual change. *Contemporary Educational Psychology, 28*, 335–356. https://doi.org/10.1016/S0361–476X(02)00039–5.

Diakidoy, I. N., Mouskounti, T., Fella, A., & Ioannides, C. (2016). Comprehension processes and outcomes with refutation and expository texts and their contribution to learning. *Learning and Instruction, 41*, 60–69. https://doi.org/10.1016/j.learninstruc.2015.10.002.

Diakidoy, I. N., Mouskounti, T., & Ioannides, C. (2011). Comprehension and learning from refutation and expository texts. *Reading Research Quarterly, 46*, 22–38. https://doi.org/10.1598/RRQ.46.1.2.

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist, 33*, 109–128. https://doi.org/10.1080/00461520.1998.9653294.

Dunbar, K., Fugelsang, J., & Stein, C. (2007). Do naïve theories ever go away? Using brain and behavior to understand changes in concept. In M. C. Lovett & P. Shah (Eds.), Thinking with data: 33rd Carnegie symposium on cognition (pp. 193–206). Mahwah: Erlbaum.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*, 101–135. https://doi.org/10.1037/0096–3445.133.1.101.

Goldberg, R. F., & Thompson-Schill, S. L. (2009). Developmental “roots” in mature biological knowledge. *Psychological Science, 20*, 480–487. https://doi.org/10.1111/j.1467–9280.2009.02320.x.

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. *Reading Research Quarterly, 28*, 117–159.

Hynd, C. (2003). Conceptual change in response to persuasive messages. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 291–315). Mahwah: Lawrence Erlbaum Associates.

Kelemen, D., Rottman, J., & Seston, R. (2013). Professional physical scientists display tenacious teleological tendencies: Purpose-based reasoning as a cognitive default. *Journal of Experimental Psychology: General, 142*, 1074–1083. https://doi.org/10.1037/a0030399.

Kendeou, P., & O’Brien, E. J. (2014). The Knowledge Revision Components (KReC) framework: Processes and mechanisms. In D. N. Rapp & J. L. G. Braasch (Eds.), *Processing inaccurate information: Theoretical and applied perspectives from cognitive science and the educational sciences* (pp. 353–377). Cambridge: MIT Press.

Kendeou, P., & van den Broek, P. (2007). The effects of prior knowledge and text structure on comprehension processes during reading of scientific texts. *Memory and Cognition, 35*, 1567–1577. https://doi.org/10.3758/BF03193491.

Kindt, M., Bierman, D., & Brosschot, J. F. (1996). Stroop versus Stroop: Comparison of a card format and a single-trial format of the standard color-word Stroop task and the emotional Stroop task. *Personality and Individual Differences, 21*, 653–661. https://doi.org/10.1016/0191–8869(96)00133–X.

Ludwig, C., Borella, E., Tettamanti, M., & de Ribaupierre, A. (2010). Adult age differences in the Stroop-color test: A comparison between an item-by-item and a blocked version. *Archives of Gerontology and Geriatrics, 51*, 135–114. https://doi.org/10.1016/j.archger.2009.09.040.

Marzocchi, G. M., Re, A. M., & Cornoldi, C. (2010). *Batteria Italiana per l’ADHD. [Italian battery for assessing ADHD]*. Trento: Erickson.

Mason, L., & Gava, M. (2007). Effects of epistemological beliefs and learning text structure on conceptual change. In S. Vosniadou, A. Baltas, & X. Vamvakoussi (Eds.), *Reframing the conceptual change approach in learning and instruction* (pp. 165–196). Oxford: Elsevier.

Mason, L., Gava, M., & Boldrin, A. (2008). On warm conceptual change: The interplay of text, epistemological beliefs, and topic interest. *Journal of Educational Psychology, 100*, 291–309. https://doi.org/10.1037/0022–0663.100.2.291.

Masson, S., Potvin, P., Riopel, M., & Brault Foisy, L.-M. (2014). Differences in brain activation between novices and experts in science during a task involving a common misconception in electricity. *Mind, Brain, and Education, 8*, 44–55. https://doi.org/10.1111/mbe.12043.

McNamara, D., & Kintsch, W. (1996). Learning from texts: Effects of prior knowledge and text coherence. *Discourse Processes, 22*, 247–288. https://doi.org/10.1080/01638539609544975.

Mikkilä-Erdmann, M. (2001). Improving conceptual change concerning photosynthesis through text design. *Learning and Instruction, 11*, 241–257. https://doi.org/10.1016/S0959–4752(00)00041–4.

Nichelli, F., Scala, G., Vago, C., Riva, D., & Bulgheroni, S. (2005). Age related trends in Stroop and conflicting motor response task findings. *Child Neuropsychology, 11*, 431–443. https://doi.org/10.1080/09297040590951569.

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*, 220–246. https://doi.org/10.1037/0033–2909.126.2.220.

Nunnally, J. C. (1978). *Psychometric theory.* New York: McGraw Hill.

Otero, Leon, J. A., & Graesser, A. C. (Eds.). (2002). *The psychology of science text comprehension*. Mahwah: Lawrence Erlbaum Associates.

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory & Cognition, 29*, 344–354. https://doi.org/10.3758/BF03194929.

Potvin, P., Masson, S., Lafortune, S., & Cyr, G. (2015). Persistence of the intuitive conception that heavier objects sink more: A reaction time study with different levels of interference. *International Journal of Science and Mathematics Education, 13*, 21–43. https://doi.org/10.1007/s10763–014–9520–6.

Qian, G., & Pan, J. (2002). A comparison of epistemological beliefs and learning from science text between American and Chinese high school students. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology. The psychology of beliefs about knowledge and knowing* (pp. 365–385). Mahwah: Lawrence Erlbaum Associates.

Salo, R., Henik, A., & Robertson, L. C. (2001). Interpreting Stroop interference: An analysis of differences between task versions. *Neuropsychology, 15*, 462–471. https://doi.org/10.1037/0894–4105.15.4.462.

Shallice, T., Marzocchi, G. M., Coser, S., Del Savio, M., Meuter, R. F., & Rumiati, R. (2002). Executive function profile of children with attention deficit hyperactivity disorder. *Developmental Neuropsychology, 21*, 43–71. https://doi.org/10.1207/S15326942DN2101_3.

Shtulman, A., & Valcarcel, J. (2012). Scientific knowledge suppresses but does not supplant earlier intuitions. *Cognition, 124*, 209–215. https://doi.org/10.1016/j.cognition.2012.04.005.

Sinatra, G. M., & Broughton, S. W. (2011). Bridging reading comprehension and conceptual change in science education: The promise of refutation text. *Reading Research Quarterly, 46*, 374–393. https://doi.org/10.1002/RRQ.005.

Tippett, C. D. (2010). Refutational text in science education. A review of two decades of research. *International Journal of Science and Mathematics Education, 8*, 951–970. https://doi.org/10.1007/s10763–010–9203–x.

van den Broek, P., & Kendeou, P. (2008). Cognitive processes in comprehension of science texts: The role of co-activation in confronting misconceptions. *Applied Cognitive Psychology, 22*, 335–351. https://doi.org/10.1002/acp.1418.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4*, 45–69. https://doi.org/10.1016/0959–4752(94)90018–3.

Vosniadou, S., Pnevmantikos, D., Makris, N., Ikospentaki, K., Lepenioti, D., Chountala, A., & Kyrianakis, G. (2015). Executive functions and conceptual change in science and mathematics learning. In R. Dale, C. Jennings, P. P. Maglio, T. Matlock, D. C. Noelle, A. Warlaumont, J. Yoshimi (Eds.), *Proceedings of the 37th annual meeting of the Cognitive Science Society: Mind, Technology, and Society*. Pasadena, CA (pp. 2529–2534). Merced: University of California.

Wright, I., Waterman, M., Prescott, H., & Murdoch-Eaton, D. (2003). A new Stroop-like measure of inhibitory function development: Typical developmental trends. *Journal of Child Psychology and Psychiatry, 44*, 561–575. https://doi.org/10.1111/1469–7610.00145.

Zaitchik, D., Iqbal, Y., & Carey, S. (2014). The effect of executive function on biological reasoning in young children: An individual differences study. *Child Development, 85*, 160–175. https://doi.org/10.1111/cdev.12145.

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES.

Q1. Please check if the author names and the affiliations are presented correctly.

Q2. Please check if the section headings are assigned to appropriate levels.

Q3. The citation "Borella et al., 2014" has been changed to "Borella and de Ribaupierre, 2014" to match the author name/date in the reference list. Please check if the change is fine in this occurrence and modify the subsequent occurrences, if necessary.

Q4. Kindly check if the Tables are presented correctly.

Q5. The reference "Vosniadou et al., 2014" is cited in the body but its bibliographic information is missing. Kindly provide its bibliographic information in the list.

Q6. The reference "Zaitchik et al., 2013" is cited in the body but its bibliographic information is missing. Kindly provide its bibliographic information in the list.

Q7. The reference "Potvin et al., 2014" is cited in the body but its bibliographic information is missing. Kindly provide its bibliographic information in the list.