Mind the reading mind: a multifaceted and methodologically diverse approach to investigating the role of attentional control and feedback in reading comprehension

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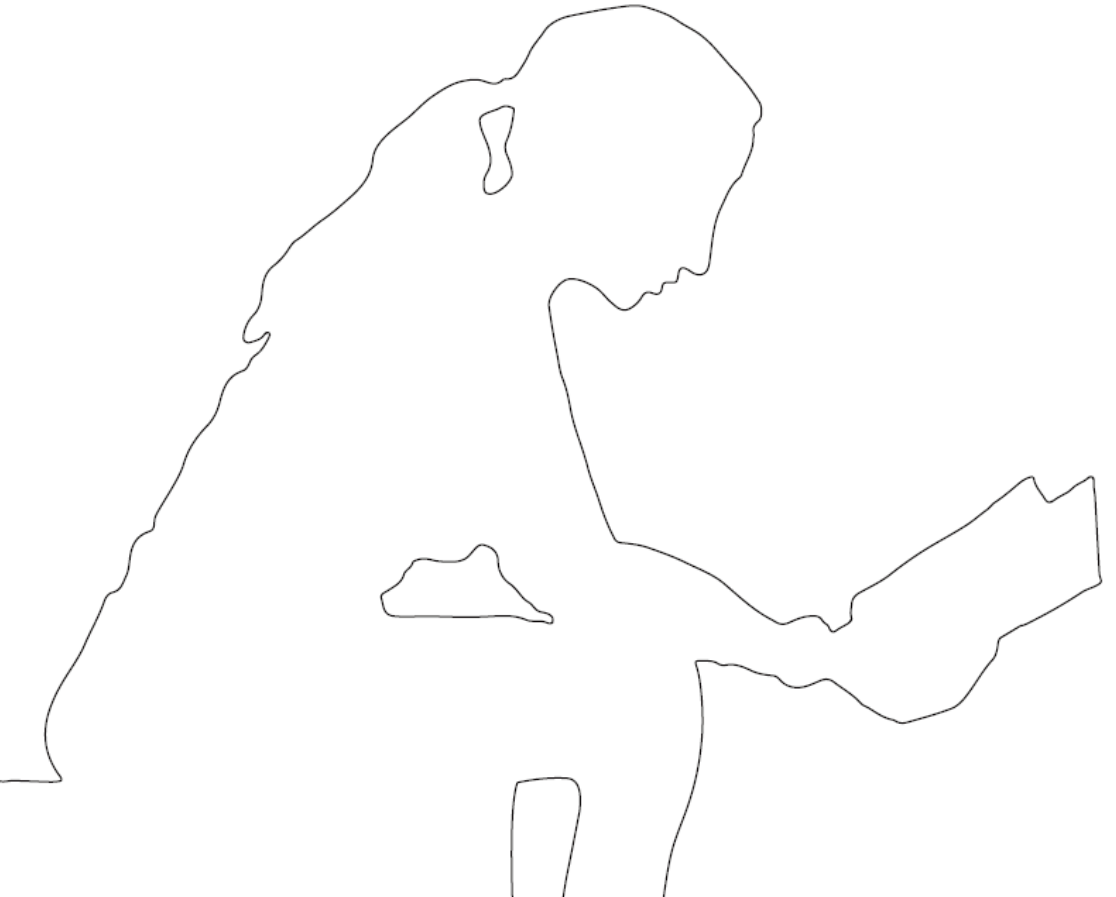

Chapter 1

General Introduction

Introduction

An essential tool for success and survival in school, as well as in private and professional life, is reading comprehension. Whereas in the early years of education there is a focus on *learning to read*, in later years, the focus shifts to *reading to learn,* a phase in which reading comprehension is a crucial vehicle for learning (see Chall, 1983; Pearson et al., 2012). To comprehend, and thereby learn from, a text, students must be able to extract the main idea from a text, understand relationships between parts of text, and link information in the text to their background knowledge or personal experiences (Organisation for Economic Cooperation and Development [OECD], 2019). Yet, still too many students experience difficulties with these skills.

Results of PISA-research over the last decade have demonstrated that, internationally, an average of 20% of 15-years old children do not reach a basic level of reading comprehension (OECD, 2010; 2014; 2016), defined as the ability to "identify the main idea in a text of moderate length, find information based on explicit, though sometimes complex, criteria, and reflect on the purpose and form of texts when explicitly directed to do so" (OECD, 2019, p. 86). In the most recent PISA-study, conducted in 2018, this percentage increased to 23%, indicating that nearly one in four children had not developed the reading comprehension skills necessary to learn from texts (OECD, 2019). Additionally, in the 2020 U.S. News and World Report ranking of *Best Countries for Education,* for half of the top ten ranked countries the average reading performance of 15-years olds had declined since the previous PISA research in 2016 (see OECD, 2019; U.S. News, 2020). Coupled with the recent PISA results this is an alarming decline in students' average reading performance. However, reading comprehension problems are not limited to primary and secondary education levels, but are also seen in higher education where reading comprehension difficulties are a common obstacle for learning (see e.g., Andrianatos, 2019; Bettinger & Long, 2009; Gorzycki et al., 2016).

Reading comprehension is seen as a complex skill (see e.g., Castles et al., 2018; Hoffman, 2017). Although in 1986, Gough and Tunmer presented the "simple view" of reading comprehension, defining it as the product of decoding skills and linguistic skills, (Gough & Tunmer, 1986; see also Hjetland et al., 2020), researchers have debated whether a "simple view" adequately explains the complex process of reading comprehension. For example, research demonstrates that decoding and linguistic skills only explain approximately half of the variance in reading comprehension skills for older children and adolescents (see e.g., Ouellette & Beers, 2010; Tilstra et al., 2009). Further, other skills and processes have been found to be critical components of reading comprehension, including strategic reading behaviour, attentional control, and motivation (e.g., Arrington et al., 2014; Kendeou et al., 2014; Kieffer et al., 2017). Conners (2009) found that for children as

young as 8 years old, attentional control was an important factor in reading comprehension, uniquely explaining 10% of the variance in reading comprehension skills, and concluded that attentional control should be seen as a third component of the simple view of reading.

Given the complex nature of reading comprehension, it follows that understanding comprehension requires a multifaceted approach that incorporates the multiple skills necessary for comprehension to occur (Israel & Reutzel, 2017). Such an approach must not only consider the product of reading comprehension (i.e., determining whether the reader has understood what has been read) but also the processes underlying reading comprehension (i.e., determining which cognitive and behavioural actions are applied during reading, and how they are applied; McNamara & Kendeou, 2011). In this dissertation, the focus is on the processes underlying reading comprehension. A thorough understanding of these underlying processes of reading comprehension is fundamental to (1) understanding individual differences in reading comprehension and (2) developing effective methods for improving reading comprehension (see Castles et al., 2018; Hoffman, 2017; Israel, 2017; Kendeou et al., 2014; McNamara & Kendeou, 2011).

A multifaceted approach to understanding reading comprehension necessitates a diversity of methodological approaches (see Israel & Reutzel, 2017; RAND Reading Study Group, 2002). For example, randomized controlled trials (RCTs) provide insight into the causal relations between variables, and are important for testing the effects of comprehension instruction and interventions. Replication studies provide insight into the generalizability of findings across participant characteristics and contexts (see Merkelbach, 2018). Research syntheses provide insight into the theoretical underpinnings of reading comprehension, and help to establish a knowledge base that can be used to inform educational practice.

In the current dissertation we apply a multifaceted and methodologically diverse approach to gain insight into both individual differences in reading comprehension and the effectiveness of instructional methods. First, we investigate the role of internal factors related to reading comprehension, namely attentional processes during reading, by combining traditional psychological measures (e.g., reading comprehension/vocabulary tests, questionnaires, self-reports) with psychophysiological measures and methods (e.g., EEG, levodopa administration, genotyping) to get a more thorough picture of what is going on when students extract meaning from text. Second, we investigate the role of external factors on reading comprehension, namely the effects of feedback on reading comprehension and on the processes underlying reading comprehension. More specifically, we conduct a meta-analysis of research on the effects of feedback on reading

comprehension and on the cognitive and affective processes related to reading comprehension.

Attentional Control and Reading Comprehension

Attentional control is a critical aspect of reading comprehension, affecting the readers' comprehension of text (Arrington et al., 2014; Conners, 2009; Dixon & Bortolussi, 2013; Feng et al., 2013; McVay & Kane, 2012; Sanders et al., 2017; Smallwood et al., 2007, 2008; Soemer et al., 2019). Yet, measuring attentional control during reading is challenging because the act of measurement itself can be a distraction to the reader. In the second chapter of this dissertation, we examine the role of attentional control in reading comprehension and review methods for measuring attentional control. We also investigate an alternative method for measuring attentional control, one that does not interrupt the natural process of reading and thus does not introduce a distraction to the reader.

It is a familiar view in universities, high schools, or study centres: Students sit at desks, or in front of a computer, reading long stretches of text they are expected to study for their courses. Staying focused while reading and studying such texts is an increasingly challenging activity given the distractions that students face in our modern-day society (see Gazzaley & Rosen, 2016; Rosen, 2017; van der Stigchel, 2018). The amount of distracting information with which students are surrounded has increased immensely over the past years as a consequence of the increased accessibility and capabilities of digital devices. Often next to the books and papers on students' desks are mobile phones, tablets, or computers, with multiple tabs open, waiting to distract the reader with information that is unrelated to the text being read. This task-irrelevant information coming from digital devices, including text messages, posts on social media, e-mails, and videos, distracts students on average 11 to 12 times per hour (Calderwood et al., 2014). It is not only this increased amount of task-irrelevant information coming from digital devices (i.e., external distractors) that causes distraction, even *thinking about the possibility* that there may be new posts on social media, new messages, or new e-mails can cause distraction (i.e., internal distractors; see also Gazzaley & Rosen, 2016; Schad et al., 2012; Smallwood, 2011). Similar to external distractors, such internal distractors draw the attention of the reader away from the task at hand, forming a challenge for readers to control their attention.

In their book called *The Distracted Mind*, Gazzaley and Rosen (2016) metaphorically describe attentional control as operating a spotlight. To operate the spotlight, one has to decide not only if the spotlight (i.e., focus) should be turned on or off, but also to anticipate when, where, and for how long the spotlight should be turned on.

Translating this metaphor into attentional control during reading, the reader has to focus attention (i.e., turn the spotlight on), from the moment he or she starts to read, until the entire text has been read and a mental representation of the text has been formed (i.e., anticipate when and for how long the spotlight should be turned on). In addition, during reading, the reader has to select and process relevant information from the text (i.e., decide where to focus the spotlight) in order to link it to background knowledge.

Research has shown that people who are better able to regulate their attention during reading (i.e., the more skilled operators of the spotlight), have a better understanding of what they read (e.g., Dixon & Bortolussi, 2013; Feng et al., 2013; McVay & Kane, 2012; Sanders et al., 2017; Smallwood et al., 2007, 2008; Soemer et al., 2019). However, one of the caveats in research on attentional control during reading, and one that serves to potentially threaten the ecological validity of the results, is the lack of direct measures of attentional control, that is, measures that do not interrupt the natural reading process (see Smallwood & Schooler, 2015). Although researchers can create experimental circumstances that challenge readers to control their attention during reading (e.g., by manipulating task difficulty or watching a sad movie just before a task; Feng et al., 2013; Smallwood et al., 2009), there is no button to turn attentional control on and off. As a consequence, most research on attentional control during reading has been based on self-reports of attentional control (see also Smallwood & Schooler, 2015). A small number of researchers have searched for objective indicators of attentional control, for example, by studying eye movement patterns during reading (e.g., Reichle et al., 2010; Schad et al., 2012; Uzzaman & Joordens, 2011), but the large majority of studies have been based on self-reports as indicators of attentional control during reading. Self-reports have two limitations, namely that the reports are based on subjective information, and that the act of self-reporting on attentional control during reading interrupts the natural reading process (for a more thorough consideration of the limitations of these self-reports, see Chapter 2). Finding an objective, non-intrusive, reliable measure of attentional control during reading could improve our understanding of attentional control during reading, and provide insights into individual differences in attentional control and the effects of these differences on reading comprehension. Therefore, in Chapter 2 we test the value of frontal TBR during reading, an EEG-measure that has been related to state attentional control during task performance in previous research (Braboszcz & Delorme, 2011; van Son et al., 2019a), as an indicator for attentional control during reading.

The Influence of Dopamine on Attentional Control and Reading Comprehension

To gain further insight into individual differences in attentional control during reading and reading comprehension, in the third chapter of the dissertation we study neurobiological – specifically dopaminergic – processes that underlie attentional control and reading comprehension. In a randomized double-blind placebo-controlled trial, we investigate the effects of administering levodopa, a precursor of dopamine (DA) in the brain, in two groups of students; a group of students carrying the DRD4 7-repeat allele (DRD4 7+), which is related to lowered levels of DA in the brain (Ariza et al., 2012), and a group of students not carrying the DRD4 7-repeat allele (DRD4 7-). First, we test the effects of administering levodopa on attentional control by using the objective EEG-measure (frontal TBR) that was examined in the second chapter of this dissertation, and a retrospective self-report of attentional control. Second, we investigate the effects of administering levodopa on reading comprehension.

Several studies have been performed over the last two decades to investigate the role of DA, and fluctuations in DA, in cognitive performance (for reviews, see Nieoullon, 2002; Westbrook & Braver, 2016). However, the exact influence of DA and fluctuations in DA in the brain on attentional control is not yet clear. The prefrontal cortex (PFC), a brain region that is rich in dopamine receptors and highly sensitive to fluctuations in dopamine (Cools & D'Esposito, 2011; Cools & Robbins, 2004), is involved in both attentional control and memory processing (see e.g., Berke, 2018; Fan et al., 2001; Gazzaley & Rosen, 2016; Melara, 2004; Miller & Cohen, 2001). Attentional control is the ability to sustain attention for prolonged periods of time. Attentional control is important during tasks such as reading that require the use of working memory to integrate information and to update knowledge in memory. Attentional control during such tasks is influenced by DA transmission in the brain (Boulougouris & Tsaltas, 2008; Braver & Cohen, 2000; Westbrook & Braver, 2016). Studies on patients with disorders associated with reduced DA transmission in the brain have demonstrated that this reduced transmission leads to problems in attentional control (Nieoullon, 2002). In line with such findings, one could hypothesize that pharmacologically increasing DA would influence attentional control during reading. Nevertheless, research has shown that the influence of increased DA levels in the brain on cognitive processes could be both positive and negative, based on the baseline level of DA in the brain. This model is called the inverted U-shape theory (Vijayraghavan et al., 2007) and states that both too low and too high levels of DA in the brain could hinder cognitive performance.

Next to the role of DA in attention control, DA is also involved in information-processing and memory formation (see e.g., Adcock et al., 2006; Boulougouris & Tsaltas,

2008; Braver & Cohen, 2000; Gazzaley & Rosen, 2016; González-Burgos & Feria-Valesco, 2008; Grossman et al., 2001; Kischka et al., 1996; Nieoullon, 2002). Studies have shown that psychopharmacological manipulations of DA levels have led to differing effects on memory performance across different learning tasks (e.g., artificial grammar learning tasks, word learning tasks) and different types of instruction (learning tasks with or without feedback; see Breitenstein, Floël, et al., 2006; de Vries et al., 2010; Knecht et al., 2004; Linssen et al., 2014). Wadley described DA as functioning as a "teaching signal," like a coach who tells his player "good job" or "bad job" to encourage future behaviour (2015, para. 10; see also Hamid et al., 2015). In this dissertation we examine whether higher DA levels in the brain during reading were beneficial for reading comprehension in a group of students carrying the DRD4 7-repeat allele and a group of students not carrying the DRD4 7-repeat allele, thereby testing the inverted U-shape theory in the case of reading comprehension.

The Role of Feedback in Supporting Reading Comprehension

In Chapters 4 and 5 of the dissertation, we shift our attention from the role of internal factors (i.e., attentional and dopaminergic processes) in reading comprehension, to the role of external factors in reading comprehension, most specifically, the role of feedback in reading comprehension. In Chapter 4, we investigate when and how to effectively provide feedback to students in order to support reading comprehension, and in Chapter 5, we examine the effects of feedback on cognitive processes (i.e., the use of reading strategies) and affective processes (i.e., motivational aspects) related to reading comprehension.

One of the hallmarks of excellent teachers is their ability to provide students with feedback (Hattie, 2012). Feedback is a vital element of reading comprehension instruction, together with deliberate practice and strategy instruction (see Crossley & McNamara, 2017). However, providing individualized feedback is a time consuming activity, time that often is not available to teachers and educational professionals. Technological innovations provide promising solutions. For example, computer applications provide a wealth of possibilities for providing individualized feedback to students during reading instruction.

Although decades of research have demonstrated that, on average, the effects of feedback on learning are positive (Azevedo & Bernard, 1995; Hattie, 2012; Jaehnig & Miller, 2007; Kluger & DeNisi, 1996; Kulhavy, 1977; Shute, 2008; van der Kleij et al., 2012, 2015), there also has been a great deal of variability in results across studies. For example, although the majority of studies have yielded positive effects, some have produced no effect, or even negative effects. Additionally, although several meta-analyses have been

performed on the effects of feedback on learning (see Hattie, 2012), the combination of a broad range of study designs and learning tasks in these meta-analyses raise questions about the validity of applying the results to the specific case of reading comprehension (see also Bergeron & Rivard, 2017). Therefore, in the present dissertation we synthesize studies that specifically investigated the effects of feedback on reading comprehension in the context of learning from text.

Two main issues in research on the effects of feedback on learning are: (1) the timing of feedback (i.e., immediate feedback or feedback that is provided some hours or days after the task; see Dempsey & Wager, 1988; Hattie & Timperley, 2007; Metcalfe et al., 2009; Mory, 2004) and (2) the richness of feedback (i.e., the amount of information provided in feedback messages; see Shute, 2008). Both issues are addressed in Chapter 4 of the dissertation. With respect to timing, we further specify immediate feedback by distinguishing feedback that is provided during reading a text from feedback that is provided after reading a text. While previous research has categorized both of these moments as immediate feedback, these two moments have different consequences for the process of integrating information in the text and in the feedback messages in the mental representation of the text that readers have to form while reading (Bangert-Drowns et al., 1991; Mullet & Marsh, 2016; Subrahmanyam et al., 2013; see Chapter 4 for a more extensive review of the different perspectives on timing of feedback).

In addition to the issue of timing, we investigate the effects of the richness of feedback included in the feedback message on reading comprehension. The "richness" of a feedback message refers to the type of information included in the feedback message. Information can range from merely stating that an answer was right or wrong, to presenting the correct answer with explaining information (see e.g., Kulhavy, 1977; Shute, 2008). Research examining the effects of richness of feedback on the reading comprehension is sparse. Furthermore, results from decades of research on feedback in learning more generally has been inconclusive about the amount of information that should be provided in a feedback message in order to optimally support learning (see Jaehnig & Miller, 2007; Kluger & DeNisi, 1996; Kulhavy, 1977; Kulhavy & Stock, 1989, Mory, 2004; Shute, 2008; van der Kleij et al., 2015).

Although insight into the effects of different features of feedback is important for developing instructional tools, gaining a thorough understanding of the effectiveness of feedback requires investigation of how feedback fosters reading comprehension. As Kluger and DeNisi (1996) stated in their *Feedback Intervention Theory* (FIT), researchers should investigate students' total reaction to feedback, not only the effect of feedback on the targeted learning outcome. In Chapter 5, we aimed to gain insight into students' total reaction to feedback by testing the effects of feedback on both cognitive processes (i.e., the

use of reading strategies) and affective processes (i.e., motivational aspects) related to reading comprehension.

An underlying cognitive process that has shown to be essential for reading comprehension is the use of reading strategies. When students are not able to effectively deploy reading strategies, for example, monitoring comprehension, questioning, rereading passages, and making inferences, their reading comprehension is negatively affected (see Gersten et al., 2001; Graesser, 2007; Palinscar & Brown, 1984). Therefore, researchers have stressed the importance of instruction in reading strategies to enhance reading comprehension, both for readers with and without difficulties in reading (see e.g., Crossley & McNamara, 2017; Edmonds et al., 2009; Gersten et al., 2001; National Reading Panel, 2000; Okkinga et al., 2018; Rosenshine & Meister, 1994). To enhance reading comprehension, feedback should help readers to develop or deploy (meta)cognitive strategies that are essential for reading comprehension by shifting their attention from performance (i.e., the product of reading comprehension) to learning itself (i.e., the processes needed to accomplish comprehension; see Hoska, 1993).

Next to supporting cognitive processes related to reading comprehension, such as the use of reading strategies, feedback could also play a role in affective processes related to reading, such as motivation. A diverse range of instructional practices has been shown to influence motivation for reading and reading engagement, which are both related to reading comprehension (see Guthrie et al., 2012; Guthrie & Wigfield, 2000; van Steensel et al., 2016). In line herewith, Hattie and Timperley (2007) in their extensive review on the impact of feedback concluded that feedback can function as a motivator for students (see also Kulhavy & Wager, 1993; ter Beek et al., 2018). The information provided in the feedback could provide students with feelings of autonomy and competence (Ryan & Deci, 2000) and might motivate them to increase cognitive effort, or engagement in the reading task (Kluger & DeNisi, 1996).

Aims and Outline of the Dissertation

The aim of the present dissertation is to gain insight into both individual difference in reading and the effectiveness of instructional methods by investigating the role of internal and external factors related to reading comprehension. Using a multifaceted and methodologically diverse approach, two major themes are considered: (1) attentional and dopaminergic processes related to reading comprehension (i.e., internal factors) and (2) the effects of feedback (i.e., an external factor) on reading comprehension and on the processes underlying reading comprehension.

In **Chapter 2**, the potential use of frontal theta/beta-ratio (TBR) as a biomarker for attentional control is examined, and previous research on the relation between attention during reading and reading comprehension is replicated. We added to the existing literature by using frontal TBR as biomarker for attentional control in addition to self-report measures that are more commonly used. More specifically, the research reported in Chapter 2 investigates the potential of frontal TBR as a biomarker for attentional control in an EEG-study in which students read two narrative texts differing in text difficulty, self-report on attentional control during reading and in daily life, and then complete a measure of reading comprehension. The use of frontal TBR as indicator for attentional control during reading could provide greater insight into the role of attentional control during reading and its relation to reading comprehension because it is a more objective measure of attentional control that does not interrupt the natural reading process.

In **Chapter 3**, the influence of small increases in dopamine on attentional control during reading and reading performance is investigated in two groups of students: one group carrying the DRD4 7-repeat allele and one group not carrying the DRD4 7-repeat allele. In a double blind placebo-controlled experiment, we investigate participants' attentional control during reading and comprehension in two conditions: one in which levodopa, a precursor of dopamine in the brain, is administered before reading, and one in which a placebo is administered.

The main theme of **Chapters 4 and 5** is the effect of feedback on reading comprehension and on the cognitive and affective processes that are related to reading comprehension. These two chapters are based on meta-analytical research of more than six decades of research on the effects of feedback on reading comprehension. In **Chapter 4,** the effects of different features of feedback are investigated to gain insight into how best to support reading comprehension in the context of learning from text. Specifically, in this chapter, the effects of timing of feedback and the richness of feedback are investigated as moderators of the effect of feedback on reading comprehension. The aim of **Chapter 5** is to further unravel the effect of feedback on reading comprehension by testing the effects of feedback on cognitive and affective processes related to reading comprehension. The effect of feedback on the use of reading strategies when reading new texts without receiving feedback was investigated, as well as the effects of feedback on motivational aspects related to reading comprehension. Subsequently, it was tested if these effects could be used to predict the size of the effect of feedback on reading comprehension.

Finally, in **Chapter 6**, a summary and critical reflection on the results of this dissertation are presented, accompanied by implications of the results and suggestions for future research.