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## Reading comprehension in elementary school children: cognitive studies of the reader, the text, and the task

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# **English Summary**

**Reading comprehension in elementary school children:**

**Cognitive studies of the reader, the text, and the task**



Reading comprehension is a multifaceted skillset important to acquire in order to participate in modern society; to learn at school, for work related communication, for social digitized interactions, and to keep up to date with news. Important developmental change in this skillset occurs between the ages of 9 and 12, when elementary school children go from learning to read to reading to learn. In this phase educators start expecting the children to use their reading comprehension skillset to gather knowledge about many different topics. However, children are of course not alone on their journey to become proficient readers. A great deal of research and educational resources are mobilized to help them on their way. The four empirical papers in this doctoral dissertation present research from a cognitive scientific perspective on three elements that are important to understand reading comprehension in scientific and educational contexts: the reader, the text, and the task (Snow & RAND, 2002; van den Broek, Fletcher, & Risden, 1993).

Within cognitive science, gaining deep comprehension of a text is described as the construction of a mental model, a situation model (Johnson-Laird, 1983; van Dijk & Kintsch, 1983). This means that the situations, events, and characters that are depicted in the text need to be envisioned in the reader's mind. Being able to construct a situation model depends on reader characteristics, text characteristics, and task demands. First, many cognitive skills and strategies are needed for a reader to construct a situation model, such as to make inferences from the text (Bowyer-Crane & Snowling, 2005; Cain & Oakhill, 1999; Graesser, Kintsch, 1994; Singer, & Trabasso, 1994). Inference generation entails reading between the lines. This requires the reader to connect different parts of the text to other parts of the text, and to connect parts of the text to their previous knowledge. By generating inferences, i.e. seeing how sentences are interconnected and enriching the situation model with previous knowledge, the reader understands that the text is not just a string of words, but that it tells a story with evolving events with causes and effects. Processes and strategies, such as inferences, that are generated while reading, are called online reading processes. Online reading processes are thought to contribute to the readers' memory representation of the text when having finished reading. The memory representation after having finished reading is called offline memory. Second, differences in text topic, difficulty, and length have an impact on what a reader can extract from the text, and thereby how rich the situation model becomes that they are constructing (e.g. van den Broek et al., 1993). When reading an easy text, for example a text that uses everyday language and has clear structure, the reader can easily construct a rich situation model. Thereby, the reader achieves a good understanding of the content. However, as soon as the text becomes more demanding, perhaps introducing new words and concepts, the reader needs to work harder to achieve a good understanding of the text. Third, the

task that the reader is given, or takes on, while reading will have an impact on the ability to construct a rich situation model (e.g. van den Broek & Kendeou, 2017). Reading a text at own free pace and being able to revisit sentences that are hard to understand, will rule a different outcome in comprehension than when trying to understand the same text but without the ability to control the speed with which the text is presented. For example, when being read to or when using a digital read-aloud device. Hence, the many complex cognitive processes that contribute to reading comprehension, likely interact with reader, text, and task characteristics (Rapp & van den Broek, 2005).

The research in this dissertation focuses predominantly on 9-12-year-old Dutch children's abilities to construct a situation model of text. This is an important phase in a child's reading development. 9-12-year olds in many western educational systems, as in the Dutch school system, transition from the phase learning to read to the phase reading to learn (e.g. Chall 1983; 1996; Poolman, Leseman, Doornbal, & Minnaert, 2017). In this phase, reading to learn, children are expected to have become fluent in word-decoding skills, and are given longer texts with the aim to teach content. However, these texts also require additional reading processes compared to the simple texts used in the first phase. Children's reading performance often drops in the transition from learning to read to reading to learn, a phenomenon called the fourth-grade slump. This drop indicates that the increased demands that come with reading more complicated texts is not gradual (Chall 1983; 1996). However, with educational practitioners' careful consideration of how to read the more difficult texts, children can comprehend and learn from the texts.

Although school and home environment may increase demands on and opportunities for the reading development of children in Dutch upper elementary school, their cognitive system is still developing. Executive functions, and brain networks supporting language skills and executive functions, continue to develop in older children and well into late adolescence (e.g. Diamond, 2013; Gathercole, Pickering, Ambridge, Wearing, 2004; Huizinga, Dolan, & van der Molen, 2006; Zielinski, Gennatas, Zhou, & Seeley, 2010). Executive functions can be described as an umbrella term for cognitive processes that allow control of thoughts and behavior (Diamond, 2013), such as working memory. Working memory can be seen as a mental workspace with a limited storage capacity, that enables keeping information in mind, and manipulating this information (Daneman & Merikle, 1996; Diamond, 2013). Working memory is important in the context of reading comprehension as it underlies the capacity and processes necessary to retain and update the content of the story as the reader proceeds through the text (e.g., Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman & Merikle, 1996).

The empirical studies in this dissertation provide insight in cognitive processes in reading and language comprehension in primarily upper elementary school children. We examined how cognitive situation-model building processes are related to reader, text, and task characteristics. Furthermore, we describe the relations among these three factors. Educators know the importance of constructing good learning contexts for students. In their mission to do so, the question “what makes some students succeed and others not?” is an everyday issue. Together with previous research, this dissertation helps in understanding the relations between the three factors and dealing with the complexity in educational practice and educational science.

In the **second chapter** we studied how children (9-11 years old) differ in online inference generation, and how these differences relate to children’s underlying reader characteristics. Children read texts from two genres, narrative and expository texts. Based on think-aloud data, we identified three profiles of readers that differ in both the number and types of inferences they generate. Elaborating Readers generated different types of inferences; they used text connecting inferences, elaborative inferences, and predictive inferences while reading. Paraphrasing Readers predominantly repeated the text by paraphrasing it. In addition, they also generated some inferences. Literal Readers mainly repeated the text literally; in fact, 60% of responses from children in this profile were literal text repetitions. Literal Readers generated few inferences. On ancillary measures, Elaborating Readers, showed significantly higher scores on word reading and non-verbal reasoning measures than did Paraphrasing, and Literal Readers. These results show that concerning reader characteristics, both lower- order cognitive processes (such as word reading) and higher-order cognitive processes (such as reasoning ability) underpin children’s differences in online reading processes. Children generally showed the same reading profiles for both narrative and expository texts. However, generally expository texts elicited fewer elaborative reading processes than narrative texts. For example, there was a smaller number of predictive inferences made when reading expository texts. In addition, a larger number of invalid elaborative inferences were found for expository texts than narrative texts. Because generating fewer elaborative inferences and generating more invalid inferences are likely to impede comprehension, these findings indicate that upper elementary school children are still developing skills to comprehend expository texts. To sum up, the current findings are in line with previous research (e.g. McMaster et al., 2012; Kraal et al., 2017) that has found reader profiles in which children build either a situation model that closely resembles the text or a situation model that is enriched by inferences. In this study, we expand on previous research by showing

that such profiles can be found in a group of children with heterogenous underlying cognitive and language abilities, and that these abilities differ between the profiles. In addition, we show that children produce a very similar set of think-aloud responses across text genres that results in the same profiles across the different texts. There were however differences in the number of inferences generated between the text genres. Hence, the results suggest a certain stability in children's text approaches with room for situational differences related to text characteristics.

In the **third chapter** we studied how online processes of children (9-11 years old) in the three reader profiles (presented in chapter two) relate to their offline text memory. Because the offline text memory is an important indicator for learning in school, research of reading profiles needs to consider the quality of memory representations. Offline memory of narrative and expository texts was studied by examining whether children remembered more central information, the gist, than peripheral information from the text after reading, i.e. whether they showed a centrality effect. Inferences help in making connections between text parts, which is important to understand the gist of a text. Therefore, we anticipated that children who generate a larger number of online inferences would show a larger centrality effect in their offline recall, compared to children who generate fewer online inferences. Meaning we hypothesized Elaborating Readers would show a larger centrality effect than Paraphrasing Readers and Literal Readers, and that Paraphrasing Readers would show a larger centrality effect than Literal Readers.

First, all groups of children showed a centrality effect for narrative texts. Elaborating Readers showed a larger centrality effect than Paraphrasing Readers. However, neither Elaborating Readers nor Paraphrasing Readers differed from Literal Readers. We suggest that these findings cannot be explained only by the number of inferences generated during reading, but we also consider reader characteristics. Elaborating readers proved to achieve higher scores on word decoding and non-verbal reasoning than both Paraphrasing, and Literal Readers. We suggest that children in each profile engage in the online reading processes that suit the cognitive capacities that underpin their reading. Although Paraphrasing Readers score lower on word decoding and reasoning tests than Elaborating Readers, Paraphrasing Readers try out some inferences while reading. Possibly, trying out inferences while having relatively underdeveloped word reading and general reasoning abilities hinders Paraphrasing Readers from achieving an offline memory representation similar to that of Elaborating Readers. Second, no centrality effects were found when the children read expository texts. In sum, expository texts elicited fewer inferences in online processes (second chapter) and no profile differences in offline comprehension (third chapter). It is possible that extracting central infor-

mation in expository texts requires additional online processes to inference generation that our measures did not capture. Previous research has often examined single inference processes in short texts. As we now examined a number of different inferences when reading longer texts, we found that the affect of inference processes on offline memory is not clear-cut, but other reader characteristics combined with inference generation may explain offline memory of a text.

In the **fourth chapter** we examined children's (9-12 year old) ability to use the temporal connectives *before* and *after* when building a situation model of sentences with two events, such as "Before you subtract a number, you should solve the multiplication". Such sentences can be grammatically complex and therefore taxing for working memory. Previous research has brought contradicting hypotheses of the role of working memory for comprehending these sentences. To expand on previous research, we examine how comprehension interacts with both working memory capacity and working memory updating ability. In two experiments we varied the position of the connectives *before* and *after* (*voordat* and *nadat* in Dutch) in the sentences, in the beginning or in the middle of the sentence. In the first experiment we asked participants to answer the question "what happened first?" and in the second experiment we asked participants to answer the question "what happened last?". By these sentence and task manipulations we could investigate whether comprehension was affected by familiarity of the connective, by the position of connective, by the position of the answer (main clause, subordinate clause, or recent clause), and by sentence chronology.

Across both experiments, we found that upper-elementary school children's comprehension was affected by clause salience, rather than the familiarity of the connective. The children were sensitive to whether the correct answer to the comprehension question was situated in the main clause or the subordinate clause. Importantly, the second experiment showed that comprehension was qualified by children's working memory updating ability and working memory capacity. Children with high working memory updating ability showed a main clause advantage, i.e. they performed well when the correct answer was situated in the main clause. Children with low working memory updating ability showed a recency effect instead, i.e. their comprehension was better when the correct answer was positioned at the end of the sentence. These results suggest qualitative differences between the comprehension of children with low and high working memory updating ability. Furthermore, the position of the connective influenced comprehension and, importantly, interacted with working memory abilities. When reading sentences with sentence-initial connectives, readers need to hold information about the connective in working memory until they have finished reading the full sentence, and

then apply the information that the connective implies. For these sentences, children's performance increased with a higher working memory capacity. When reading sentences with sentence-medial connectives, readers need to update their mental representation mid-sentence. For these sentences, children's performance increased with a higher working memory updating ability. Together, these findings indicate that upper-elementary school children's comprehension of sentences containing temporal connectives is affected by reader characteristics where there are dissociable contributions of working memory capacity and working memory updating.

Contradicting hypotheses in previous literature examining connectives stemmed from two issues; research either examined working memory capacity or working memory updating (results related to reader characteristics), and research either used a reading task or a listening task (results related to task characteristics). In chapter four we disentangled the relation with the two aspects of working memory. In the fifth chapter we researched task characteristics by means of a reading task or a listening task.

In the study presented in the **fifth chapter** we examined comprehension of sentences with target words of high and low predictability in two modalities: reading and listening. We started this examination in an adult population (mean age 22 years old). The participants read sentences with target words of high and low predictability. In the following example 'aquarium' is thought to be a highly predictable word "Peter thinks that tropical fishes are very beautiful. At home, he has a lot of different types swimming in an aquarium/bowl." However, in the following example 'bowl' is thought to be a highly predictable word "The boy was very happy with his new goldfish. At home he immediately put the fish in a bowl/ an aquarium with fresh water." We investigated whether working memory updating is taxed differently when reading or listening to sentences leading up to a highly predictable or less predictable word, using the ERP component N400 (The N400 component of the ERP provides an online measure of meaning processing in the brain while listening), eye-tracking (time spent on reading a word provide an online measure of meaning processing), and a working memory updating task. We predicted that a reading task taxes working memory less than a listening task as the reader has the possibility to go back and reread target words that seem less predictable.

First, there was a moderate positive correlation between the reading task and the listening task. In other words, this finding indicates that comprehension processes have both commonalities and differences in reading and listening. In addition, results indicate that working memory is more taxed in the listening task than in the reading task, and comprehension is related to both individual differences in

working memory, and task demands such as the possibility to revisit the text. In the reading task, the group of participants with high working memory and the group of participants with low working memory looked equally long at highly and moderately predictable words at first gaze. In addition, both groups of participants looked back at less predictable words equally often. In the listening task, only participants with low working memory showed a pronounced N400 effect towards less predictable words, suggesting they struggle to make sense of it. Hence, there is an interaction between reader characteristics of working memory and the task demands that affect comprehension. Research concerning modality differences can have educational benefits as listening software are sometimes used in schools as reading aids. However, further research should include elementary school children because it is difficult to make direct comparisons of results concerning an adult population since children's working memory is still developing.

To sum up, reader characteristics - such as the ability to use inferences, word decoding, reasoning abilities and working memory- interact with text and task characteristics. To fully understand children's development of reading comprehension, research needs to consider the contextual demands, e.g. text and task demands, it occurs within. This implies that educational practitioners need to support children's reading development in each new context.

