Learning from texts : extending and revising knowledge

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C O N T E N T S

CHAPTER

1

General Introduction

Introduction

Learning environments have undergone great changes in the past decades. One of the most striking changes is the digitalization of learning materials. Paper texts are still important sources of information, but students nowadays also have access to an almost unlimited amount of digital texts that are available through the Internet. Reading comprehension skills are necessary to be able to learn from these texts. Students need to understand each individual text, and select and integrate information from multiple sources in order to construct a mental representation of the topic. These skills are not new, but what *is* new is that they have become more important in school settings, professional environments and personal situations than they were in the past (Common Core State Standards, 2010; National Research Council, 2012; NRO, 2016; OECD, 2015). Although the availability of information enables more learning opportunities, it also increases the risk of learning incorrect information because sources can be unreliable, biased, or incomplete (Britt & Rouet, 2011). Again, this is not a new challenge for students and teachers, but it has become more important than before due to easier access to incorrect information.

In response to the educational challenges that are the result of the increasing availability of information, many governmental institutions have adapted the national educational standards by putting more emphasis on integration skills and skills involved in revising inaccurate knowledge, with the aim of improving learning materials, assessment, and instruction (Common Core State Standards, 2010; SLO, 2006). Only a few studies have been conducted to assess the ability to integrate information across multiple sources, but the little that is known suggests that the educational standards concerning integration across texts are not met yet. For example, two reports show that children struggle with tasks requiring integration of multiple texts (Sabatini, O'Reilly, Halderman, & Bruce, 2014; Sheehan, Kostin, & Persky, 2006).

The purpose of the current dissertation is to gain insight into the processes that are involved in learning from (multiple) texts in adults and children. Behavioral data were collected of the learning process and the resulting knowledge representation. In addition, the effects of individual differences in reading comprehension ability and working memory were considered. Before describing the individual chapters of this dissertation, a brief overview of the topic learning from texts is provided. In this overview two types of learning conceptual knowledge are differentiated; learning that results in *extending* conceptual knowledge and learning that results in *modifying* incorrect conceptual knowledge (van den Broek, 2010).

The Expansion of Knowledge

One form of learning is *extending* knowledge[1] about a certain topic by reading texts. This process starts with processing texts and must eventually lead to the construction of a coherent mental representation of the information in long-term memory (Graesser, Singer, & Trabasso, 1994; Kintsch, 1988; Trabasso, van den Broek, & Suh, 1989; van den Broek, Risden, Fletcher, & Thurlow, 1996). Although comprehension is necessary for constructing knowledge representations from texts (Donovan & Bransford, 2005; Glynn & Muth, 1994), it is not always sufficient to create a *permanent* representation of the topic. For instance, information that has been encountered in a text and comprehended may not be recalled at a later moment in time. This may happen due to failure to encode information from the text permanently or due to failure to recognize that text information encountered earlier is relevant in a new context. It is not clear which processes contribute to the construction of a permanent knowledge representation that can be applied in different contexts (i.e. a knowledge representation that is decontextualized). This is largely because in the past research has focused predominantly on 1) assessing what is remembered shortly after reading, which does not necessarily reflect the permanency of knowledge in memory after a longer time interval, and 2) processing narratives, which are rarely used in formal learning situations (Lorch, 2015), and 3) processing single texts, which does not necessarily contribute to the decontextualization of knowledge (Lobato, 2006).

Knowledge extension usually occurs as a result of multiple learning experiences, for example through reading multiple texts (e.g. from books, news articles, websites, etc.). Research is relatively limited, but insights concerning this topic are gradually increasing (Bråten, Britt, Strømsø, & Rouet, 2011; Britt & Rouet, 2011, 2012). A central issue is *how* multiple texts are integrated in a single knowledge representation. The links between texts are often implicit and it is the reader's task to connect different sources of information in order to create a complete knowledge representation. This is not an easy task, because the boundaries between multiple texts can be large (Britt, Rouet, & Braasch, 2013). For example, texts may lack in content overlap (Britt, Perfetti, Sandak, & Rouet, 1999; Kurby, Britt, & Magliano, 2005), texts may be processed at different times and in different locations, or texts may be inconsistent with each other (Stadtler & Bromme, 2014). It is therefore important to address which cognitive processes are involved in integrating information across multiple texts. One such process is activation of information from previous texts during reading.

[1] In this dissertation knowledge refers to information that can be represented by at least one idea unit and that is encoded in memory.

If readers activate information from previously processed texts during reading and recognize that this information is related to the current text, connections between different texts can be established (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; McRae & Jones, 2013; van den Broek, Risden, et al., 1996). Activation of prior text information is crucial for integration within texts (Kendeou, Rapp, & van den Broek, 2003), and may be crucial for integration *across* texts as well (Britt et al., 1999; C. A. Perfetti, Rouet, & Britt, 1999).

The Development of Integration Skills

As children move up the grades, they are supposed to connect information within increasingly extensive texts and between an increasing number of texts (Hatcher, 2000; Mesmer, Cunningham, & Hiebert, 2012). Children are hardly ever included in research about integration across texts (but see Wolfe and Goldman (2005) for an exception) and research concerning the development of skills involved in integrating information across multiple texts is absent. In contrast, the development of inferencing skills *have* been studied and given that certain types of inferences require integration skills (e.g. text-connecting inferences) these findings possibly generalize to the development of integration across texts. More specifically, it has been demonstrated that children improve their ability to make inferences as they get older (Oakhill & Cain, 2012; Oakhill, Cain, & Bryant, 2003). Generalizing these findings to integration of information across texts should reveal similar developmental patterns.

In part, developmental improvements in the ability to integrate information may be driven by the development of working memory (Cain, Oakhill, & Bryant, 2004; Seigneuric & Ehrlich, 2005) which is strongly related to learning (Cowan, 2014). Working memory is a cognitive function that allows one to temporary store and process information. The development of working memory may enable developing readers to temporarily store and process more information at the same time, across larger distances, which may result in more complex and elaborate knowledge representations of the texts (Daneman & Carpenter, 1980).

The Modification of Knowledge

Another form of learning is *modifying* existing (incorrect) knowledge (i.e. misconceptions). Misconceptions are quite common among students of all ages, either as a result of naïve conceptions of the world (e.g. "The Earth is flat, because the horizon looks flat") or as a result of exposure to unreliable sources (e.g. repeated exposure to the image of an ostrich putting its head in the ground in cartoons). Exposure to unreliable sources has become a bigger issue due to the advent of the Internet, which allows fast and effortless distribution of unreliable information. Many websites make no attempt to check the reliability of information. The increased availability of inaccurate and unreliable information is a worrisome development as misconceptions have been shown to be quite pervasive (Carey, 2009; Chi, 2005; Novak, 1988; Vosniadou & Brewer, 1992).

A central question is therefore how information should be transmitted to students to accomplish knowledge revision. Because texts are one of the most common ways of delivering information, several studies investigated how texts need to be structured to accomplish knowledge revision in students with misconceptions. Traditionally, misconceptions are targeted by providing students with a text with the correct information. In this text the incorrect background knowledge is usually ignored. The rationale behind this approach is that mentioning the correct information strengthens this information in memory, which makes it more likely that the information will be recalled in the future. However, simply explaining the correct information without referring to the misconception may cause comprehension problems, because the correct information in the text does not match prior knowledge. For example, students who believe that seasons are caused by the distance of the Sun towards the Earth may be confused when reading that seasons are caused by the tilt of the Earth towards the Sun. As a result, these students may not encode the correct information about the tilt in memory because it makes their representation incoherent (Maier & Richter, 2013; Stadtler, Scharrer, & Bromme, 2012).

Another way to accomplish knowledge revision is by using a refutation text format: The incorrect information is explicitly mentioned and refuted and the correct information is explained. It has been argued that mentioning both correct and incorrect information (successively) is important (van den Broek & Kendeou, 2008), because it enables compare-contrast processes, which could lead to detection of the incongruence, dissatisfaction with prior knowledge and, discrepancy resolution (Chi, 2008; Chinn & Brewer, 1993; McCrudden, 2012; Posner, Strike, Hewson, & Gertzog, 1982). These processes have been argued to facilitate encoding of the revised knowledge in memory (van den Broek & Kendeou, 2008).

In general, refutation texts have been shown to be more effective than traditional science texts (Broughton, Sinatra, & Reynolds, 2010; Diakidoy, Kendeou, & Ioannides, 2003; Diakidoy, Mouskounti, Fella, & Ioannides, 2016; Diakidoy, Mouskounti, & Ioannides, 2011; Kendeou & van den Broek, 2007). However, science texts without refutations can also be effective in revising knowledge, for example when they have a text structure in which two contrasting positions are compared by pointing out similarities and differences (Diakidoy et al., 2016; van den Broek & Kendeou, 2008). Which approach is best has been argued to depend on the type of knowledge that needs to be revised (Chi, 2013). For example, refutation texts are quite effective in changing knowledge that can be represented by one or a few idea units (Guzzetti, Snyder, Glass, & Gamas, 1993), whereas elaborate science texts with a compare-contrast format have been shown to be quite effective in changing more complex knowledge such as knowledge schemata (Chi, Roscoe, Slotta, Roy, & Chase, 2012).

The extent to which knowledge revision is successful after reading a text is often determined by assessing changes in pre- to post-test performance on knowledge tests, using the same or very similar items for the pre- and post-test (see for example Diakidoy et al., 2016; Kendeou, Walsh, Smith, & O'Brien, 2014). However, an important educational objective is that students apply revised knowledge in new contexts as well. For example, when biology teachers tell their students that global warming is not caused by natural influences but merely by human influences, they do not only expect their students to be able to apply this knowledge at the exams, but they also want their students to be aware of this outside the school context. This requires spontaneous application of revised information to new situations. Research regarding spontaneous application of revised knowledge as a result of reading refutation texts is limited. The few studies that have been conducted show that students are able to transfer revised knowledge to new situations when explicitly asked to do so (Kendeou, Braasch, & Bråten, 2016) or when asked to think aloud (McCrudden & Kendeou, 2014). But whether students apply revised knowledge spontaneously during natural reading situations has not been examined.

Aims

The general aim of this dissertation is to gain insight into the process of learning from (multiple) texts. The dissertation consists of a literature review and reports on several empirical studies. The specific aims of each chapter are to:

1. Review available literature on learning from texts and synthesize findings from the field of reading comprehension and memory (Chapter 2).
2. Create and evaluate a paradigm for studying integration processes across texts in adult readers (Chapter 3).
3. Determine whether children are able to integrate information across texts during reading and whether these processes are reflected in the knowledge representation of the texts (Chapter 4).
4. Investigate whether refutation texts are effective in achieving transfer of revised misconceptions in adult readers (Chapter 5).

Approach

All empirical studies in this dissertation followed an experimental design. Each study included behavioral measures of the reading *process* and of the resulting knowledge *representation*. With regard to the process, reading times were measured because reading times are assumed to be reflective of underlying cognitive processes (Rayner, 1977). For example, delayed reading times can reflect a failure to integrate contradictive information, due to a mismatch between currently processed information and prior text information ("The rulver is brown. […] It is difficult to see the rulver in the white snow") or background knowledge ("Cookies are sour."). Furthermore, reading times do not require a covert response of the reader, allowing students to read the texts in a relatively natural, unobtrusive way.

Contradictions can be used to determine whether information from previous experiences (i.e. prior parts of the text or background knowledge) is activated during reading and contradictions may be informative about integration processes. Several studies in this dissertation use the logic of the contradiction paradigm. In the contradiction paradigm the processing time of the same information is compared in two conditions: A condition in which the information is preceded by consistent information and a condition in which the information is preceded by inconsistent information (e.g. Albrecht & O'Brien, 1993). Any difference in reading time can only be attributed to differences in the preceding information, and must therefore reflect the activation of prior text information. The direction of the effect may be informative of integrative processes. For example, a delay in reading times may reflect difficulty integrating information. In Chapter 3 and 4 the contradiction paradigm was adapted to study the activation of information from previous texts when reading multiple texts about the same topic.

The same logic can be applied in studies investigating prior knowledge activation in the context of knowledge revision. There are two ways in which the activation of prior knowledge can be studied: 1) the processing time of the correct information is compared for students with inaccurate knowledge and accurate knowledge (e.g. Kendeou & van den Broek, 2007; Kendeou et al., 2014; van den Broek & Kendeou, 2008), or 2) the processing times of the correct information is compared for students that are assumed to have revised their inaccurate prior knowledge with those that are not assumed to have revised their inaccurate prior knowledge (e.g. Kendeou & van den Broek, 2007; Kendeou et al., 2014; van den Broek & Kendeou, 2008). Again, the compared information is usually the same in both conditions, therefore, reading time differences must reflect differences in prior knowledge activation. In Chapter 5 the second approach was used: Activation of prior knowledge was investigated for students with common misconceptions who read refutation texts (which are argued to lead to knowledge revision) and non-refutation texts (which are argued not to lead to knowledge revision).

With regard to the knowledge representation, free recall and questions were used (that is, free recall in Chapter 3 and 4 and questions in Chapter 3, 4 and 5). In free recall students are asked to report everything they can remember about one or multiple texts. Free recall can be useful to gain insight into the text representation. The influence of the experimenter in this case is minimal; the students report what they remembered from the text without interference of the experimenter. Recall reports can be used to analyze a variety of aspects of the text representation: Amount of encoded information, specific content information, relations within and across texts, etc. In addition, specific questions were used, first because we predicted that some students would not recall any text information in the free recall sessions and needed more cues, and second because responses to more specific questions can be informative about retrieval of specific information of interest.

The samples consisted of undergraduate university students (Chapter 3 and 5) and children from 4th and 6th grade (Chapter 4). In one study (Chapter 4) several measures of individual differences were taken into account: A sentence span task to measure working memory (Daneman & Carpenter, 1980; Swanson, Cochran, & Ewers, 1989) and a national standardized reading comprehension test (Cito, 2013a, 2013b) to measure reading comprehension ability. The studies involving university students took place in laboratory settings at the university, whereas the study involving children took place at their schools in a separate room. Each participant was tested individually.

Chapter Overview

The remainder of this thesis consists of four chapters and a discussion.

The second chapter provides an overview of models that explain the process of learning from texts and empirical findings that have contributed to our knowledge about learning from texts. The chapter provides a definition of learning and describes how the act of comprehending is related to the act of learning. It explains how several factors may influence learning from texts, such as individual differences, text factors, development, learning mechanisms, and number of texts.

The third chapter focuses on one subskill of learning from texts: Making connections across multiple texts. An empirical study was conducted to evaluate a new research paradigm (i.e. the multiple-text integration paradigm) that uses the same logic as the contradiction paradigm (Albrecht & O'Brien, 1993). The multiple-text integration paradigm was used to study activation of prior text information in the context of multiple texts. In addition, recall reports were analyzed to inspect the knowledge representation that was constructed from the texts.

In the fourth chapter the experimental materials that were used previously (see Chapter 3) were adapted to make them suitable for children. Because integrations skills were expected to undergo major developments in childhood (as described in Chapter 2), children from different grades were included (Grade 4 and 6). Again, reading times and recall reports were used to gain insight into learning from texts. In addition, measures of reading comprehension ability and working memory were taken into account to determine whether these characteristics influence learning from texts.

The fifth chapter discusses the potential usefulness of refutation texts to enhance application of revised knowledge in new situations. An empirical study was conducted to determine whether readers with incorrect knowledge revise their knowledge after reading a refutation text and if so, whether they spontaneously apply this knowledge to new situations, in this case, when reading a new text. Reading times and responses to application questions were used as indications of the knowledge revision process.

CHAPTER 2

Meaningful Learning From Texts: The Construction of Knowledge Representations

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Introduction

The main goal of formal education is to provide students with high-quality conceptual background knowledge that they are able to apply, both inside and outside of the academic situation in which they acquired it. This knowledge can be used to manage everyday situations (taking care of bills, reading formal letters) and to perform well in more advanced educational and professional settings (Barnett & Ceci, 2002). Conceptual knowledge can be acquired in many different ways, but a substantial amount of conceptual knowledge is delivered by using texts in some form –e.g., expository print, digital texts. Although it is possible to memorize information in such texts by rote learning of superficial textual features, meaningful learning requires a deep level of comprehension.

In the past decades, knowledge about learning from text has mainly focused on what is remembered from short, single, and often narrative texts directly after reading. However, recently there has been more attention for deeper *learning* from texts, which often involves integration of longer, multiple, expository texts. In accordance with this development, the goal of this book chapter is to describe the processes that are involved in meaningful learning of conceptual knowledge. In doing so, we pay particular attention to the interplay between learning and comprehension. Consideration of this interplay is important for various reasons. One reason is that comprehension is a necessary component of meaningful learning -although, as we will argue, not a sufficient one. A second reason to consider comprehension in the study of learning is the fact that prior research has yielded a detailed understanding of the processes and products of comprehension, which can provide a useful foundation for investigating processes and products in learning. Reading comprehension theories are not only informative about the way texts are comprehended but also about the cognitive architecture that is involved in general comprehension, reasoning, problem solving, and learning (McNamara & Magliano, 2009). All of these processes involve key elements that are well described in the reading comprehension literature, such as activation of prior knowledge, integration of information, validating information, process monitoring, memory, and so on. Reading comprehension theories therefore can form the basis for understanding learning from texts. In this book chapter we describe the processes and strategies that contribute to meaningful learning from texts. We combine insights from the reading comprehension literature and from the learning literature to gain a better understanding of the underlying mechanisms involved in learning from text. In doing so, we consider both the processes and the products of learning. We conclude by discussing important questions that may be fruitful directions for future research.

The Products of Learning: Knowledge Representations

Learning and Comprehension

It is important to describe what we mean by learning and how that differs from comprehension. Many researchers use similar definitions to describe comprehension and learning. For example, Kintsch (1980) defines comprehension as "the process of continuous modification of knowledge structures", and learning as "the transformation of knowledge structures". Moreover, comprehension and learning are frequently used interchangeably, without defining differences. It is theoretically as well as educationally relevant to differentiate between the process of creating a meaningful mental representation of a text during reading, to which we refer as comprehension, and the encoding of that information in long-term memory, to which we refer as learning. Comprehension involves building a mental representation of the text (often called a situation model) in which features from the text and knowledge retrieved from long-term memory are integrated. In contrast, learning is defined as a *relatively permanent change in knowledge and behavior as a result of experience* -in this case: reading-, i.e., a relatively long-term change in the reader's knowledge representation itself (Shuell, 1986). In the case of knowledge acquisition through reading this relatively permanent change requires that the presented information is encoded in a mental representation that is accessible at later points in time. Whether reading was successful in changing the knowledge representation permanently can therefore only be examined after passage of time.

Reciprocal Relation between Learning and Comprehension

The fact that comprehension and learning are often used interchangeably may be due to the reciprocal relation between them. Reading and comprehending texts can result in learning from these texts, and knowledge that is learned from these texts can, in turn, be used to facilitate comprehension and learning from subsequent texts (Adams, Bell, & Perfetti, 1995; Britton, Stimson, Stennett, & Gülgöz, 1998; Cook, 2005; Kendeou et al., 2003; McNamara, Kintsch, Songer, & Kintsch, 1996; Ozuru, Dempsey, & McNamara, 2009; Recht & Leslie, 1988). That comprehension affects learning is illustrated by the finding that textual adaptations aimed at improving comprehension also improve learning (Britton & Gülgöz, 1991; Gilabert, Martínez, & Vidal-Abarca, 2005; McNamara et al., 1996). Moreover, individuals with good comprehension skills often learn better, as reflected by higher academic science achievements, than do individuals with poor comprehension skills (O'Reilly & McNamara, 2007). But knowledge (the result of learning) also affects comprehension. For example, an important aspect of comprehension is making inferences: Drawing on background knowledge to identify relations that are implied by the text or to activate information that is not explicitly mentioned in the text. The importance of knowledge in comprehension is illustrated by the following example: It is easier to comprehend the sentence “Kevlar sails were used because there was little wind” if one has knowledge about the characteristics of Kevlar sails (Noordman & Vonk, 1992). Moreover, high levels of background knowledge can compensate for poor comprehension skills. It has been demonstrated that poor comprehenders with elaborate knowledge about a certain topic are able to reach the same level of understanding as good comprehenders when reading a text that relates to their knowledge (Recht & Leslie, 1988).

Knowledge Representations

When learning from texts is successful, it leads to a (relatively permanent) representation in long-term memory, i.e., a knowledge representation. There are several models of long-term memory representations. These models differ in the way knowledge is organized in memory, the level of granularity in which knowledge is represented, and the way knowledge representations are thought to develop. It is beyond the scope of this chapter to provide a full review of these models but see McRae and Jones (2013) for a recent overview. Most recent models assume that knowledge is represented in structured networks of interconnected nodes. Kintsch, for example, describes such knowledge structures to represent conceptual knowledge (Kintsch, 1988), with nodes referring to concepts or propositions and links between the nodes to relations between the concepts or propositions. The links represent associations between nodes, and these links can vary in strength.

The long-term availability of knowledge structures depends on the coherence of knowledge structures. For example, it is easier to remember logically ordered information than arbitrarily ordered information (Bauer, 2013). It has been hypothesized that knowledge representations in memory are organized based on shared semantic characteristics and/or associations (McRae & Jones, 2013). In line with this view, knowledge structures facilitate learning in three ways. First, knowledge structures facilitate encoding (R. C. Anderson, 1984; Brewer & Treyens, 1981; Tse et al., 2007). Consider learning that the ibis has multiple characteristics (e.g., it has feathers, it flies, it has long legs, etc.) and that it is related to ‘birds’. By linking ‘ibis’ to the knowledge structures that represents ‘birds’, a learner does not need to encode all characteristics related to ‘birds’, but instead only encodes that the ibis is a bird (Collins & Quillian, 1969). This makes it easier to encode other characteristics of the ibis. Second, knowledge structures facilitate retrieval. Knowledge structures (e.g., ‘birds’) incorporate a collection of characteristics (e.g., feathers, flying, beaks), thereby providing multiple retrieval cues to the target concept (i.e., ‘ibis’) (R. C. Anderson & Pichert, 1978; Bransford & Johnson, 1972; Rawson & Kintsch, 2002, 2004; Spilich, Vesonder, Chiesi, & Voss, 1979; Voss, Vesonder, & Spilich, 1980). Third, knowledge structures facilitate spontaneous learning of information that was not presented. For example, when learning that the ibis is a bird the learner may also encode that the ibis lays eggs, even if this was not explicitly stated. This may occur through an inference triggered by shared characteristics or associations with knowledge already represented in memory. The ibis-example shows the importance of having coherent knowledge representations in memory. How coherence is established over the course of development is still a point of discussion (McRae & Jones, 2013).

The ultimate goal of learning is creating a high-quality knowledge representation. By comparing the knowledge representations of experts and novices, we can gain insight into the characteristics of high-quality knowledge representations. Experts differ from novices in the amount and quality of knowledge they have, which is often a result of extensive experience and deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993). Another characteristic of expert knowledge is that it is decontextualized, meaning that knowledge is not tied to a specific learning context. As a result the knowledge can be applied to a wide range of situations, a process called *transfer*. Experts' extensive knowledge is organized in chunks of concepts that are highly associated to one another and only weakly associated with elements of other (less related) chunks. The organization of knowledge in chunks helps experts to recognize and remember more complex problems compared to novices (Newell & Simon, 1972). Moreover, their extensive background knowledge provides more possibilities to relate new knowledge to an existing knowledge structure, thereby facilitating encoding (Spilich et al., 1979). In contrast, knowledge of novices is often limited, lacks coherence and is more dependent on the context (DiSessa, Gillespie, & Esterly, 2004). Moreover, knowledge of novices is often influenced by misconceptions. These misconceptions arise from naïve theories about the world based on intuition and perception (Vosniadou & Brewer, 1992).

Based on this brief summary of research comparing experts and novices, it can be concluded that a high-quality knowledge representation is extensive, organized, and decontextualized. In addition, high-quality knowledge is accurate, meaning that it coincides with the community's (e.g., teacher, text book) prevailing standards (e.g., of the teacher, the textbook). Novices become experts with accumulated experience and practice, but the question is how information that is encountered in a text for the first time eventually becomes high quality knowledge. According to Kintsch (1988), knowledge representations are relatively fixed and cannot flexibly adapt to the continuously changing situation as a reader progresses through the text. If knowledge representations would be constantly updated, these representations would fail to reach the level of permanency necessary to be functional. The text representation therefore serves as an intermediate level of representation, between the text and the knowledge representation. With each new sentence, the representation of the text is being updated to incorporate the incoming information. This intermediate level of text representation allows the reader to represent a flexible and temporary situation that is true for a given text without leading to immediate permanent changes in knowledge. Text representations could lead to changes in knowledge representations, but this depends on the situation (more details about those situations that lead to learning are described later in this chapter) (Kintsch, 1988).

Text Representations

Text comprehension is a reading process that results in the construction of a mental representation of the text that is analogous to a mental representation of knowledge in long-term memory (Kintsch, 1988). Similar to knowledge representations, text representations can be depicted as networks, with each node representing text information or related background knowledge, and each link representing the relation between the nodes. The nodes can represent text information or background knowledge of various grain sizes: Individual words, propositions, paragraphs etc. The links can represent various relations, but it is common to represent the text as a network of causal and referential relations (Graesser et al., 1994; Kintsch, 1988; van den Broek, 1988, 1989a, 1989b, 1990). The relations vary in strength, for example some story events ('pushing a vase') are stronger causes of subsequent events ('the vase breaks') than other causes ('touching a vase'). When comprehension is successful, the representation of the text contains individual text elements that are related to each other, as well as to relevant background knowledge. Thus, an important characteristic of text representations is that they consist of both explicitly mentioned information from the text and implicit information that is inferred from the text and the reader's background knowledge.

To be successful at comprehending a text, readers must attain coherent representations of the text. Coherence can be accomplished by organizing text representations in a certain way (e.g., Trabasso, Secco, and van den Broek (1984); (van den Broek & Gustafson, 1999). First, text representations are organized to fit mental schemata that readers have of different text structures. Most narratives have similar text structures and the ordering of text elements in a narrative tends to adhere to similar rules across different stories (i.e., most stories start with a setting, then an event is described, leading to a goal to be accomplished by the protagonist and attempts to reach that goal, etc., see research on story grammars (e.g., Mandler & Johnson, 1977; N. L. Stein & Glenn, 1979). Text representations that readers construct from a text are likely to include information that fits these story schemata (Mandler & Johnson, 1977). Discrepancies between the reader's text representation and information presented in the text (e.g., recall of information that was not described in the text, or recall of the text events in a different order) can sometimes be attributed to deviations of the texts from story schemata and are caused by the tendency to map text representations onto known story schemata (e.g., Bartlett, 1932). Expository texts have more diverse structures than narratives do, but nevertheless common expository text structures have been identified, including comparison, problem/solution, causation, and collections of descriptions (Meyer & Freedle, 1984; Ray & Meyer, 2011). Similar to representations of narratives, readers' text representations of expository texts are often structured in a way that matches the readers' text schemata (Meyer, Brandt, & Bluth, 1980).

Second, coherence of a text representation can be increased by including meaningful relations between text elements. The nature of these relations depends on the situation, but causal and referential relations seem to be included most frequently (Kintsch, 1988; McNamara, 2007; Trabasso et al., 1984; van den Broek, 1988, 1990). Other types of relations involve spatial, temporal, motivational, and emotional relations (Graesser & Clark, 1985; Schank & Abelson, 1977; van den Broek & Gustafson, 1999; Zwaan, Magliano, & Graesser, 1995). Relations are not always explicitly stated in the text, and therefore often need to be inferred based on background knowledge. These inferred relations further strengthen a text representation. In summary, coherence can be accomplished by using common text schemata to organize text representations and by incorporating (causal) relations between text elements into text representations (Trabasso & van den Broek, 1985).

To determine the characteristics of *high quality* text representations it is informative to compare the text representations of good and poor comprehenders. An important difference between these groups of readers concerns the extent to which their text representations contain literal information from the text relative to information that can be inferred from the text (Collins & Quillian, 1969; Fletcher, Chrysler, van den Broek, Deaton, & Bloom, 1995; van den Broek & Gustafson, 1999). Poor comprehenders have the tendency to extract more literal (text-base) information from the text than good comprehenders (McMaster et al., 2012), whereas good comprehenders infer more of the situation that is conveyed by the text (O'Brien, Albrecht, Hakala, & Rizzella, 1995) and, as a consequence, represent more gist information in their text representations (Bean & Steenwyk, 1984; Chi, De Leeuw, Chiu, & Lavancher, 1994; Wong, 1985). Similarly, good comprehenders incorporate more background knowledge in their text representations to create coherence. A second important difference concerns the extent to which readers incorporate central information in their text representation. Good (i.e., more skilled or more developed) readers include more central information than poor readers (van den Broek, 1989b; Wolman, van den Broek, & Lorch, 1997). In addition, good readers include less inaccurate information and their text representations are more organized (Elbro & Buch-Iversen, 2013; J. R. Miller & Kintsch, 1980). Overall, poor readers recall less information from the text after reading (J. R. Miller & Kintsch, 1980).

From Text Representations to Knowledge Representations

In the preceding sections we have described that text and knowledge representations can both be described as interconnected mental representations. The difference between text and knowledge representations is best illustrated by comparing their permanency and degree of decontextualization. Text representations are quite temporary and closely linked to the text, whereas knowledge representations are more permanent and decontextualized. Learning starts with creating a mental representation of the text (Figure 2.1, black upward arrow). The construction of a text representation is influenced by background knowledge (black downward arrow). The text representation can gradually evolve to become part of one's knowledge representation, a process we call learning (white arrow). It should be noted that even though in the figure the distinction between text representation and knowledge representation is portrayed as dichotomous, in reality the two types of representation may be best described as being on a continuum. Whether a text representation eventually becomes a knowledge representation depends on the processes that occur during reading, which will be described next.

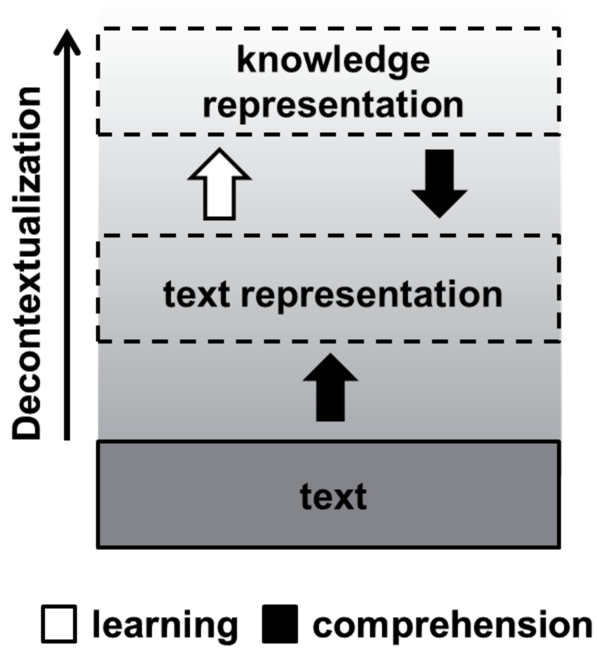

Figure 2.1 Representations in comprehension and learning.

The Processes That Contribute to Learning from Texts

The construction of a mental representation relies on an intricate combination of cognitive processes. With respect to the construction of a representation from a text, these processes are described in great detail in current models of reading comprehension (see McNamara & Magliano, 2009, for a review). In comparison, little is known about the processes by which a learner constructs or updates a knowledge representation. What is known about the processes by which readers construct a text representation may be very useful to gain insight in the processes by which a learner constructs a knowledge representation (Kirby, Cain, & White, 2012; McNamara & Magliano, 2009). In both contexts the crucial component is the identification and integration of semantic relations into a representation. Research on text comprehension has shown that there are two types of processes that contribute to the construction of text representations: Passive and strategic processes. These types of processes are likely to play a role in the construction of knowledge representations as well. In the following sections we discuss passive and strategic processes as they take place when constructing text and knowledge representations.

Passive Processes

According to models of text comprehension, information needs to be activated in working memory in order to become part of a representation (Albrecht & O'Brien, 1993; Kintsch, 1988; van den Broek, 1995). Activation can occur through passive processes that are not under the control of the reader (Gerrig & McKoon, 1998; McKoon, Gerrig, & Greene, 1996; Myers & O'Brien, 1998; O'Brien, 1995). Memory-based models of text comprehension propose that, as the reader proceeds through the text, information from the text automatically activates information from previous parts of the text that are related to the concepts that are being read (Albrecht & O'Brien, 1993; Klin & Myers, 1993; O'Brien, Duffy, & Myers, 1986; van den Broek, Young, Tzeng, & Linderholm, 1999). Background knowledge that is associated with the information in the text also becomes activated, as a result of a spread of activation through concepts that have overlapping semantic and contextual features (Gerrig & O'Brien, 2005). The process of spread of activation is passive, dumb, and unrestricted (Gerrig & O'Brien, 2005). It is passive in that it occurs without active effort or control on the part of the reader. All knowledge that is associated with the text that triggered the activation becomes activated. The process is dumb in that activation is based on superficial characteristics. For example, even refuted knowledge becomes activated if it has some degree of associative overlap with concepts in the currently read sentence (O'Brien, Rizzella, Albrecht, & Halleran, 1998). Finally, it is unrestricted in that information from the text activates all associated information, even if that information does not contribute to understanding of the text (Cook, Halleran, & O'Brien, 1998). For example a sentence such as 'he bought her a ring' can activate associations that relate to ringing a bell.

The information that is most strongly activated will enter working memory (Myers & O'Brien, 1998; O'Brien & Myers, 1999). Several factors have been found to influence the extent to which a concept is activated. Among them are a) the frequency with which the memory trace is activated (either directly by repetition in the text, or by featural overlap with other concepts), b) the amount of elaboration on the concepts in the text, c) the richness of the interconnected network of the concept in memory, d) the presence of distractors, and e) the focus of attention (Albrecht & O'Brien, 1993; Cook et al., 1998; Garrod, Freudenthal, & Boyle, 1994; Gerrig & O'Brien, 2005; O'Brien, Raney, Albrecht, & Rayner, 1997; O'Brien et al., 1998). In addition, the extent of activation depends on the type of information. Information that provides causal explanations and referential grounding is particularly likely to be activated, as this type of information is inherently interconnected (Kendeou, Smith, & O'Brien, 2013; O'Brien & Myers, 1987; Trabasso & van den Broek, 1985).

When multiple pieces of information are simultaneously active in working memory, relations can be formed (van den Broek & Kendeou, 2008). A common distinction is made between relations between different parts of the text (connecting/bridging inferences) and relations between the text and background knowledge (knowledge-based inferences). The first may be the result of close proximity of two pieces of information in the text or reactivation of previous text information, resulting in co-activation (O'Brien, 1987; O'Brien et al., 1995; O'Brien, Plewes, & Albrecht, 1990). The second is the result of activation of background knowledge through associations or cues that are activated by the currently read text or stated in close temporal proximity to the text (Myers & O'Brien, 1998). An example of a connecting /bridging inference is when 'Lauren' is related to 'she' when reading: "Lauren likes animals. She does not eat meat". An example of an knowledge-based inference is when a reader relates the statement that Lauren does not eat meat with the statement that she likes animals, as 'eating animals' in the text may have activated the background knowledge that animals in the meat industry are not treated well.

According to the Landscape Model (Linderholm, Virtue, Tzeng, & van den Broek, 2004; van den Broek et al., 1999), the text representation is a direct result of the amount of activation during reading: The stronger concepts are (co-) activated during reading, the more likely it is that they enter working memory and that they (and their relations) become part of the text representation. Computer simulations of the reading process based on the Landscape Model suggest that activations during reading are indeed highly predictive of the resulting text representation (van den Broek, Risden, et al., 1996). In particular, activation of causal and referential information seems to be a major predictor of whether information is included in text representations. Similarly, by investigating readers' summaries and recall of texts, it has been found that the number of causal relations that a concept has in the text and whether the concept is part of the causal sequence of events (causal chain) in the text, are strong predictors of the inclusion of the concept in a text representation (Trabasso et al., 1984; Trabasso & van den Broek, 1985; van den Broek, 1988; van den Broek & Trabasso, 1986).

Passive processes such as those that influence the construction of a mental representation of a text are also likely to play a role in the construction of knowledge representations in the context of learning. Knowledge representations can be the result of reading text parts once, but more frequently they are the result of reading text parts repeatedly. Multiple encounters with texts about the same topic increase the activation of particular pieces of information, thereby stimulating more permanent encoding. There is a vast amount of literature supporting claim that repetition (by reinstatements or rereading) facilitates long-term memory

(Amlund, Kardash, & Kulhavy, 1986; Bromage & Mayer, 1986; Mayer, 1983). Eye-tracking methods show that rereading results in faster reading of already processed materials (Foster, Ardoin, & Binder, 2013; Raney & Rayner, 1995), indicating that the information is familiar and, thus, that it has been encoded in memory. Once information is encoded in memory more attention can be devoted to other information during rereading, which consequently is likely to improve memory for the other information as well (Samuels, 1979).

Furthermore, repeatedly encountering the information in *different* contexts, for example by reading different texts about the same topic, facilitates encoding even further by fostering more elaborate and more densely interconnected networks of knowledge. For example, new vocabulary is learned better in variable contexts than repeated exposure in the same context (J. R. Anderson & Reder, 1979; Bolger, Balass, Landen, & Perfetti, 2008). The explanation for this is that the mental representation of the information is enriched by the many relations and concepts that are activated by the varied contexts (Craik & Lockhart, 1972). This is turn facilitates retrieval, because multiple cues that are available lead to access of the information in memory. Experiencing information in various contexts also facilitates the process of decontextualization; it allows for comparisons across situations, enabling one to extract the commonalities across different contexts and to ignore what is context-specific (Chen & Daehler, 2000; DiSessa & Wagner, 2005; Fuchs et al., 2003; Lobato, 2006). As a result, the possibility that the learners will recognize that the learned information applies to a new situations increases (Bransford, Brown, & Cocking, 2000). We will return to the issue of learning from multiple texts below.

Strategic Processes

Activating information from memory and making inferences can also result from a deliberate act by intentionally directing attention to specific information. The main difference between passive and strategic learning processes is that strategic learning processes are goal-directed and volitional. Strategic processes are effortful and deliberate but with practice they may become automatized (Afflerbach & Cho, 2009). In reading comprehension a more effortful strategic approach is often triggered when automatic processes do not lead to a sufficient level of comprehension. Evaluation of the level of comprehension is based on the reader's standards of coherence (van den Broek, Bohn-Gettler, Kendeou, Carlson, & White, 2011; van den Broek, Risden, & Husebye-Hartman, 1995). These standards reflect the degree of comprehension that the reader wants to attain. When the standards are not met through automatic processes, strategies can be used to reach a sufficient level of comprehension. A reader may also have learning standards that reflect the degree of learning the learner wants to attain. Even when readers believe that they have sufficient comprehension of the text to meet their comprehension standards, it is possible that they implicitly or explicitly feel that they have not reached the level of learning they want to attain. When the learning standards are not met learning strategies may be used to reach the desired level of learning. Unfortunately, it is difficult to judge during reading whether something is learned or not (Thiede, Anderson, & Therriault, 2003). Readers often base their judgments about future retrievability of information on current retrievability of the information, however immediate recollection does not always relate to delayed recollection (Thiede & Anderson, 2003).

Several strategies can be used to learn from texts. The list of strategies described in the following paragraphs is not comprehensive, but includes a selection of strategies that are promising for improving meaningful learning from text. Strategies that improve learning from texts can be divided in three categories: Strategies that target reading comprehension processes, strategies that target retention/memory processes, and strategies that target transfer processes. A combination of these three types of strategies is most likely to contribute to meaningful learning from texts. Of course, strategies that target one of these processes often also improve the other processes.

The first set of strategies target different components of reading comprehension. These strategies can be used before, during, or after reading and all focus on relating different pieces of information within the text and the reader's background knowledge to create a strong, coherent representation of the text. The most effective strategies focus on inference making (Elbro & Buch-Iversen, 2013; McMaster et al., 2012), self-explaining the text (McNamara, O'Reilly, Best, & Ozuru, 2006), self-questioning (Wong, 1985), organization (summarizing, overviewing before reading, reading titles) (Afflerbach & Cho, 2009; Bean & Steenwyk, 1984; Rinehart, Stahl, & Erickson, 1986), directing attention (adjusting reading speed, focusing attention on important information, reading titles, applying reading goals), rereading and looking back in the text (Afflerbach & Cho, 2009), text structure (detecting signal words in text with compare-contrast formats) (Meyer et al., 1980; Meyer & Poon, 2001), and comprehension monitoring (Chan, Cole, & Barfett, 1987). Comprehension strategies are often also effective in improving retention of the text; something that has been comprehended is retained better than something that has not been not comprehended (Morris, Stein, & Bransford, 1979).

The second set of strategies target retention processes. The goal of these strategies is to create durable memory traces for the learning materials, to enable learners to remember the information over time, often regardless of comprehension. The effectiveness of most of these strategies have been demonstrated mainly with simple learning materials such as word pairs, but some of these strategies have also been applied successfully to learn from more complex and educationally appropriate learning materials such as texts (Roediger & Pyc, 2012). Common retention strategies are: (distributed) rehearsal (repeated studying) (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Newell & Rosenbloom, 1981), elaboration (relating learning material to prior knowledge) (Bradshaw & Anderson, 1982), organization (for example with graphic organizers) (Novak, 1990), and retrieval practice (Bjork, 1975).

The third set of strategies target transfer processes. Even though comprehension and retention are necessary for transfer, they are not sufficient (Royer, 1979). Transfer is the process of applying knowledge in novel situations that are distinct from the situations in which the knowledge was learned (Day & Goldstone, 2012). Central to this definition of transfer are the components 'novel' and 'distinct', implying that transfer strategies should focus on recognizing that a novel context (to which the knowledge has to be applied) has similarities with the context in which the information was learned, and ignoring differences between the situations that are not relevant. Strategies that are successful in improving transfer are therefore strategies that focus on making comparisons and relating multiple examples of similar and different concepts (Richland, Stigler, & Holyoak, 2012), self-explaining (Chi, Bassok, Lewis, Reimann, & Glaser, 1989), looking for cues that expose the deep similarities between the novel situation and background knowledge (Chi & VanLehn, 2012), and generating examples to create awareness of the broad applicability of information in different contexts (Engle, 2006; Engle, Lam, Meyer, & Nix, 2012).

Together these three sets of strategies enable the learner to effectively encode textual information to his or her permanent store of background knowledge. Each learning situation requires a different set of strategies and readers have the challenge to select and apply the right strategies from their repertoire to accomplish a sufficient level of comprehension and learning. For example, a student may need strategies that target comprehension, retention and transfer when learning about the digestive system in a textbook, whereas only strategies that target retention are necessary when learning about the gender of nouns in Spanish from a book. Good learners are flexible when switching between different learning situations such as described in these examples.

Mechanisms

The mechanisms that underlie the strategies that were described in the previous section can be divided into two categories: Consolidation and enrichment of the mental representation. In terms of mental network models discussed above, consolidation involves strengthening the nodes and relations that make up the knowledge representation that is gained from the learning experience, and enrichment involves elaboration and expansion of the knowledge representation. Note, however, that most strategies incorporate both mechanisms, thereby contributing to the effectiveness of the strategies.

Consolidation and enrichment mechanisms also have been used to explain why strategies that require more effort and deep processing are generally more effective (Craik & Lockhart, 1972; Slamecka & Graf, 1978), even though students prefer easy ways of learning (Bjork, 1994; Schmidt & Bjork, 1992). Actively generating information (which requires effort) is argued to strengthen information and relations in memory (consolidation) (Hirshman & Bjork, 1988), and to reactivate related information from memory which may result in relations with prior knowledge (enrichment). Deep processing (which often involves extracting meaning) is argued to involve elaboration and, as a result, enrichment of the representation (Bradshaw & Anderson, 1982).

Learning from Multiple Texts

Multiple Text Representations

In the preceding sections, we have described how information extracted from a text is gradually incorporated into a mental representation of the text and, in case of learning, into a knowledge representation. Frequently, learning involves integration of information from multiple texts because learning complex concepts requires multiple learning episodes and because a single text almost never provides all the necessary information (Britt & Rouet, 2012). Thus, many educational tasks require students to search for multiple texts and to create a single mental representation encompassing the information from the multiple texts. Examples of such tasks are writing essays, preparing presentations, and reading multiple chapters of a book for a test. Comprehending multiple texts requires skills that differ, in part, from those required for comprehending single texts. The Documents Model (Britt et al., 1999; Britt & Rouet, 2012) proposes that comprehension of a single text leads to building a mental representation of that particular text, and that comprehension of multiple texts requires in addition, an *intertext model*, incorporating a representation of the source of the texts. This includes information that qualifies the text, such as information about the author, where the text was encountered, etc. The *intertext model* also includes information about how multiple texts relate to each other in terms of content and author. For example, two texts could be classified as being inconsistent with each other, or as presenting opposite views. Multiple text comprehension also requires the creation of a single integrated representation of the content information from the multiple texts (*integrated mental model*).

This representation includes content information that is abstracted from multiple texts and is integrated with background knowledge. It is likely that the intertext model and the integrated mental model interact with each other. Tagging a source as unreliable may lead to exclusion of information from the text in the integrated mental model. Moreover, a text may be represented as reliable when it describes information that was already central in an integrated mental model that has been constructed based on previous texts.

Passive Processes

Reading multiple texts about a topic can be a powerful way to enhance learning, because repeated exposure to information in different contexts may create strong and rich knowledge representations that are decontextualized. A challenge in integrating multiple texts is relating pieces of information from different texts that do not co-occur within each text. Learning relations requires simultaneous activation of the components that are part of the relation (i.e., co-activation) and hence can become related. One way to improve the likelihood of co-activation of specific concepts is to use clues in one text that prompt spontaneous reactivation of information in the other texts (Bauer, King, Larkina, Varga, & White, 2012; Bauer, Varga, King, Nolen, & White, 2015). Bauer and colleagues (Bauer et al., 2012; Bauer & San Souci, 2010; Bauer et al., 2015) studied factors that facilitate integration from multiple auditory narratives that are also relevant in the context of integrating information from multiple texts. Their results showed that integration is facilitated by surface similarity -in this case because each story involved the same protagonists- as well as prompts that link to previously presented narratives (Bauer et al., 2012; Bauer et al., 2015). Similarities and prompts may reactivate information from previous experiences, leading to co-activation and, as a result, integration of the information in memory.

Strategic Processes

Multiple texts may be similar, different, overlapping, or inconsistent with one another, and strategies should be used to generate a coherent mental representation that incorporates these intertextual relations (Lenski, 1998). The relations between multiple texts are often not described explicitly, so it is important that reading strategies target generation of these relations by the readers. Research focusing on compare-contrast text formats in single text learning can be used as a stepping stone for understanding integration of information from multiple texts. Readers find it difficult to read single texts with compare-contrast text formats (Englert & Thomas, 1987), but clue words that signal relations between text parts (e.g., “in contrast, …”) improve comprehension (Williams et al., 2005). These findings suggest that it may be useful to teach learners reading strategies for generating clue words that relate information from different texts and, thereby, enable the reader to make the relations between the different texts more explicit. Likewise, interventions that improve knowledge about text structure of single compare-contrast texts (Meyer & Ray, 2011; Williams et al., 2014) could inform about how to improve integration of multiple texts. For example, in one study (Williams et al., 2005) children were taught to answer text-structure-focused questions such as “What two things is this paragraph about? How are they the same? How are they different?”. Similarly, children could be taught to answer questions such as “What things are these texts about? How are they the same? How are they different?”. Other strategies that may be used to make between-text relations are self-explanation and self-questioning (D. K. Hartman, 1995). Finally, as texts may differ in terms of reliability, strategies that help judging the importance, quality, and trustworthiness of the source are necessary to differentiate between conflicting accounts (Braasch, Bråten, Strømsø, Anmarkrud, & Ferguson, 2013; Bråten, Strømsø, & Britt, 2009; Britt & Rouet, 2012; Wiley et al., 2009) and to make the selection of information that will form the final knowledge representation.

Reader and Text Characteristics

Educators have the challenging task to support students who struggle with learning from texts. They have to identify students’ abilities and select (or write) texts that fit their educational needs. Failures to identify the causes of problems with learning from texts can have major implications for students’ educational careers. A comprehension problem in the early grades impacts knowledge acquisition, which on its turn affects future comprehension, leaving students with a knowledge gap that increases over time. Consider the findings reported by Hart and Risley (1995), that the breadth of vocabulary of high-performing students is twice as large as that of low-performing students in 1st grade, but four times as large in 12th grade. Likewise, there are consistent developmental differences in children’s comprehension and learning skills. It is important to be aware of such differences in both research and educational contexts.

Given the increasing use of texts as a source of knowledge as children progress in schools, the necessity to identify individual and text factors that explain differences in learning from texts becomes even more important in higher grades. Individuals that have insufficient comprehension and learning skills, missing or inaccurate background knowledge, or poor executive functions, are at risk to fail to learn from texts. In addition, text factors such as coherence of the text and text complexity may result in differences in learning from texts.

Individual and Developmental Differences

Comprehension skills. As a result of maturation as well as experience, reading comprehension skills undergo significant changes in childhood and adolescence. One crucial skill that improves with development is inference making (Lynch et al., 2008; Thompson & Myers, 1985). It has for example been demonstrated that 7-year-old children make more inferences in general, and more causal inferences in particular, than do 4-year-old children (Thompson & Myers, 1985). In addition, developmental changes occur in individuals' sensitivity to text structure: The ability to detect central information in the text significantly improves with age, with highly related text units being recalled, summarized, and rated as important more often in older children (Lynch et al., 2008; Trabasso et al., 1984; van den Broek, 1989b; van den Broek, Helder, & van Leijenhorst, 2013; van den Broek, Lorch, & Thurlow, 1996). Other comprehension skills that improve with age and experience are comprehension monitoring skills (Oakhill & Cain, 2012). Older children detect more inconsistencies in texts (van der Schoot, Reijntjes, & van Lieshout, 2012). In addition, older children have a larger repertoire of reading- and learning strategies (Paris, Lindauer, & Cox, 1977). Moreover, older children have more knowledge about text genres. They are better at processing difficult expository text genres such as compare-contrast and descriptive texts (Englert & Hiebert, 1984). As comprehension is an important factor in learning from text, the development of these skills and strategies will facilitate learning from texts as well.

Background knowledge. Background knowledge is an important factor in an individual's ability to learn from texts. As we described above, the relation between comprehension and learning is reciprocal and background knowledge is crucial for comprehension and learning from texts. Learning from texts may fail when background knowledge is absent, not adequately accessed, or simply inaccurate. Background knowledge develops over time, with increases in the amount of knowledge (Bjorklund, 1987; Chi, 1978; Chi, Glaser, & Rees, 1982), in the quality of knowledge (Vosniadou & Brewer, 1992, 1994), and in accessibility of knowledge (Chi, 1976). These developments in background knowledge result from formal educational activities as well as from informal learning situations. Repeated encounters with learning materials across different situations strengthen the memory trace for that knowledge and help the reader to recognize situations to which the information applies (Barnett & Ceci, 2002; Butler, Godbole, & Marsh, 2013; Gick & Holyoak, 1983). Unfortunately, the learning context is not always optimal. Sometimes students make inaccurate inferences because of limited understanding of the learned materials, miscategorization of encountered concepts, or limited understanding about what constitutes knowledge (Vosniadou, 2013). This could lead to misconceptions in memory. Misconceptions are quite common among students and even adults. They are difficult to change, particularly when they regard abstract and unobservable concepts and processes (Chi & Roscoe, 2002). Some of those misconceptions may be the result of normal development (e.g., Piaget, 1952; Vosniadou & Brewer, 1992). Children's knowledge is often based on what they have observed in the world, although many concepts can only be explained by things that are unobservable. For example, many young children believe the Earth is flat, because they *perceive* the horizon as being flat, and they reason that it needs to be flat or else people would fall off. An understanding of the shape of the Earth is only possible when the children are able to understand that some things are not what they seem to be, and when they understand the concept of gravity. Background knowledge can change without formal instruction (Vosniadou & Brewer, 1992). However, some misconceptions may continue to exist because individuals may fail to learn the accurate information due to poorly constructed learning materials or limited support from the environment.

In addition to knowledge about facts, events, and other individual units of information, background knowledge also encompasses knowledge of language to express that knowledge, in particular vocabulary. Both the quantity and quality of an individual's word representations increases through experience (Nagy, Herman, & Anderson, 1985; Richter, Isberner, Naumann, & Neeb, 2013; Verhoeven & van Leeuwe, 2008). The increase in vocabulary is particularly large in primary school, with estimates of learning 15 words a day (Hirsch, 2003). It is likely that many words are learned from texts, because texts are major sources of knowledge in schools. Conversely, the breadth and depth of an individual's vocabulary are important for learning from texts, because richer mental representations of the words foster stronger and broader activation of concepts that are associated in memory and, hence, contribute to inference making and knowledge construction (de Leeuw, Segers, & Verhoeven, 2014; C. Perfetti & Stafura, 2014; Swanborn & de Glopper, 1999).

Executive functions. Executive functions refer to a set of top-down mental processes that enable controlled goal-directed behavior, and are needed when it is not possible (or advisable) to rely on automatic processes (Diamond, 2013). Executive functions show a protracted development (Diamond, 2013; Huizinga, Dolan, & van der Molen, 2006), which may influence reading comprehension and learning from texts, particularly when strategic processes are involved. Furthermore, there is considerable evidence that individual differences in executive functions explain differences in reading comprehension (Borella, Carretti, & Pelegrina, 2010; Kieffer, Vukovic, & Berry, 2013; Locascio, Mahone, Eason, & Cutting, 2010; Sesma, Mahone, Levine, Eason, & Cutting, 2009) and learning in general (see J. R. Best, Miller, & Jones, 2009, for a review). Highly developed executive functions help to more efficiently distribute mental resources by flexibly focusing on relevant information, ignoring irrelevant information and by monitoring and changing information that enters working memory. Given that attention is a major component of comprehension and learning, developmental and individual differences in the ability to flexibly and effectively attend to different parts of texts can explain differences in learning from texts.

Text Characteristics

Even if individuals have highly developed skills and knowledge, learning from text could fail due to text factors. Texts need to be written in a clear, coherent way so that readers can extract the message that the author wants to transfer to the reader. In general, texts that stimulate active (causal) inferential processing provide the best learning results (Gilabert et al., 2005; Linderholm et al., 2000; McNamara et al., 1996; Vidal-Abarca, Martínez, & Gilabert, 2000). Expository texts are often more difficult to read than narrative texts because of their complex and diverse structures and because students usually have less experience with these texts (R. M. Best, Rowe, Ozuru, & McNamara, 2005; Lorch, 2015). However, cues such as headers may improve comprehension and learning by directing attention to relevant information and to the structure of the presented information (Lorch, 1993; Lorch & Lorch, 1996; Lorch, Lorch, & Klusewitz, 1995). Learning from texts is most optimal when the texts match the individual characteristics of the reader. Specifically, to stimulate active processing in the reader texts need to be of adequate difficulty, matching the readers' comprehension skills and background knowledge (Britton & Gülgöz, 1991; Linderholm et al., 2000; McNamara, 2001; McNamara et al., 1996; McNamara & Kintsch, 1996; O'Reilly & McNamara, 2007).

Improving Learning from Texts

Strategy training. Learning from texts can be improved by teaching how to effectively use reading and/or learning strategies. If individuals use ineffective, superficial strategies such as skimming (i.e., glancing through the text quickly), learning is not likely to occur. There are many interventions that teach students to use effective reading comprehension strategies (for overviews see: (Duke & Pearson, 2002; Gersten, Fuchs, Williams, & Baker, 2001; Graesser, McNamara, & VanLehn, 2005; McNamara, 2007; Meyer & Poon, 2001). However, the long-term and generalization effects of those interventions often are not established (e.g., Berkeley, Scruggs, & Mastropieri, 2009; Gajria, Jitendra, Sood, & Sacks, 2007; Gersten et al., 2001). In addition, the effectiveness of learning strategies should be determined, particularly with respect to the transfer of knowledge to different situations. Such investigations would help identify effective strategies that increase learning from texts. In the context of the current theoretical framework, instruction in strategies that contribute to the construction of a coherent and strongly (inter)connected knowledge representation are most likely to prove successful.

Activation of background knowledge. Learning from texts may also be improved by providing or activating additional background information. Meaningful learning involves two phases: Encoding and retrieval. Often, information is encoded in one context, and its relevance needs to be recognized later when the information needs to be reactivated and applied in a different context. Interventions or strategies aimed at constructing knowledge representations should target both the encoding and the retrieval phase. When learners lack the required background knowledge teachers may consider providing texts or other materials that provide background information (Lipson, 1982). Interventions that target the activation of background knowledge are effective in improving comprehension (Elbro & Buch-Iversen, 2013). Also, cues could be provided that activate existing knowledge and this facilitates transfer to new situations (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980). Supplying individuals with the learning materials in varied contexts could improve decontextualization and abstraction of information that needs to be learned, making it more likely that transfer of the information will occur to different contexts (Bolger et al., 2008; Chen & Mo, 2004). Other factors that improve transfer are surface similarity of the encoding and retrieval phase, instructions focused at comparing the current problem with previously acquired knowledge, and priming a transfer mind-set (Day & Goldstone, 2012). Teachers should be careful in determining whether students lack knowledge or are unable to retrieve knowledge because these situations require different solutions. A lack of knowledge requires supplying the information to the students, whereas the inability to retrieve information requires the use of cues to retrieve the knowledge. Furthermore, students may activate inaccurate background knowledge, which could seriously interfere with learning (Lipson, 1982). Teachers should make sure to refute these misconceptions and to explain the accurate information, for example by using refutation texts (Kendeou & O'Brien, 2014; Kendeou & van den Broek, 2007; Kendeou et al., 2014).

Concluding Remarks

In this chapter, we described learning from text, focusing both on the processes and the products of learning. An important distinction was made between learning from texts and comprehension of texts. Although comprehension is necessary for meaningful learning, it is not sufficient. Multiple encounters with the information in different texts and in different contexts and using learning strategies contribute to the gradual transition from text representations to knowledge representations. Knowledge representations differ from text representations in that they are more permanent and decontextualized. Nevertheless, text and knowledge representations influence each other in reciprocal ways -comprehension facilitates learning and knowledge facilitates comprehension- making it hard to disentangle the relations.

The research community will have to progress in two directions to gain a better understanding of learning from text. First, to fully understand the gradual transition from text representation to knowledge representation, researchers will be have to combine different measures to assess the processes that contribute to comprehension processes, learning processes, and long-term learning outcomes (knowledge representations) within a single study. Comprehension can be tested either during or directly after reading a text, with the text present. Learning outcomes however, should be tested with long-term measures because knowledge representations may change over time due to consolidation and forgetting. Consolidation is reflected in the ability to retrieve information after a delay but not immediately after the learning episode (Bauer, Evren, Starr, & Pathman, 2011). Memory may also decline after a delay, by processes of forgetting and interference. These changes in memory make immediate measures of knowledge representations unreliable predictors for future knowledge representations. Learning from text should therefore be assessed by combining short- and long-term measures.

Second, studies have to assess the extent to which learning leads to decontextualized knowledge. Whereas reading comprehension studies often assess how well information was comprehended within the context of the text, assessment of learning should also focus on how well the information can be applied to solve novel problems within a different context (Valencia & Pearson, 1987). Few studies have used questions that focus on application of information to novel situations. This is surprising, given that the aim of reading texts in educational settings is to extract knowledge that can be used in novel situations in the future. Asking the participant to apply the knowledge in novel situations, for example by having them analyze case studies, write argumentation papers, describe analogies, generate examples or solve problems, could inform about the extent to which the knowledge is decontextualized.

In addition, schools and teachers should become more aware that there are various levels of learning and that they should determine which level of learning they want their students to achieve (Bloom, 1956; Krathwohl, 2002). When the

goal is to teach reading comprehension, it may suffice to assess whether the information in the text can be summarized or whether the main points can be extracted. In contrast, when the goal is to attain high-quality knowledge that can be transferred readily, teachers may need to assess application of knowledge. Thus, different target levels of learning call for different types of assessment and teaching approaches.

In this chapter we have drawn on findings from the research literature on the comprehension of texts and extended those to the context of *learning* from texts. More insights into how information is processed and how these processes may lead to the desired learning products should be targeted in future research and, and this, we hope, will inform educators to provide optimal learning context for students.

CHAPTER

3

Learning From Texts: Activation of Information From Previous Texts During Reading

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Abstract

Learning often involves integration of information from multiple texts. The aim of the current study was to determine whether relevant information from previously read texts is spontaneously activated during reading, allowing for integration between texts (experiment 1 and 2), and whether this process is related to the representation of the texts (experiment 2). In both experiments, texts with inconsistent target sentences were preceded by texts that either did or did not contain explanations that resolved the inconsistencies. In experiment 1, the reading times of the target sentences introducing inconsistencies were faster if the preceding text contained an explanation for the inconsistency than if it did not. This result demonstrates that relevant information from a prior text is spontaneously activated when the target sentence is read. In experiment 2 free recall was used to gain insight into the representation after reading. The reading time results for experiment 2 replicated the reading time results for experiment 1. However, the effects on reading times did not translate to measurable differences in text representations after reading. This research extends our knowledge about the processes involved in multiple text comprehension: Prior text information is spontaneously activated during reading, thereby enabling integration between different texts.

Introduction

Learning from multiple texts is becoming increasingly important in our digitalized society. In addition to traditional paper texts, knowledge is now also delivered through websites, apps, e-mails and other new media. These different sources of information allow readers to learn about topics from multiple angles, providing texts that partially overlap and partially complement each other (Britt & Rouet, 2012; Britt et al., 2013; Goldman, 2004; Rouet & Britt, 2011). To accomplish complete understanding of a certain topic, readers must integrate information from multiple texts. It has been argued that making connections between texts is one of the most difficult reading skills (Pearson & Hamm, 2005; Sheehan et al., 2006). However, little is known about the reading processes involved when reading multiple texts. The aim of the current study is to determine if connections between texts are created spontaneously during reading and, if so, if they affect the memory representation of the texts after reading.

Intertextual Integration During Reading

Comprehension of multiple texts may involve processes that are similar to those involved in single text comprehension, including integration of new information with information stored in memory. Building on memory-based theories about single text comprehension (Albrecht & O'Brien, 1993; McKoon & Ratcliff, 1992; van den Broek, Risden, et al., 1996), it could be argued that information from prior texts becomes available passively without the control of the reader. Theories about single text comprehension suggest that prior information will be rapidly activated and entered into working memory through a process of resonance or spread of activation across semantic networks (Myers & O'Brien, 1998; O'Brien & Myers, 1999). This allows the construction of connections and inferences between different parts of the text and between the text and background memory (Kintsch, 1988; McNamara & Magliano, 2009; van den Broek, Risden, et al., 1996). Activation of prior information depends on featural overlap between current and prior information – including overlap of protagonist, action, or context – and results in faster processing of the new information (Dell, McKoon, & Ratcliff, 1983; Duffy & Rayner, 1990; O'Brien et al., 1986). For example, it has been demonstrated that it takes less time to resolve an anaphor that shares several characteristics with an antecedent than an anaphor that shares only a few characteristics with an antecedent (e.g. when the anaphor is a synonym of the antecedent) (Dell et al., 1983; McKoon & Ratcliff, 1980).

There might also be differences in the processing of single and multiple texts. For example, featural overlap across multiple texts may be reduced due to differences in superficial characteristics related to the context in which the information was read (e.g., when two texts are read in a different location, time, or modality) and the source of information (e.g., the person or organization providing the information). When featural overlap is low, prior text information may not be activated during reading a subsequent text, and connections between texts may not be created. The first experiment was designed to gain more insight into on-line processes during reading multiple texts. More specifically, we wanted to determine whether concurrent activation of information from multiple texts occurs during reading. Because concurrent activation is argued to be a precondition of integration within single texts (Kendeou & O'Brien, 2014), we anticipate that it will be important for integration across multiple texts.

Intertextual Integration in Memory Representations after Reading

With respect to the representation of text information in memory, comprehension of multiple texts is successful when readers construct a representation that integrates the most important information from different texts to create a coherent whole (Britt et al., 1999). Text representations can be visualized as networks with nodes representing concepts from the texts and background memory, and links representing connections between the concepts. A representation of multiple texts requires connections between information units from different parts of a single text (intratextual connections) and connections between information units from different texts (intertextual connections). During reading, each subsequent text may change, strengthen or add nodes and links to the existing memory representation. However, it does not necessarily follow that different texts are integrated into one shared memory representation.

There are several factors that influence whether multiple texts are integrated in memory. One important factor is conceptual consistency between the texts. If information from different texts is inconsistent, it is difficult to integrate the information into a single representational network. Readers could cope with this by tagging the inconsistent information to different sources in memory or by qualifying connections with labels such as 'is inconsistent with' (Britt et al., 1999).

Another factor that influences intertextual integration in memory is the context in which the texts are presented (e.g., the physical, temporal, and functional context) and the source of the information. The larger the distance between the contexts in which the texts are read, the more difficult it will be to integrate the information in memory because it may be less obvious that the texts are related. This may result in compartmentalization of the representation, showing mainly intratextual connections and fewer intertextual connections. Even when the distance in reading contexts is small, a perceptual or semantic boundary may be sufficient to elicit distinct reading processes that hinder intertextual integration. For example, research has shown that different processes occur at

the beginning and the end of a text (Gernsbacher, 1990). It has been argued that the beginning of a text functions as a foundation to which new information is mapped (Gernsbacher, 1990). With every new text, this process may start anew (Britt et al., 2013). Moreover, wrap-up effects have been perceived at constituent boundaries (Just, Carpenter, & Woolley, 1982), such as at the end of clauses (Aaronson & Scarborough, 1976), sentences (Rayner, Kambe, & Duffy, 2000), and arguably texts as well. These processes may contribute to compartmentalization of the representation of different texts, making it more difficult to create intertextual connections. The second experiment was designed to gain insight into how multiple text processes during reading relate to the resulting memory representation. Specifically, we wanted to know whether readers are more likely to include intertextual connections in memory in situations in which intertextual connections help to restore comprehension and whether the processing time of information during reading multiple texts is related to the prominence of that information in memory.

Experiment 1

The goal of the first experiment was to examine whether readers access information from a previously read text when it is relevant to understanding the text they are currently reading. To test this, we created a multiple text integration paradigm based on the contradiction paradigm (Albrecht & O'Brien, 1993). Using the contradiction paradigm, it has been demonstrated that information is processed more slowly when it is preceded by inconsistent information than when it is preceded by consistent information. This shows that prior information from the same text is activated during reading of subsequent sentences. In the multiple-text integration paradigm we also included consistent texts (Consistent condition) and texts with inconsistencies. The texts with inconsistencies were preceded by separate texts that either contained information that could be used to restore coherence in the subsequent text by explaining the inconsistency (Inconsistent-with-explanation condition), or by texts that contained neutral information that could *not* be used to restore coherence in the subsequent text (Inconsistent-without-explanation condition). If information from the first text is available during reading of the second text, then the activation of explanatory information should facilitate processing of the second text because the explanation restores coherence of the text. If the first text does not provide an explanation, coherence cannot be restored and processing will not be facilitated. Consider reading "*A rulver is brown. It is difficult to see in the white snow.*" The second sentence, in which the inconsistency unfolds, presumably requires a longer time to process compared to the same phrase in the Consistent condition, "*A rulver is white. It is difficult to see in the white snow.*", because the information is difficult to integrate with prior knowledge. However, coherence could be restored by activating information from a previous text that stated that "*In the winter, the rulver's fur changes to white.*" With this information you can infer that rulvers are brown in the summer and that they become white in the winter, which makes them difficult to see in the white snow. Reading times are expected to be faster in this case. If the previous text does not provide an explanation, then the inconsistency in the second text remains unresolved and reading times are not expected to speed up.

Method

Participants

Participants were 27 Leiden University undergraduates studying education sciences or psychology. Informed consent was obtained for all participants. All participants had good or corrected eyesight and lacked reading problems or learning disabilities. Students could submit to participate in the study by signing up at the Leiden University Research Participation system. Participation was rewarded with course credits. Participants' ages ranged between 18 and 32 with a mean of 19.2 years (2.3 *SD*). All participants were female except one.

Materials and design

Example materials are presented in Table 3.1. The texts described 30 topics in expository text format[1]. The texts were short in length (with an average number of 5.5 sentences) and described information about animals, persons, objects, countries, and events. Fictitious topics were used to equate prior knowledge, by replacing the names of real-world topics by fictitious ones (e.g., the text about the 'rulver' was based on the polar fox). For each topic there were three versions of the text/text pair, which were counterbalanced across subjects: Consistent texts; inconsistent texts in combination with preceding texts containing an explanation; and inconsistent texts in combination with preceding texts omitting an explanation.

Thus, the Inconsistent-with-explanation condition consisted of two texts. The first text contained an explanation for an inconsistent target sentence in the second text. The target sentence in the second text was always the penultimate sentence of the text, and the information in this sentence was inconsistent with the information that preceded the target sentence in the same text.

The Inconsistent-without-explanation condition also consisted of two texts, but in this condition the first text did not contain an explanation for the inconsistent target sentence in the second text. Instead, the first text described additional information about the topic.

The Consistent condition consisted of only one text. This text was similar to the second text in the Inconsistent conditions, with the exception that the information that preceded the target sentence was consistent with the target sentence. The target sentences were exactly the same in the three versions of each topic, but differed between different topics. The target sentences had an average length of 61 (SD = 19) characters.

Table 3.1 *Example Text Materials Showing Three Versions of the Topic 'The Rulver'.*

	Inconsistent-with-explanation	Inconsistent-without-explanation	Consistent
Text 1	The rulver is an animal that lives on heathland. It has a pretty brown fur for which hunters can get a lot of money. But in the winter they stop hunting the rulver. *In the winter, the color of the rulver's fur changes to white.*	The rulver is an animal that lives on heathland. It has a pretty brown fur for which hunters can get a lot of money. But in the winter they stop hunting the rulver. *The hunters have to get their money from another source to be able to get enough income.*	-
Text 2	The rulver's fur has a beautiful brown color and is therefore very popular. Many hunters search for rulvers. But in the winter they stop hunting the rulver. It is not easy to spot the rulver in the *white* snow. The hunters have to wait until the snow disappears.	The rulver's fur has a beautiful brown color and is therefore very popular. Many hunters search for rulvers. But in the winter they stop hunting the rulver. It is not easy to spot the rulver in the *white* snow. The hunters have to wait until the snow disappears.	The rulver's fur has a beautiful white color and is therefore very popular. Many hunters search for rulvers. But in the winter they stop hunting the rulver. It is not easy to spot the rulver in the white snow. The hunters have to wait until the snow disappears.

Note. The differences between first texts in the Inconsistent-with-explanation and Inconsistent-without-explanation condition are italicized. The underlined word is what makes the underlined target sentence inconsistent (in the Inconsistent-with-explanation and Inconsistent-without-explanation conditions) or consistent (in the Consistent condition). These sample texts are translated from Dutch.

Procedure

Each testing session lasted about an hour. Participants first received verbal instructions about the procedure of the experiment on the computer. They were told that they were going to read texts sentence-by-sentence and they were asked to read these texts for comprehension and to answer questions about these texts. The questions were included to determine whether the participants were paying attention.

After the verbal instructions, participants were asked to read the same instructions on the screen, and they performed one practice trial. The experimenter gave feedback during the practice trial if necessary. If participants demonstrated comprehension of the task during the practice trial, they were instructed to continue through the remainder of the experiment individually and feedback was no longer provided.

Before each text was presented, “NEXT TEXT” was presented in the center of the display screen to indicate the beginning of a new text. The next screen showed a fixation cross in the center of the screen that was presented for a variable interval of between 500 and 2500ms. Sentences were presented one by one. Participants were instructed to read at their own pace. They could progress to the next sentence by pressing the space bar. To prohibit readers from skipping a sentence by accidentally double-hitting the space bar, the program did not respond to a press if it occurred within 500ms of the previous press. Also, if readers took longer than 10.000ms to read a sentence the program automatically continued to the next sentence. After reading each text, participants were presented with a question about a section of the text; the question was the same in all conditions. The questions could be answered with yes or no. The participants were instructed to keep their thumbs on the space bar, and their index fingers on the “yes” and “no” keys at all times (the “S” and “L” keys on the keyboard). They did not receive feedback about the accuracy of their answers.

Recording Data

Reading times between onset of presentation of each sentence and the press of the space bar were recorded. The analyses involved the reading times of the target sentences and the sentences that followed the target sentences (the latter to investigate spillover effects).

Results

Before analyzing the data, the responses to the questions and the reading times were inspected. On average, participants answered 89% of the questions correctly, which shows they were paying attention to the texts. Reading times that deviated over 2.5 standard deviations on both the subject and item means were removed, assuming these were situations in which participants were not following the task instructions (for example because they were distracted). Less than 1% of the data were removed using this criterion. The descriptives are displayed in Table 3.2

Table 3.2 *Mean Reading Times (in ms) and Standard Deviations (in parentheses) for the Target Sentences for each Condition in Experiment 1*

Condition	Mean (SD)
Inconsistent-with-explanation	2685.23 (1252.34)
Inconsistent-without-explanation	2904.04 (1388.90)
Consistent	2618.84 (1321.11)

As the distribution of the reading times was skewed to the right, the reading times were transformed by taking the natural log of each score to make the distribution more symmetrical (Richter, 2006). Because of the multilevel structure of the data (Richter, 2006), reading times were analyzed using hierarchical linear models using R-statistics software and the LmerTest package. Item-level reading speeds were clusters at Level 1 and subjects and items were clusters at Level 2, with the items nested within conditions. Subjects and items were treated as random effects whereas the conditions were treated as a fixed factor with three levels[2]. Degrees of freedom are estimated with Satterthwaite's approximation method (Kuznetsova, Brockhoff, & Christensen, 2015; SAS Technical Report R-101, 1978; Satterthwaite, 1941). Effects will be classified as significant when $p <.05$. Restricted maximum likelihood was used to fit the models. First a baseline model was fit with random intercepts for subjects and items, and this model was compared to a model that also included the conditions.

The results show that adding the conditions made a significant contribution to the model compared to a baseline model ($\chi^2(2) = 12.59$, $p = .002$). In agreement with previous research, the mean reading time of the target sentence in the Inconsistent-without-explanation condition was significantly slower than the mean reading time of the target sentence in the Consistent condition ($b = .10$, $SE = .03$, $t(748) = 3.46$, $p < .001$). In addition, the mean reading time of the target sentence in the Inconsistent-with-explanation condition was significantly faster than the mean reading time of the target sentence in the Inconsistent-without-explanation condition ($b = .07$, $SE = .03$, $t(743)= 2.43$, $p = .016$). There were no significant differences in average reading times of the target sentence in the Inconsistent-with-explanation and the Consistent condition ($b = .03$, $SE = .03$, $t(748) = 1.07$, $p = .29$). The sentence that followed the target sentence was also analyzed, but the conditions did not significantly contribute to the model compared to a baseline model, indicating that there were no spill-over effects ($\chi^2(2) = 2.38$, $p = .304$).

Summary of Results Experiment 1

The results of experiment 1 demonstrate that prior texts with explanations facilitated processing of inconsistent information in the subsequent texts. This shows that information from prior texts is activated during reading. The reading speed in the Inconsistent-with-explanation condition was more similar to the Consistent condition than the Inconsistent-without-explanation condition, suggesting that activation of the information from prior texts helped to restore coherence. The results are in accordance with the notion that memory-based processes extend beyond textual boundaries: The inconsistent information in the second text seems to have passively activated the explanation from the first text. This experiment is the first to show that intertextual integration (i.e. activation of prior texts) takes place during reading.

Experiment 2

Intertextual Integration and Prominence of Information in Memory

In the single text research it has been repeatedly demonstrated that reading processes influence the memory representation of the texts (van den Broek, Risden, et al., 1996). One purpose of experiment 2 was therefore to determine whether intertextual connections are included in the memory representation of the texts. This was done by asking readers to recall what they remembered from the texts after having read several other texts in between. Two aspects of the memory representation were investigated: 1) Intertextual integration, and 2) Inclusion of different types of information.

Experiment 1 provided evidence for the activation of prior text information during reading a second text. This means that information from two texts was active at the same time and this is a necessary precondition for intertextual integration (Kendeou & O'Brien, 2014; Kendeou et al., 2014; van den Broek & Kendeou, 2008). If co-activation of the two texts indeed led to intertextual integration during reading, it is likely that these connections will also be included in the memory representation. Intertextual integration in memory was assessed by determining whether readers report unique information from both texts in one recall session.

Memory is often better for inconsistent information because it is more salient (e.g. Rojahn & Pettigrew, 1992; Sakamoto & Love, 2004; Stangor & McMillan, 1992). It could be argued that the inconsistency is more salient in the Inconsistent-without-explanation condition than in the Inconsistent-with-explanation, because in this condition it cannot be resolved with information from the text. Therefore, it can be expected that the inconsistency is more prominent in memory. Furthermore, previous research has shown that information that is activated more often or longer during reading is more prominent in the memory representation (van den Broek, Risden, et al., 1996). This would also lead to the expectation that the inconsistency is more prominent in the memory representation in the Inconsistent-without-explanation condition than in the Inconsistent-with-explanation condition, because the target sentence was read slower. Alternatively, because readers strive for coherence, readers may choose to ignore information that does not fit the representation (Maier & Richter, 2013; Stadtler et al., 2012). The inconsistent information may therefore be less prominent in memory in the Inconsistent-without-explanation condition than in the Inconsistent-with-explanation condition. To examine the prominence of the inconsistency in the memory representation, we determined whether readers recalled the target and/or context information, which both make up the inconsistency.

Elaboration

To ensure that observed differences between conditions are based on differences in semantic representation in memory rather than in superficial memory traces, recall was administered after a delay. Such a delay carries the potential risk that information would decay from the memory representation, thereby decreasing the chance of observing differences in representation between the conditions. Therefore, in experiment 2 the central information in the initial texts was expanded by elaborating on the explanation (in the Inconsistent-with-explanation condition) and on neutral information (in the Inconsistent-without-explanation condition, to match the text length). Previous research has shown that elaborated information results in richer memory representations than unelaborated information (Bradshaw & Anderson, 1982) and this improves activation of elaborated information at a later moment in time because of the multiple retrieval routes. To allow for comparisons with experiment 1, and to leave open the possibility that elaboration interacts with the experimental conditions, elaboration was included as an additional factor: Elaboration and explanation were combined in a 2x2 design with four inconsistent conditions formed by crossing (1) the presence vs. absence of an explanation, and (2) the presence vs. absence of elaboration).

Method

Participants

Participants were 32 Leiden University undergraduates studying education sciences or psychology. Informed consent was obtained for all participants. All participants had good or corrected eyesight and lacked reading problems or learning disabilities. Students could submit to participate in the study by signing up at the Leiden University Research Participation system. Participation was rewarded with course credits or gift cards (whatever they preferred). Participants' ages ranged between 18 and 28 with a mean of 20.7 years (2.2 *SD*). Of all participants, 26 were female and 6 were male.

Materials and Design

The design and materials of Experiment 2 were based on Experiment 1 but slight changes were made to fit the purposes of experiment 2. First, to examine the effects of elaboration on reading times and recall, experiment 2 included two additional inconsistent conditions in which the first texts were extended with three to five sentences. In the elaborated Inconsistent-with-explanation condition, the additional sentences expanded the section of the context text that provided the explanation for the target sentence. For example, in the text about the rulver the explanation is elaborated by describing the mechanisms (sunlight, melanin) that cause the change in color of its fur. In the Inconsistent-without-explanation condition, the added information was irrelevant to the target sentence. The Consistent condition was not included in experiment 2. All other text characteristics were kept as similar as possible. Taken together, experiment 2 included four inconsistent conditions formed by crossing two factors: (1) presence vs. absence of an explanation, and (2) presence vs. absence of elaboration. As in experiment 1, the reading times of the target sentences and the sentences that followed the target sentences were recorded.

Second, participants in experiment 2 were asked to recall what they remembered from each text after reading four text pairs. Participants were asked to report the most important information they remembered from the text. The questions always followed the same format: “What do you remember from the text about topic X?”, where X represents the main topic of the two texts (often the fictitious animal/object/person, for example the ‘rulver’). Participants were asked to type their answers on the computer. Next, a question was asked about the target sentence. For example, the target sentence “*It is difficult to see in the white snow*” would be queried by “*Why is it difficult to see the rulver in the white snow?*”. The right answer to this question involves the explanation (“*its fur turns white in the winter*”). The purpose of this question was to check whether the manipulation of elaboration on the explanation was effective. If elaboration prevents the decay of important information from memory, than recall of the explanation should be higher in the elaborated conditions compared to the unelaborated conditions.

Procedure

The procedure was the same as in experiment 1 with the exceptions that participants had to recall information from the texts and answer questions about the texts after reading four text pairs. In addition, the text-based questions from experiment 1 were omitted to save time. The memory questions were presented in the same order as the participants read the texts. Due to the addition of the memory questions, the testing session lasted on average half an hour longer than in experiment 1. Four participants did not complete the entire test because of time limitations.

Scoring Free Recall

All variables were scored dichotomously (yes/no). To assess integration we used a liberal criterion: Integration was scored positively when participants mentioned unique information from both the first and the subsequent text. Integration was scored negatively when participants reported information from only the first or the second text, or from neither text. To assess recall of the inconsistency, three variables were created. One variable indicated whether readers mentioned information from the target sentence, and one indicated whether readers mentioned the context information with which the target sentence is inconsistent. The scoring was done by the first author and a trained research assistant. The inter-rater reliability was high ($.85 \leq \kappa \leq .95$). Disagreements were resolved by discussions.

Results

Reading Times

The same selection criterion as in experiment 1 was used to remove outliers (less than 1% of the data were deleted). The descriptives are displayed in Table 3.3.

Table 3.3 *Mean Reading Times (in ms) and Standard Deviations (in parentheses) for the Target Sentences for each Condition in Experiment 2*

	With-elaboration	Without-elaboration
Inconsistent-with-explanation	2104.93 (1127.05)	2130.07 (1046.38)
Inconsistent-without-explanation	2313.91 (1180.54)	2394.24 (1347.69)

The data were analyzed analogously to experiment 1. The results show that adding the two factors Explanation (with or without) and Elaboration (with or without) together made a significant contribution to the model ($\chi^2(3) = 16.85$, $p < .001$). However, only the factor of Explanation made a significant contribution to the model ($b = .09$, $SE = .03$, $t(1008) = -2.90$, $p = .004$). The mean reading time of the target sentence in the Inconsistent-with-explanation condition was significantly faster than the Inconsistent-without-explanation condition, replicating the results of experiment 1. Elaboration did not make a significant contribution ($b = .02$, $SE = .03$, $t(1008) = .67$, $p = .501$) nor did the interaction between Explanation and Elaboration ($b = -.01$, $SE = .05$, $t(1008) = -.13$, $p = .898$).

To determine spill-over effects, the same analysis was repeated with the reading times on the sentence that followed the target sentence as dependent measure. The results were analogous to the results on the target sentence:

Inconsistent-with-explanation texts were read faster than Inconsistent-without-explanation texts (b = .09, SE = .03, t(1004) = 3.22, p = .001). The other effects were not significant.

Free Recall

Free recall was analyzed using the same procedures as in the previous analyses with the exception that now *logistic* hierarchical linear models were applied with Maximum Likelihood to fit the models. Table 3.4 provides an overview of the mean proportions of the recall measures for each condition.

For integration, neither of the two factors contributed to the model compared to the baseline model ($\chi^2(3)$ = 4.45, p = .22), suggesting that Explanation and Elaboration did not have an effect on general inter-textual integration of the two texts.

For recall of the inconsistency (i.e. target and context information), the result show that memory was the same regardless of the condition the texts were presented in. More specifically, recall of the context information was similar in all conditions ($\chi^2(3)$ = 3.69, p = .30) and recall of the target information as well ($\chi^2(3)$ = 3.79, p = .28).

Table 3.4 *Proportion of Integration in Recall Reports and Recall of Context and Target Information for Each Condition in Experiment 2.*

Explanation	Elaboration	Mean Integration (SD)	Mean Target (SD)	Mean Context (SD)
Yes	Yes	.82 (.39)	.43 (.50)	.57 (.50)
Yes	No	.75 (.43)	.47 (.50)	.62 (.49)
No	Yes	.79 (.40)	.43 (.50)	.59 (.49)
No	No	.78 (.42)	.49 (.50)	.54 (.50)

Manipulation Check

With regard to the results on the specific question that cued the explanation, the model with the factor Elaboration included had a better fit compared to the baseline model ($\chi^2(1)$ = 12.69, p < .001). Recall of the explanation was higher in the elaborated condition (M = .75, SD = .43) compared to the unelaborated condition (M = .63, SD = .48), ($b_{elaboration}$ = .75, SE = .21, z = 3.56, p < .001). This finding shows that the manipulation of elaboration was successful.

Summary of Results Experiment 2

The results of experiment 2 demonstrate that prior texts with explanations facilitated processing of inconsistent information in the subsequent texts. This replicates experiment 1 and provides converging evidence that information from prior texts is activated during reading and that activation of prior text information facilitates the reading process (as reflected by faster reading times). Experiment 2 did not find evidence for a relation between the reading processes and the resulting memory representation. Differences in the activation of information during reading were not reflected in differences in intertextual integration and prominence of information in memory (i.e. the inconsistency).

Discussion

Learning from texts often involves the integration of information from multiple texts. Intertextual integration requires the activation of information from a prior text during reading of a subsequent text. The goal of the present study was to determine whether information from a previously read text is spontaneously activated during reading of a novel text and whether this affects the representation of the texts. The results of the first experiment show that the processing of inconsistent information was faster when a prior text contained an explanation for the inconsistency. In the second experiment, memory of the texts after a delay was assessed in addition to the reading processes. The reading processes showed a similar pattern as in experiment 1. Two aspects of memory were investigated: Intertextual connections and prominence of information (i.e. the inconsistency) in memory. Results indicate that the processing differences did not affect the presence of intertextual connections that were encoded in memory, nor did it influence the prominence of the inconsistent information in memory.

Intertextual Integration During Reading

The results of both experiments show that prior texts with explanations speed up processing of inconsistencies in a subsequent text. This suggests that activation of the explanations from previously read texts facilitated the resolution of the inconsistent information during reading, resulting in more coherence and, consequently, in faster reading. Results from prior research have demonstrated facilitative effects of background knowledge on text comprehension (Elbro & Buch-Iversen, 2013; McNamara et al., 1996; McNamara & Kintsch, 1996). The current study extends these findings by showing that recently read texts about the same topic also facilitate comprehension of subsequent texts.

Because participants in the current study did not receive instructions to integrate information across texts, it is likely that the explanations were activated spontaneously. This is in line with memory-based theories of information processing developed in the context of single-text processing (Albrecht & O'Brien, 1993; McKoon & Ratcliff, 1992; van den Broek, Risden, et al., 1996). As in the context of single texts, spontaneous activation of prior text information may have been triggered by featural overlap between the preceding and subsequent text (Albrecht & Myers, 1998; Albrecht & O'Brien, 1993; O'Brien & Albrecht, 1991), for example because they were about the same topic. This featural overlap may have led to co-activation of the prior and current text information and, consequently, to intertextual integration (Kendeou & O'Brien, 2014).

Activation of prior information has been shown to spread from recently read and more central information in memory to more distant and less central information in a backward parallel search (O'Brien, 1987; O'Brien et al., 1990). In the condition with explanation, the explanation may have been quickly activated during a backward parallel search because the previous text was read recently and had a high featural overlap with the current text. In the conditions without explanation, there was no explanation to be activated during a backward parallel search. The failure of the activation process to locate any connections that might resolve the inconsistency may have led to an extended search process that took more time, explaining the relatively long reading times on target sentences in the conditions without explanations.

Although not central to the purposes of the study, it is interesting to note that the results of experiment 2 show that elaboration of information in the first text did not influence the processing speed of the target information in the second text. This is not surprising, given that the activation of prior text information was already optimal in the condition with explanations and without elaboration (i.e. the processing speed was the same as when reading consistent information). It is possible, however, that elaboration does facilitate activation of prior text information in more challenging situations. Additional research is necessary to draw reliable conclusions about the influence of elaboration on activation of prior text information.

Intertextual Integration in Memory Representations after Reading

The second experiment was designed to investigate the relation between intertextual reading processes and the resulting memory representation. Free recall was used to assess memory for intertextual connections and prominence of the inconsistency. There were no significant differences between the conditions on either measure. This seems inconsistent with previous findings that reading processes correlate with memory (Tzeng, van den Broek, Kendeou, & Lee, 2005; van den Broek, Risden, et al., 1996). One possible explanation for the lack of an effect on these measures is that relatively small differences in processing during reading (as between the conditions in our studies) are not sufficient to produce more permanent effects on memory. It is also possible, however, that there *were* effects on memory but that a recall task is not able to capture these effects. For example, with regard to intertextual connections in memory, a dichotomous recall score such as the one used in the current experiment may not be sensitive enough to reveal differences in intertextual integration between the conditions. It may be that the differences in reading times reflect differences in the amount or intensity of processing and this is fact *did* translate into more or better intertextual connections in memory. A recall score that only distinguishes between the presence or absence of an intertextual connection might not be able to capture these differences. Another limitation of the recall task is that it requires respondents to make a decision about what to report and this may not accurately reflect the actual memory representation (McKoon & Ratcliff, 2015). It is possible for example, that students decided to leave out inconsistent information in trials where they did not have explanations for the inconsistencies to make their reports more coherent. This leads to more equal recall scores between the conditions even when memory for the inconsistency is higher in the condition without explanations. Other measures, such as priming, might be more effective in demonstrating effects of reading processes on memory.

Elaboration also did not affect any of the memory measures. However, it is possible that elaboration does affect the memory measures in more challenging situations. For example, when the distance between the first and the second text is larger the explanation may be forgotten, making it impossible to activate the information during a subsequent text. Elaboration may prevent this from happening.

Facilitating Intertextual Integration

The multiple text integration paradigm has shown to be useful in investigating multiple text comprehension processes Future studies can use this paradigm to investigate factors that facilitate or decrease intertextual integration in more challenging situations. A reasonable first step would be to increase the textual or physical distance between the texts to determine which factors decrease intertextual integration in more difficult situations. In addition, as with integration within a single text, intertextual integration may be affected by text factors such as featural overlap and strategies, and individual differences such as working memory, background knowledge etc. Finally, to obtain a better indication of the characteristics of the memory representation, different measures could be used, including more implicit measures such as priming, which minimize post-reading strategic processes (McKoon & Ratcliff, 2015).

In conclusion, it is common to encounter different treatments of the same topics in different sources. To form an integrated perspective on a complex topic, readers must (at least implicitly) recognize when something they are currently reading overlaps with knowledge they have gained from another source. Such recognition is the first step to integrating related information from multiple sources. The multiple text integration paradigm introduced in this study is a first step towards understanding the processes underlying the integration of information across multiple sources.

CHAPTER

4

Children's Integration of Information Across Texts: Reading Processes and Knowledge Representations

Under revision

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Abstract

Constructing a knowledge representation from multiple texts requires the integration of information across texts. The aim of the current study was to determine whether children are able to integrate information across texts during reading and whether information from different texts is integrated in their knowledge representation. A sample of 105 children in Grade 4 and 6 participated in the experiment. The multiple-text integration paradigm was used to study integration processes across texts during reading. Recall and (application) questions were used to analyze integration of information from different texts in the resulting knowledge representations. Individual differences in reading comprehension ability and working memory were also taken into account. The results indicate that children in both grades integrate information across texts during reading and that they integrate information across texts in their knowledge representations. Reading comprehension ability and working memory were unrelated to the process of integrating information across texts and the integration of information across texts in knowledge representations. The current study extends previous research by showing that already in fourth grade, children spontaneously integrate information across multiple texts during reading. Results will be discussed in relation to the different mechanisms that may be involved in integration of information across texts.

Introduction

Textbooks are one of the most important sources of information in education. However, due to the growing quantity and availability of information on the Internet, learning and integrating information across *multiple* texts has become more and more common. This development poses challenges on learning that were previously restricted to expert readers only (Goldman, 2015). These challenges need to be taken into account when designing school curricula, teacher instruction, and student assessment. Therefore, it is vital to improve our understanding of the skills and processes that are involved when constructing a knowledge representation from multiple texts. The aim of the current study was to determine whether children in primary school can learn from multiple texts and if so, whether learning is influenced by individual and developmental differences in reading comprehension ability and working memory.

Integration Processes and Integration in Memory

Learning is a broad concept that can refer to a variety of processes (Alexander, Schallert, & Hare, 1991; Beker, Jolles, & van den Broek, in press; Shuell, 1986). In the current article this focus is on one aspect of learning from multiple texts: The integration of information across texts. The integration process roughly consists of two phases: A) the process of integrating information across texts during reading B) integrating text information in memory (including relations across texts). Both of these aspects are important for achieving the educational standards that are relevant for learning from multiple texts in education (Common Core State Standards, 2010; OECD, 2015).

Learning from multiple texts starts with processing a single text. During reading, each piece of information that is being processed activates associated information in memory, including previous parts of the same text and background knowledge (Albrecht & O'Brien, 1993; McKoon & Ratcliff, 1992; van den Broek, Risden, et al., 1996). When reading multiple texts about the same topic, information from an earlier text can also be activated when reading a later text (Beker, Jolles, Lorch, & van den Broek, 2016; Britt & Rouet, 2012; C. A. Perfetti et al., 1999), leading to co-activation of information from the two texts (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; Kintsch, 1988; McRae & Jones, 2013; van den Broek, Risden, et al., 1996). As a result, a connection can be established between the co-activated information elements from the two texts. This connection can be associative or more meaningful, for example, causal. According to the Landscape Model, two factors determine whether information and relations are integrated in memory: The amount and the frequency of (co-)activation of information during reading (van den Broek, Risden, et al., 1996). A third factor that may affect incorporation of information in memory is whether (similar) information is processed in different contexts, which may lead to an enriched knowledge representation (Beker et al., in press). Given this hypothesized correspondence between integration processes and integration of information in memory, one would expect that a failure to integrate information in memory can be traced back to problems with integration processes during reading. This why it is important to study both the integration process and the resulting knowledge representation. In the next section we provide a brief review about previous efforts to investigate integration processes and integrated knowledge representations in children.

Integration of Text Information

There are three lines of research that focus on integration using texts. For each line of research the most important findings with regard the process of integration across texts and the resulting knowledge representation will be summarized.

Integration Within Single Texts

One line of research focuses on integration of information within single texts. A number of studies measured integration after reading by asking questions that require integration. These studies showed that children are able to integrate information in a single text (Cain & Oakhill, 1999; Oakhill, 1982, 1984) and make connections between text information and background knowledge, at least when explicitly prompted (Barnes, Dennis, & Haefele-Kalvaitis, 1996; Cain, Oakhill, Barnes, & Bryant, 2001). Other studies have demonstrated that children are able to integrate information spontaneously *during reading* (Casteel, 1993; Coté, Goldman, & Saul, 1998; Danner & Mathews, 1980; Lynch & van den Broek, 2007; McMaster et al., 2012). However, it is evident that children sometimes struggle with tasks that require integration of information, such as detecting inconsistencies (Markman, 1977, 1979; Vosniadou, Pearson, & Rogers, 1988). The question is whether these findings apply to integration processes between *multiple* texts as well. Some inherent properties of multiple texts could make integration between multiple texts more challenging. For example, the information is usually separated over a larger distance (Beker et al., 2016), one text can be inconsistent with another text (Stadtler & Bromme, 2014), and overlap between the texts may not be recognized (Kurby et al., 2005).

Integration Across Multiple Texts

A second line of research focuses directly on integration of information from multiple texts. This field has only recently started to emerge, so there are only a few studies that measured integration during reading and its relation with the resulting knowledge representation (e.g. Cerdán & Vidal-Abarca, 2008; D. K. Hartman, 1995; Kurby et al., 2005; Strømsø, Bråten, & Samuelstuen, 2003). Overall, the results from these studies indicate that advanced readers integrate information across texts during reading and incorporate connections across texts in memory. There are only a few studies involving children. In one study children aged 11 to 13 were asked to think-aloud while reading two conflicting historical texts (Wolfe & Goldman, 2005). These children were also asked to answer questions that involved several aspects of learning after reading was finished (i.e. integration, complex reasoning, detecting similarities and differences). The results showed that children integrated multiple texts during reading and that this process was positively related to learning (Wolfe & Goldman, 2005). However there also are indications that developing readers struggle with integration of information across texts (Pearson & Hamm, 2005; Sheehan et al., 2006). For example, in a large reading comprehension assessment, sixth graders particularly struggled with tasks that required integration of multiple texts (Sabatini et al., 2014). Furthermore, one study showed that high school students tend to prefer one source and ignore others in building a representation from multiple texts (Wineburg, 1991). Whether younger children integrate multiple texts spontaneously during reading is largely unexplored, even though children are supposed to master these skills already in primary school, for example in writing or presentation tasks (Common Core State Standards, 2010).

Integration Across Multiple Auditorily Presented Texts

A third line of research concerns integration across texts by very young children using auditorily presented texts (Bauer et al., 2012; Bauer & San Souci, 2010; Bauer et al., 2015). Bauer and colleagues had children aged 4 to 6 listen to story pairs that each included one stem fact (e.g. "groups of dolphins are called pods", "dolphins communicate by clicking and squeaking"). After a short time interval the children were asked questions that required them to integrate the stem facts after processing the materials (e.g. "how does a pod talk?"). The results showed that 4-6 year old children were able to integrate information across auditorily presented texts. It is not clear whether these findings generalize to reading situations. Furthermore, the way children respond to prompts *after* processing does not always reflect what happens spontaneously *during* processing (Rapp, van den Broek, McMaster, Kendeou, & Espin, 2007), so prior findings regarding integration across auditorily presented texts after processing may not generalize to spontaneous integration during reading.

The Current Study

Based on these three lines of research it can be concluded that connecting information across texts is an important skill that needs to be mastered by children in primary school, but that there are indications that children may struggle with this skill. We introduce a controlled way to investigate the spontaneous integration processes in young readers that can shed light on factors that facilitate or hinder integration across multiple texts. The aim of the current study was to determine: 1) whether children spontaneously integrate information across texts during reading and 2) whether they incorporate intertextual connections (i.e. connections linking different texts) in memory. In order to answer these questions the multiple-text integration paradigm was used (Beker et al., 2016). In this paradigm the second text of a text pair contains an internal inconsistency. There are two conditions. In the first condition this inconsistency can be resolved by activating an explanation from the first text. In the second condition the inconsistency cannot be resolved by activating information from the first text. The only difference between the conditions therefore, is whether the first text provides an explanation for the second text or not, so any difference in the processing of the second text can only be attributed to activation of information (i.e. the explanation) from the first text. Previous research in adults has demonstrated that the inconsistent target sentence in the second text is processed faster in the condition with explanations than in the condition without explanations (Beker et al., 2016). This was ascribed to activation of information from the first text during reading of the second text, leading to co-activation of information from both texts. Several theoretical models state that co-activation of information leads to integration by forming a connection between the pieces of information that are co-active (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; Kintsch, 1988; McRae & Jones, 2013; van den Broek, Risden, et al., 1996). The present study examined whether children also process the inconsistent target sentence faster in the condition with explanations than in the condition without explanations, indicating that they spontaneously activate information from a previous text while reading a subsequent text. This is a prerequisite for integration of information across texts. As this study is the first to investigate implicit, spontaneous integration processes across different texts, we purposely kept the distance between consecutive texts small. By providing optimal conditions for integrating information across texts we establish a baseline that allows for comparisons to situations in which integrating information across different texts becomes more challenging.

In order to examine whether children incorporate intertextual connections in the knowledge representation we asked children to recall the texts. Recall can be useful to gain insight into text representations built from multiple texts (Britt & Sommer, 2004). Children were asked to report everything they remembered from the text without interference of the experimenter. We used a general measure of the knowledge representation because we were interested in spontaneous integration of information across texts and we therefore did not want to prompt deliberate integration across texts. By identifying the source of each information unit we determined how integrated information from multiple texts was in the knowledge representation: The number of switches *between* the texts was taken as a measure of integration. It was expected that if children demonstrate activation of prior text information during reading a subsequent text (as indicated by a difference in reading times between the condition with and without explanation), this should be reflected in the knowledge representation, because co-activation of prior and current text information may lead to constructing or strengthening a connection between the two co-activated elements (van den Broek, Risden, et al., 1996). In analyzing the recalls, the focus was on indications of integration, but because more integration may also have a positive effect on overall memory for the texts, a measure of total recall was also included.

Individual and Developmental Differences

Single-text processing studies have demonstrated that integrative processes are more difficult for children with poor reading comprehension skills, and for children with low working-memory abilities (Cain & Oakhill, 2007; Garner, 1981; Hacker, 1997; Helder, Van Leijenhorst, & van den Broek, 2016; Long, Oppy, & Seely, 1994, 1997; McMaster et al., 2012; Oakhill, 1982; Oakhill & Yuill, 1986; Oakhill, Yuill, & Parkin, 1988; van der Schoot et al., 2012). Measures of reading comprehension ability and working memory were included in the current study to determine whether they also interact with integration across multiple texts during reading. If reading comprehension ability and working memory positively affect integration across texts, then the effects of conditions (with and without explanations) would more strongly affect children with good reading comprehension skills and good working memory skills than children with poor reading comprehension skills and poor working memory skills on both the reading time measures and the measure of intertextual connections in memory. In addition, reading comprehension ability and working memory would also have a main effect on encoding of intertextual connections in memory. Although not of primary interest, there may also be main effects of reading comprehension ability and working memory on reading times. Faster reading may indicate more automatic decoding processes, leaving more working memory resources for reading comprehension processes (C. A. Perfetti, 1985), and possibly integration processes.

In the current study we included children in elementary school from grade 4 because they master the basic reading skills and because at this age children are expected to integrate information across texts, as prescribed by the national educational standards (Expertisecentrum Nederlands [Expertise Centre Netherlands], 2010). Many skills related to reading comprehension and memory formation continue to develop from childhood into adulthood (Kendeou, van den Broek, White, & Lynch, 2009; Oakhill & Cain, 2012; van den Broek, 1997). Therefore, we also included children from grade 6 to determine whether there are grade-related differences between grade 4 and 6 in the ability to integrate information across different texts. Based on previous studies we expected main effects of grade on reading times (Fuchs & Fuchs, 1993) and integration (Bauer & San Souci, 2010). In addition, we expected that the effects of the conditions with and without explanations more strongly affected in grade 6 than children in grade 4 on the reading times measures, which would reflect grade-related differences in integration during reading.

Method

Participants

The research sample consisted of 105 children from Grade 4 (N = 54 with 30 girls and 24 boys, Mean age = 9.9, SD = 0.4) and Grade 6 (N=51 with 30 girls and 21 boys, Mean age = 11.9, SD = 0.4) from four Dutch primary schools. Informed consent was obtained from the parents. Only children with good or corrected eyesight, a lack of developmental and reading disorders, were included in the experiment. Participation was rewarded with a small gift.

Materials and Design

Text materials. We created a child-friendly version of the multiple-text integration paradigm (Beker et al., 2016). Children read expository[1] text pairs, in which the second text contained an internal inconsistency, and the first text either contained or did not contain an explanation, that either could or could not help resolve the inconsistency (the Inconsistent-with-explanation and Inconsistent-without-explanation condition respectively). The texts used in prior research were adapted to fit the reading level of children in Grade 4 and 6. To check whether the difficulty level of the adapted texts was appropriate for children in Grade 4 and 6, a reading index was used that provides an indication of the difficulty of the texts based on a variety of text characteristics, namely, the (Dutch) Cito reading index for primary education, or P-CLIB (Evers, 2008; Staphorsius, Verhelst, & Kleintjes, 1996). The average reading index score of the adapted texts indicated that the texts were appropriate for children in Grade 4 and 6. In a pilot study a

[1] Expository texts were used because it is common to use this genre to present new ideas (Singer, 2015).

separate group of children in grade 4 and 6 judged the texts for consistency (yes/no judgment). Only texts that were appropriate for the experimental manipulation were used in the current study.

The topics of the expository texts were realistic but fictitious, to limit the influence of background knowledge. There were 20 different topics, including animals, persons, objects, countries, and events, which were based on real-world knowledge (e.g. the text about the 'rulver' was based on the polar fox). For each topic there were two versions of each text pair, which were counterbalanced across subjects: A text with an inconsistency in combination with a preceding text that contained an explanation for the inconsistency, and a text with an inconsistency in combination with a preceding text that *omitted* an explanation for the inconsistency. In the condition with explanation, the first text described an explanation that could resolve the inconsistency. In condition without explanation, the first text described additional information about the topic that could not resolve the inconsistency. The texts with inconsistencies were the same in both conditions. The texts had an average length of 8 sentences. The inconsistency was manifested in the target sentence, which was always the penultimate sentence of the text. The target sentences were between 50 and 53 characters in length. Example materials are presented in Table 4.1.

Table 4.1 *Example Text Materials Showing Two Versions of the Topic 'The Rulver'.*

	Inconsistent-with-explanation	Inconsistent-without-explanation
Text 1	The rulver is an animal with a short tail. The rulver lives mainly on the moors, but sometimes also in the woods. The rulver has a pretty brown fur. This fur can be used to make clothing. Hunters can get a lot of money for this fur. *In the winter the rulver's fur turns white.* *Its' brown fur fell off in the fall.* *After this, new white hairs start to grow.* *White camouflage is better against the snow.*	The rulver is an animal with a short tail. The rulver lives mainly on the moors, but sometimes also in the woods. The rulver has a pretty brown fur. This fur can be used to make clothing. Hunters can get a lot of money for this fur. *That is why they try to catch rulvers.* *They catch fewer rulvers than they used to.* *Because there are not many rulvers left.* *The hunters are not happy about this.*
Text 2	The rulver's fur can be used to make coats. To get this fur, the rulver is being hunted in the summer. The rulver's fur has a special brown color. You don't see this brown color on other animals. In the winter the hunt for the rulver stops. <u>Because then you cannot see the rulver in the white snow.</u> The hunt can resume in June.	The rulver's fur can be used to make coats. To get this fur, the rulver is being hunted in the summer. The rulver's fur has a special brown color. You don't see this brown color on other animals. In the winter the hunt for the rulver stops. <u>Because then you cannot see the rulver in the white snow.</u> The hunt can resume in June.

Note. The differences between first texts in the Inconsistent-with-explanation and Inconsistent-without-explanation condition are italicized. The underlined word is what makes the underlined target sentence inconsistent (in the Inconsistent-with-explanation and Inconsistent-without-explanation conditions). These sample texts are translated from Dutch.

The texts within a pair were designed to be independent and could be comprehended individually because of their syntactic structure (with the exception of the part with the inconsistency in the second text). Every text began with an introductory sentence, ended with closing sentence, and each concept was introduced as if it were new. This was expected to increase the awareness among readers that they are reading multiple texts and not just paragraphs of a single text.

Questions. The children received three types of questions. The first type of question (comprehension question) was a multiple choice question with two alternatives (yes/no). The purpose of this question was twofold: A) To test whether children were paying attention to the task and B) to indicate that the child finished reading the text. The question always concerned literal information the preceding text and was the same in all conditions. The second type of question (recall question) was an open question about the main topic of the text. The question always followed the same format: “What do you remember from the text about topic X?”, where X represents the main topic of the text pair (often the fictitious animal/object/person, for example the ‘rulver’). The third type of question (application question) was an open question. The purpose of this question was to create a task that stimulates reading for learning. These questions always introduced a problem in a novel setting that required the application of the explanation from the text. For example, in the rulver text the application question was: “Imagine walking in a natural history museum. You are walking past all sorts of mounted animals. Suddenly you see two rulvers, one brown rulver and one white rulver. Why do you think they have a different color?”.

Working Memory. Children completed a translated version of the sentence span task of working memory (originally created by Daneman & Carpenter, 1980; but adapted by Swanson et al., 1989). This task involved the processing and storage of sentences and words. Children listened to sets of unrelated sentences, answered a comprehension question about one of these sentences, and then recalled the last word of each sentence. There were six levels that increased in difficulty, and each level consisted of two sets. The items at the easiest level consisted of two sentences and the items at the most difficult level consisted of six sentences. There were 10 sets in total. The task was stopped either when children were not able to answer the comprehension question correctly or when they were not able to recall at least one word in each set within one level. The final score was calculated as the total number of questions answered correctly and the total number of words recalled correctly (regardless of the order in which the answers were given).

Reading Comprehension Ability. The Cito test for reading comprehension is a national standardized norm-referenced test (Cito, 2013a, 2013b). In this test, children read a variety of texts and have to answer multiple-choice questions about these texts. Cito reading comprehension tests are administered twice each year in each grade to assess children’s reading comprehension skills. Performance scores of the Cito test for reading comprehension for Grade 4 and 6 were obtained from the teachers of the children. The most recent test results were used. On average, the test was administered two months before the experiment. The ‘level scores’ were included in the analyses, which consist of five levels, ranging from I (i.e. the highest level) to V (the lowest level), each level representing 20% of the range of norm scores. These levels indicate the level of reading comprehension ability based on norms from a large sample of children of the same age. 90-95% of the schools in the Netherlands use the Cito test for reading comprehension, so the norms are representative (Egberink, Janssen, & Vermeulen, 2015). The Cito assessment for reading comprehension in Grade 4 and 6 has good reliability and validity (Egberink et al., 2015).

Procedure

Children first received verbal instructions about the procedure of the reading task. They were told that they were going to read texts sentence-by-sentence. They were asked to read these texts for comprehension and to answer several questions about these texts. Some questions were asked immediately after reading the texts and some questions after a delay (i.e. the recall and application questions were provided after reading four text pairs). Half of the children received a hint about the relatedness of the text pairs. Because the presence/absence of a hint did not influence any of the measures of interest, this factor was left out of the analyses.

After the verbal instructions, children were asked to read the same instructions on the screen, and they performed two practice trials. If necessary the experimenter gave feedback during the practice trials. When children demonstrated comprehension of the task during the practice trials, they were instructed to continue to the remainder of the experiment individually and feedback was no longer provided.

Before each text was presented, the message “next text” was presented in the center of the display screen to indicate the beginning of a new text and thereby increasing the boundary between texts that were part of a pair and between texts with different topics. This message was presented in capitals to increase the awareness that children were going to read a new text that was distinct from the previous text. The next screen showed a fixation cross in the center of the screen that was presented for a variable interval of between 500 and 2500ms before each sentence. Following this fixation cross, sentences were presented one by one in the center of the screen. Children were instructed to read at their own pace and they could progress to the next sentence by pressing the space bar. To prohibit children from skipping a sentence by accidentally double-hitting the space bar, the program did not respond to a press if it occurred within 500ms of the previous press. Also, if children took longer than 15.000ms to read a sentence the program automatically continued to the next sentence. After reading each text, children were presented with one comprehension question. The children were instructed to keep their thumbs on the space bar, and their index fingers on the "yes" and "no" keys at all times (the "S" and "L" keys on the keyboard). They did not receive feedback about the accuracy of their answers. The order in which the text pairs were presented was counterbalanced across subjects, and the order in which the texts that belonged to one pair was presented was fixed, with the text with the inconsistency always immediately following the text with or without explanation (but as with each text, separated by a question and the message "next text"). After reading four text pairs, the children were asked to answer the recall question. The recall questions were always presented in the same order as the topics were presented to the children in the texts. Children were asked to report only the most important information from the text. In case of a nonresponse (no response or "I don't know") the experimenter asked a question (e.g. "don't you remember anything about topic X?") to elicit a response. After each free recall question, an application question was asked. In case of a nonresponse (e.g. silence or "I don't know") the experimenter told the child that they were allowed to use their imagination. When children only said yes or no, the experimenter asked why. Children were asked to report their answers verbally and their responses were recorded with an audio tape recorder.

Each testing session lasted about 70 minutes on average, with a short break after reading twelve text pairs and answering the corresponding questions. Ten children had additional breaks during the experiment due to (unexpected) obligations at school. Additional breaks always took place after a block of four texts pairs and the corresponding questions, to make sure that the time delay between reading and answering questions was similar for all blocks in all children.

Scoring

Recall. Children's auditory responses were transcribed, parsed into idea units, and coded. One idea unit generally comprised a semantically meaningful clause (consisting of a subject and main verb), which was coded based on the source of the information: 1) the first text of the pair, 2) the second text of the pair, 3) both texts, 4) background knowledge. Non-meaningful, incomplete clauses ("he was…[silence]") etc.) and metacognitive responses such as "I don't remember" were excluded from the analysis. Next, the number of source switches between the first and the second text was counted, ignoring information that could not be traced down to one unique text (code type 3) and that was not from either text (code type 4). 25% of the responses were coded by two raters (the first author and several trained faculty members). The remaining responses were coded by the first author only. Agreement between the raters was good (Mean Cohen's κ = 0.68).

Application questions. Responses to the application questions were coded as 'correct' when children used (parts of) the explanation from the first texts to answer the question, and 'incorrect' when they gave a different response. Two raters (the first author and a trained faculty member) coded 25% of the responses to the application questions. The remaining answers were coded by the first author only. Agreement between the raters was good (Cohen's κ = 0.69).

Results

Reading Times

Before analyzing the data, the responses to the questions and the reading times were inspected. On average, children answered 87% of the questions correctly, which demonstrates that the children were processing the texts. Reading times that deviated over 2.5 standard deviations on both the subject and item means were removed, assuming that these reflect processes that are not of interest in the current study (Ratcliff, 1993). Less than 1% of the data were removed using this criterion. The descriptives are presented in Table 4.2.

Table 4.2 *Descriptives for Each Condition in Each Grade (Reading Times in Milliseconds)*

	Condition	*M*	*SE*
Grade 4	Inconsistent-with-explanation	3654.34	73.90
	Inconsistent-without-explanation	3791.60	74.01
Grade 6	Inconsistent-with-explanation	3360.23	60.51
	Inconsistent-without-explanation	3607.30	66.87

As the distribution of the reading times was skewed to the right, the reading times were transformed by taking the natural log of each score to make the distribution more symmetrical (Richter, 2006). Because of the multilevel structure of the data (Richter, 2006), reading times were analyzed using hierarchical linear models using R-statistics software and the 'lmerTest' and 'effects' packages.

Item-level reading speeds were clusters at Level 1 and subjects and items were clusters at Level 2, with the items nested within conditions. Subjects and items were treated as random effects whereas the predictors (Condition, Grade, Reading Comprehension Ability, and Working Memory) were treated as fixed factors. Continuous predictors (i.e. Working Memory) were centered around the grand mean. Degrees of freedom were estimated with Satterthwaite's approximation method (Kuznetsova et al., 2015; SAS Technical Report R-101, 1978; Satterthwaite, 1941). Effects were classified as significant when $p < .05$. Restricted maximum likelihood was used to fit the models. The model was built in two steps. In the first step a model that included Condition was compared to a model without predictors (i.e. the baseline model) by statistically testing the improvement in model fit using likelihood ratio tests. Condition significantly improved the model compared to the baseline model ($\chi^2(1) = 15.73$, $p < .001$). The mean reading time of the target sentence in the Inconsistent-with-explanation condition was significantly faster than the mean reading time of the target sentence in the Inconsistent-without-explanation condition ($b = .05$). In the second step, the main effects of the background variables (Grade, Reading Comprehension Ability, and Working Memory) and the two-way interactions between Condition and each background variable were added to the model that only included Condition to determine whether the effect of Condition was qualified by an interaction with the background variables. The background variables and interactions did not significantly improve the model ($\chi^2(6) = 8.11$, $p = .230$). An overview of the model comparisons is presented in Table 4.3.

Table 4.3 *Descriptives for Each Condition in Each Grade (Recall Data)*

		Integration[a]		*Total Recall*[b]	
	Condition	*M*	*SE*	*M*	*SE*
Grade 4	Inconsistent-with-explanation	1.01	.06	4.13	.14
	Inconsistent-without-explanation	.92	.05	4.21	.15
Grade 6	Inconsistent-with-explanation	1.23	.05	4.86	.15
	Inconsistent-without-explanation	.96	.05	4.73	.15

[a] *The score represents the mean integration scores on each topic*
[b] *The score represents the mean number of recalled idea units on each topic*

Recall

There was a moderate amount of missing data: 23% of the responses did not involve content-specific information. This was possibly due to the limited number of cues in the recall question. More specifically, the question contained only one non-specific recall cue (e.g. 'the animal') in combination with the unfamiliar topic (e.g. 'the rulver'). This information may not have been sufficient to recall which of the four preceding unfamiliar topics had to be retrieved. Notably, in 53% of the trials on which children did not report content-specific information during free recall, they *did* recall text information spontaneously in response to the subsequent application questions, possibly because these questions contained additional cues. This suggests that the recall task itself provides a relatively low estimate of what the children have represented of the texts. Because the application questions did not explicitly prompt recall and, therefore, not all children took the opportunity to report what they remembered after listening to the application question, the recall analyses were based on the responses to the recall questions only.

The descriptives are presented in Table 4.4. The integration scores were analyzed using hierarchical linear models using the same procedures and following the same steps as in the previous analyses (Table 4.3). Condition contributed significantly to the model compared to the baseline model ($\chi^2(1) = 16.98$, $p < .001$). The integration score was higher in the Inconsistent-with-explanation condition compared to the Inconsistent-without-explanation condition ($b = .19$). Addition of the background variables and interactions significantly improved the model ($\chi^2(6) = 22.63$, $p < .001$). In particular, Reading Comprehension Ability was positively related to integration scores ($t(169) = 3.94$, $b = .167$). However, this effect was not significant after correcting for total recall ($p = .330$). There were no other main or interaction effects.

Table 4.4 *Model Comparisons*

		Model fit			
Model	Tested Against	Reading Times	Integration	Total Recall	Application[a]
Baseline	Condition	$\chi^2(1) = 15.73$*	$\chi^2(1) = 16.98$*	$\chi^2(1) = .01$	-
Condition	Condition + Condition*RCA + Condition*WM + Condition*Grade	$\chi^2(6) = 8.11$	$\chi^2(6) = 22.63$*	$\chi^2(6) = 16.95$*	$\chi^2(3) = 43.43$*

Note: RCA = Reading Comprehension Ability; WM = Working Memory. All models contain a random intercept over persons and items. The model fit measures reflect comparisons between the two models in the left two columns. The asterisk indicates an interaction between predictors.
[a]For the application measure the variable Condition was excluded from the model because only the responses in the Inconsistent-with-explanation condition were taken into account.
* $p < .01$

Total recall was analyzed using hierarchical linear models using the same procedures as in the previous analyses (Table 4.3). Condition did not contribute significantly to the model compared to the baseline model ($\chi^2(1) = 0.01$, $p = .909$). However, the background variables and interactions significantly improved the model ($\chi^2(6) = 16.95$, $p = .009$). In particular, Reading Comprehension Ability was positively related to total recall ($t(130) = 3.40$, $b = .53$). There were no other main or interaction effects.

Application questions

The primary purpose of the application questions was to create a task that stimulates reading for learning. However, the responses to these questions may be of interest, particularly to explore the potential effects of individual differences in the background variables. Application scores were analyzed using logistic hierarchical linear models, using the same model building procedures as in the previous analyses (Table 4.3). Only the responses in the Inconsistent-with-explanation condition were analyzed, because only these questions could be answered by applying the knowledge from both texts in a pair. The background variables explained a significant amount of variance of application scores ($\chi^2(3) = 43.43$, $p < .001$). In particular, there was a main effect of Reading Comprehension Ability; the ability to comprehend texts was positively related to application scores ($z = 5.60$, $b = .46$, $p < .001$). There was also a main effect of Grade ($z = 3.08$, $b = .46$ $p = .018$); children from sixth grade performed better on the application questions ($M_{proportion\_correct} = .55$, $SE = .02$) than children from fourth grade ($M_{proportion\_correct} = .42$, $SE = .02$). Working memory did not affect the performance on application questions.

Discussion

An important goal in education is to learn from multiple texts (Common Core State Standards, 2010). This requires processing individual texts, as well as integrating and encoding information from multiple texts. If learning is successful, the knowledge representation constructed from multiple texts can be used to solve novel problems. In the current study two aspects of learning from multiple texts were investigated in primary school children: The learning process and the resulting knowledge representation. The research questions were 1) whether fourth and sixth grade children integrate information across texts during reading and 2) whether they incorporate intertextual connections in memory. In investigating these questions, differences in reading comprehension ability, working memory, and grade were taken into account.

Integration Across Texts During Reading

The multiple-text integration paradigm was used to determine whether information from previous texts was spontaneously activated during reading of subsequent texts (Beker et al., 2016). The processing speed of inconsistent target sentences in subsequent texts was faster when prior texts contained explanations for the inconsistencies than when prior texts lacked explanations. Thus, in the condition with explanations information from the current and the previous text was available at the same time during reading. This co-activation of current and previous text information may enable the creation of connections across texts (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; Kintsch, 1988; McRae & Jones, 2013; van den Broek, Risden, et al., 1996). This is the first study to show that children as young as 9 attempt to relate information across texts by spontaneously activating information from previous texts during reading subsequent texts. This is in line with what has been observed in adults using the same paradigm (Beker et al., 2016) and in older children (aged 11-13) using think-aloud methods (Wolfe & Goldman, 2005). It extends previous findings by showing that integration across texts occurs *spontaneously* during reading using an unobtrusive measure (Bauer et al., 2012; Bauer & San Souci, 2010; Bauer et al., 2015; Wolfe & Goldman, 2005).

Although the current results seem to conflict with previous studies that showed that children particularly struggle with integrating information across texts (Sabatini et al., 2014; Sheehan et al., 2006), there are important differences between the current study and previous studies that explain the seemingly contradictory conclusions. First, whereas previous studies used explicit questions, we used an implicit measure to inspect integration of information across texts. Second, in the current study we created optimal conditions for integration information across texts (i.e. by using experimenter-designed texts) whereas in previous studies the conditions may have been more challenging (i.e. by using ecologically valid texts). Thus, successfully integrating information across texts may depend on the situation. Future studies should focus on manipulating different aspects of the situation to determine under what circumstances integrating information across texts becomes more challenging. By gradually increasing the difficulty of the materials we could determine when and why children sometimes fail to integrate information across texts.

An unresolved question in the current study is whether co-activating information actually led to integrating the information in a meaningful way. It is possible that overlap in key terms between the first and the second text led to activation of information from the first text but that this did not lead to a meaningful connection (such as a causal relation, e.g. 'the rulver is difficult to see in the white snow *because* it changes color in the winter') and instead only an associative connection. Future research could employ think-aloud methods in combination with the multiple-text paradigm to determine whether co-activated information was related and if so, whether the relation was meaningful (for example, causal), associative, or both.

Constructing a Knowledge Representation From Multiple Texts

The knowledge representation of the texts was analyzed by asking children to recall as much as they could from the texts. There was more integrated recall when connecting the two texts could restore comprehension, i.e., in the conditions that provided explanations compared to the conditions that lacked explanations. Processing times of the target sentence suggest that that integration during recall was the result of co-activation of information during reading. This is in line with how several models describe the integration process and consistent with several empirical findings (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; Kintsch, 1988; McRae & Jones, 2013; van den Broek & Kendeou, 2008; van den Broek, Risden, et al., 1996). Importantly, the effect was not a byproduct of higher recall in general, because there were no differences between the conditions on total recall. In prior research, adults did not show a condition difference in the integration of information in their knowledge representation (Beker et al., 2016). However, these null-results may have been caused by the use of a different, possibly less sensitive, coding procedure, which makes it difficult to compare the results with those from the present study. Another way to shed light on the apparent discrepancy between adults and children is by conducting a new study that includes different measures of knowledge representations (such as primed recognition measures) and to directly compare adults with children on these measures using the same materials. Recall procedures such as the one employed in the current study have some limitations (e.g. selectivity in what a participant reports) that may be obviated by using (a combination) of other measures.

Individual Differences in Integration Across Texts

In the current study, two sources of individual differences were taken into account, reading comprehension ability and working memory. Reading comprehension ability did not affect the process of activating information from prior texts during reading, nor did it affect the construction of knowledge representations. This may reflect the test used to measure reading comprehension ability, which focused on the ability to comprehend individual texts (Cito, 2013a, 2013b). The processes involved in constructing a representation from a single text may be different from those involved in constructing a representation from multiple texts (Stadtler, Scharrer, Brummernhenrich, & Bromme, 2013).

Working memory did not affect processing speed, nor did it affect the integration of information in children's knowledge representations. The absence of an effect of working memory is in contrast with studies showing that this skill is important for reading single texts (Borella et al., 2010; Cain et al., 2004; Seigneuric & Ehrlich, 2005). It could be the case that the distance between the texts was too small, enabling both low- and high-span readers to keep information from the first text activated. Alternatively, it is possible that working memory is not important for the integration of information across multiple texts, and that instead differences in long-term memory affect the process of intertextual integration (Le Bigot & Rouet, 2007). For example, it may be that information from a previous text was no longer active for all children, so that only those children that efficiently encoded and retrieved information from a previous text from long-term memory integrated information across different texts.

Developmental Patterns in Integration Across Texts

In contrast to what was expected based on previous work (Bauer & San Souci, 2010), there were no differences across grades in the ability to integrate information across texts; children in fourth and sixth grade showed similar processing times and knowledge representations. This may be due to the simplicity of the task. The current study was intentionally designed to minimize the challenges posed by the separate texts, to encourage learning from multiple texts (Beker et al., 2016). Therefore, differences across grades may have been negligible. It is possible that more challenging multiple text situations allow for a wider range of (strategic) processes, which may differentiate children in different developmental stages. Future research should address this possibility, which could increase our knowledge about the boundary conditions that determine success or failure in multiple text situations.

Individual Differences in Transfer

Reading comprehension ability and grade affected the ability to apply information from a text to a new situation (i.e. transfer). Good comprehenders performed better on this task than poor comprehenders. There are several explanations for this effect. Good comprehenders may have constructed better knowledge representations of the texts than poor comprehenders (Oakhill, 1982), or their knowledge representation was more available, which helped them to answer the application questions. Furthermore, children in Grade 6 performed better than children in Grade 4, suggesting that the ability to transfer develops over time. This is consistent with other research on the development of transfer skills (Thibaut & French, 2016).

Mechanisms Involved in Integration Processes

One issue concerns the interpretation of the direction of the reading time difference between the conditions. The difference could either reflect a speed-up in the condition with explanation or a reduced slow-down. Although we did not include a baseline measure to distinguish between these accounts, we can speculate about the direction of the effect based on previous research. There are (at least) two possibilities: The effect can be explained in terms of inconsistency resolution or in terms of pre-activation. According to the inconsistency resolution account, the inconsistency in the target sentence is first detected, and this triggers activation of previous text and background information. In the condition with explanation this would lead to a reduced slow-down, because activation of the explanation from the first text helps resolve the inconsistency. In the condition without explanation, the inconsistency would trigger an (unsuccessful) memory search, resulting in longer processing times. According to the pre-activation account, the information from previous parts of the text and background knowledge is already activated before processing the target sentence, for example due to featural overlap (Myers & O'Brien, 1998; van den Broek, Risden, et al., 1996). In the condition with explanation this would lead to increased efficiency in processing the target sentence because it readily fits prior knowledge. In this case, the reader may not even experience an inconsistency. In the condition without explanation this would lead to longer processing times, because the target sentence does not fit the knowledge representation. Recent insights in the field of predictive inferences are in favor of the pre-activation account (for a review, see Kutas, DeLong, & Smith, 2011). Furthermore, a previous study using the multiple-text integration paradigm demonstrated that the processing speed of the inconsistent target sentence in the condition with explanation was comparable to the processing speed of the same target sentence in a consistent situation, providing further support for the pre-activation account (Beker et al., 2016). Whatever the mechanism is that leads to activation of prior text information, both accounts explain how information from prior texts is activated during reading the target sentence, enabling co-activation of information from both texts and possibly integration. The accounts only differ in when co-activation begins: Before or during reading the target sentence. Future research should be done to gain more insight into the fundamental processes that underlie integration across multiple texts.

Limitations

To increase the distinctive boundary between the two texts three or four cues were provided: An intervening task (a comprehension question), an explicit message ("next text"), implicit text structure cues (e.g. introducing each topic in the second text as if it were new), and, for half of the children, hints that each text was part of a pair (e.g. "You are going to read *two texts* in a row. When reading the *second text*, try to think of the *first text*."). We did not include a single text control group so it may be that children did not always perceive the texts in one pair as distinct. Nevertheless, this study provides a foundation for investigating intertextual integration processes in a controlled way in more ecologically valid situations in future research. The paradigm can easily be extended to study spontaneous integration processes during reading in situations in which integration is more challenging for children. We view the current study as an initial step in investigating integration of information across texts in children. A reasonable second step would be to increase the textual or physical distance between the texts to determine which factors decrease intertextual integration in more difficult situations. In addition to factors that affect integration within single texts (e.g. featural overlap, reading strategies, etc.), factors that are particularly relevant in the context of multiple texts could also be taken into account (e.g. reliability of the sources, different writing styles, etc.).

Concluding Remarks

It has been argued that learning from multiple texts may be difficult for children, for example when children do not recognize the relatedness of the texts (Bauer et al., 2012; Kurby et al., 2005), when the distance between the texts is large (Beker et al., 2016), or when children are taught to process texts in isolation of other texts (J. A. Hartman & Hartman, 1994). However, the results in the current study suggest that under certain circumstances children *do* process texts in relation to other texts. Children demonstrated integrative processing across texts during reading and integrated information from different texts in memory. These results provide a first step towards gaining more insight into the process of learning from multiple texts and can be used as a starting point to reveal factors that facilitate or inhibit learning from multiple texts.

CHAPTER

5

Refutation Texts Enhance Transfer of Knowledge

Under revision

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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).

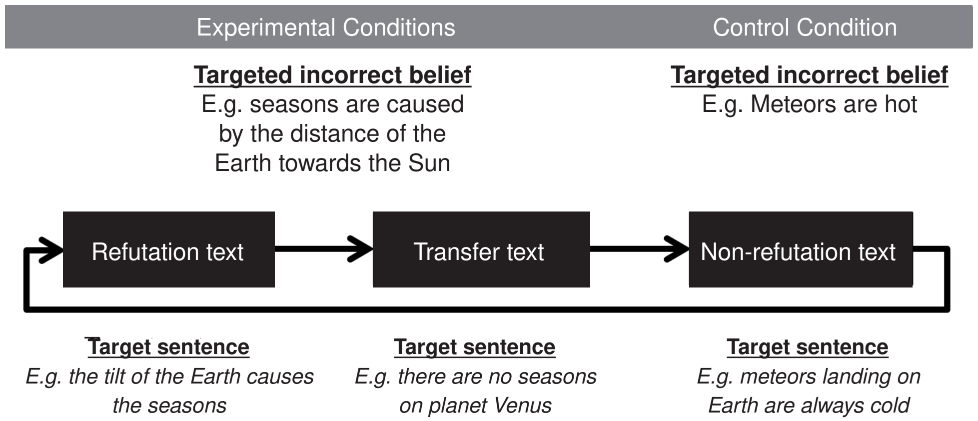

Figure 5.1 Demonstration of the order in which the texts in different conditions were presented in Experiment 1. Each participant went through six of these loops (18 texts in total).

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, η_p^2 = .28), but not by items (F_2 (2, 15) = 2.32, p = .113, η_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.

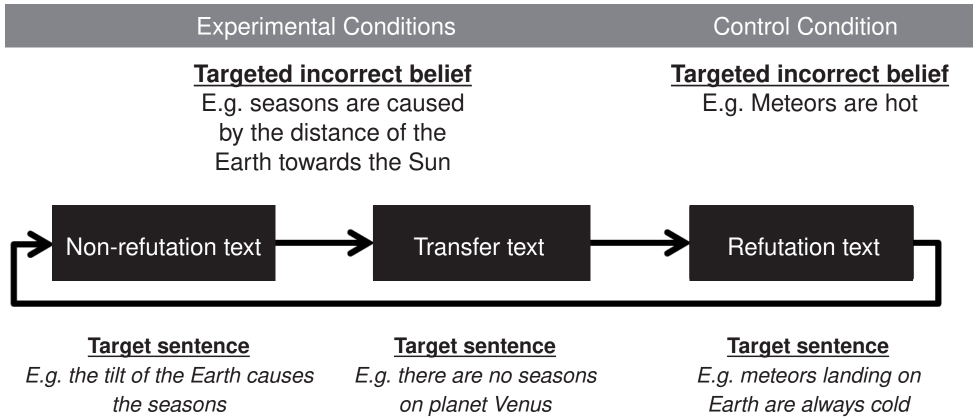

Figure 5.2 Demonstration of the order in which the texts in different conditions were presented in Experiment 2. Each participant went through six of these loops (18 texts in total).

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.

APPENDIX A

Example Texts of Experiment 1

Refutation Text

Introduction (7 sentences, 100 words)
The Parker family was vacationing at their favorite spot at a scenic New England lake. Every summer they would rent the same cabin right on the water. The two brothers, Jack and Ryan enjoyed water skiing. It was an exceptionally hot day so the boys decided to gear up for some water skiing. Jack had trouble adjusting his life jacket because his hands were dripping with sweat. Frustrated, he asked his brother why it was always so hot in the summer and always so cold in the winter. Mrs. Parker, who was reading a science textbook, overheard her boys talking.

Refutation (2 sentences, 33 words)
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.

Explanation (6 sentences, 100 words)
The textbook stated the Earth is actually farther away from the Sun during summer in the Northern Hemisphere than the winter. Seasons are caused by the Earth being tilted on its axis. As the Earth orbits the Sun, different parts of the world receive different amounts of direct sunlight. The textbook illustrated while the Sun is farther away during summer, the Northern Hemisphere is tilted towards the Sun. Thus due to the tilt, the days are longer and there is more direct sunlight. In the winter, even though the Sun is closer, the Earth is tilted away from the Sun.

Filler (4 sentences, 60 words)
After patiently listening to their mom talk about the seasons, the boys went back to getting ready for water skiing. The boys agreed that they would take turns on the water skis. It was still too hot, so they decided to head home. They knew their mom would quiz them, so they reread the textbook to confirm that it is

Target Sentence with Correct Outcome (37-43 characters)
the tilt of the Earth causes the seasons.

Spillover (5-8 words)
The boys were very happy with their answer.

Closing (6 sentences, 90 words)
Jack and Ryan ran to the kitchen to make a snack. Although they had not been on the lake for long, the hot sun made them very hungry. After their snack the two boys decided to play video games. Even though Jack and Ryan enjoyed playing video games they discussed how much they would rather be outside water skiing. Finally the sun went down and the temperature cooled off. The boys excitedly checked the weather channel and hoped for a cooler day so that they could enjoy more water skiing.

Comprehension question (immediately after reading)
Were Jack and Ryan going water skiing? (yes)

Transfer Text (Same as in Experiment 2)

Introduction (7 sentences, 100 words)
A group of ladies were taking a computer course at the local community center. The center organized courses for the elderly because they wanted to help them to manage the digital society. Agnes and Fran sat close to the teacher so that they could ask a lot of questions. This was the second time they took the course and they still did not understand how the computer worked. Today they had to complete an assignment about the planets. They had to use the internet and a word processing program to write an essay. Agnes and Fran wanted to start immediately.

Filler (2 sentences, 33 words)
Agnes opened the internet browser by following the steps described in the manual, and searched for ‘planets’. Agnes and Fran clicked on the first result on the list to read the first article.

Cue for revised belief (*tilt of planet*) (6 sentences, 100 words)
The website described how the planets differ from each other and from planet Earth. The women were encouraged to make a table on the computer so they could organize the characteristics of different the planets. They searched the manual for instructions on how to make a table that had columns for various planet features such as names, size, temperature, degrees of tilting, and atmosphere conditions. 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 Venues has no tilt at all.

Filler (4 sentences, 60 words)
The website provided other information about Venus. The women spent the next hour finding information about planets. They were happy to have learned how to make tables on the computer, knowing that this skill would help them on other projects. They were also excited about the planet facts they had learned. Agnes and Fran figured their friends would not know

Target Sentence with Correct outcome (37-43 characters)
there are no seasons on planet Venus.

Spillover (5-8 words)
Agnes and Fran learned lots of new things.

Closing (6 sentences, 90 words)
By browsing through the internet they also read about the shape of orbits around the sun. An elliptical orbit causes a planet to come closer to the sun during some seasons, making the temperature rise. When the orbit is circular, like on Earth and Venus, the distance to the Sun stays the same. Therefore, this will not influence the temperature. The course assignments were designed not only to teach computer skills, but also to demonstrate the usefulness of these skills. That is why Agnes and Fran found the assignments interesting.

Comprehension question (immediately after reading)
Was the course at the community center? (yes)

Non-Refutation Text

Introduction (7 sentences, 100 words)
Kate was out for her nightly run. Halfway through the run, she stopped at a corner to rest and stretch. Kate looked up at the clear night sky while she took a sip from her water bottle. She saw a meteor falling beyond the trees and she watched until it hit the ground. She quickly ran about 400 yards to the site where the meteor landed. When she arrived there were already several people there. She noticed that her neighbor Jerry, an astronomy professor at the local university, had also come down the street to see what was going on.

Non-Refutation (2 sentences, 33 words)
Kate was excited because she had never seen a meteor on the ground before. Jerry, the professor, offered to run home to get an astronomy book, so they could learn about the meteor.

Non-Explanation (6 sentences, 100 words)
The professor told them that there were so many fascinating movies made about space, and so many more exciting things written on the topic. Everyone at the scene began talking about their favorite movies about space. The group could not believe it when Kate mentioned she hadn't seen any of the Star Wars movies. 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.

Filler (4 sentences, 60 words)
Kate continued to stare at the meteor. She had never seen anything like this in person before, and figured that would be true of many people here. What if a television crew came to interview witnesses? She could be on TV! She had to come across as smart if she was interviewed. She listened carefully as Jerry assured everyone that

Target Sentence with Correct Outcome (37-43 characters)
meteors landing on Earth are always cold.

Spillover (5-8 words)
Police cars were now arriving at the scene.

Closing (6 sentences, 90 words)
In situations like these they had to make sure that no one was approaching the meteor. They had to make sure that researchers would get the opportunity to investigate the area. People were not allowed to take pieces of the meteor back home. If the meteor was special, it would be transferred to a museum to add to their collection. The police told the crowd they had to go home because they needed to block off the area. Kate decided to sprint home to tell her family about the news.

Comprehension question (immediately after reading)
Was Kate out for a walk? (no)

Transfer problem test questions (after reading all 18 texts)

Refutation text
Consider a planet that has extreme seasons. The difference in temperature between the summer and the winter is large. Explain what could be the cause of this pattern of extreme seasons and how would this pattern influence temperatures in the summer and in the winter.

Non-refutation text
Consider a meteor that landed on planet Z. Explain if whether this meteor is hot or cold, what influenced the temperature of the meteor, and how.

APPENDIX II

A

Example Texts of Experiment 2

Non-Refutation Text

Introduction (7 sentences, 100 words)
The Parker family was vacationing at their favorite spot at a scenic New England lake. Every summer they would rent the same cabin right on the water. The two brothers, Jack and Ryan enjoyed water skiing. It was an exceptionally hot day so the boys decided to gear up for some water skiing. Jack had trouble adjusting his life jacket because his hands were dripping with sweat. Frustrated, he asked his brother why it was always so hot in the summer and always so cold in the winter. Mrs. Parker, who was reading a science textbook, overheard her boys talking.

Non-Refutation (2 sentences, 33 words)
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.

Non-Explanation (6 sentences, 100 words)
Mrs. Parker was always encouraging her boys to find out the answers to questions they had by reading textbooks. She thought this was a good way to teach them. If her sons had to find the answers themselves, they would remember them better. Sometimes Jack and Ryan found reading textbooks annoying. They would ask their mom what a certain word meant and rather than just tell them, they had to stop what they were doing and go find the dictionary. They knew there was no point in asking her because their mom was not going to give them the answer.

Filler (4 sentences, 60 words)
After patiently listening to their mom talk about the seasons, the boys went back to getting ready for water skiing. The boys agreed that they would take turns on the water skis. It was still too hot, so they decided to head home. They knew their mom would quiz them, so they reread the textbook to confirm that it is

Target Sentence with Correct Outcome (37-43 characters)
the tilt of the Earth causes the seasons.

Spillover (5-8 words)
The boys were very happy with their answer.

Closing (6 sentences, 90 words)
Jack and Ryan ran to the kitchen to make a snack. Although they had not been on the lake for long, the hot sun made them very hungry. After their snack the two boys decided to play video games. Even though Jack and Ryan enjoyed playing video games they discussed how much they would rather be outside water skiing. Finally the sun went down and the temperature cooled off. The boys excitedly checked the weather channel and hoped for a cooler day so that they could enjoy more water skiing.

Comprehension question (immediately after reading)
Were Jack and Ryan going water skiing? (yes)

Transfer Text
-See Appendix I-

Refutation Text

Introduction (7 sentences, 100 words)
Kate was out for her nightly run. Halfway through the run, she stopped at a corner to rest and stretch. Kate looked up at the clear night sky while she took a sip from her water bottle. She saw a meteor falling beyond the trees and she watched until it hit the ground. She quickly ran about 400 yards to the site where the meteor landed. When she arrived there were already several people there. She noticed that her neighbor Jerry, an astronomy professor at the local university, had also come down the street to see what was going on.

Refutation (2 sentences, 33 words)
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.

Explanation (6 sentences, 100 words)
The professor explained that the high speed of the meteor when it enters the atmosphere causes it to melt or vaporize its outermost layer. The hot molten layer quickly blows off. The inside of the meteor does not have time to heat up again before passing through the atmosphere. This is all because meteors are poor conductors of heat. Jerry told the crowd that many meteors that make it to Earth are actually found covered in frost, and that these are known as meteorites. Despite this information, they all decided it was still a good idea not to touch it.

Filler (4 sentences, 60 words)
Kate continued to stare at the meteor. She had never seen anything like this in

person before, and figured that would be true of many people here. What if a television crew came to interview witnesses? She could be on TV! She had to come across as smart if she was interviewed. She listened carefully as Jerry assured everyone that

Target Sentence with Correct Outcome (37-43 characters)
meteors landing on Earth are always cold.

Spillover (5-8 words)
Police cars were now arriving at the scene.

Closing (6 sentences, 90 words)
In situations like these they had to make sure that no one was approaching the meteor. They had to make sure that researchers would get the opportunity to investigate the area. People were not allowed to take pieces of the meteor back home. If the meteor was special, it would be transferred to a museum to add to their collection. The police told the crowd they had to go home because they needed to block off the area. Kate decided to sprint home to tell her family about the news.

Comprehension question (immediately after reading)
Was Kate out for a walk? (no)

Transfer problem test questions (after reading all 18 texts)

Non-refutation text
Consider a planet that has extreme seasons. The difference in temperature between the summer and the winter is large. Explain what could be the cause of this pattern of extreme seasons and how would this pattern influence temperatures in the summer and in the winter.

Refutation text
Consider a meteor that landed on planet Z. Explain if whether this meteor is hot or cold, what influenced the temperature of the meteor, and how.

CHAPTER 6

Summary and Discussion

Summary

The aim of the current dissertation is to gain insight into the processes that are involved in learning from (multiple) texts in adults and children. The dissertation consists of five chapters. The first chapter introduces the topic of 'learning from texts' and provides an overview of the chapters that form the body of this dissertation. Two types of learning are differentiated: 1) learning as *extending* knowledge and 2) learning as *revising* existing knowledge. The second chapter includes a literature review in which relevant theories and current knowledge about learning from texts are summarized. This chapter identifies important knowledge gaps. In an attempt to begin to close the knowledge gaps Chapters 3, 4 and 5 describe studies that focus on relating multiple texts and revising knowledge. Specifically, in Chapter 3 a new research paradigm is introduced that can be used to study the process of integration across multiple texts. In Chapter 4 this research paradigm is used to study integration processes across texts in children. Chapter 5 describes a study that focuses on refutation texts. In this study the transfer of revised knowledge across texts is investigated. The remainder of the current chapter provides a more elaborate summary of Chapters 2 till 5, reflections and suggestions for future research.

Chapter 2: Literature Review

In Chapter 2 the literature on reading comprehension and memory is synthesized and reviewed to provide an overview of current knowledge about learning from texts. Because of overlap in the way comprehension and learning are defined in existing literature, a definition of each process was provided. Comprehension was defined as the process of building a (temporary) mental representation of the text that can be used to understand later parts of the texts or to answer questions about the text directly after reading. Learning was defined as the process of constructing a relatively permanent knowledge representation that can be used in a variety of situations in the (near and far) future (i.e. a representation that is decontextualized). Several factors were suggested that may contribute to the transition from a text representation to a knowledge representation. We argued that most of the suggested factors influence learning either by affecting the consolidation of information (for example, by repeatedly processing information) or by enriching information (for example, by processing information in different contexts). The main conclusions from the literature review are derived from synthesizing findings from several studies and models, but empirical evidence testing these conclusions has yet to be provided. The review targets important knowledge gaps in the existing literature and provides a basis for theoretically grounded hypotheses that can be empirically tested in the future. The studies reported in Chapters 3 to 5 demonstrate first attempts to close the knowledge gaps.

Chapter 3 and 4: Expanding Knowledge By Reading Texts

Adults (Chapter 3). In the two studies reported in Chapter 3, we created a new research paradigm that was used to investigate one aspect of integration across multiple texts: The activation of previous text information during reading subsequent texts. The multiple-text integration paradigm provides an implicit measure of spontaneous activation of information from previous texts. In this paradigm, information is presented in text pairs of which the second text contains an inconsistency. In one condition this inconsistency can be resolved by applying information from the first text (i.e. the explanation), but in the other condition this inconsistency remains unresolved. Differences in processing time of the inconsistent target sentence can demonstrate whether the explanation from previous texts was active during reading.

The results of Experiment 1 and 2 show that the inconsistency in the second text is processed faster when the first text provides an explanation for the inconsistency in the second text, compared to when the first text lacks an explanation for the inconsistency in the second text. This demonstrates that the information from the first text is spontaneously activated during reading the second text. To determine whether the reading time difference reflects a slow-down or speed-up, the conditions with and without explanations were compared to a consistent control condition in Experiment 1. The reading times in the condition without explanations slowed down relative to the control condition, whereas the reading times in the condition with explanations did not slow down relative to the control condition. This may be explained by a backward parallel search process, which should take less time when explanations are readily available, as is the case in the condition with explanations.

The reading time results in studies 1 and 2 support the hypothesis that information from previous texts is spontaneously activated during reading subsequent texts. This is in line with the description of passive reading processes in several models (Albrecht & O'Brien, 1993; Kintsch, 1998; van den Broek, Risden, et al., 1996). These models assume that information activates associated information in memory when there is sufficient featural overlap. The results suggest that there was sufficient overlap between the texts, thereby enabling the activation of prior text information. However it cannot be determined whether prior text information was still active or whether prior text information was reactivated because we did not collect data about the activation of prior text information before reading the target sentence.

In addition to measuring the reading times, the second study in Chapter 3 was extended by adding a measure of the mental representation (free recall). Free recall was included to analyze knowledge presentations. The expectation was that reading processes affect the construction of knowledge representations.

Therefore, the effect of the conditions with and without explanations on reading times should also be reflected in the knowledge representations. There was no consistent condition in Experiment 2, but the other conditions (with and without explanations) were the same as in Experiment 1. The representations were analyzed on several aspects, but none differed between the conditions with and without explanations. Apparently, the differences in reading times did not result in differences in the mental representation, at least not on the aspects that were analyzed. This is counter to what was expected based on the Landscape Model (van den Broek, Risden, et al., 1996), which assumes that processing patterns correspond with the resulting memory representations. This lack of an effect is possibly due to limitations in the measures that were used to assess the mental representation.

Children (Chapter 4). In this chapter children's' ability to integrate information across texts during reading was investigated. We used the same multiple-text integration paradigm as in Chapter 3 and tested a sample of children from Grade 4 and 6. Reading times of the inconsistent target sentences were compared between the condition in which the preceding text provided an explanation and the condition in which the preceding text did not provide an explanation. The results replicated those found for adults: Children read target sentences faster when they were preceded by texts containing explanations than when they were preceded by texts that lack explanations. This effect was found for both 4th and 6th graders. This shows that children also spontaneously activate information from previous texts during reading subsequent texts.

Free recall was also analyzed to determine whether the knowledge representation differed between the conditions with respect to connections across texts (i.e. intertextual integration). Children in both grades demonstrated more integration across texts in the condition with explanations compared to the condition without explanations. This is in line with what was expected based on the hypothesized correspondence between processing information and remembering information (van den Broek, Risden, et al., 1996): The reading time results suggest that information from both texts is concurrently activated, which may have led to integration in memory (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; McRae & Jones, 2013; van den Broek, Risden, et al., 1996). This result differs from what was found for adults. This discrepancy may be the result of using different criteria to code integration in the recall reports in each study. Because the results in the child study are consistent with common theories, it is conceivable that the criteria that were used in the child study were more appropriate.

Individual differences in reading comprehension ability and working memory were also inspected. Reading comprehension is necessary for integrating information across texts: If two individual texts are not comprehended, they cannot be meaningfully integrated. However, reading comprehension ability did not interact with the manipulations on both the reading time and recall measures, suggesting that it was unrelated to the ability to integrate information across texts during reading. This is surprising as comprehension involves the ability to integrate information *within* texts, and logically, this should be related to the ability to integrate information *across* texts. Both processes involve (re) activation of previous text information, comparison of previous text information to incoming information and integration of previous and incoming information in memory. The lack of an effect could be explained by ceiling effects: If the texts are easy to comprehend, then readers do not need advanced comprehension skills that could otherwise facilitate integration.

With regard to working memory ability it was expected that it would positively affect the ability to integrate information across texts. Working memory is a cognitive function that allows one to temporary store and process information in memory (for a review, see Cowan, 2014). It was argued that more advanced working memory skills enable readers to connect more information at the same time, across larger distances, which may result in more complex and elaborate knowledge representations of the texts (Just & Carpenter, 1992). However, working memory did not significantly interact with the conditions on both the reading time and recall measures, suggesting that it was unrelated to the ability to integrate information across texts. Similar to the reading comprehension result, the lack of an effect of working memory may reflect a ceiling effect. If task demands are low, then even readers with poor working memory may be able to integrate information across texts. This would explain the discrepancy between the results in the current dissertation and previous studies that did find a relation between working memory and the ability to integrate information within texts and learning (Cain et al., 2004; Daneman & Carpenter, 1980, 1983; García-Madruga, Vila, Gómez-Veiga, Duque, & Elosúa, 2014).

It can be expected that reading comprehension ability and working memory do affect integration across texts in challenging multiple text situations. Both sets of skills develop gradually as children move up the grades (Kendeou et al., 2009; Oakhill & Cain, 2012), and children who develop these skills sooner may be able to handle more complex integration situations than children that develop these skills later. The combined results in the studies in Chapter 3 and 4 show that the multiple-text integration paradigm is sensitive to differences in activation of prior text information. The paradigm could be used in future studies to determine under what circumstances readers activate information from previous texts when the situation becomes challenging, for example, when the distance between the texts is larger. This is especially relevant for children, who often struggle with complex cognitive tasks because they are in the process of developing skills that are required for these tasks (Chapter 2).

Chapter 5: Revising Knowledge By Reading Texts

Another form of learning is targeted in Chapter 5: Revising misconceptions by reading texts. In Chapter 5 two studies are described that examine whether students with misconceptions learn from refutation texts and if so, whether their revised knowledge can be applied during reading a new text. A sample of undergraduate students in which certain misconceptions were common was selected. In Experiment 1, participants read refutation texts, transfer texts and non-refutation texts. Transfer texts were always preceded by refutation texts. The refutation and transfer texts had different story contexts, but the transfer text required activation of the same belief that was refuted and explained in the refutation text. The non-refutation text served as a control and required activation of a different belief. Each text contained a target sentence that required activation of the correct belief. Previous studies have shown that information that is inconsistent with prior beliefs is processed slower than information that is consistent with prior beliefs (e.g. Albrecht & O'Brien, 1993). Therefore, our expectation was that correct information is processed slower by readers with incorrect beliefs than by readers with revised (correct) beliefs. The first hypothesis concerned replication of previous working showing that refutation texts are more effective in revising incorrect prior beliefs than non-refutation texts. This should be reflected by faster reading times for a target sentence that requires activation of the correct belief in the refutation condition compared to the non-refutation. The second hypothesis and of main interest 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. The results of Experiment 1 supported our hypotheses.

Experiment 2 was conducted to answer two remaining questions. First, is the observed transfer effect in Experiment 1 going to disappear when transfer texts are preceded by non-refutation texts that target the same beliefs? Second, could the effects of conditions be alternatively explained by differences between the target sentences across conditions? Experiment 2 was designed to address these two questions. In Experiment 2, participants read non-refutation texts, transfer texts, and refutation texts. The transfer text followed directly after the non-refutation text and involved the same belief, but each text described different story settings. The refutation text required activation of a different belief and was included as a control. Again, the first hypothesis was that the reading time of the target sentence is slower in the non-refutation condition compared to the refutation condition. The second hypothesis was that reading a non-refutation does not lead to knowledge revision and transfer of revised knowledge. Thus, reading times of target sentences in transfer texts should be slower than those in refutation texts. 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. Because we expected the effects found in Experiment 1 to be due to conditions, we expected the transfer effect to disappear. More specifically, our hypothesis was that the target sentence in the transfer condition is read slower than the target sentence in the refutation condition. The results confirmed our hypotheses and are in line with the conclusions that were drawn in Experiment 1: Refutation texts facilitate transfer of revised knowledge to a bigger extent than non-refutation texts.

In Experiment 1 and 2 a transfer problem test was also administered. The purpose of this test was to obtain converging evidence for the effect of transfer from refutation texts to different situations. In this transfer problem test, students answered questions that required transfer of the revised knowledge. In both studies, students scored significantly higher when they read refutation texts compared to when they read non-refutation texts. So again, refutation texts were more effective in accomplishing transfer of revised knowledge than non-refutation texts.

The results of the two studies are in line with the Knowledge Revision Components (KReC) framework. This framework distinguishes five principles that are central to the knowledge revision process: 1) encoding, 2) passive activation, 3) co-activation, 4) integration, and 5) competing activation (Kendeou & O'Brien, 2014). In the KReC framework, it is assumed that once a misconception is encoded in memory it cannot be erased from memory (principle 1). As a result, it can be passively activated in the future (principle 2), for example, when a text is encountered that relates to the misconception. Knowledge revision will occur only when: The misconception is concurrently processed with the correct information (principle 3), the integrated representation that includes the misconception and the correct information is encoded in memory (principle 4), and the correct information is more dominant than the misconception in the integrated memory representation (principle 5). In the studies in Chapter 5, the refutation text facilitated concurrent activation of the misconception and the correct information by explicitly stating the correct and incorrect information in close proximity in the text (in line with principle 3). Consequently, co-activation may have led to integration of the misconception and correct information in memory. In addition, explanations may have facilitated the construction of rich, interconnected representations (Kendeou et al., 2014), which may have facilitated the dominance of the revised knowledge in memory. The richness and interconnectedness of the representation may also explain why the revised knowledge was maintained at the transfer text and at the post-test (in line with principle 4 and 5).

The combined results of both studies and both measures demonstrate that refutation texts can facilitate transfer of revised knowledge to new situations. The question that remains is whether knowledge that is revised through refutation texts also transfers to different situations than those that were investigated in Chapter 5. There is no evidence that reading a single refutation text with explanation allows readers to transfer the revised knowledge to different physical, temporal, functional, and social contexts (Barnett & Ceci, 2002). However, as long as knowledge revision concerns knowledge that can be represented as a single idea unit (such as in the current study), the prediction based on the KReC framework is that the effect should transfer to different situations as well.

Discussion and Future Research

The chapters of this dissertation advance our understanding of several aspects of learning from texts by investigating different types of learning (knowledge extension and knowledge revision), by including several measures of learning (the learning process and the resulting knowledge representation), and by considering individual and developmental differences.

Learning From Texts: Processes

When comparing the process of extending prior knowledge from multiple texts and the process of revising prior knowledge by reading texts, some interesting similarities emerge. Both processes have been hypothesized to involve a) activation of prior information, b) co-activation of information, and c) integration of information. In the case of extending knowledge from multiple texts, this concerns activation of information from previous texts, as well as co-activation and integration of information across texts. In the case of revising knowledge, the processes involve activation of information from memory, as well as co-activation and integration of correct information from the text and misconceptions (Kendeou & O'Brien, 2014). These three processes are central in many models of reading comprehension (Goldman & Varma, 1995; Kintsch, 1988; van den Broek, Risden, et al., 1996) and memory (McRae & Jones, 2013). The results of the empirical studies are consistent with these models and extend existing models by showing that processes that operate during single text comprehension also apply to multiple text situations. In all experiments, information from previous texts (with explanations in Chapter 3 and 4, and with refutations in Chapter 5) was (re)activated during reading subsequent texts. This is in line with models describing multiple text comprehension (Britt et al., 1999; Britt et al., 2013; C. A. Perfetti et al., 1999).

From the studies in this dissertation one may conclude that multiple text processes are not different from single text processes. But although readers may indeed require the same toolbox of reading strategies when reading single and multiple texts, there are several reasons why readers might process single and multiple texts differently. First, readers may have different expectations when reading single or multiple texts (Stadtler et al., 2013). In single texts, authors are expected to make relations explicit. As a consequence, readers may not attempt to infer relations themselves. In multiple texts, readers may be aware that most relations across texts are not explicit, because the texts can be written by different authors. This may stimulate readers to actively construct these relations. Second, multiple texts allow more dynamic processing. For example, readers can choose which text to process first, whereas the order in which information in single texts is presented is more fixed (although readers of course could process paragraphs in single texts in orders different than those determined by the author). Third, reading multiple texts is usually more challenging than reading single texts (for example, because the texts can be inconsistent), and as a result, readers may need to be more skilled at using certain reading strategies and they need to use reading strategies more frequently. These are just three examples, but there may be more reasons why the same information is processed differently in single texts compared to multiple texts.

This dissertation advances our knowledge about passive and spontaneous processes involved in learning from texts, but it does not address strategic reading processes. The texts that were used in the studies of this dissertation were relatively short, did not include source information, did not describe complex topics and were presented shortly after another. Therefore, strategic reading processes may not have been necessary. However, complex learning situations such as those encountered in schools often do require a strategic approach (Anmarkrud, Bråten, & Strømsø, 2013; Britt & Sommer, 2004; Cerdán & Vidal-Abarca, 2008; Hagen, Braasch, & Bråten, 2014; Wolfe & Goldman, 2005). Future studies should focus on the interplay between passive and strategic processes to determine how they affect processing of complex textual materials, such as those that are used in schools (van den Broek, 2010)

Methods for Investigating Learning Processes

Intertextual integration. In this dissertation a new method to study intertextual integration was introduced; the multiple-text integration paradigm (Chapter 3 and 4). Previously, the process of reading multiple texts was studied mainly by using think-alouds (Anmarkrud et al., 2013; Wolfe & Goldman, 2005), strategy reports (Bråten & Strømsø, 2011), and software that allows monitoring of reading behavior (Vidal-Abarca & Martínez, 2002). Many of these measures reflect strategic approaches and conscious decisions. However, *passive* reading processes have been argued to be the default reading mode when processing texts when there is no need to use strategic reading processes (Albrecht & O'Brien, 1993; McKoon & Ratcliff, 1992; van den Broek, Risden, et al., 1996) and readers are not always aware of those processes. The multiple-text integration paradigm has proven effective to study passive reading processes of which readers are not always aware. Now that the usefulness of the paradigm is established in a relatively artificial setting in this dissertation, important follow-up research should use this paradigm with more ecologically valid multiple texts. This may be informative for schools and educators.

It is important to note that the multiple-text integration paradigm can only be used to determine whether information from prior texts was *active* during reading. Whether other processes such as inconsistency detection, inconsistency resolution, etc. operated during reading the target sentence cannot be determined. In order to gain insight into these processes other measures may be more appropriate, such as think-aloud methods or eye-tracking. Obviously, there is not 'one' superior method, so the recommended approach is always to use several methods to investigate different aspects and to provide converging evidence for proposed hypotheses (B. W. Miller, 2015).

Knowledge revision. In this dissertation a new method to study transfer of revised knowledge was introduced (Chapter 5). Traditionally, transfer is assessed by asking students to report their solution to a novel problem (Alonso-Tapia, 2002). This requires students to retrieve the previously acquired knowledge and to verbalize their response. A potential risk with this method is that some students have the required knowledge but somehow are not able to verbalize a response. The advantage of the method in the current dissertation is that students do not have to consciously retrieve the knowledge, nor do they have to verbalize their answer, they just have to read a text and from their reading times it can be inferred whether they have spontaneously activated prior knowledge, thereby showing transfer.

In the transfer research domain there has been considerable discussion about what classifies as near and far transfer (Barnett & Ceci, 2002). When evaluating the 'distance' between the learning task (in the current dissertation; reading the refutation text) and the transfer task (in the current dissertation; reading the transfer text) with respect to the taxonomy of far transfer (Barnett & Ceci, 2002), the transfer task in this dissertation would probably be classified as 'near' transfer, because several aspects of the learning and transfer context were the same (time, surroundings, task, etc.). However, certain aspects could be easily modified in future research using the same research paradigm. For example, the transfer text could be presented at a later moment in time: Days, weeks or months later. The transfer text could also be presented in a different physical context, for example at home instead of at the laboratory.

It is important to keep in mind that reading times were used, and therefore the only thing that we can relatively safely conclude is whether information was active or not. An important component of the transfer process that is not exposed with our method is whether the activated information was used to comprehend the situation. It is possible that revised knowledge was merely activated because it was cued by the transfer text, but that readers did not understand how it was relevant to the transfer situation. Again, different measures such as think-aloud and eye-tracking should be used to answer questions related to resolution processes.

Learning From Texts: Knowledge Representations

Knowledge representations are the result of learning processes. In the literature review in Chapter 2 (ideal) knowledge representations are characterized as relatively permanent and decontextualized (i.e. being applicable to new situations), which differentiates them from text representations. It was concluded that the transition from text to knowledge representations is facilitated by consolidation and enrichment processes. Consolidation and enrichment can be accomplished by repeatedly and deeply processing the information in a variety of contexts. These and other insights from Chapter 2 were obtained by generalizing empirical findings and theories from related research fields (e.g. reading comprehension, memory) to the topic 'learning from texts'. In the studies in this dissertation, we did modest attempts to take permanency and decontextualization of the knowledge representation into account. To assess the permanency of the knowledge representation, we used free recall and questions in Chapter 3, 4 and 5. These measures revealed that information from texts is retained shortly after processing the information. However, to get a more accurate reflection of the permanency of the information in memory measures should be administered at least one day later, but preferably weeks or months later. To assess decontextualization of the knowledge representation, we asked participants to apply the information from texts to answer application questions in Chapters 4 and 5. These measures revealed that information from regular texts (Chapter 4) and refutation texts (Chapter 5) was applied to new situations, indicating that the knowledge representation was decontextualized. However, our measure of decontextualization is limited, because the link between the learning phase (i.e. reading texts) and the application phase (i.e. answering questions and reading texts) was quite clear: Both phases were part of a single testing session that took place in the same setting. This may not reflect the ability to apply information in a setting that is more different from the learning setting. To get a more accurate reflection of decontextualization of information measures should administer the text in situations that are more different. Barnet and Ceci's taxonomy could be used as a guideline to increase differences. For example, the learning and application phase could be situated in different rooms, with a greater time interval between them, and the texts could be embedded in several other texts to make the link less obvious.

This dissertation advances our knowledge about constructing knowledge representations by providing a clear definition of knowledge representations and by suggesting several factors that affect the construction of knowledge representations, based on an extensive search of the literature. Although these factors have not been empirically tested in the context of 'learning from texts' in ways suggested in the review, they are based on theories that are supported by studies in several other contexts. For example, the finding that repeatedly processing information leads to consolidation of that information is agreed on by most (if not all) scientists and evidence for this fundamental principle is numerous. This makes it reasonable to expect that the same applies to repeatedly processing information in texts.

The Development of Skills That Are Involved in Learning From Texts

In Chapter 4 integration across texts was compared for fourth and sixth graders. Contrary to expectation, the children in both grades showed similar integration behavior. The results suggest that both groups of children were able to activate information from previous texts during reading subsequent texts, and integrate information across texts in memory. There are several explanations for the lack differences between the grades. Integration performance may have reached ceiling levels either due to 1) fully developed integration skills for children in both grades, or 2) low task demands. The first explanation is inconsistent with a recent report showing that children in grade 6 struggle with tasks that require integration skills (Sabatini et al., 2014). This report suggests that children in grade six still need to develop integration skills to some extent. The second explanation therefore seems more likely: Advanced integration skills were not necessary, so all children were able to do the task.

One factor that may affect the development of skills that are involved in learning from texts but that is not included in this dissertation is background knowledge. The relation between background knowledge and future learning from texts is reciprocal: A knowledge advantage early in life can have profound effects on future learning, putting those who started with a lag even more behind as the years progress (the Matthew effect, see Stanovich, 1986). For example, several studies have shown that the knowledge gaps that exist between children from different economic backgrounds increases over the years (for a review, see Neuman, 2006). The importance of background knowledge on future learning can be illustrated with the following example. Consider students that learn about an unfamiliar concept (e.g. 'ibis'). When linking this concept to existing categorical knowledge that they already have (e.g. 'birds'), they do not have to encode information that is already encoded (e.g. 'feathers'), they only have to link the new concept to the category (e.g. 'an ibis is a bird). This example shows that having background knowledge about categories saves cognitive resources when learning new information and that these resources can instead be used to encode other information.

It is noteworthy that many cognitive functions necessary for learning start developing well before children receive formal reading instructions. Comprehension skills and background knowledge for example, develop by listening, communicating, observing and interacting with people but also by using animations, movies, etc. (for example, see Kendeou et al., 2005). This may help future learning from texts. For example, listening comprehension skills and vocabulary knowledge at pre-reading age have been demonstrated to be predictive of future performance in reading comprehension (Kendeou et al., 2009). Thus, development of skills involved in learning from texts starts early in life. Therefore, it is important to take experience at a pre-reading age into account when studying learning from texts.

Teaching Learning From Texts

By synthesizing previous research with the findings from the current dissertation several practical implications can be derived. Below a selection of practical interventions are suggested that may improve integration across texts and knowledge revision.

Integration across texts. The current dissertation shows that children are able to spontaneously activate information from previous texts during reading and integrate intertextual connections in memory, even when they have poor comprehension skills or poor working memory. This may seem in contrast with studies showing that children struggle with intertextual integration (Sabatini et al., 2014; Sheehan et al., 2006). As mentioned this discrepancy could be the result of differences in the materials used; the texts used in the studies in this dissertation were quite easy and short. Thus, children are able to integrate information across texts, but there may be development in terms of the complexity of integration processes children can handle.

Our study indicates that children have a basic level of intertextual integration skills. However, in and outside schools children may have to process multiple texts in more challenging situations that require advanced intertextual integration skills. For example, children may need to integrate more than two texts when writing an essay. Although we did not investigate these situations, we can speculate which factors contribute to success or failure in integrating information across texts. First, information from previous texts needs to be available (either because information is still active or because information is encoded in memory). This can be accomplished by using memory strategies for example. Second, during reading subsequent texts, information from previous texts needs to be passively or strategically (re)activated. Passive activation processes are guided by featural overlap (Albrecht & Myers, 1998; Albrecht & O'Brien, 1993; Cook et al., 1998; McKoon & Ratcliff, 1980; O'Brien & Albrecht, 1991). This implies that as long as there is a cue available that related back to previous texts, children should be able to activate information from previous texts. This is a testable hypothesis that should be tested in the future. How many cues are required or how strong the cue must be may depend on the child and on the learning situation. If the goal is to acquire information from multiple texts, overlap must be optimized. But if the goal is to train integration skills it may be better to gradually decrease overlap. Once information from previous texts is (re)activated during reading connections across texts can be established. The third and final step involves encoding these connections in memory. Again, memory strategies can be used to accomplish this.

Interventions and strategies that promote prior knowledge activation have been studied extensively. Three examples of interventions or strategies that were originally used to study activation of prior knowledge will be described and extended to activation of prior *text information*. Small changes in these interventions or strategies may make them suitable for activating prior text information in multiple text situations.

First, self-explaining the text during reading helps students to activate prior knowledge, because activating prior knowledge is often necessary to comprehend the text (Chi, De Leeuw, et al., 1994). This strategy may therefore also be useful for reading multiple texts, because it may trigger readers to notice that they need information from previous texts in order to explain the current text. Students can be trained to improve their self-explanation skills. The Self-Explanation Reading Training (SERT) for example, improves students' ability to self-explain during reading (McNamara, 2004). Future studies could use the

SERT in the context of multiple texts, to determine whether the training may be beneficial for reading multiple texts as well.

Second, graphic organizers stimulate readers to activate prior knowledge and relate this to information in the text (Ausubel, 1963). In graphic organizers information is visualized as nodes that are interconnected. Graphic organizers have been used to visualize information from single texts and its connections to background knowledge (for a meta-analysis, see Kim, Vaughn, Wanzek, & Wei, 2004). Similarly, graphic organizers may be used as scaffolds to activate prior text information and relate information across multiple texts. In a recent intervention children were taught to use graphs to activate prior knowledge to make gap-filling inferences in texts (Elbro & Buch-Iversen, 2013). These graphs were used to visualize missing links between sentences within a text, making students aware of the importance of prior knowledge activation. The intervention significantly improved reading comprehension ability, demonstrating that the skills that were taught transferred to situations without graphs. Teachers could construct similar graphs to stimulate students to activate information from prior texts and to connect information *across* multiple texts. This may help students to become aware of the importance of prior text activation during reading multiple texts. As a result, students may spontaneously activate information from prior texts in future situations in which they do not have graphs to scaffold this process.

Third, pre-reading activities have been shown to activate prior knowledge. Teachers can organize classroom discussions in which students share personal experiences that relate to the topic of the text before reading (Au, 1979; Langer, 1981) or they can ask specific questions that trigger students to activate prior knowledge (Graves & Graves, 2003; Reutzel, 1985). Students can be asked to predict the content of the text based on previewing text, for example by reading the titles and looking at the pictures in the text (Graves, Cooke, & Laberge, 1983). A similar approach can be applied in the context of multiple texts, but using prior texts as sources of information. For example, teachers could ask students to recall what they have read in previous meetings in subsequent lessons.

The activities self-explaining, using graphic organizers and pre-reading were explained in the context of children in classrooms, but obviously these activities may also be appropriate for adults. Adult readers are probably more skilled at integrating information across texts due to experience, but the demands for this population are also higher. This may put them at risk for failing to integrate information across texts. One challenge is the absence of a teacher and consequently increased personal responsibility to select and integrate information across texts. When future research has established the conditions in which adults fail to integrate information across texts, adult readers can be made aware of possible pitfalls and they can be explained ways to avoid these pitfalls (such as by using the three activities that are described in the previous paragraphs).

Knowledge revision. Chapter 5 demonstrated that refutation texts are effective for revising knowledge and applying revised knowledge in new situations. A practical implication is that teachers can use refutation texts to accomplish these goals in schools, at least when it concerns misconceptions that can be represented by a single idea. The advantage of using refutation texts is that they can be disseminated to a large group of students at the same time. Students simply have to read a text and no other preparations are necessary.

The underlying principles that are used to explain the effectiveness of refutation texts are: Co-activation, integration and competing activation (Kendeou & O'Brien, 2014). Other methodologies that are based on the same principles may also be useful for revising knowledge. For example, compare-contrast text structures (that lack explicit refutations) could trigger these processes as well. In compare-contrast text structures two opposing positions are described and compared, focusing on similarities and differences. This naturally involves activating two positions at the same time (i.e. co-activation), which could lead to integration and, if one position is clearly favored (e.g. by a convincing explanation), dominance of one position in the mental representation. Compare-contrast texts can be made even more effective by *training* students to process texts with a compare-contrast structure (for a review, see Meyer & Ray, 2011), for example by teaching them to focus on words that signal comparisons (such as 'however' or 'in contrast'). However, this requires a text to explain both the incorrect and the correct depiction of the situation in one text. These texts are not always available and may therefore need to be construed by teachers. A different approach is to collect two texts with opposing positions, one describing the correct and the other the incorrect depiction of the topic. In this situation, interventions such as those suggested in the previous paragraph in the context of multiple texts could be used to achieve co-activation (e.g. by having students self-explain the text).

Other types of interventions that were originally designed to facilitate solving analogies and constructing abstract representations from multiple examples may be informative for revising knowledge as well. These two activities have in common that both involve relating information, identifying relevant similarities and ignoring irrelevant differences. In the case of analogies this involves recognizing that 'deep' structures of the analogies are similar whereas superficial structures may differ. In the case of abstraction this involves recognizing that examples share characteristics that belong to one abstract category, but may differ with respect to characteristics that are irrelevant to the abstract category. Interventions that have been suggested in these domains improve the ability to relate information across analogies or examples, so similar interventions may be useful in the context of relating correct and incorrect information. For example, it has been demonstrated that providing hints improves the ability to solve analogies (for a review, see Day & Goldstone, 2012). Similarly, hints could be used to remind students that their (incorrect) prior beliefs were false and this may improve maintenance of the revised knowledge in memory. For example, teachers can provide students with hints that consist of refutations with short explanations each time the topic is discussed in the classroom (i.e. "Remember that you thought X, but then you learned that it is actually Y, *because* Y… ").

Conclusion

The aim of this dissertation was to gain insight into the processes that are involved in the construction of knowledge representations from texts in both adults and children. A literature review and three empirical studies were conducted to achieve this aim. All empirical studies demonstrate that both adults and children are able to learn information from texts spontaneously: Previously read texts help them to extend and revise their knowledge. This dissertation includes innovative research methods that can be used in follow-up research to determine which factors affect knowledge extension and revision in more challenging situations. The literature review could inspire future research to determine which factors should be investigated in follow-up studies. Eventually, these studies may lead to practical interventions. Interventions that are proven effective should then be integrated into school curricula. Hopefully, this dissertation will motivate other researchers to follow up on the line of research that was presented in this dissertation. This will bring us closer to achieving one of the most important 21st century goals. That is, enabling students of all ages and differences in cognitive abilities and background knowledge to construct permanent and decontextualized knowledge representations from multiple (digital) texts.

NEDERLANDSE SAMENVATTING

S

Leren van Teksten: Het Uitbreiden en Veranderen van Kennis

Samenvatting

Het doel van de studies die beschreven zijn in deze dissertatie was om meer inzicht te krijgen in de processen die betrokken zijn bij het leren van (meerdere) teksten door volwassenen en kinderen. Deze dissertatie richt zich op twee soorten leren: 1) het opdoen van nieuwe kennis en 2) het veranderen van (foutieve) bestaande kennis. In de hoofdstukken waarin de empirische studies worden beschreven (hoofdstuk 3 t/m 5) wordt een experimentele aanpak gehanteerd, waarbij steeds gekozen is voor het gecombineerd verzamelen van data over het leer*proces* en over het *resultaat* van het leerproces (d.w.z. de mentale representatie die men opbouwt van teksten). In de volgende paragrafen wordt een samenvatting van ieder hoofdstuk weergegeven.

Hoofdstuk 1

In het eerste hoofdstuk wordt het onderwerp van deze dissertatie geïntroduceerd: leren van teksten. In het hoofdstuk wordt uiteengezet dat bepaalde leervaardigheden belangrijker zijn geworden dan vroeger, als gevolg van maatschappelijke en technologische ontwikkelingen. Het internet bijvoorbeeld, bevat een grote hoeveelheid informatie en wordt vaak geraadpleegd om kennis op te doen over nieuwe onderwerpen. Door de grote hoeveelheid informatie die beschikbaar is via het internet, moeten leerlingen informatie uit verschillende bronnen kunnen selecteren en integreren. Een deel van de internetbronnen bevat bovendien foutieve informatie en leerlingen moeten hier mee om kunnen gaan. Er zijn aanwijzingen dat zowel kinderen als (jong)volwassenen moeite hebben bij het leren van meerdere teksten. Om hen hierbij goed te kunnen helpen is het van belang om de onderliggende leerprocessen en leermechanismen te doorgronden.

Hoofdstuk 2: theoretisch kader

In hoofdstuk 2 wordt het proces van leren van teksten beschreven door gebruik te maken van inzichten uit onderzoek naar begrijpend lezen en naar het geheugen. De definities van de processen ‘leren van teksten’ en ‘begrijpend lezen’ in de literatuur overlappen vaak. Het zowel voor theorievorming als voor het onderwijs belangrijk om onderscheid te maken tussen deze het proces waarbij er a) een betekenisvolle mentale representatie wordt gecreëerd van een tekst tijdens het lezen (begrijpen) en b) het proces waarbij informatie uit teksten worden opgeslagen in het lange termijn geheugen (leren). Begrijpend lezen is gedefinieerd als het proces waarbij een *tijdelijke* mentale representatie wordt geconstrueerd van een tekst (of tekstonderdeel). Deze tekstrepresentatie kan gebruikt worden als basis om andere onderdelen van de tekst te begrijpen en om vragen over een tekst te kunnen beantwoorden, direct na het lezen van een tekst. Leren van teksten is gedefinieerd als het proces waarbij een relatief *permanente* mentale representatie wordt gevormd van de informatie uit een tekst. Deze kennisrepresentatie kan gebruikt kan worden in diverse situaties in de (nabije en verre) toekomst. Dat betekent dat de kennisrepresentatie gedecontextualiseerd is: de informatie kan toegepast worden ongeacht de context waarin de informatie moeten worden toegepast. Omdat leren van een tekst begint met het begrijpen van een tekst is het belangrijk om te achterhalen hoe de overgang van een tekstrepresentatie naar een kennisrepresentatie plaatsvindt. Er worden in hoofdstuk 2 verschillende factoren uiteengezet die mogelijk bijdragen aan de overgang van een tijdelijke tekstrepresentatie naar een meer permanente, gedecontextualiseerde kennisrepresentatie. De verwachting is dat twee soorten factoren hier aan kunnen bijdragen: factoren die het consolidatieproces beïnvloeden (bijvoorbeeld door informatie herhaald aan te bieden) en factoren die het verrijkingsproces beïnvloeden (bijvoorbeeld door informatie in verschillende contexten aan te bieden). De uiteenzetting in hoofdstuk 2 is gebaseerd op het samenbrengen van de literatuur over begrijpend lezen en de literatuur over geheugenprocessen, maar empirisch bewijs voor de gestelde positie ontbreekt nog voor een deel. Door belangrijke kennishiaten te identificeren in de bestaande literatuur, biedt hoofdstuk 2 mogelijkheden om theoretisch gefundeerde verwachtingen te formuleren die empirisch getest kunnen worden in vervolgonderzoek. De studies die gerapporteerd worden in hoofdstuk 3 tot en met 5 zijn eerste pogingen om bestaande kennishiaten te verminderen.

Hoofdstuk 3 en 4: het opdoen van nieuwe kennis door het lezen van teksten

Volwassenen (hoofdstuk 3). In de twee studies die gerapporteerd worden in hoofdstuk 3, wordt gebruik gemaakt van een nieuw onderzoeksparadigma om leesprocessen te onderzoeken die een rol spelen bij het leren van meerdere teksten. Dit onderzoeksparadigma kan inzicht verschaffen in een specifiek aspect van het proces waarbij informatie uit meerdere teksten wordt geïntegreerd, namelijk het activeren van informatie uit eerder gelezen teksten tijdens het lezen van een nieuwe tekst. In het ‘multipele teksten integratie’ paradigma wordt het proces op een impliciete manier gemeten door de leestijden te registeren. Een belangrijke assumptie van het paradigma is dat leestijden onderliggende cognitieve processen reflecteren. Informatie die niet met voorkennis strookt, leidt bijvoorbeeld tot een langere leestijd en dat betekent dat er sprake is van detectie van de mismatch tussen voorkennis en de informatie (Albrecht & O’Brien, 1993). Het onderzoeksparadigma zit als volgt in elkaar. Leerlingen krijgen informatie in tekstparen gepresenteerd, waarbij de tweede tekst van een tekstpaar een inconsistente zin bevat zoals: 'De rulver is bruin. De rulver is moeilijk te zien in de witte sneeuw.' Ieder tekstpaar wordt in één van de twee condities aangeboden. In de ene onderzoeksconditie kan de inconsistentie opgelost worden door informatie uit de eerst gelezen tekst van het tekstpaar te activeren, want daarin staat een verklaring voor de inconsistentie beschreven, zoals: 'de rulver verandert in de winter van kleur naar wit.' In de andere onderzoeksconditie (de controle conditie) kan de inconsistentie in de tweede tekst niet opgelost worden door informatie uit de eerst gelezen tekst te activeren, omdat hierin de verklaring ontbreekt. Omdat de inconsistente zin in beide onderzoekscondities exact hetzelfde is, kunnen verschillen in verwerkingstijd van de inconsistente zin in de tweede tekst alleen verklaard worden door het aspect waarin de condities van elkaar verschillen, namelijk de informatie uit de eerste tekst. Als de verwerkingstijd van de inconsistente zin verschilt tussen de onderzoekscondities, reflecteert dit dus of informatie uit een eerder gelezen tekst geactiveerd wordt tijdens het lezen. Omdat de informatie in de onderzoeksconditie waarin de eerste tekst een verklaring bevat helpt om de inconsistentie in de tweede tekst te begrijpen, zou het kunnen dat dit zorgt voor een snellere verwerkingstijd van de inconsistente informatie.

De resultaten van Experiment 1 en 2 laten inderdaad zien dat de inconsistentie in de tweede tekst sneller verwerkt wordt wanneer de eerste tekst een verklaring bevat voor de inconsistentie dan wanneer een verklaring in de eerste tekst ontbreekt. Dit laat zien dat de informatie uit de eerste tekst spontaan geactiveerd wordt tijdens het lezen van de tweede tekst. De resultaten ondersteunen dus de hypothese dat informatie uit eerder gelezen teksten spontaan geactiveerd wordt tijdens het lezen van daaropvolgende teksten. Dit komt overeen met hoe leesprocessen gekarakteriseerd worden in verschillende modellen die het leesproces beschrijven (Albrecht & O'Brien, 1993; Kintsch, 1998; van den Broek, Risden, Fletcher, & Thurlow, 1996). Deze modellen gaan ervan uit dat tijdens het lezen, informatie uit de tekst spontaan andere informatie activeert, wanneer er in het geheugen een associatie bestaat tussen dat wat gelezen wordt en andere informatie.

Naast het verzamelen van de leestijden, is in Experiment 2 ook andere informatie verzameld, namelijk informatie die een indicatie geeft van de mentale representatie die een lezer opbouwt van een tekst. Lezers werden gevraagd om na het lezen van een aantal tekstparen te beschrijven waar de teksten over gingen. Door de antwoorden van de lezers te bestuderen kan inzicht verkregen worden in wat lezers in hun mentale representatie opslaan na het lezen van teksten. De verwachting die voortvloeit uit verschillende modellen van het leesproces is dat er een relatie is tussen de leesprocessen die plaatsvinden tijdens het lezen en de mentale representatie die het resultaat is van de leesprocessen. Indien dat zo is, dan zou een veranderde leestijd (aangenomen dat dit leesprocessen reflecteert) moeten leiden tot een andere mentale representatie. Verschillen die de onderzoekscondities tijdens het lezen veroorzaken zouden dus ook moeten leiden tot verschillen in mentale representaties tussen de twee onderzoekscondities. Wat volwassenen rapporteerden over de teksten is geanalyseerd op verschillende aspecten. Uit de resultaten blijkt dat de onderzoeksconditie (met of zonder verklaring in de eerste tekst) geen invloed had op (de geanalyseerde aspecten van) de mentale representatie. De verschillen in leesprocessen resulteerden blijkbaar niet in verschillen in de mentale representaties van de teksten, althans, niet voor de aspecten die zijn geanalyseerd. Dit is niet wat je zou verwachten op basis van leesmodellen zoals het 'Landscape Model' (van den Broek et al., 1996). Dit leesmodel beschrijft namelijk dat leesprocessen van invloed zijn op de mentale presentaties van teksten. Mogelijk komt het ontbreken van de verwachte effecten door beperkingen in de maat die gebruikt is om inzicht te krijgen in de mentale representatie (namelijk, zelfrapportage).

Kinderen (hoofdstuk 4). In dit hoofdstuk is hetzelfde multipele-teksten integratie onderzoeksparadigma gebruikt als dat beschreven is in hoofdstuk 3, maar het onderzoek is ditmaal uitgevoerd bij kinderen uit groep 6 en groep 8. Wederom werden de leestijden van inconsistente zinnen in een tweede tekst van een tekstpaar vergeleken in situaties waarbij deze tekst voorafgegaan werd door een tekst met een verklaring en situaties waarbij deze tekst voorafgegaan werd door een tekst zonder verklaring. De resultaten bij kinderen laten een zelfde patroon zien als bij volwassenen in het voorgaande hoofdstuk: kinderen lezen de inconsistentie sneller wanneer ze eerder een tekst hadden gelezen met een verklaring dan wanneer ze eerder een tekst hadden gelezen zonder verklaring. Dit is het geval voor zowel kinderen uit groep 6 als voor kinderen uit groep 8. Dit laat zien dat ook kinderen spontaan informatie uit eerdere teksten activeren wanneer ze nieuwe teksten lezen.

Net als in Experiment 2 bij de volwassenen, is in dit onderzoek de kinderen gevraagd om na het lezen van te teksten te vertellen wat ze zich nog van de teksten konden herinneren. Dit keer is één specifiek aspect van de mentale representatie geanalyseerd: het leggen van verbanden tussen teksten. Dit proces wordt ook wel intertekstuele integratie genoemd. Uit de resultaten bleek dat kinderen in zowel groep 6 als groep 8 een meer geïntegreerde mentale representaties hebben wanneer de tekstparen in de onderzoeksconditie met verklaring zijn aangeboden dan wanneer de tekstparen in de onderzoeksconditie zonder verklaring zijn aangeboden. Dit komt overeen met wat je zou verwachten over de aangenomen relatie tussen leesprocessen en het opbouwen van een mentale representatie zoals beschreven in bijvoorbeeld het leesmodel

'Landscape Model' (van den Broek et al., 1996).

Verondersteld wordt dat wanneer verschillende stukjes informatie tegelijkertijd actief zijn in het geheugen tijden het lezen dit leidt tot een verband tussen deze stukjes informatie in het geheugen (Goldman & Varma, 1995; Kendeou & O'Brien, 2014; McRae & Jones, 2013; van den Broek et al., 1996). Het lijkt dus dat er een relatie is tussen de leesprocessen en de mentale representatie: in het huidige onderzoek was informatie uit een eerder gelezen tekst actief tijdens het lezen van een daaropvolgende tekst (zoals vastgesteld via de leestijdmaat), waardoor er co-activatie was van de informatie uit twee de teksten en als gevolg daarvan integratie van informatie in de mentale representatie (zoals vastgesteld via de zelfrapportage). Wat opvalt is dat dit resultaat anders is bij de kinderen dan bij de volwassenen in hoofdstuk 3. Een mogelijke verklaring is dat er in het experiment met kinderen gevoeligere scoringsmethoden gebruikt zijn om de mentale representatie te analyseren. Dit suggereert dat de criteria in de studie bij kinderen geschikter zijn om inzicht te krijgen in de mentale representatie.

In de studie die in hoofdstuk 4 staat beschreven zijn ook individuele verschillen in begrijpend lezen en werkgeheugen meegenomen in de analyses. Begrijpend lezen is een vaardigheid die nodig is om informatie uit verschillende teksten te kunnen integreren. Wanneer een deel van de tekst niet begrepen wordt, is het moeilijk om dit deel in verband te brengen met een ander deel van de tekst. In tegenstelling tot de verwachting was begrijpend lezen echter niet van invloed op het leggen van verbanden tussen verschillende teksten, zowel wat betreft de leestijdenmaat als wat betreft de maat van de mentale representatie. Dit is opvallend aangezien een belangrijk onderdeel van begrijpend lezen het leggen van verbanden *binnen* teksten is en logischerwijs zou dit verwant moeten zijn aan het leggen van verbanden *tussen* teksten. Beide processen omvatten namelijk het (re)activeren van eerdere informatie, het vergelijken van eerdere informatie met nieuwe informatie en het integreren van die informatie. Een mogelijke verklaring is dat er sprake is van een plafond-effect. Als teksten gemakkelijk te begrijpen zijn, dan maakt het niet uit of de lezer vaardig is in begrijpend lezen of niet: verbanden zullen gelegd worden ongeacht iemands niveau.

De verwachting met betrekking tot het werkgeheugen was dat er een positief verband zou zijn met het integreren van informatie uit verschillende teksten. Het werkgeheugen is een geheugenfunctie die iemand in staat stelt om informatie tijdelijk op te slaan en tegelijkertijd te verwerken (voor een overzichtsartikel, zie Cowan, 2014). De veronderstelling was dat een beter werkgeheugen ervoor zorgt dat lezers meer informatie (tijdelijk) kunnen vasthouden en verwerken, waardoor ze verbanden over grotere afstanden zouden moeten kunnen leggen (Just & Carpenter, 1992). Dit zou moeten resulteren in een volledigere en complexere mentale representatie van teksten. In tegenstelling tot de verwachting bleek er echter geen verband te zijn tussen werkgeheugen en het leggen van verbanden tussen verschillende teksten, zowel wat betreft de leestijdenmaat als de maat voor de mentale representatie. Ook dit zou verklaard kunnen worden door een plafond-effect. Als de leestaak gemakkelijk is, kunnen zelfs lezers met een zwak werkgeheugen informatie uit verschillende teksten integreren. In andere studies waar wel een verband is gevonden tussen werkgeheugen en het integreren van informatie in een tekst was de leestaak mogelijk uitdagender dan in de huidige studie (Cain, Oakhill, & Bryant, 2004; Daneman & Carpenter, 1980, 1983; García-Madruga, Vila, Gómez-Veiga, Duque, & Elosúa, 2014).

Het valt te verwachten dat begrijpend lezen en werkgeheugen invloed hebben op het integreren van informatie uit verschillende teksten wanneer de leestaak uitdagender is dan wellicht het geval was voor de kinderen in ons onderzoek. Beide vaardigheden ontwikkelen gestaag tijdens de kindertijd (Kendeou, van den Broek, White, & Lynch, 2009; Oakhill & Cain, 2012). Kinderen die deze vaardigheden eerder onder de knie hebben zijn mogelijk beter in staat om complexere leertaken aan te kunnen waarbij informatie uit meerdere teksten geïntegreerd moet worden dan kinderen bij wie deze vaardigheden zich later ontwikkelen. De gecombineerde resultaten uit hoofdstuk 3 en 4 laten zien dat het multipele-teksten integratie onderzoeksparadigma geschikt is voor het vaststellen wanneer informatie uit eerder gelezen teksten actief is. Het onderzoeksparadigma kan dus gebruikt worden in toekomstig onderzoek om te bepalen onder welke omstandigheden lezers informatie uit eerdere teksten activeren, bijvoorbeeld in uitdagendere leersituaties, zoals wanneer de afstand tussen de teksten die een tekstpaar vormen groter is dan in het huidige onderzoek. Dit is met name relevant voor de doelgroep kinderen, omdat zij in hun ontwikkeling ondersteund moeten worden om complexe cognitieve taken in en buiten school aan te kunnen.

Hoofdstuk 5: het veranderen van voorkennis door het lezen van teksten

In hoofdstuk 5 is de tweede vorm van leren onderzocht: het veranderen van incorrecte kennis (ook wel misvattingen genoemd) door het lezen van teksten. Door teksten op een goede manier te structureren kunnen ze bijdragen aan het leerproces. Een tekst met een zogeheten weerleggingsstructuur is bijvoorbeeld bijzonder effectief in het veranderen van incorrecte voorkennis. In weerleggingsteksten wordt de misvatting beschreven en weerlegd voordat de correcte informatie wordt beschreven. Er worden in hoofdstuk 5 twee studies beschreven waarin wordt onderzocht of studenten met incorrecte voorkennis die weerleggingsteksten lezen, de nieuw geleerde kennis spontaan toepassen tijdens het lezen van een nieuwe tekst (een zogeheten 'transfertekst'). Aan het onderzoek deed een groep studenten mee onder wie bepaalde misvattingen veel voorkomen. Een voorbeeld van een dergelijke misvatting is dat de seizoenen op aarde worden veroorzaakt door de afstand van de aarde tot de zon, waarbij dus de aarde dichter bij de zon staat dan in de winter. Dit is incorrect: de seizoenen op aarde worden bepaald door de helling van de as van de aarde ten opzichte van de zon. In de zomer helt het halfrond waar het zomer is naar de zon toe en het halfrond waar het winter is van de zon af. In Experiment 1 lazen de studenten steeds teksten in drie onderzoekscondities: weerleggingsteksten, transferteksten en teksten zonder weerleggingen. Ze lazen de teksten in deze condities altijd in deze volgorde (dus altijd eerst de weerleggingstekst, dan de transfertekst en dan de tekst zonder weerleggingen). Er was altijd een verband tussen de weerleggingstekst en de transfertekst. De verwachting was dat lezers met incorrecte voorkennis de correcte informatie leren door weerleggingsteksten te lezen en dat ze de correcte informatie vervolgens kunnen toepassen in een transfer tekst. In het voorbeeld van de seizoenen op aarde beschrijft de weerleggingstekst eerst de veelvoorkomende misvatting met betrekking tot de afstand van de aarde ten opzichte van de zon, en vervolgens wordt er expliciet gezegd dat dit incorrect is en dat de juiste verklaring te maken heeft met de helling van de as van de aarde. In dit voorbeeld wordt de informatie ingebed in een verhaal over twee jongens die aan het waterskiën zijn. In de transfertekst over dit onderwerp is de verhaalcontext verschillend en zijn er andere hoofdpersonen, namelijk twee dames op leeftijd die een computercursus volgen. Ook al zijn de weerleggingstekst en de transfertekst ingebed in een verschillende verhalende context, de teksten doen beroep op dezelfde correcte informatie om een bepaalde zin (hierna genoemd targetzin) te kunnen begrijpen. Deze targetzin volgt in de weerleggingstekst nadat de correcte informatie is beschreven. Dus als iemand leert van de weerleggingstekst zou die persoon in staat moeten zijn de targetzin te begrijpen. Omdat transferteksten altijd volgen op weerleggingsteksten zou iemand die leert van de weerleggingstekst in principe ook in staat moeten zijn de nieuw geleerde kennis die is opgedaan uit de weerleggingstekst toe te passen tijdens het lezen van de targetzin in de transfertekst. Hiervoor moet een lezer wel doorhebben dat er een verband is tussen de weerleggingstekst en de transfertekst. Omdat de weerleggings- en transferteksten over verschillende onderwerpen gaan kan het zo zijn dat lezers het verband niet herkennen. De teksten zonder weerlegging vormen de controleconditie. In deze teksten wordt een andere misvatting aangestipt, bijvoorbeeld de misvatting dat men maar 10% van zijn of haar hersenen gebruikt. In tegenstelling tot de weerleggingstekst

wordt de misvatting in de tekst zonder weerlegging niet expliciet aangestipt of weerlegd. Bovendien wordt de correcte informatie niet beschreven. De correcte informatie is dus in principe niet beschikbaar voor lezers met misvattingen. Ook de teksten zonder weerleggingen bevatten een targetzin waarvoor de correcte informatie nodig is om die te kunnen begrijpen. De verwachting is dat een lezer met misvattingen moeite zal hebben met het begrijpen van deze zin. In het onderzoek zijn de leestijden van de targetzin vergeleken tussen de verschillende onderzoekscondities. Eerder onderzoek heeft uitgewezen dat informatie die inconsistent is met voorkennis langzamer verwerkt wordt dan informatie die consistent is met voorkennis (e.g. Albrecht & O'Brien, 1993). Daarom is de verwachting dat de targetzin (waarvoor de correcte informatie nodig is om deze te kunnen begrijpen) langzamer wordt verwerkt door lezers met incorrecte voorkennis (misvattingen) dan door lezers die de correcte kennis aangeleerd hebben gekregen (in dit experiment d.m.v. weerleggingsteksten).

Het eerste doel van het onderzoek betreft replicatie van eerder werk waarin aangetoond werd dat weerleggingsteksten effectiever zijn in het veranderen van incorrecte voorkennis dan teksten zonder weerleggingen. Dit zou gereflecteerd moeten worden door snellere leestijden van de targetzin (waarvoor de correcte informatie nodig is) in de onderzoeksconditie met weerleggingen in vergelijking met de onderzoeksconditie zonder weerleggingen. Het tweede en tevens belangrijkste doel van het onderzoek betreft de toepassing van de nieuw aangeleerde kennis uit weerleggingsteksten naar nieuwe situaties, een proces dat transfer genoemd wordt. Als lezers weerlegde kennis kunnen toepassen in een nieuwe situatie, namelijk tijdens het lezen van de transfer tekst, dan zou dat gereflecteerd moeten worden in de leestijden van de targetzin. Voor het begrijpen van de targetzin is de correcte informatie nodig en daarom zou deze sneller gelezen moeten worden wanneer leerlingen de nieuw aangeleerde kennis toepassen in de transfertekst, dan wanneer leerlingen de nieuw aangeleerde kennis niet toepassen of wanneer ze incorrecte kennis toepassen (zoals wanneer iemand met een misvatting een tekst zonder weerleggingen leest). De resultaten uit Experiment 1 komen overeen met deze verwachtingen. Ook de resultaten uit een tweede experiment, waarmee enkele alternatieve verklaringen kunnen worden uitgesloten, komen overeen met de deze verwachtingen.

In Experiment 1 en 2 is ook een test afgenomen waarbij studenten toepassingsvragen moesten beantwoorden. Deze test is bedoeld om te testen of studenten de correcte informatie konden toepassen in nieuwe situaties wanneer ze daar expliciet om gevraagd werden. Het doel van deze test is om additioneel bewijs te vinden voor de effectiviteit van weerleggingsteksten met betrekking tot transfer van aangeleerde (voormalig incorrecte) kennis naar nieuwe situaties. In zowel Experiment 1 en 2 scoren studenten significant hoger op de transfertest wanneer ze weerleggingsteksten lezen dan wanneer ze teksten lezen zonder weerleggingen. Ook met deze transfermaat is dus aangetoond dat weerleggingsteksten effectiever zijn in het bereiken van transfer van correcte kennis naar nieuwe situaties dan teksten zonder weerleggingen.

De resultaten van de twee experimenten in hoofdstuk 5 sluiten aan bij het Knowledge Revision Components (KReC) framework. Dit framework onderscheidt vijf principes die centraal staan bij het proces van kennisverandering: 1) opslaan van informatie in het geheugen, 2) passieve activatie van informatie in het geheugen, 3) co-activatie van twee of meer stukjes informatie, 4) integratie van informatie in het geheugen en 5) competitieve activatie van twee conflicterende stukjes informatie (Kendeou & O'Brien, 2014). In het KReC framework wordt aangenomen dat wanneer men eenmaal een misvatting heeft opgeslagen in het geheugen, deze informatie niet meer gewist of overschreven kan worden (principe 1). Het gevolg hiervan is dat de misvatting altijd de potentie heeft om (automatisch) geactiveerd te worden in de toekomst (principe 2), bijvoorbeeld wanneer men een tekst leest die relateert aan de misvatting. Een misvatting kan alleen veranderen wanneer a) de misvatting *tegelijkertijd* met de correcte informatie geactiveerd wordt (principe 3), b) er een verband wordt gelegd tussen de misvatting en de correcte informatie en dat dit verband wordt opgeslagen in het geheugen (principe 4), en c) de correcte informatie sterker gepresenteerd wordt in het geheugen dan de misvatting (principe 5). De effectiviteit van weerleggingsteksten in hoofdstuk 5 kan verklaard worden doordat ze processen faciliteren die aansluiten bij de principes van het KReC framework. In de weerleggingsteksten wordt de misvatting namelijk expliciet genoemd en direct daarna volgt een beschrijving van de correcte informatie, waardoor de misvatting en de correcte informatie tegelijkertijd actief zijn (principe 3). Door deze co-activatie, kan er een verband gelegd worden tussen de misvatting en de correcte informatie (principe 4). Omdat vervolgens de correcte informatie uitgebreid wordt toegelicht in de tekst, wordt de mentale representatie van de correcte informatie versterkt (Kendeou, Walsh, Smith, & O'Brien, 2014). Door deze solide representatie van de correcte informatie wordt de kans vergroot dat de correcte kennis wordt toegepast in nieuwe situaties en niet de misvatting (principe 5), precies zoals gebleken is in de experimenten van hoofdstuk 5.

Hoofdstuk 6: samenvatting, discussie en conclusie

Er worden in hoofdstuk 6 vijf thema's aangestipt die de individuele hoofdstukken overstijgen.

Leerprocessen. Hoewel het opdoen van nieuwe kennis (hoofdstuk 3 en 4) en het veranderen van incorrecte bestaande kennis (hoofdstuk 5) verschillende processen lijken, zijn veel onderliggende processen vergelijkbaar. Zowel het opdoen van nieuwe kennis als het aanpassen van bestaande kennis vereist namelijk het activeren van bestaande kennis, het co-activeren van bestaande en nieuwe kennis en het integreren van bestaande en nieuwe kennis in het geheugen. Deze processen staan centraal in vele modellen van leren en lezen.

Meten van leerprocessen. In de empirische studies die worden beschreven in deze dissertatie (hoofdstuk 3 tot en met 5) worden innovatieve experimentele methoden gebruikt om op impliciete manier inzicht te krijgen in het leerproces. Door te kijken hoe leestijden beïnvloed worden door subtiele veranderingen in de tekst, kan afgeleid worden welke processen er plaatsvinden tijdens het leren van teksten. In het verleden zijn vaak expliciete methoden gebruikt om informatie in te winnen over het leerproces. Die hebben als nadeel dat een lezer zich er bewust van moet zijn. Het voordeel van de studies in de huidige dissertatie is dat ze inzicht geven in spontane leerprocessen waar lezers zich niet van bewust hoeven zijn.

Mentale representaties. Leren van teksten is succesvol wanneer een lezer een (correcte) mentale representatie opbouwt van de tekst. Het is belangrijk dat deze mentale representatie a) duurzaam is en dus dat de informatie later ook nog beschikbaar is, en b) gedecontextualiseerd is, en dus dat de informatie in de mentale representatie toegepast kan worden in nieuwe situaties. Er zijn in deze dissertatie diverse pogingen gedaan om meer inzicht te krijgen in deze kenmerken van mentale representaties. Dit is gedaan door vrij snel na het lezen verschillende soorten (toepassings-)vragen te stellen aan de lezer. De gehanteerde benadering kent echter beperkingen. Het tijdsinterval was bijvoorbeeld vrij kort, waardoor er weinig zicht is op of de informatie op langere termijn beschikbaar bleef. In toekomstig onderzoek wordt daarom aanbevolen om naast de gehanteerde maten in het huidige onderzoek ook andere maten te gebruiken, om meer inzicht te krijgen in de factoren die bijdragen aan de duurzaamheid en decontextualisatie van mentale representaties die opgebouwd worden van teksten.

Ontwikkeling. Hoewel er tot nu toe nog weinig onderzoek is gedaan naar het proces waarbij kinderen nieuwe kennis opdoen uit meerdere teksten zijn er indicaties dat kinderen dit soms lastig vinden (Sheehan, Kostin, & Persky, 2006). Ze vinden het bijvoorbeeld moeilijk om verbanden te leggen tussen verschillende teksten. Het is aannemelijk dat kinderen de vaardigheden die ze hierbij nodig hebben nog niet goed ontwikkeld hebben en dat ze die pas op latere leeftijd ontwikkelen, wanneer ze meer ervaring hebben en meer instructie op dat gebied hebben gekregen. Wel is het zo dat een deel van de benodigde basisvaardigheden al aanwezig zijn bij kinderen aan het einde van de basisschool. Dat blijkt uit de studie die beschreven wordt in hoofdstuk 3. Kinderen activeerden spontaan informatie uit eerder gelezen teksten tijdens het lezen van een nieuwe tekst. Kinderen uit groep 6 lijken het hierbij even goed te doen als kinderen uit groep 8. Het is aannemelijk dat ontwikkelingsverschillen zich wel zullen manifesteren wanneer kinderen met complexere leertaken worden geconfronteerd. Een belangrijke onderzoeksvraag die beantwoord zal moeten worden in toekomstig onderzoek is daarom in welke situaties kinderen moeite hebben met het opdoen van nieuwe kennis uit meerdere teksten en hoe deze benodigde vaardigheden zich ontwikkelen. Individuele verschillen in cognitieve vaardigheden en achtergrondkennis kunnen verklaren waarom het ene kind het beter doet dan het andere kind bij het leren van teksten. Op basis van de literatuur kunnen persoonskenmerken geselecteerd worden (zoals achtergrondkennis) die naar verwachting een belangrijke rol spelen bij leren van meerdere teksten. Maar ook kenmerken van de tekst of de leeromgeving (zoals instructies) spelen waarschijnlijk een rol bij succesvol leren van teksten.

Vaardigheden onderwijzen. Omdat in deze dissertatie geen onderzoek is gedaan naar praktische manieren om leren van teksten te verbeteren moeten de praktische implicaties die gedaan worden in de dissertatie met name gezien worden als suggesties voor vervolgonderzoek, zodat in de toekomst empirisch vastgesteld kan worden wat wel en niet werkt. Wat betreft het leggen van verbanden tussen meerdere bronnen van informatie is de verwachting, gebaseerd op de literatuur, dat positieve resultaten behaald kunnen worden door in te spelen op drie verschillende aspecten. Ten eerste moet informatie uit teksten die in het verleden zijn gelezen beschikbaar zijn tijdens het lezen van nieuwe teksten. De beschikbaarheid van informatie in het geheugen kan bijvoorbeeld worden verbeterd door geheugenstrategieën toe te passen. Ten tweede moet informatie uit verschillende teksten tegelijkertijd geactiveerd worden zodat verbanden kunnen worden gelegd. Dit kan bijvoorbeeld door de lezer een teken te geven waardoor de lezer herinnerd wordt aan eerder gelezen teksten. Ten derde moeten de verbanden die zijn gelegd worden opgeslagen in het geheugen. Ook hier kunnen geheugenstrategieën voor gebruikt worden. Een paar andere voorbeelden van manieren waarop deze drie factoren gestimuleerd kunnen worden zijn het gebruiken van een strategie waarbij de lezer informatie uit teksten aan zichzelf uitlegt, het organiseren van informatie uit teksten in figuren zoals een ‘mindmap’ en het uitvoeren van activiteiten vóórdat de lezer aan het lezen van een nieuwe tekst begint om voorkennis op te halen.

Wat betreft het veranderen van bestaande (incorrecte) kennis is de verwachting, gebaseerd op de literatuur, dat positieve resultaten behaald kunnen worden door in te spelen op drie processen: co-activatie, integratie en competitieve activatie. De effectiviteit van weerleggingsteksten kan verklaard worden doordat ze deze drie processen beïnvloeden. Maar er zijn ook andere manieren om deze drie processen te faciliteren. Zo kan co-activatie en integratie van correcte en incorrecte informatie gestimuleerd worden door aandacht te geven aan signaalwoorden die tegenstrijdigheden signaleren en kunnen hints lezers erop wijzen dat er vergelijkingen moeten worden gemaakt.

Conclusie

Het doel van deze dissertatie was om meer inzicht te krijgen in de processen die betrokken zijn bij het construeren van (relatief) duurzame mentale representaties bij kinderen en volwassenen. Een literatuuroverzicht en drie empirische studies zijn uitgevoerd om dit doel te bereiken. De empirische studies laten zien dat zowel volwassenen als kinderen in staat zijn om spontaan kennis op te doen uit teksten en die toe te passen in een nieuwe tekst. Het lezen van teksten zorgde ervoor dat lezers hun kennis uitbreidden (hoofdstuk 3 en 4) en veranderden (hoofdstuk 5). Deze dissertatie omvat innovatieve onderzoeksmethoden die gebruikt kunnen worden in vervolgonderzoek om te bepalen welke factoren van invloed zijn op het uitbreiden en veranderen van voorkennis in meer uitdagende situaties. Hoofdstuk 2 kan toekomstig onderzoek inspireren om te bepalen welke specifieke factoren onderzocht zouden moeten worden. Op de lange termijn zouden deze toekomstige studies kunnen leiden tot praktische interventies. Interventies die effectief blijken te zijn kunnen vervolgens geïntegreerd worden in schoolcurricula. Hopelijk motiveert deze dissertatie andere onderzoekers om deze lijn van onderzoek voort te zetten. Dit zal ons dichter bij het bereiken van een van de belangrijkste doelen van de 21ste eeuw brengen, namelijk om studenten van alle leeftijden en met verschillende achtergronden in staat te stellen om (relatief) permanente mentale kennisrepresentaties op te bouwen van (verschillende, papieren en digitale) teksten, waardoor studenten deze kennis kunnen toepassen in verschillende situaties, in en buiten school.

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CURRICULUM VITAE

CV

Katinka Beker was born on the 9th of September in 1988 in Rotterdam, the Netherlands. She graduated from the Maerlant College Brielle in 2006. Katinka obtained her Bachelor's degree in Psychology in 2009 at the Erasmus University Rotterdam, The Netherlands, specializing in Cognitive and Biological Psychology and in Educational and Developmental Psychology. In 2010 she received her Master's degree in Psychology at the Erasmus University Rotterdam, specializing in Educational and Developmental Psychology. During the years of 2008-2010, she worked as a research assistant. After graduating she worked as a teacher at the Erasmus University Rotterdam. In 2011 she started working as a researcher and teacher at the Vrije Universiteit Amsterdam and at the Windesheim University of Applied Sciences. In the summer of 2011 she started her PhD research project at Leiden University which was supervised by Prof. Dr. Paul van den Broek and Dr. Dietsje Jolles at the Brain and Education Laboratory at the department of Education and Child Studies. As part of her PhD research project Katinka spent four months in Dr. Panayiota Kendeou's Text Group laboratory at the University of Minnesota in 2014 as a guest researcher. In September 2016 Katinka started working at the government, at the ministry of Education, Culture and Science.

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LIST OF PUBLICATIONS

P

Published articles

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Beker, K., van den Broek, P., & Jolles, D. D. Children's integration of information across texts: Reading processes and knowledge representations.