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Mind wandering and reading comprehension in secondary school children

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ABSTRACT

This study investigated predictors of mind wandering during reading and their effects on comprehension in a sample of secondary school children. One hundred and twenty-five eighth-graders read either an easy, moderately difficult, or difficult version of an expository text and subsequently answered a number of comprehension questions. Students were asked about their thoughts during reading, their propensity to mind wander in various life situations, as well as their interest in the topics of the text. Overall, the results were consistent with the general mind wandering literature: More difficult texts were associated with lower topic interest, more mind wandering during reading, and worse comprehension. Topic interest was negatively related to mind wandering during reading. Furthermore, the propensity to mind wander in daily life had both a positive effect and a negative effect on comprehension, the latter being mediated by mind wandering during reading. Based on these results, it is argued that mind wandering may benefit school children's reading comprehension if it is applied in appropriate situations and for activities that promote comprehension.

1. Introduction

The following situation may sound familiar to most of us: We are reading a text in preparation for an upcoming exam. After a couple of minutes scanning the text line by line, however, we notice that we don't quite remember what we just read. Perhaps we were thinking about something pleasant ("Tomorrow's my birthday and I will get a lot of presents") or something unpleasant ("Sigh, I really gotta clean this room."), something in the future ("I have to call Peter later") or something in the past ("Why did she leave me?"). Whatever it was, it made us focus on our internal world instead of the text's contents.

Such 'drifting off' with one's thoughts is a common experience in almost every part of daily life (Killingsworth & Gilbert, 2010; Klinger, 2013; McVay, Kane, & Kwapil, 2009). It is, therefore, not surprising that these 'task-unrelated thoughts' or episodes of 'mind wandering' (MW) have received a great deal of interest in recent psychological and educational research (e.g., Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Kane & McVay, 2012; Smallwood & Schooler, 2015). Part of this interest is related to the ubiquity of MW in our daily lives (McVay et al., 2009; Killingsworth & Gilbert, 2010) and its substantial impact on our actions. In particular, MW that occurs during the execution of a given task usually impairs performance in that task; and this is particularly true for reading comprehension and other learning-related tasks (e.g., D'Mello, 2019; Feng, D'Mello, & Graesser, 2013;

Fulmer, D'Mello, Strain, & Graesser, 2015; Mills, Graesser, Risko, & D'Mello, 2017; Smallwood, McSpadden, & Schooler, 2008; Soemer & Schiefele, 2019).

However, current research on MW during reading has mostly been limited to adult samples, leaving the question as to whether the findings may generalize to secondary school children open for further investigation. Given the importance of reading as one of the primary means of knowledge acquisition in school, it is imperative to investigate when and why school children tend to engage in MW instead of focusing on reading a given text, and what costs and benefits this behavior may have with regard to comprehension. A second limitation of previous research is that it has rarely considered the potentially beneficial effects associated with one's individual propensity to mind wander on reading, although some studies point to the possibility that such effects may exist (Baird et al., 2012; Baird, Smallwood, & Schooler, 2011; Singer & Antrobus, 1963, 1970; Singer & Schonbar, 1961; Zhiyan & Singer, 1997).

The present study was thus conducted with two overall aims. First, we sought to replicate several findings from the general literature on MW during reading with a sample of secondary school children. Specifically, we sought to demonstrate that MW during reading impairs comprehension, that more difficult texts lead to more MW during reading, and that part of the negative effect of text difficulty on MW can be explained by reductions in topic interest (Soemer & Schiefele, 2019).

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The second aim of the present study was to distinguish MW as a specific state during reading from one's overall propensity to mind wander in various life situations (trait-level MW) and investigate the potentially beneficial aspects of MW with regard to comprehension.

1.1. Mind wandering during reading

In the context of experimental and educational psychology, MW is often characterized as thoughts that occur during an ongoing task (e.g., reading) without having a direct relation to this activity, and without being directly cued by task stimuli or other external events (Kane & McVay, 2012; Smallwood & Schooler, 2015; cf. D'Mello, 2019). Such thoughts may be initiated and sustained with or without intention or awareness (Seli, Risko, Smilek, & Schacter, 2016), may consist of a single thought or a sequence of thoughts (Klinger, 2013), and may lack strong constraints regarding their contents (Christoff et al., 2016). Most importantly, MW is often found to impair performance when it occurs during the execution of a task that requires relatively strong attentional control (Kane & McVay, 2012).

With regard to reading, research has demonstrated that MW is associated with both reduced memory for a text's contents and less inference-making. For example, in a notable study by Smallwood et al. (2008), participants read a detective story and answered a number of comprehension questions afterwards. MW was measured by interrupting the participants from time to time during reading and asking them whether they were thinking about something related or unrelated to the text, just prior to the interruption. Because some of these probes were placed at specific locations in the text, Smallwood et al. were able to demonstrate that participants who were experiencing MW episodes during reading certain 'critical' passages were less likely to remember these passages' contents and were less likely to draw inferences based on information from these passages (e.g., the identification of the villain).

Detrimental effects of MW on comprehension have also been observed in individual-difference studies. In particular, there tends to be a negative relationship between individuals' tendency to experience MW during task execution and performance in these and other tasks, including reading comprehension (e.g., McVay & Kane, 2012; Soemer & Schiefele, 2019; Unsworth & McMillan, 2013). A common interpretation of these results is that some individuals are better than others at focusing attention on a given task (i.e., reading) by preventing the initiation of a MW episode or by more quickly refocusing on this task once a spontaneous MW episode occurs (Kane & McVay, 2012; Soemer & Schiefele, 2019).

1.2. Mind wandering during reading and topic interest

Given the usually negative impact of MW on comprehension, an important question for educational research is which individual-difference factors potentially promote or hinder the occurrence of MW. Whereas a great deal of MW research and theory has been devoted to cognitive predictors of MW (e.g., McVay & Kane, 2012; Mills et al., 2017), relatively few studies thus far have addressed the role of motivational predictors of MW during reading or other cognitively-demanding tasks (Fulmer et al., 2015; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Wammes, Risko, & Smilek, 2016; Soemer & Schiefele, 2019; Unsworth & McMillan, 2013). That being said, motivational factors have been extensively studied in the domain of reading where prior research has highlighted, among other motivational variables, 'topic interest' as one of the key predictors of comprehension (e.g., Ainley, Hidi, & Berndorff, 2002; Fulmer & Tulis, 2013; Schiefele, 1999, 2009; Schiefele & Krapp, 1996). Topic interest is often considered as being composed of an 'individual' component and a 'situational' component (Ainley et al., 2002; Hidi, 2001; Schiefele, 1999, 2009). The former refers to a relatively stable affective-evaluative orientation toward a given subject area (e.g., biology), whereas the latter can be

conceptualized as a temporary state that is elicited by specific features of a text such as personal relevance, novelty, vividness, or readability (Schraw, Flowerday, & Lehman, 2001).

Based on this conceptualization of topic interest, prior reading research has consistently found a positive relationship between measures of interest and measures of reading comprehension (e.g., Ainley et al., 2002; Schiefele & Krapp, 1996), and this relationship has often been explained by assuming that greater interest leads to a larger amount of attentional resources that are allocated to a text (e.g., Hidi, 2001). This, in turn, is thought to improve memory for a text's contents and to enable deeper text processing. As a result, a reader will not only remember more facts but also have a richer mental model of the text (Kintsch, 1988).

Although most prior research on topic interest has not directly been concerned with MW during reading, a natural connection between the two research areas exist in that MW is often characterized as being closely dependent on attentional resources and attentional control. Resource competition theories of MW, for example, assume that a MW episode cannot persist without sufficient attentional resources allocated to it (Smallwood & Schooler, 2015), whereas other influential theories state that MW reflects a failure to focus attention on the main task (e.g., Kane & McVay, 2012). While a discussion of the commonalities and differences between these theories is beyond the scope of this paper, it is important to note that both kinds of theories predict that MW does not occur as long as attention is sufficiently focused on reading. Consequently, both predict that factors that improve one's focused attention on a text (i.e., topic interest) will reduce the likelihood of experiencing a MW episode and thereby attenuate its negative effect on comprehension. Viewed from a different angle, MW may be seen as a potentially important mediator variable that explains the positive relationship between topic interest and reading comprehension that has been found in prior research.

Evidence for these predictions comes from a number of previous studies on MW during reading that included measures of topic interest. In one study conducted by Unsworth and McMillan (2013), for example, 150 adult participants read an introductory political science text and answered a number of multiple-choice comprehension questions afterwards. To obtain an estimate of MW frequency, the authors relied on the same experience sampling method as Smallwood et al. (2008). In addition, participants also provided ratings on a number of items some of which were designed to measure topic interest. Using structural equation modeling (SEM), Unsworth and McMillan (2013) demonstrated that their measure of topic interest explained a considerable part of the variance in MW rates. Furthermore, MW rates fully mediated the positive relationship between topic interest and comprehension.

Subsequently, Soemer and Schiefele (2019) were able to replicate and extend these findings using a similar methodology. In their study, 216 adult participants read various texts of low, moderate, or high difficulty and subsequently rated their interest in the topics of the texts. MW was again measured using experience sampling. In addition, Soemer and Schiefele (2019) distinguished between intentionally initiated or sustained ('voluntary') MW and spontaneously occurring ('involuntary') MW (Seli, Risko, et al., 2016). It turned out that both forms of MW were negatively related to topic interest. Furthermore, involuntary (but not voluntary) MW partially mediated the positive effect of topic interest on reading comprehension.

In sum, prior research conducted with adult samples largely supports the idea that MW is an important mediator process in the relationship between topic interest and reading comprehension. As noted, this also makes sense from a theoretical point of view, because topic interest is thought to lead to a better allocation of attentional resources to reading and away from reading-unrelated activities (Hidi, 2001).

1.3. Mind wandering during reading and text difficulty

In addition to studying individual-difference variables, prior

research with adult samples has investigated how text-related factors may influence the occurrence of MW during reading. An important variable in this regard is the degree of challenge that a text poses to the reader; in other words, a text's difficulty or complexity. In educational research, text difficulty is often operationalized based on text characteristics that are known to contribute to both subjective text difficulty and objective comprehension performance, such as the distribution of word frequencies, word lengths, and sentence lengths. These factors are weighted and combined into easy-to-use 'readability' formulas that express text difficulty in form of a single number, a school grade-level or a category (e.g., Björnsson, 1968; Flesch, 1948).

Readability formulas have been extensively used over decades by both educational practitioners and researchers (Benjamin, 2012). In the context of MW research, several previous studies have used readability manipulations as operationalizations of objective text difficulty and investigate the effect of these manipulations on MW rates. For example, Feng et al. (2013) carried out revisions of a number of text passages that were taken from a standardized reading comprehension test in order to create versions of these passages that were higher in readability compared to the original ones. The researchers then let their participants read either the revised 'easy' versions or the original 'difficult' versions of the passages and measured their participants' MW during reading using experience sampling. As a result, Feng et al. observed more frequent MW for the 'difficult' passages compared to the 'easy' passages. Referring to an aforementioned theory of MW, which sees MW as a result of attentional control failures (Kane & McVay, 2012; McVay & Kane, 2012), a natural explanation for the observed positive relationship between text difficulty and MW rates is that difficult texts pose a greater challenge to attentional control and thereby promote more frequent control failures. These control failures, in turn, may lead to the initiation of MW episodes that impair memory for a text's contents and inference-making.

In line with this explanation and the study of Feng et al. (2013), several subsequent studies have reported similar results (Forrin, Risko, & Smilek, 2019; Mills et al., 2017; Mills, D'Mello, & Kopp, 2015), including the previously mentioned study of Soemer and Schiefele (2019), which also investigated the relationships between text difficulty, on the one hand, and topic interest and MW on the other. In that study, it was found that topic interest fully mediated the effect of text difficulty on MW rates, meaning that more difficult texts were perceived to be less interesting, and less interest was accompanied by more frequent MW.

It must be noted that some studies have reported non-significant main effects of text difficulty on MW or interactions between text difficulty and a third variable with regard to MW. For example, in the study of Forrin et al. (2019), text difficulty had a greater effect on MW rates if the texts were presented sentence-by-sentence (as in the study of Feng et al., 2013), compared to a page-wise presentation (cf. Mills et al., 2015; Soemer & Schiefele, 2019). Similarly, Fulmer et al. (2015) reported a text difficulty vs. topic preference interaction with regard to MW and comprehension, such that difficult versions of less preferred texts were accompanied by fewer (rather than more frequent) MW reports, whereas higher test scores were obtained for difficult versions of preferred texts. Importantly, however, no significant main effects of text difficulty on MW rates or comprehension were reported.

Taken together, apart from a number of experiments showing non-significant main effects of text difficulty on MW rates (Forrin et al., 2019, Experiment 1a; Fulmer et al., 2015), the majority of studies conducted with adult samples has found a positive relationship between text difficulty and MW. That is, in these studies, reading more difficult texts was associated with more MW, and experiencing more MW episodes was negatively associated with comprehension.

1.4. Potential benefits of mind wandering for reading

The literature discussed so far has primarily been concerned with

predictors and the detrimental effects of MW that occurs while carrying out a given task. There is, however, an earlier line of research on 'daydreaming' that started in the 1950's and dealt with trait-level differences in MW and related phenomena (e.g., Singer & Antrobus, 1963, 1970; Singer & Schonbar, 1961; Zhiyan & Singer, 1997). Importantly, this research did not restrict itself to MW that occurs while carrying out a task with strong attentional demands, but also investigated MW in situations involving no specific main task such as walking or being on a bus.

In contrast to the more recent research discussed before, research on daydreaming has demonstrated positive associations between MW and a number of individual difference variables such as storytelling creativity (Singer & Schonbar, 1961) and problem solving ability (Singer & Antrobus, 1963). On the theoretical side, these associations have been explained based on a distinction between three empirically separable factors of MW called *positive-constructive daydreaming*, *guilty-dysphoric daydreaming*, and *poor attentional control* (Huba, Aneshensel, & Singer, 1981). Whereas the last of these factors essentially conforms to what is typically associated with MW nowadays, positive-constructive daydreaming has been suggested as being beneficial for cognition, creativity, problem solving and future planning (e.g., Singer & Antrobus, 1963; Zhiyan & Singer, 1997).

Some researchers have recently taken up the idea that MW might be important for cognition and explored potential benefits of MW in various tasks (e.g., Klinger, 2013; Klinger, Marchetti, & Koster, 2018; Mills, Herrera-Bennett, Faber, & Christoff, 2018). For example, Baird et al. (2012) examined the effect of MW during a 12-minute incubation period between a first trial of the *Unusual Uses Task* (UUT) – a task which requires participants to come up with as many unusual uses for a given object as possible – and a second trial of that task. They found that carrying out a filler task during the incubation period that maximized the occurrence of MW increased performance on the second trial of the UUT. In line with earlier investigations on daydreaming, the results of Baird et al. (2012) suggest that MW may promote the generation of novel mental content and thereby facilitate creative problem solving. Further highlighting the functional role of MW in cognition, evidence has been provided showing that MW can promote episodic memory consolidation (Wang et al., 2009), spaced practice (Schooler et al., 2011), and the generation of novel mental content (Mills et al., 2018). Given that episodic memory and novel content generation are likely beneficial for reading comprehension (consolidation and elaboration of a text's contents), it may be argued that part of the processes that occur during MW should actually promote comprehension under certain circumstances. In other words, although MW can be associated with failures to avoid task-unrelated thoughts when one has to focus on the text, readers with a high propensity to MW should nevertheless be better at constructing rich mental models of the text (Kintsch, 1988).

One way to obtain empirical support for this novel hypothesis is to demonstrate a positive association between trait-level MW and comprehension once the negative effects associated with poor attentional control are partialled out. Although this has not been attempted before (to our best knowledge), there already exists evidence in favor of the hypothesis that MW can benefit comprehension. This evidence comes from a study by Mrazek, Phillips, Franklin, Broadway, and Schooler (2013) that had the original purpose of developing and validating a new trait-level MW questionnaire. The validation process involved measuring high school and middle school students' trait-level MW, MW rates during a reading task, and comprehension performance. Whereas the authors found the to-be-expected positive correlations between trait-level MW and MW during reading (high school: $r = 0.23$; middle school: $r = 0.30$) and negative correlations between MW during reading and comprehension (high school: $r = -0.19$ and middle school: $r = -0.25$), the results also showed positive correlations between trait-level MW and comprehension (high school: $r = 0.15$; middle school: $r = 0.05$).

Although the latter correlations were non-significant in both

Fig. 1. Path model corresponding to the hypotheses as described in the main text. ‘+’ and ‘-’ indicate the to-be-expected signs of the coefficients. ‘0’ indicates the expectation of a non-significant effect.

samples and not further discussed in their article, a re-analysis of the [Mrázek et al. \(2013\)](#) data based on the reported correlation matrices and standard deviations revealed a number of interesting results. First, regressing comprehension on both trait-level MW and MW during reading, it turned out that the beta weights reflecting the direct effects of trait-level MW on comprehension, controlling for MW during reading, are larger than the bivariate correlations (high school: $b = 0.21$, $p = 0.025$; middle school: $b = 0.13$, $p = 0.244$) and significant for the high school student sample. Such results are indicative of a suppression effect, meaning that the bivariate correlations likely underestimate the positive effect of trait-level MW on comprehension, because trait-level MW highly correlated with MW during reading (which, in turn, had a negative effect on comprehension). At the same time, the analysis also revealed marginally negative effects of trait-level MW on comprehension mediated by MW during reading (high school: $b = -0.06$, $p = 0.075$; middle school: $b = -0.09$, $p = 0.056$).

Consistent with the above theoretical considerations, these results suggest that MW may indeed have both positive and negative effects on comprehension. However, given that these effects were neither predicted nor analyzed by [Mrázek et al. \(2013\)](#), and are thus considered exploratory, and given that some the effects that were found in this analysis were only marginally significant, carrying out a replication is clearly warranted.

2. The present study

To summarize, the literature on MW during reading suggests that MW during reading has a negative impact on comprehension and that topic interest and text difficulty are negatively related to MW during reading. Furthermore, the results of at least two studies suggest that MW during reading may be a major mediator process in the usually positive relationship between topic interest and reading comprehension ([Soemer & Schiefele, 2019](#); [Unsworth & McMillan, 2013](#)). However, our knowledge of these relationships mainly comes from research with adult samples (mostly university students), and we therefore do not know whether the reviewed findings can be transferred to school student populations who differ from adults in a number of important ways, such as reading expertise, executive control capabilities, familiarity with different topics, and MW propensity and focus ([Ye, Song, Zhang, & Wang, 2014](#)). These differences may affect the relationships that have been found in prior research with adult samples. For example, adults' higher reading skills will likely be associated with more automatic text processing and lower attentional demands, meaning that comprehension may be less affected by MW during reading. Furthermore, eighth

graders are a generally more heterogeneous population compared to a cognitively selected group of university students, and this heterogeneity might have consequences for the strength of the various relationships we investigate. Thus, a replication of the findings with school student samples is clearly warranted.

A second point is that previous studies have not explicitly addressed the potentially positive effects of MW on comprehension, and the difference between MW during reading and trait-level MW. This difference could be crucial because the negative impact of MW on comprehension may merely reflect a failure to limit MW to moments in which it is useful; that is, although individuals with a greater trait-level propensity to MW may tend to experience more attentional control failures during reading, they may actually profit from their greater capacity to consolidate their memories and generate novel mental content.

In order to investigate these possibilities, we carried out an experiment with 125 eighth-graders from a German secondary school. Each student read one of three versions of a text and subsequently answered a number of multiple-choice comprehension questions. The three texts were about the human lungs and differed only in readability (see [Appendix A.1](#)). After having completed the comprehension test, students filled out a questionnaire concerning their MW during that specific reading situation, their propensity to experience MW in various life situations (trait-level MW), and their topic interest and topic familiarity; the latter being included in the study as a control variable.

2.1. Hypotheses

Fig. 1 summarizes our hypotheses in form of a path model. First, we expected to replicate the negative effect of MW during reading on comprehension that has been found in several prior studies with adult samples (e.g., [Feng et al., 2013](#); [McVay & Kane, 2012](#); [Soemer & Schiefele, 2019](#); [Unsworth & McMillan, 2013](#)). Second, we expected topic interest to have a positive direct effect on comprehension, consistent with prior research on topic interest ([Schiefele, 1999](#)), and an indirect positive effect through reducing MW as has been found in previous studies ([Soemer & Schiefele, 2019](#); [Unsworth & McMillan, 2013](#)). Third, we expected to replicate the finding of [Soemer and Schiefele \(2019\)](#), showing that text difficulty reduces comprehension both directly and indirectly through having a negative effect on topic interest. Consistent with [Soemer and Schiefele \(2019\)](#), we additionally predicted that the effect of text difficulty on MW would be fully mediated by topic interest. Finally, with regard to trait-level MW, we predicted that this variable would have a positive direct effect on comprehension based on the above theoretical considerations and the

re-analysis of the data of Mrazek et al. (2013). At the same time, we predicted that trait-level MW would also be positively related to MW during reading, consistent with prior research (e.g., Mrazek et al., 2013; also see McVay et al., 2009). However, because MW during reading has previously been found to impair comprehension, trait-level MW was predicted to have two opposing effects: a positive direct effect on comprehension by promoting mental model building, and a negative indirect effect by promoting MW during reading.

2.2. Method

2.2.1. Participants

One hundred and twenty-five eighth-grade students ($M_{age} = 13.91$; $SD_{age} = 0.72$; $N_{female} = 64$) were recruited from three secondary schools located close to a large city in North-East Germany. The majority of the participants ($N = 104$) were German native speakers or bilinguals ($N = 10$). One participant did not indicate his or her native language. The remaining ten participants were German non-native speakers and thus a priori excluded from the analyses, leaving us with a sample of 115 participants ($M_{age} = 13.85$; $SD_{age} = 0.65$; $N_{female} = 60$). The participants were randomly split into three groups, with each group reading one of three versions of a text differing in readability. We will attach the labels ‘easy’, ‘moderate’, and ‘difficult’ to these three versions (one has to keep in mind, however, that these labels do not have a meaning on an absolute difficulty scale). Due to the exclusion of ten participants based on their native language, the number of participants was slightly uneven across conditions ($N_{easy} = 37$, $N_{moderate} = 41$, $N_{difficult} = 37$).

2.2.2. Text material

An informative text about the functioning of the human lungs was selected from an eighth-grade biology book and subsequently adapted to create three text versions that differed in readability (see Appendix A.1). The ‘easy’ version of the text was created by exchanging low-frequency words for high-frequency synonyms of these words, and by splitting and shortening sentences in the original ‘moderate’ text.¹ The ‘difficult’ version of the text was analogously created by exchanging high-frequency words with low-frequency synonyms, and by lengthening and merging sentences in the original text.

The success of this readability manipulation was verified by computing two readability indexes that are commonly used for the German language (see Appendix A.2), the ‘Läsbarhetsindex’ (LIX; Björnsson, 1968; Lenhard & Lenhard, 2014–2017) and the ‘Flesch Reading Ease’ (FRE; Flesch, 1948) adapted to German (Amstad, 1978). According to the original publication of Björnsson (1968), ‘very easy’ texts score below 20 on the LIX scale, ‘easy’ texts between 20 and 30, ‘moderate’ texts between 30 and 40, ‘difficult’ texts between 40 and 50, and ‘very difficult’ texts above 60. With regard to the German language, Lenhard and Lenhard (2014–2017) note that LIX scores lower than 40 are typical for children’s books, whereas scores between 40 and 50 are typical for fiction (narrative texts), scores between 50 and 60 for nonfiction (expository texts, newspapers etc.), and scores above 60 for technical literature. The FRE is constructed a similar way with one main difference to the LIX being that high scores indicate high readability. According to Amstad (1978), FRE scores can be categorized into ‘very difficult’ (< 30), ‘difficult’ (30 to 50), ‘moderately difficult’ (50 to 60), ‘moderate’ (60 to 70), ‘moderately easy’ (70 to 80), ‘easy’ (80 to 90), and ‘very easy’ (> 90).

As can be seen in Table 1, the readability manipulation was successful insofar as the readability of the three text versions progressively decreased by about the same interval between subsequent levels. Thus, one could be confident that the ‘difficult’ version would pose a greater challenge to the readers than ‘moderate’ version, and the latter would

Table 1

Readability-related statistics for the three versions of the text (LIX = readability index of Björnsson, 1968; FRE = Flesch Reading Ease readability index of Flesch, 1948; German-language formula by Amstad, 1978).

	Easy version	Medium version	Difficult version
LIX	34.32	41.52	47.52
FRE	81.76	72.14	61.36
Number of words	426 (160)	429 (182)	438 (187)
Number of sentences	43	36	29
Average sentence length	9.91	11.92	15.1

pose a greater challenge to the readers than the ‘easy’ version.

2.3. Instruments

2.3.1. Mind wandering during reading

MW during reading was measured with a retrospective questionnaire consisting of the following five items (approximate English translation): “I had ___ distracting thought(s) during reading”, “I thought a lot about the content of the text during reading” (reversed item), “I concentrated on the text during reading” (reversed item), “I had a lot of thoughts during reading that did not have anything to do with the text”, and “I read the text carefully” (reversed item). Participants answered these questions on a 4-point rating scale, the options being “not once”, “a few times”, “a number of times”, “many times” for the first question, and “strongly disagree”, “disagree”, “agree” “strongly agree” for the remaining four questions. Each question was represented by a single indicator variable in the later SEM analyses.

Note that using a retrospective questionnaire here was a departure from previous studies investigating MW during reading. However, questionnaires are an accepted method in the general literature on mind wandering, and using them tends to produce similar results as the more widely-used probing method (D’Mello, 2019). Furthermore, retrospective questionnaires have the general advantage over probing that participants are not interrupted during the to-be-studied process (here, reading); and thus, there is no danger of altering their natural behavior with regard to this process. In addition, questionnaires can be easily used in a common classroom setting such as the one in the present study.

Trait-level Mind Wandering. Trait-level MW was measured with eleven items that were adapted from the ‘Imaginal Processes Inventory’ (IPI) of Singer and Antrobus (1970). These items dealt with the frequency of daydreaming in daily life, the tendency to drift off with one’s thoughts during certain situations and memory for the daydreams (see Appendix B for a complete item list). Each item had four response alternatives: “rarely”, “not often”, “often”, “very often” for items asking the participants to indicate frequencies, and “strongly disagree”, “disagree”, “agree”, “strongly agree” for the remaining items.

2.3.2. Topic interest

Participants were required to rate their topic interest with one item (“I found this text interesting”) on a 4-point rating scale, the response alternatives being “strongly disagree”, “disagree”, “agree”, “strongly agree”.

Reading Comprehension. Participants were asked to answer 13 questions with four answer alternatives in paper-and-pencil format (see Appendix C). The questions were created with the goal of encompassing word-level, sentence-level, and text-level comprehension. Each question was scored as either correct or incorrect and was represented by an indicator variable in the later analysis.

Control Variables. Participants were asked to indicate their topic familiarity with two items: “How much knowledge did you already have related to the topic?”, “How much did your prior knowledge influence comprehension?”. To foreshadow the results, the two items correlated rather weakly ($r = 0.08$), suggesting that they likely measured different

¹ Frequency norms were taken from the website www.dwds.de/?q=&from=wb.gewwart (last accessed in May 2017).

constructs. For this reason, we decided to use only the first item in the later analysis, because this item seemed to be more closely related to what we originally intended to measure compared to the second.² Apart from topic familiarity, age and gender were added as control variables.

2.4. Procedure

All participants were tested in their usual classroom within a 2-week period using pencil-and-paper tests. At the beginning of the experiment, the participants were verbally instructed by a trained experimenter and additionally received written instructions. Besides explaining to them that they were going to take a 'reading comprehension test', the written instructions also contained a short paragraph stating that they would be asked about their MW during reading at a later point in time. To ensure that the participants had understood the instructions, they were allowed to ask questions before the experiment began.

At the beginning of the experiment, participants first read the text and subsequently answered the comprehension questions. Once a participant proceeded to the first test question, he or she was not allowed to go back to the text. After finishing the comprehension questions, participants filled out a number of sheets containing the questionnaires about MW during reading, trait-level MW, topic interest, and topic familiarity items. All tasks were completed within 40 min of time (the usual duration of a class minus 5 min of verbal instruction).

The study was approved by the Ministry of Education of the State of Brandenburg, Germany (78/2016). In addition, it was ensured that the study was carried out in accordance with the guidelines of the [British Psychological Society \(2000\)](#), including written informed consent and confidentiality of data, as well as personal conduct.

3. Results

Approximately 1% of the data contained missing cells due to some participants not responding to some of the questionnaire items or comprehension questions. We used the expectation maximization algorithm to replace these missing values ([Graham, 2009](#)). To determine the reliability of the instruments consisting of multiple items, we used Ordinal Alpha as a measure of internal consistency, which has been argued to be more appropriate for ordinal item response data than the more popular Cronbach's Alpha ([Gadermann, Guhn, & Zumbo, 2012](#)). The internal consistency of the MW questionnaire (Ordinal Alpha = 0.79) and the trait-level MW questionnaires (Ordinal Alpha = 0.88) were acceptable to good according to conventional standards. On the other hand, the internal consistency of the reading comprehension scores were slightly below what is usually considered being acceptable at group level (Ordinal Alpha = 0.67). We therefore conducted a factor analysis based on the polychoric correlation matrix of all indicator variables and found that two items loaded very weakly and negatively on a single comprehension factor (-0.01 and -0.05). Exclusion of these items led to a substantial improvement in internal consistency for this measure such that Ordinal Alpha was now within the acceptable range (Ordinal Alpha = 0.73).

3.1. Descriptive statistics

Means, standard deviations, and correlations among the modeled variables are displayed in [Tables 2 and 3](#). Distributional characteristics of the indicator variables can be found in [Table 4](#). Overall, the directions of the correlations matched our expectations. Comprehension was positively related to topic interest and topic familiarity, but negatively

related to MW during reading and text difficulty. Furthermore, MW during reading was negatively related to both topic interest and topic familiarity. Finally, trait-level MW was positively related with both reading comprehension and MW during reading, whereas the latter was negatively related to reading comprehension, consistent with our theoretical considerations regarding the two opposing effects of MW on comprehension and the re-analysis of [Mrazek et al.'s \(2013\)](#) data.

3.2. Structural equation modeling (SEM)

The structural equation model shown in [Fig. 2](#) was estimated using the software Mplus, version 7.4. ([Muthén & Muthén, 1998–2015](#)). MW during reading, trait-level MW, and reading comprehension were modeled as latent variables. The latent variable referring to MW during reading was represented at the level of individual items, whereas comprehension and trait-level MW were each represented by three-item parcels. This was done because the use of parcels results in a higher reliability and a lower likelihood of distributional violations of a given construct when there are many indicators for a latent variable, as is in the present case ([Little, Cunningham, Shahar, & Widaman, 2002](#)). Furthermore, because topic interest and topic familiarity were measured on ordinal scales, the corresponding variables were treated as ordinal predictors. Finally, the hierarchical structure of the data – subjects were nested in schools – was taken into account by allowing intercepts to vary per school (using the *type = complex* option in Mplus). [Fig. 2](#) shows the estimated model with the corresponding standardized coefficients (indicators and control variables are omitted for clarity). The fit of the model was very good according to common criteria: $\chi^2 = 115.611$, $df = 92$, $p = 0.049$, CFI = 0.979, TLI = 0.974, RMSEA = 0.047.

As regards to our first research aim – the replication of previous findings with a sample of secondary school children – the results confirmed the presence of negative effects of MW during reading ($\beta = -0.37$, $p = 0.006$) and of text difficulty ($\beta = -0.29$, $p = 0.001$) on reading comprehension, in line with the literature studying adult samples ([Feng et al., 2013](#); [Soemer & Schiefele, 2019](#); [Unsworth & McMillan, 2013](#)). Furthermore, topic interest had a strong negative impact on MW during reading ($\beta = -0.54$, $p < 0.001$), whereas its direct positive effect on reading comprehension remained non-significant ($\beta = 0.08$, $p = 0.705$). Given the assumption of our model that interest determines subsequent MW rates, this result may be taken as evidence for a mediation of the usually positive relationship between topic interest and reading comprehension through MW during reading (cf. [Soemer & Schiefele, 2019](#)). Consistent with this interpretation, the indirect effect of topic interest on comprehension via MW during reading turned out to be statistically significant ($\beta = 0.20$, $p = 0.005$). Note that the non-significant direct effect of topic interest on reading comprehension should be taken with caution since it does not represent evidence for the real absence of this effect. In fact, a post-hoc power analysis indicated a relatively low power of 0.28 to detect this effect assuming that it existed.

Two other noteworthy results in this context are the marginally significant negative effect of text difficulty on topic interest ($\beta = -0.18$, $p = 0.078$) and the marginally significant indirect effect of text difficulty on MW during reading via topic interest ($\beta = 0.10$, $p = 0.077$). Taking into account that the direct effect of text difficulty on MW during reading was non-significant ($\beta = -0.03$, $p = 0.376$), the results are in line with the direction of previous findings in adult samples, suggesting that more difficult texts promote MW episodes, but that this effect seems to be fully mediated by topic interest. Due to the marginal significance of these effects, however, one should be cautious at this point. In fact, post-hoc power analyses indicated a relatively low power of 0.44 to detect the direct effect of text difficulty on TUTs and 0.38 to detect the direct effect of text difficulty on topic interest, assuming that these effects existed.

Taken together, apart from the non-significant direct effect of topic

² Note that the results reported later do not change substantially when the second item is included instead of the first. The main difference is that correlation between trait-level MW and the second item is non-significant, whereas it is significant between trait-level MW and the first item.

Table 2

Bivariate correlations, means, and standard deviations. Correlations are polychoric for the case of two ordinal variables and polyserial for the case of one ordinal and one continuous variable.

	Comprehension	MW d. reading	Trait-level MW	Text difficulty	Topic interest	Topic familiarity	Age
Comprehension							
MW d. reading	−0.36***						
Trait-level MW	0.33*	0.37***					
Text difficulty	−0.28***	0.17†	−0.05				
Topic interest	0.35*	−0.50***	0.16***	−0.19*			
Topic familiarity	0.13	−0.18†	−0.11*	−0.25***	0.05		
Age	−0.16	0.03	−0.05	−0.06	−0.14	−0.04	
Gender ^a	−0.01	−0.23†	0.20	−0.03	0.23***	−0.02	−0.04
<i>M</i>	2.80	2.07	2.44	–	2.16	2.31	13.85
<i>SD</i>	0.66	0.52	0.52	–	0.98	0.66	0.65

MW = mind wandering.

*** $p < 0.001$.

* $p < 0.05$.

† $p < 0.10$.

^a Coding: 0 = male, 1 = female.

Table 3

Means and standard deviations broken down by difficulty level.

	Easy version	Medium version	Difficult version
Age	13.92 (0.60)	13.80 (0.68)	13.84 (0.69)
Comprehension	2.97 (0.49)	2.84 (0.70)	2.58 (0.67)
Trait-level MW	2.39 (0.75)	2.55 (0.63)	2.43 (0.81)
MW d. reading	1.94 (0.47)	1.98 (0.47)	2.30 (0.65)
Topic familiarity	2.35 (0.68)	2.54 (0.60)	2.03 (0.64)
Topic interest	2.41 (0.93)	2.06 (1.09)	2.03 (0.90)

MW = mind wandering.

Table 4

Distributional characteristics of the indicator variables and parcels.

	<i>M</i>	<i>SD</i>	Skewness	Kurtosis
Age	13.85	0.65	0.35	0.08
Comprehension 1	2.80	1.09	−0.57	−0.67
Comprehension 2	1.39	0.83	0.07	−0.56
Comprehension 3	2.14	0.85	−0.69	−0.32
Trait-level MW 1	2.44	0.66	0.35	−0.56
Trait-level MW 2	2.65	0.67	0.01	−0.34
Trait-level MW 3	2.47	0.77	0.13	−0.76
MW d. reading 1	2.07	0.82	0.53	−0.12
MW d. reading 2	2.70	0.84	−0.01	−0.70
MW d. reading 3	2.13	0.92	0.48	−0.57
MW d. reading 4	2.18	0.97	0.38	−0.83
MW d. reading 5	2.05	0.91	0.32	−0.92
Topic familiarity	2.31	0.66	0.08	−0.16
Topic interest	2.16	0.98	0.40	−0.89

MW = mind wandering.

interest on reading comprehension and the marginal significance of some effects, our results are remarkably similar to those of Soemer and Schiefele (2019), and they are generally in line with other prior research (Feng et al., 2013; Mills et al., 2015; Unsworth & McMillan, 2013).

With regard to our second research aim – investigating the relationships between trait-level MW, and MW during reading and reading comprehension – the results suggest that the latter has two mutually opposing effects on comprehension. First, trait-level MW was found to be a significant positive predictor of comprehension ($\beta = 0.33$, $p < 0.001$), suggesting that school students' trait-level MW may actually benefit comprehension. Second, trait-level MW was a significant positive predictor of MW during reading ($\beta = 0.47$, $p < 0.001$) meaning that students who have a strong propensity to mind wander in various life situations tend to do so during reading as well. Finally, apart from the positive direct effect on comprehension, trait-level MW

also had a negative effect on comprehension mediated through MW during reading ($\beta = -0.17$, $p < 0.001$).

Regarding the control variables, we found significant effects of age ($\beta = -0.23$, $p < 0.001$) and topic familiarity ($\beta = 0.10$, $p = 0.012$) on reading comprehension. The effect of gender was non-significant, however ($\beta = -0.03$, $p = 0.792$). Topic interest and topic familiarity were positively related to each other ($\beta = 0.12$, $p = 0.035$), which makes sense given that an individual usually has more knowledge related to the topic that he or she is interested in (Alexander, Kulikowich, & Jetton, 1994). Finally, trait-level MW was negatively related to topic familiarity ($\beta = -0.12$, $p < 0.001$) and positively related to topic interest ($\beta = 0.15$, $p < 0.001$).

4. Discussion

The present study was conducted with two overall aims in mind: First, we sought to replicate previous findings investigating the relationships among text difficulty, topic interest, and MW during reading with a sample of secondary school children (e.g. Soemer & Schiefele, 2019; Unsworth & McMillan, 2013). Second, we sought to find evidence for the novel hypothesis that MW has both positive and negative effects on comprehension. The positive effects of MW on comprehension were hypothesized to arise because MW supports memory consolidation (Wang et al., 2009) and novel content generation (Mills et al., 2018). The negative effect of MW on comprehension, in contrast, was predicted based on prior research showing that MW during reading can impair extracting important information from a text (e.g., Smallwood et al., 2008).

To reiterate the most important findings, we replicated the negative effects of MW during reading and text difficulty on comprehension that have previously been found with adult samples (most often university students). Furthermore, topic interest had a positive indirect effect on comprehension by reducing MW during reading, whereas the direct effect was non-significant. Our results also suggest that text difficulty may have an additional indirect effect on comprehension through reducing topic interest (which, in turn, reduces MW during reading), although this effect was only marginally significant in the present study. Overall, these results are generally consistent with previous studies with adult samples; that is, in both adult and (more heterogeneous) child samples, mind wandering during reading is overall harmful; and more interesting and easier texts (in terms of their readability) are associated with fewer MW episodes.

As regards the second main research question, a novel, though predicted, result of the present study is that trait-level MW had a strong positive impact on both reading comprehension and MW during reading; that is, it seemed to improve comprehension even after

Fig. 2. Path model with standardized coefficients (control variables are omitted for clarity). Solid, dashed and dotted lines indicate significant ($p < 0.05$) marginally significant ($p < 0.10$) and non-significant ($p \geq 0.10$) effects, respectively.

controlling for text difficulty, topic interest, and MW during reading, while it also seemed to harm comprehension by promoting MW during reading (mediator effect). Our preferred interpretation of these mutually opposing effects is that heavy mind wanderers are generally better at generating mental models from a text and enriching them with elaborative inferences which overall improves comprehension (Kintsch, 1988). The flipside of their natural tendency to generate mental content decoupled from the external input, however, is that they miss important information in the text, with the known negative consequences for comprehension (Smallwood et al., 2008). Thus, it could be that individuals with a strong propensity to mind wander in various situations are less aware of the immediate costs of MW during reading, and therefore tend to ‘let it happen’ even in inappropriate situations. Additionally or alternatively, these individuals may simply be worse at suppressing inappropriate MW episodes; that is, MW that occurs despite the individuals’ best effort to focus on reading. This latter interpretation would be in line with the influential control-failures account of MW (Kane & McVay, 2012; McVay & Kane, 2012) that states that individual differences in attentional control capability negatively predict the ability to suppress MW. Overall, the results are also predicted by Singer’s three-factor conceptualization of trait-level MW, which includes a “positive-constructive” factor that should have a positive effect on comprehension and a “poor attentional control” factor that should lead to more control failures during reading and thus be negatively related to comprehension.

What are the practical consequences of these findings? With regard to the particular result that MW during reading impairs comprehension, an obvious conclusion is that school teachers should seek to set up conditions that reduce MW during reading as much as possible. Both our results and previous research suggest that topic interest will be a key variable in this regard (Ainley et al., 2002; Fulmer & Tulis, 2013; Hidi, 2001; Schiefele, 1999, 2009; Schiefele & Krapp, 1996); that is, in order to reduce harmful MW and support mental model building, we propose that educators should focus on factors that promote interest prior to or during reading. There are a number of ways to accomplish this, such as giving students meaningful choices and autonomy support with regard to what and/or how to read (Schraw et al., 2001; Stroet, Opdenakker, & Minnaert, 2013), providing background knowledge (Alexander et al., 1994; Minnaert, 1999), and teaching the use of interest-enhancing strategies (Sansone & Thoman, 2005). The increase in topic interest should result in a reduction in MW during reading and, thus, improve comprehension.

In addition, our results suggest that it is crucial to create texts that are well-written in terms of their readability. This is not a self-evident

conclusion because one may argue that challenging children’s reading skills is important for improving them. While this may be true, we hypothesize that there may be an ideal intermediate level of challenge that is both beneficial for developing children’s reading skills while simultaneously limiting the danger of inappropriate MW with the aforementioned negative consequences for comprehension (Xu & Metcalfe, 2016).

With regard to the findings that suggest that MW is not per se harmful or, in fact, may even be beneficial under certain circumstances, looking for ways to reduce MW in children as a whole may be the wrong path to take with regard to improving their reading skills. Instead, children will likely profit more from interventions that optimize their use of MW for reading comprehension and learning in general. We regard this as an exciting possibility that awaits further investigation in future studies.

5. Alternative model

At this point, it must be emphasized that we have assumed that low interest causes participants to stop caring about the text and either deliberately initiate a MW episode or continue an already ongoing episode. This reasoning fits well with prior research on the effects of interest that view (a lack of) focused attention as an important mediator variable in the relationship between topic interest on comprehension performance (e.g., Hidi, 2001). This reasoning is also in line with prior research on the effects of interest on mind wandering (e.g., Soemer & Schiefele, 2019; Unsworth & McMillan, 2013). However, because we measured both MW during reading and topic interest after reading, it might be argued that, instead of topic interest only affecting the occurrence of a MW episode, the episodes themselves may have affected topic interest, or both variables may have affected each other. To address this potential objection, we estimated an alternative model in which the directional path going from topic interest to MW during reading was replaced with a bidirectional path (see Fig. 3). This alternative model essentially expressed a more cautious view on the data with regard to the causal ordering of MW and topic interest while leaving all other assumptions intact.

Both the fit of the alternative model ($\chi^2 = 117.995$, $df = 92$, $p = 0.352$, CFI = 0.977, TLI = 0.971, RMSEA = 0.050) and the strength of the associations between the variables within the model were comparable to the initial model. In particular, there were significant negative effects of MW during reading ($\beta = -0.48$, $p = 0.015$) and text difficulty ($\beta = -0.30$, $p = 0.003$) on comprehension. Furthermore, the direct effect of topic interest on reading

Fig. 3. Alternative path model with standardized coefficients (control variables are omitted for clarity). Solid, dashed and dotted lines indicate significant ($p < 0.05$) marginally significant ($p < 0.10$) and non-significant ($p \geq 0.10$) effects, respectively.

comprehension remained non-significant ($\beta = 0.02$, $p = 0.945$). However, given the positive bivariate correlation between the two measures ($r = 0.35$, $p = 0.026$) and given the strong correlation between topic interest and MW during reading ($\beta = -0.62$, $p < 0.001$), the reduction of the effect of interest on comprehension points to a substantial amount of shared variance between topic interest and MW during reading with regard to comprehension. Thus, even if one does not make the strong assumption of a causal relationship between topic interest and MW during reading, the two constructs seem to be closely related to each other.

Another noteworthy result was the direct effect of text difficulty on MW during reading remained non-significant ($\beta = -0.03$, $p = 0.376$). Furthermore, the two opposing effects of trait-level MW on comprehension that were found in the initial model remained significant; that is, there were a direct positive ($\beta = 0.45$, $p < 0.001$) and an indirect negative ($\beta = -0.23$, $p = 0.018$) effect mediated through MW during reading. Finally, the associations regarding the control variables remained largely the same. The only major difference to report is that the correlation between topic interest and topic familiarity was non-significant in this model ($\beta = 0.01$, $p = 0.956$).

Taken together, changing the directional path between topic interest and MW during reading to a bidirectional path did not substantially affect our conclusions with regard to several important effects found in the initial model. Text difficulty and MW during reading still had a substantial impact on comprehension, and topic interest was still highly correlated to MW during reading and shared a large amount of variance with regard to comprehension. Finally, trait-level MW still had its two opposing effects on comprehension.

6. Limitations and directions for future studies

Before concluding this article, we would like to point out a number of limitations of our study. Firstly, we relied on self-reports to measure MW during reading and trait-level MW. Using these self-reports we

implicitly assume that children are able to understand and reflect on the measured constructs. Furthermore, because the reports refer to past states, we assume that children's memory is accurate enough to make reliable reports (cf. Zhang, Song, Ye, & Wang, 2015). However, it is well possible that these assumptions do not hold; in particular, that children are not able to correctly remember how often they drift off with their thoughts during reading or how often they experience MW in daily life. One way to avoid this limitation in future studies could be to combine retrospective questionnaires with on-line measures of MW. With regard to trait-level MW, one may follow the path of McVay et al. (2009) who equipped their participants with personal digital assistants (PDAs) and randomly probed their thoughts several times during the day. Since many children possess smartphones nowadays, it would be possible to obtain estimates of children's individual MW propensity in various daily life situations with a specialized app. With regard to measuring MW during reading, future studies could implement the previously mentioned probing method, in which individuals are probed from time to time during reading and asked whether or not they were focusing on the text. One drawback of conducting such a study, however, would be that a classroom setting could no longer be used.

Another potential limitation of the present study is that topic interest was measured with a single item, while it is usually regarded as a multifaceted construct that needs to be measured with multiple-item questionnaires (cf. Schiefele, 1999, 2009). Furthermore, a general issue with single-item measurements is that they contain considerable measurement error. The consequences are potential problems with reliability and an underestimation of the strength of the associations with other variables. In the present case, it could be that some of the non-significant and marginally significant effects could have been avoided with a multiple-item measurement of topic interest. Thus, it seems desirable for future studies to use instruments for measuring topic interest that have previously been validated in other studies (Schiefele, 1999, 2009).

Appendix A. Readability manipulation

A.1. Example (approximate English translation)

A) Easy version

"The alveoli are very small. They have a diameter of only 1/5 mm. But there are a lot of them in the lungs. Both lungs together have around 300 to 750 million alveoli. These alveoli cover an area of about 100 square meters. That's around 50 times the area of the body."

B) Moderate version

“The alveoli are very small having a diameter of only 1/5 mm, but there are a lot of them. Both lungs together have around 300 to 750 million of alveoli, which cover an area of about 100 square meters. That's around fifty times the area of the body.”

C) Difficult version

“The alveoli are miniscule having a diameter of only 1/5 mm, but they are numerous. Both lungs together dispose of between three-hundred and five-hundred millions of alveoli, which cover an area of about hundred square meters, which is about fifty times the body's surface.”

A.2. Indexes

A) Läsbarhetsindex (LIX; Björnsson, 1968; Lenhard & Lenhard, 2014–2017)

$$LIX = \frac{N_W}{N_P} + \frac{N_L}{N_W} \times 100$$

N_W = number of words

N_P = number of periods/sentences

N_L = number of words with more than six letters

B) Flesch Reading Ease (FRE; Flesch, 1948; Amstad, 1978).

$$FRE = 180 - ASL - (58.5 \times ASW)$$

ASL = average sentence length

ASW = average number of syllables per word

Appendix B. Trait-level mind wandering questionnaire

Note that all items are approximate English translations. The response alternatives for the following items were “rarely”, “not often”, “often”, “very often”.

1. I daydream _____.
2. I _____ drift off with my thoughts.
3. I would characterize myself as somebody who _____ gets lost in thoughts.
4. I _____ remember my daydreams and think about them.
5. I daydream _____ in my free time.
6. I daydream _____, when I have to do something that's uninteresting.

The response alternatives for the following items were “strongly disagree”, “disagree”, “agree”, “strongly agree”.

7. When I can't concentrate on something, I start to daydream.
8. Instead of focusing on class, I often think about something that's nothing to do with class.
9. During class I often lose myself in thoughts that are unrelated to the topics of the class.
10. I often dream about past events or imagine some event in the future.
11. I often daydream on a long journey (on the bus/train/plane).

Appendix C. Example comprehension questions (approximate English translation)

1. Which condition increases the likelihood that dust sticks to the surface of the bronchi? (sentence-level)

- a) The bronchi are covered by many alveoli.
- b) A lot of dust reaches the bronchi.
- c) The alveoli are not sufficiently coated with mucosa.
- d) Many alveoli are damaged.

2. What is ‘silicosis’? (word-level)

- a) It is another technical term for ‘alveoli’.
- b) It is the technical term for a disease caused by residual dust in the lungs.
- c) It is the technical term for the breathing of mineworkers.
- d) It is the technical term for insufficient oxygen supply.

3. Hans is playing soccer with his friends. After 10 min of playing he says: “I need a break, I'm completely out of breath.” What could that mean with regard to what you just read in the text? (text-level)

- a) Hans' body needs more oxygen.
- b) Hans' body needs more carbon dioxide.

- c) Hans is not good at sports.
d) There is not enough oxygen in the air.

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