On the Relationships Between Mind-Wandering, ADHD, Engagingness, and Effort

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Existing research on mind-wandering (MW) has found that adults with attention-deficit hyperactivity disorder (ADHD) experience it more frequently and find it more disruptive to their daily lives than individuals without the disorder (Franklin et al., 2017). However, little research has been done on the academic costs of frequent and disruptive MW associated with ADHD. In addition, past theoretical work has made a distinction between *intentional* and *unintentional* MW (Grodsky & Giambra, 1990; Seli, Risko, Smilek, & Schacter, 2016), but has not examined how effort to stay on-task informs this distinction. To address these distinct lines of research, we conducted an omnibus study to examine how ADHD symptomatology related to MW while reading engaging and unengaging textbook content (Experiment 1A), as well as how reports of intentional and unintentional MW related to reported effort to stay on-task (Experiment 1B). For Experiment 1A, we found that ADHD symptomatology predicted higher rates of inattention for unengaging texts, and that this effect was stronger for unengaging texts that were read second. However, we found no evidence for an effect of ADHD symptomatology on reading comprehension. For Experiment 1B, we found that reports of intentional MW were associated with moderate effort to remain on-task, contradicting existing theory and suggesting alternative distinctions may be more theoretically and practically useful. Together, both lines of research broaden our understanding of the practical consequences and theoretical nuances of mind-wandering.

Acknowledgements

This work would not have been possible without the invaluable direction and feedback of my supervisor, Dr. James Danckert, at every stage of this project. Additionally, I extend thanks to my readers, Dr. Daniel Smilek and Dr. Britt Anderson, for their time and feedback in the final stages of this thesis. I would also like to thank my colleagues Allison Drody, Dr. James Boylan, Dr. Jhotisha Mugon, Dr. Andriy Struk, and Nicole Stuart for their advice and assistance throughout the design, implementation, and piloting phases of my thesis experiments. Finally, I would like to thank my fiancée Hannah, for her endless assistance, support, and patience throughout the completion of this thesis. I could never have done this without her.

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Dedication

I dedicate this thesis to my mother, Robin. You have encouraged and supported me in more ways than I could ever count, and you have always fought for me when I needed someone in my corner. I could not ask for a better parent or friend.

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Chapter 1: Introduction

The ability to sustain attention on a task, even if it is not inherently engaging, is an important function in everyday life. From driving a car, to reading an instruction manual, to having a face-to-face conversation, the ability to maintain focus is necessary. On the other hand, the ability to daydream and allow our minds to wander is likewise important: instead of letting unused cognitive resources go to waste (e.g., while doing simple tasks such as washing the dishes or walking to work), we can use those resources to think through current concerns, reflect on the past, come up with ideas, or enjoy a momentary escape from reality. Although this sort of off-task thought is healthy and adaptive in many cases (Baars, 2010), it can quickly become a problem when we fail to regulate it properly. This is especially true for tasks that require deep, sustained attention: getting lost in thought while painting a wall is one thing, but getting lost too deeply in thought while driving can have much greater consequences.

The experience of becoming “lost in thought” is a prototypical case of the cognitive phenomenon known as mind-wandering (MW). Although the precise definition of “mind-wandering” is a matter of some debate among cognitive scientists (Seli et al., 2018; Irving & Glasser, 2020), it is generally used to refer to thought that is both task-unrelated and stimulus-independent (i.e., unrelated to any current external task, and not focused on external perceptual information; unless otherwise specified this will be the default definition of mind-wandering used throughout this thesis, for more detailed discussion see Smallwood & Schooler, 2015 for a review). Given that mind-wandering is an extremely prevalent phenomenon, with some research estimating that it makes up over 40% of all waking thought (Killingsworth & Gilbert, 2010), it is important to understand the practical correlations and consequences of mind-wandering. Existing research in this domain has found that mind-wandering has a number of beneficial and harmful correlates. For example, mind-wandering is associated with higher levels of creativity and problem-solving skills (Preiss, Cosmelli, Grau, & Ortiz, 2016), but has also been associated with decreased awareness of dangers while driving (Qu et al., 2015) and impaired academic performance (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012).

The present thesis examines mind-wandering from both a practical and theoretical standpoint. We conducted an omnibus study intended to examine two separate-but-related questions regarding the nature of mind-wandering: first, from a practical perspective, how does mind-wandering relate to ADHD symptomatology in the context of academic reading, and how does this relationship differ based on the engagingness of the reading material? Second, from a theoretical standpoint, how does reported effort to stay on-task relate to whether mind-wandering episodes are reported as being intentional or unintentional? Although these two aims were explored within a single experimental setup, they will be treated here as separate experiments.

Chapter 2: Experiment 1A - Mind-Wandering, ADHD, and Reading Engagingness

Difficulty with sustained attention and frequent off-task thought is a common symptom of Attention Deficit Hyperactivity Disorder (ADHD), a neurodevelopmental disorder characterized by problematic levels of inattention, hyperactivity, or both (Barkley, 1997; Tucha et al., 2009). Specifically, individuals with ADHD tend to have difficulty maintaining focus in situations where there is no immediate reward for doing so, which is theorized to be due to deficits in inhibitory and executive control systems (Barkley, 1997). Despite frequently being thought of as a childhood disorder, deficits associated with ADHD often persist into adulthood: a global meta-analysis found that between 2% and 3% of adults worldwide met the DSM criteria for the disorder (Simon, Czobor, Bálint, Mészáros, & Bitter, 2009). Adult ADHD is particularly common in university students, with estimates ranging between 2% to 12% , depending on the methodology and criteria used (DuPaul, Weyandt, O'Dell, & Varejao, 2009; Garnier-Dykstra, Pinchevsky, Caldeira, Vincent, & Arria, 2010). In particular, Garnier-Dykstra and colleagues (2010) found that 10.3% of their student sample that lacked a prior diagnosis of ADHD nevertheless reported clinical levels of symptomatology, suggesting that ADHD in university students may well be underreported. Given that sustained attention is essential for reading textbooks, reviewing notes, learning during lectures, and many other tasks necessary to succeed in a university environment, the real-world academic consequences of inattention related to adult ADHD demand further research.

Recently, researchers have begun to make connections between the attentional impairments associated with ADHD and the cognitive construct of mind-wandering (MW). An early study from Shaw and Giambra (1993) found that adults with a prior ADHD diagnosis reported higher rates of task-unrelated thoughts than controls during a vigilance task. More recently, Franklin and colleagues (2017) examined the relation between ADHD and mind-wandering in depth using a number of scales, in-lab cognitive tasks, and daily-life experience sampling via a Palm Pilot. Their results showed that ADHD symptomatology was positively correlated with rates of mind-wandering, both within and outside the lab, and negatively correlated with meta-awareness of one's own mind-wandering. Notably, Franklin and colleagues (2017) also found that participants with higher ADHD symptomatology were more likely to report their daily mind-wandering episodes as being detrimental to their lives. Seli and colleagues (2015) examined how ADHD related to mind-wandering with and without intention and found that ADHD symptomatology was significantly correlated with self-reported *unintentional* mind-wandering but not with *intentional* mind-wandering (i.e., deliberate shifts of focus to off-task thoughts). This finding might explain why individuals with ADHD tend to report their mind-wandering as being more disruptive: the more often someone's mind unintentionally wanders, the more likely it is that MW will hinder their attentional focus at inopportune times. Finally, a recent meta-analysis examining the ADHD/MW link concluded that ADHD symptomatology is associated with high rates of unintentional MW, which interfere meaningfully with the lives of those who have it (Lanier, Noyes, & Biederman, 2019).

A common paradigm for studying mind-wandering in the lab is the reading task, in which participants read one or more passages of text and are occasionally interrupted by semi-random thought probes asking about their state of focus just prior to the probe. This paradigm is well-suited to the study of ADHD in university students, given that reading is frequently required of students and is a task in which deficits in sustained attention are likely to impair learning and comprehension. As noted by Smallwood and colleagues (2007), successful extraction of information from a text requires a deep level of processing and engagement to parse the semantic meanings of words into concepts. As such, any amount of mind-wandering is likely to prevent successful encoding of information. Indeed, existing studies of mind-wandering during reading have found that rates of probe-caught MW correlate negatively with reading comprehension (Schooler, Reichle, & Halpern, 2004; Unsworth & McMillan, 2013) and that MW during critical parts of a narrative text can prevent readers from understanding key parts of a story (Smallwood, McSpadden, & Schooler, 2008). Similarly, research on mind-wandering during university lectures has found that MW is negatively correlated with the amount of lecture material retained (Risko et al., 2012).

To date, research has yet to examine how the engagingness (or lack thereof) of reading material affects the ADHD/mind-wandering relationship. Existing work on mind-wandering has found that people report higher rates of MW while reading content they rate as uninteresting (Giambra & Grodsky, 1989). This relationship appears to be due to low topic interest correlating strongly with lower motivation levels, which in turn causes higher rates of task-unrelated thought (Unsworth & McMillan, 2013). Given that a key inattentive symptom of ADHD is difficulty maintaining focus in low-motivation situations (Barkley, 1997), we might expect individuals with high ADHD symptomatology to report uniquely high rates of mind-wandering while reading content they find unengaging. Conversely, we might expect mind-wandering rates to be similar between individuals with high and low symptomatology for more engaging content.

To address this question, we recruited undergraduate students with varying levels of ADHD symptomatology to participate in a study where they each read two textbook excerpts: one more likely to be engaging, and one less likely to be engaging, with the order of the texts counterbalanced between participants. Reading comprehension for the texts was measured via multiple-choice questions, and participants' attentional states were measured throughout using semi-random thought probes. The format of the reading task was designed to closely resemble real-world reading, with full and richly formatted pages of text being displayed on the computer screen, and free navigation between pages allowed via the arrow keys. Additionally, to account for potential confounds and mediators, measures of state boredom, motivation, effort to stay on-task, and depressive symptoms were collected during the experimental session.

For this study, we were interested in two key aspects of the relationship between ADHD and mind-wandering during reading: first, does the engagingness of reading material affect the correlation between ADHD symptomatology and the amount of reported MW? Second, if there is a significant ADHD/MW correlation for either type of text, does this translate to practical impairments in reading comprehension or reading speed? Although the purpose of this study was exploratory, our broad hypotheses were that ADHD symptomatology would be associated with higher rates of mind-wandering, that this relationship would be stronger for texts reported to be less engaging, and that MW would impair reading comprehension. Together, these hypotheses also predict that comprehension for less engaging texts will be worse for people with high ADHD symptomatology, as a consequence of increased MW. As a secondary research question, we were interested in the degree to which the ADHD/MW relationship was accounted for by depressive symptoms, given that depression is up to three times more common in individuals with ADHD than the general population (Katzman, Bikley, Chokka, Fallu, & Klassen, 2017; Adler, Faraone, Sarocco, Atkins, & Khachatryan, 2019) and is similarly associated with higher rates of MW (Deng, Li, & Tang, 2014).

2.2 Methods

Participants

Thirty-nine participants (13 male, 26 female, M_{age} = 19.7, age range: 17–25) were recruited from the SONA undergraduate participant pool at the University of Waterloo, none of whom reported having a prior diagnosis of ADHD. All participants were compensated in the form of bonus course credit. One participant did not initially understand the text navigation controls and spent over 15 minutes on the first page of text, and was thus excluded from any further analysis.

To ensure a relatively even distribution of ADHD symptomatology in the final sample, we used existing screening data to classify students as having either low, medium, or high inattentive ADHD symptoms and attempted to recruit an equal number from each group[1].

Materials

Rating Scales

The 6-item Adult ADHD Self-Report Scale - Screener v1.1 (ASRS-S; Kessler et al., 2005), based on the DSM-IV criteria for the disorder, was used to measure the extent of ADHD symptoms in participants. This scale consists of four questions relating to inattentive symptoms (e.g. "how often do you have problems remembering appointments or obligations?") and two

[1] Due to campus closure in response to COVID-19, only individuals in the 'low' and 'medium' symptom ranges were recruited prior to the end of data collection.

questions relating to hyperactive symptoms (e.g. “how often do you feel overly active and compelled to do things, like you were driven by a motor?”), each rated on a scale from 0 (“never”) to 4 (“very often”), and was chosen for its brevity and extensive validation (Hesse, 2013; Silverstein, Alperin, Faraone, Kessler, & Alder, 2018). The ASRS-S was completed by participants online as one of several scales and questionnaires included in the University of Waterloo SONA mass-testing for Fall 2019. For the purpose of screening participants prior to recruitment, scores on the four questions relating to inattentive symptoms were summed and used to determine whether each respondent’s inattentive ADHD symptoms were low (total score under 5), moderate (total score between 5 and 9, inclusive), or high (total score above 9).

In addition, a modified version[2] of the Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001) was administered to participants. Participants were asked to report the extent to which they experienced various depressive symptoms over the past two weeks (e.g. “little interest or pleasure in doing things”), with each symptom reported on a scale of 0 (“not at all”) to 3 (“nearly every day”). This scale was chosen due to its brevity and extensive validation across populations (Martin, Rief, Klaiberg, & Braehler, 2006) and cultures (Adewuya, Ola, & Afolabi, 2006). To facilitate the administration and scoring of the PHQ, a computerized version was written in Python and integrated into the rest of the experiment program. Participants indicated their responses via mouse clicks and were able to change their answers at any point before submitting the questionnaire.

[2] One question on the PHQ relating to suicidal ideation was removed from the scale to avoid the duty-to-disclose given the research team’s qualifications.

Reading Material

Reading materials for the task were excerpts from four different textbooks, each edited to a length of approximately 4,000 words. All four excerpts were from textbooks released under a Creative Commons licence, allowing them to be edited and redistributed freely without breaching copyright. Two of the excerpts were chosen because they were a priori considered to be unlikely to be rated as engaging by participants: “Introductory Trade Issues”, adapted from the first chapter of “International Trade: Theory & Policy” (Suranovic, 2010), and “Risk Management and Legal Liability”, adapted from the 11th chapter of “Introduction to Tourism and Hospitality in BC” (Webster, 2015). The other two excerpts were chosen because they were deemed a priori to be more likely to be rated as engaging by readers: “Crime and Criminals”, adapted from chapter 7.3 of “Sociology: Understanding and Changing the Social World” (University of Minnesota, 2010), and “Achieve Personal Success”, adapted from chapter 2 of “Human Relations” (Dias, 2012). These chapters were selected based on informal ratings from researchers in the Danckert lab, who rated a number of textbook excerpts on how boring they found the material based on the first page of text.

Table 1

Page counts, sentence counts, word counts, and Flesch-Kincaid grade levels for all four textbook excerpts used during reading tasks.

Textbook Excerpt	*Page Count*	*Sentence Count*	*Word Count*	*Grade Level*
More Likely Engaging				
Crime and Criminals	11	132	3764	13.3
Achieve Personal Success	13	174	4123	12.5
Less Likely Engaging				
Introductory Trade Issues	12	142	4130	14.6
Risk Management & Legal Liability	15	100	3939	19.8

During the editing process, all four textbook chapters were first converted to the plain-text Markdown format from their original HTML and e-book formats, preserving section headings and bold and italic text. Then, all figures and tables were removed from the excerpts, along with their corresponding in-text references, ensuring that all reading material consisted only of section headings and plain text. Sections of the longer chapters were then removed until their lengths were close to 4,000 words. After finalizing the excerpts, the Markdown documents were rendered to pages of text for use in the experiment using LaTeX and a custom Python script. Each page of text had margins of 3.0 degrees of visual angle on all sides, with the main body of text being rendered in double-spaced 0.4° TeX Gyre Pagella font.

To measure reading comprehension for each of the four excerpts, 10 multiple-choice comprehension questions were created for each excerpt with four possible answers for each question. Reading comprehension questions were presented to participants via the experiment program, which randomized the order of responses and automatically calculated the response accuracy for each question. Questions and answers were rendered in 0.55° Source Sans Pro font, with questions in bold and answers in normal typeface.

Equipment and Software

The experiment paradigm was programmed in Python using the KLibs framework and run on 23″ Dell OptiPlex all-in-one computers running Windows 10. The experiment code, along with instructions on how to replicate the task, are available upon request. All stimuli were displayed on the computers' built-in LCD monitors at a resolution of 1920 x 1080 pixels and a refresh rate of 60 Hz. Responses were collected via a USB keyboard and mouse.

Procedure

Participants in groups of one to three were brought into a group testing room at the University of Waterloo, containing four identical computers separated by dividers. After entering the lab, they were each seated in front of a computer at a viewing distance of approximately 57 cm and were provided with informed consent forms to read and sign. Once informed consent had been obtained, participants were given instructions on how to navigate the reading material using the keyboard and were set up to begin the experiment.

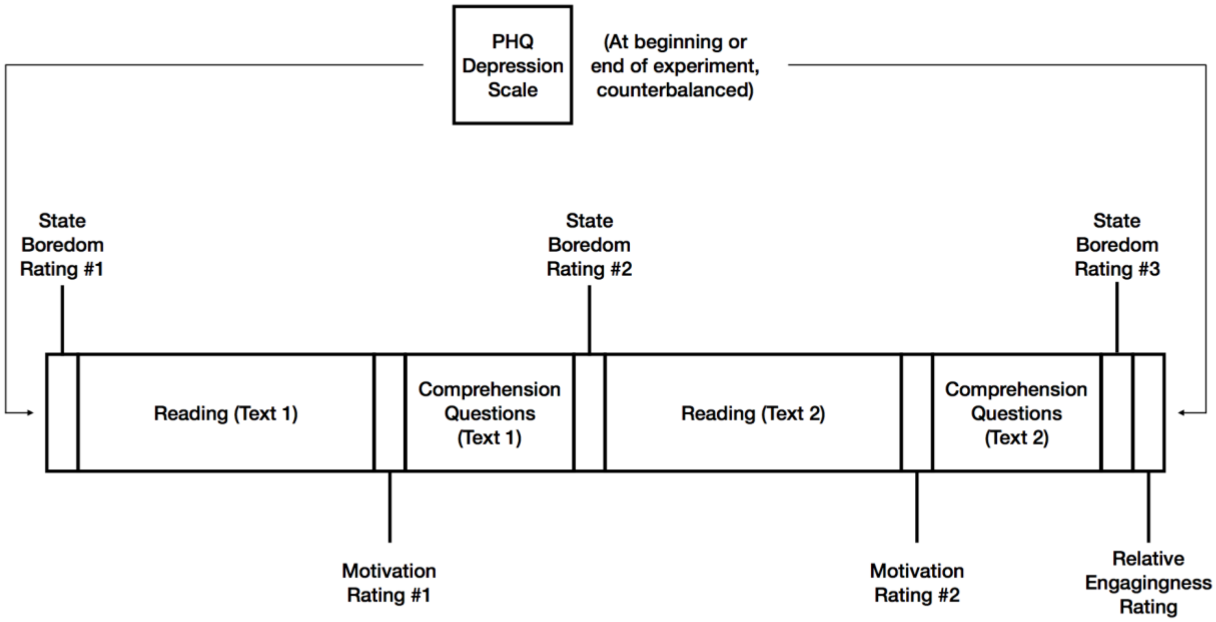

Figure 1. The structure of the experimental task, indicating the sequence of individual ratings and sub-tasks throughout.

The overall structure of the full experimental session is illustrated in Figure 1. Each participant either began or ended the task with the completion of the PHQ, the sequence of which was counterbalanced between participants. The full session contained two reading tasks: one for an engaging text, and one for an unengaging text, with the order of engagingness counterbalanced between participants. Attentional state and effort to stay on-task were measured throughout both reading tasks using semi-random thought probes. Each reading task was also followed by a motivation probe, asking participants how motivated they had been to read the previous text attentively. Motivation probes were followed by multiple-choice comprehension quizzes on the content of the previous text. State boredom was measured at three different points throughout the task using self-report probes: just prior to the first reading task, and immediately following both sets of comprehension questions[3]. After the final state boredom probe, participants were asked to rate the engagingness of the second text they read, relative to the first one.

During the reading tasks, pages of text were presented on screen, which participants were able to navigate freely using the left and right arrow keys on the keyboard[4]. This method of presentation was chosen to resemble real-world textbook reading, in contrast to some earlier studies that presented single words or sentences on screen at a time and only allowed forward movement through the text (e.g., Smallwood et al., 2008; Feng et al., 2013). When participants pressed the right arrow key while on the last page of a text, they were presented with a screen informing them that they had reached the end of the excerpt, and could either press the “y” key to proceed to comprehension questions or press the left arrow key to return to the text. Thought probes appeared semi-randomly during reading to ask participants about their attentional state and level of effort to stay focused just prior, with each probe following the previous probe (or the start of the reading) by a random interval between 30 and 119 seconds to minimize the predictability of probe onsets. There were no time limits for the reading tasks, meaning that the number of thought probes presented varied between participants and texts based on reading speed and random chance: during a 10 minute interval, a participant could receive as few as five

[3] State boredom probes were included to address questions outside the scope of this thesis. As such, data from these probes are not reported or discussed in the analysis.

[4] Screenshots illustrating the appearance of the rendered text, along with additional screenshots from the task, can be found in Appendix A.

probes (if all were spaced 119 seconds apart) or as many as 20 (if all probes were spaced 30 seconds apart). The observed probe frequencies for each of the four texts are provided in Table 2.

Table 2

Means, medians, and standard deviations for thought probe frequencies across all texts, in units of seconds between probes. Mean probe frequencies are also re-expressed in units of probes per minute.

Textbook Excerpt	*M*	*Median*	*SD*	*Mean Probes / Min.*
Likely Engaging				
Crime and Criminals	72.5	73.0	25.3	0.827
Achieve Personal Success	77.4	79.0	25.2	0.775
Likely Unengaging				
Introductory Trade Issues	70.7	68.0	26.6	0.849
Risk Management & Legal Liability	76.7	76.5	25.4	0.782

Each thought probe consisted of two components: a mind-wandering probe, and an effort probe. The mind-wandering probe was a 5-alternative forced-choice (5-AFC) query that asked participants "Were you reading attentively just now?", with the possible responses being listed in Table 3. Participants responded to these queries by clicking a response with the mouse cursor, which was facilitated by a translucent grey rectangle appearing over whichever response option the mouse cursor was currently hovering over. Effort probes appeared immediately following each mind-wandering query, asking participants "How much effort were you putting into staying on-task?" on a continuous scale from 0% to 100% (see Figure 2a). After making a response, participants were able to return to the reading task by clicking a "continue" button.

Table 3

Possible response types for the mind-wandering portion of thought probes, along with their corresponding phrasings.

Measured Domain of Attention	*Response Wording*
Attentive Reading	"Yes, I was reading attentively"
Unintentional Mind-Wandering	"No, my thoughts had unintentionally wandered from the text"
Intentional Mind-Wandering	"No, I was intentionally thinking about other things"
External Distraction	"No, I was distracted by something else around me"
Mind-Blanking	"No, my mind had gone temporarily blank"

Computerized visual analog scales were used for effort probes, state boredom probes, motivation probes, and ratings of relative text engagingness, all of which are illustrated in Figure 2. These scales spanned 75% of the screen width and contained tick marks at the 0%, 25%, 50%, 75%, and 100% locations, with corresponding questions appearing above the scale in large bold text. Participants responded by clicking on the slider, causing a translucent blue slider button to appear at the clicked location and a "continue" button to appear underneath the scale. Participants could then finalize their response by clicking the "continue" button or adjust their selection by clicking elsewhere on the scale.

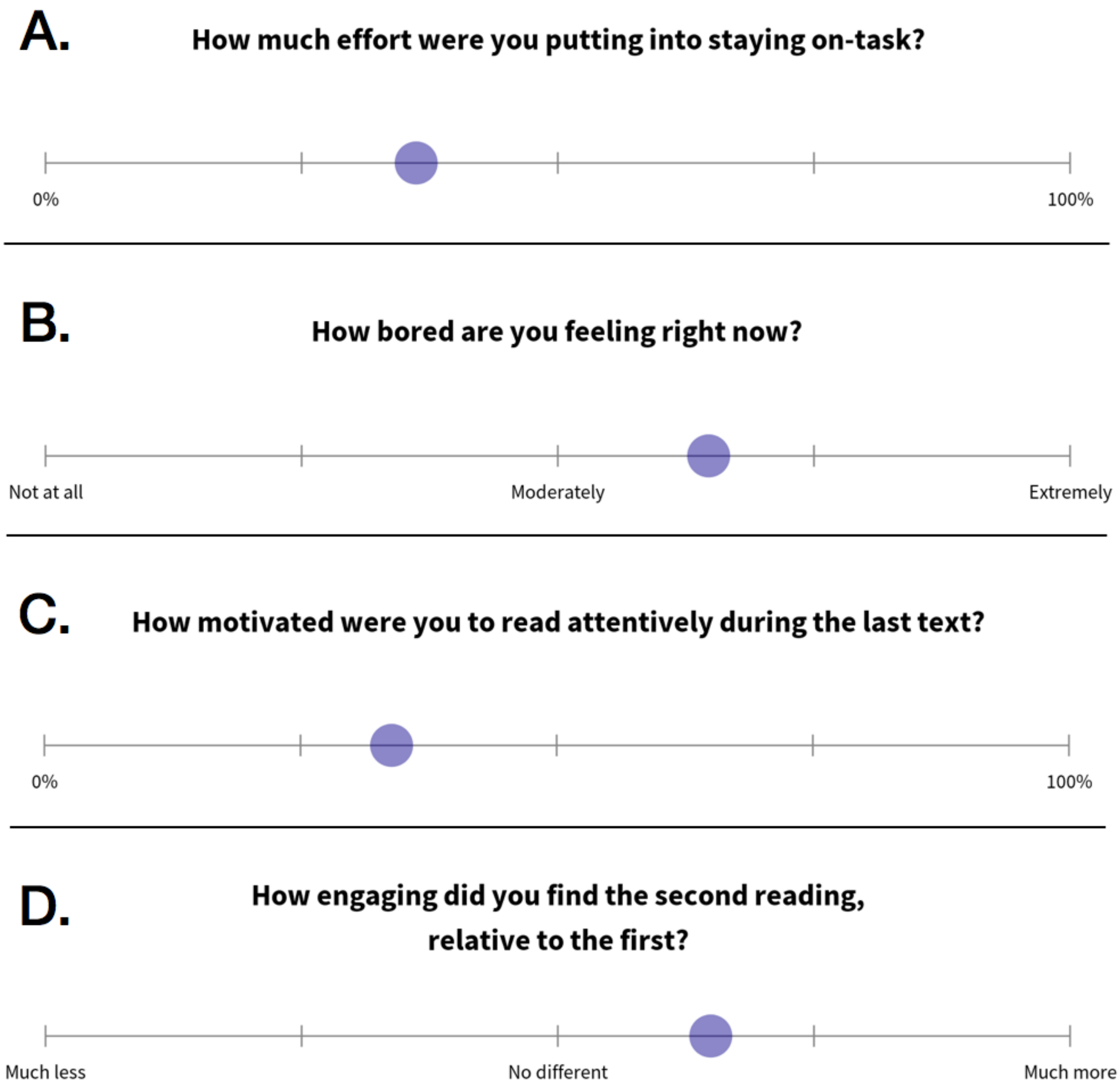

Figure 2. The appearance, wording, and anchor points for the different visual analog sliders used throughout the task. The distance between the sliders and the question text has been modified for the purpose of illustration.

2.3 Results

All data analysis was performed using version 3.6.0 of the R statistical software (R Core Team, 2019), with Bayesian modelling being performed using the brms package (Bürkner, 2017;

see Appendix B for more details). The results of these models are in the form of posterior probability distributions, which describe the likelihoods of different values of each of a model's parameters, based on the data and the design of the model. These distributions are approximated using samples (see McElreath, 2020 for a detailed explanation), which are summarized using the median sample values and highest density intervals (HDIs), which indicate the range of a parameter's most probable values for a given percentage of the distribution (e.g., a 90% HDI would contain the 90% of the posterior most likely to contain the true value of the parameter, given the model and data).

In place of traditional null-hypothesis significance testing (NHST), all observed effects are instead described as being either "highly credible", "weakly credible", or "not credible", based on different probability thresholds chosen a priori. Specifically, effects where the 90% HDI does not contain zero (i.e., over 95% of the posterior is either above or below zero) are described as "highly credible", effects where the 90% HDI contains zero but the 60% HDI does not (i.e., over 80% of the posterior is either above or below zero) are described as "weakly credible", and effects where the 60% HDI contains zero are described as "not credible".

Descriptive Statistics

Prior to formal modelling, we performed a manipulation check to verify that all participants had actually rated the texts we expected to be engaging as the more engaging of the two texts (see above). On a scale of -100% (much less engaging) to 100% (much more engaging) presented at the end of the task, with 0% indicating no difference in engagingness, participants reported the "more likely engaging" text as being approximately 50% more engaging than the "less likely engaging" text, Median = 51.7%, IQR = [7.9%, 93.1%], with 84.2% of participants finding the “more likely engaging” text the more engaging of the two. For the remaining 15.8% of participants who reported finding the “less likely engaging” text more engaging, the “engaging” coding of the two texts was reversed such that the text each participant found most engaging was treated as such for all subsequent analyses. After reverse-coding these participants, the median engagingness difference was 58.8%, IQR = [44.9%, 93.1%].

Overall, rates of reported attentive reading were high across both engaging and unengaging texts, with participants reporting attentive reading on 67.7% of all probes, unintentional MW on 21.7%, intentional MW on 3.2%, mind-blanking on 2.4%, and external distraction on the remaining 5.1%. Relative to the engaging texts, participants reported less attentive reading when reading unengaging texts (62.5% vs. 72.1%), while reporting more unintentional MW (22.2% vs. 21.3%), intentional MW (4.8% vs. 1.7%), mind-blanking (4.0% vs. 1.0%), and distraction (6.5% vs. 3.9%), as illustrated in Figure 3.

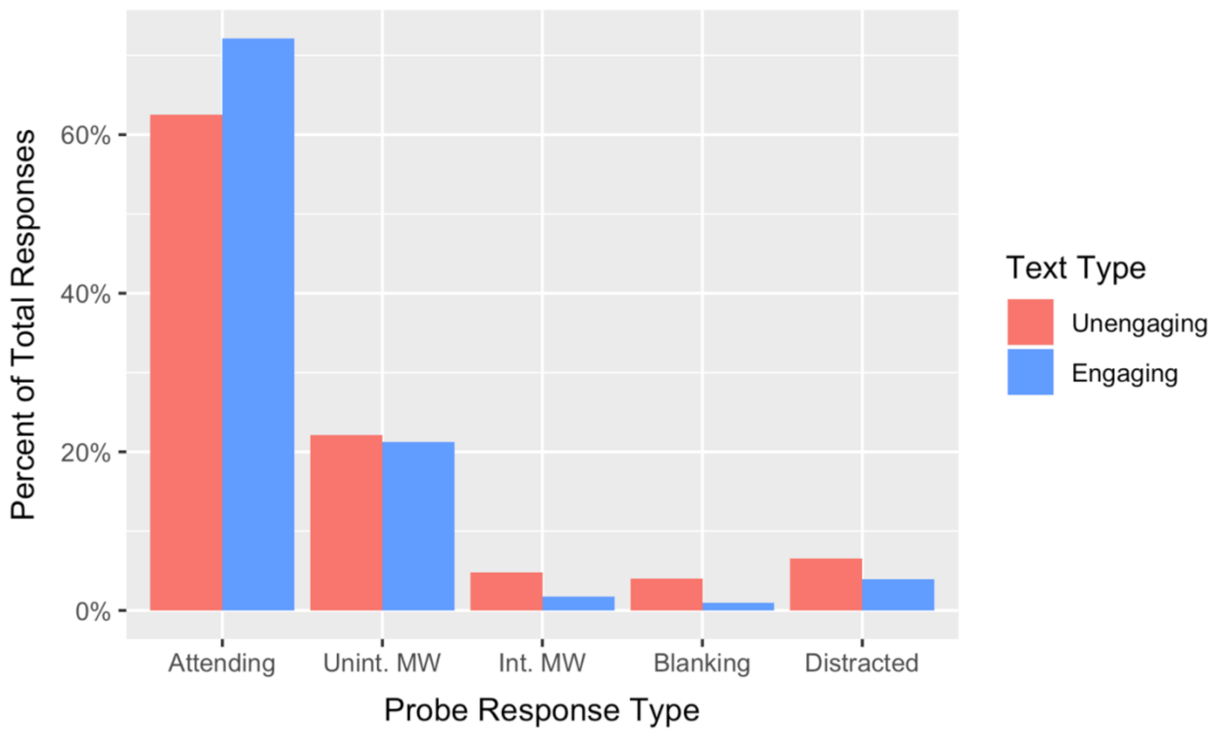

Figure 3. Raw proportions of each possible attention probe response across less-engaging and more-engaging texts.

Scores on comprehension quizzes were moderate, with mean accuracies of 62.6% for more engaging texts and 53.7% for less engaging texts (58.2% overall). Total scores on the ASRS-S Screener were moderate-to-low, M = 8.9, SD = 3.1, possible range: 0 - 24, as were scores on the PHQ, M = 7.7, SD = 4.5, possible range: 0 - 24. Participants reported moderate overall levels of motivation to read attentively, M = 55.5%, SD = 26.1%. The average reading time per text was approximately 15 minutes, M = 14.2 min, SD = 6.7 min, with reading times being faster for the second text of the session, M = 10.7 min, SD = 5.4 min, relative to the first text, M = 17.7 min, SD = 6.0 min. Despite this difference in reading time, mean reading comprehension was only marginally lower for texts that were read second relative to texts that were read first (56.8% vs 59.5%).

Inattention & Mind-Wandering

To model how various factors affected attentional state during reading, we used mixed-effects logistic regression models, modelling the likelihood of a given probe response type (e.g., unintentional MW) as a binary outcome, and treating text engagingness as a within-subjects factor nested on the level of the participant. Scores on the ASRS and PHQ were z-scored prior to modelling, and slopes for these predictors are reported in units of change in log-odds of the outcome per one standard deviation of the predictor. Contrast coding was used for all categorical variables.

To examine whether the relationship between ADHD symptomatology and overall inattention varied between less-engaging and more-engaging texts, we conducted a logistic regression on the probability of attentive reading, using total ADHD symptomatology, text engagingness, text order, and interactions between the three as predictors. Additionally, PHQ score was added as a covariate to the model to control for depressive symptoms as a confound. The results of the model revealed a highly credible main effect of engagingness, with attentive reading being higher for more engaging texts, $b^* = -0.68$, $HDI_{90\%} = [-1.11, -0.22]$, a highly credible effect of text order, with more reported attentive reading during the first text than the second text, $b^* = 0.54$, $HDI_{90\%} = [0.10, 1.00]$, and a weakly credible main effect of ADHD symptomatology, with higher ASRS scores predicting lower attentiveness, $b^* = -0.25$, $HDI_{90\%} = [-0.63, 0.16]$, $HDI_{60\%} = [-0.45, -0.05]$, but no credible main effect of depressive symptoms, $b^* = -0.15$, $HDI_{60\%} = [-0.35, 0.03]$. Importantly, the model also revealed a weakly credible two-way interaction between ADHD symptomatology and text engagingness, with higher ASRS scores predicting lower attentive reading rates for less engaging texts but not for more engaging texts,

b^* = -0.43, $HDI_{90\%}$ = [-0.89, 0.04], $HDI_{60\%}$ = [-0.65, -0.19], and a weakly-credible two-way interaction between ADHD symptomatology and text order, with ADHD scores having a stronger negative correlation with attentive reading during the second text than the first, b^* = -0.43, $HDI_{90\%}$ = [-0.89, 0.04], $HDI_{60\%}$ = [-0.65, -0.19], as illustrated in Figure 4. All other second and third-order interactions were not credible.

Figure 4. Relationship between total ADHD symptomatology and reading attentiveness for both more and less engaging texts, holding depressive symptoms constant. Ribbons around regression lines indicate 90% HDIs of the estimates.

To examine how ADHD symptomatology, text engagingness, and text order related specifically to rates of unintentional mind-wandering, the above model was re-run using unintentional MW vs. all other responses as the binary outcome variable. This follow-up model revealed a weakly credible main effect of text order, with higher unintentional mind-wandering during the second text, b^* = -0.31, $HDI_{90\%}$ = [-0.77, 0.18], $HDI_{60\%}$ = [-0.55, -0.07], but revealed no credible main effects of ADHD symptomatology, b^* = 0.16, $HDI_{60\%}$ = [-0.03, 0.33], text engagingness, b^* = 0.15, $HDI_{60\%}$ = [-0.11, 0.37], or depressive symptoms, b^* = 0.12, $HDI_{60\%}$ = [-

0.03, 0.30]. However, there were weakly credible two-way interactions between ADHD symptomatology and text engagingness, b^* = 0.26, $HDI_{90\%}$ = [-0.23, 0.74], $HDI_{60\%}$ = [0.04, 0.53], and ADHD symptomatology and text order, b^* = -0.43, $HDI_{90\%}$ = [-0.93, 0.04], $HDI_{60\%}$ = [-0.66, -0.18], along with a three-way interaction between ADHD symptomatology, engagingness, and text order, b^* = -0.79, $HDI_{90\%}$ = [-1.87, 0.30], $HDI_{60\%}$ = [-1.37, -0.27], with higher ASRS scores predicting more unintentional MW only for less engaging texts that occurred second in the session (Figure 5). All other second-order effects were not credible.

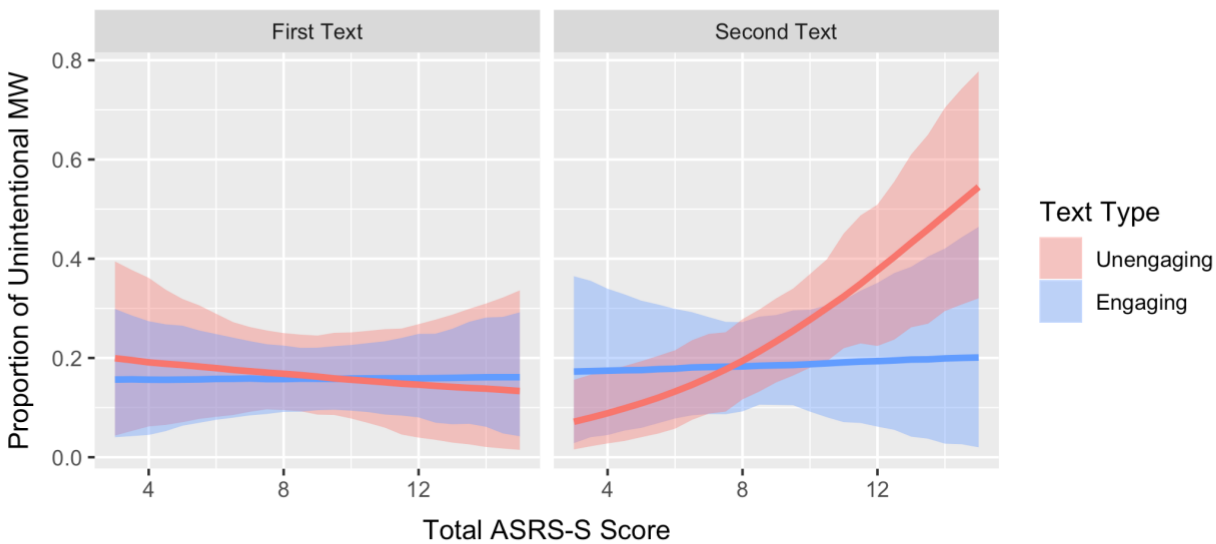

Figure 5. Relationship between total ADHD symptomatology and unintentional MW across text order and text engagingness, holding depressive symptoms constant. Ribbons around regression lines indicate 90% HDIs of the estimates.

Reading Comprehension

To assess how reported inattention and ADHD symptomatology related to reading comprehension, we conducted an additional set of mixed-effects logistic regression models, with response accuracy for individual comprehension questions being the binary outcome variable. The first of these models was designed to assess how ADHD symptomatology, text engagingness, text order, and their interactions affected reading comprehension. As illustrated in Figure 6, this model revealed a highly credible main effect of engagingness, with comprehension being higher for more engaging texts, $b^* = -0.47$, $HDI_{90\%} = [-0.92, -0.04]$, but no credible main effects of text order, $b^* = -0.01$, $HDI_{60\%} = [-0.21, 0.21]$, or ADHD symptomatology, $b^* = -0.08$, $HDI_{60\%} = [-0.19, 0.04]$. None of the second or third-order interactions were credible.

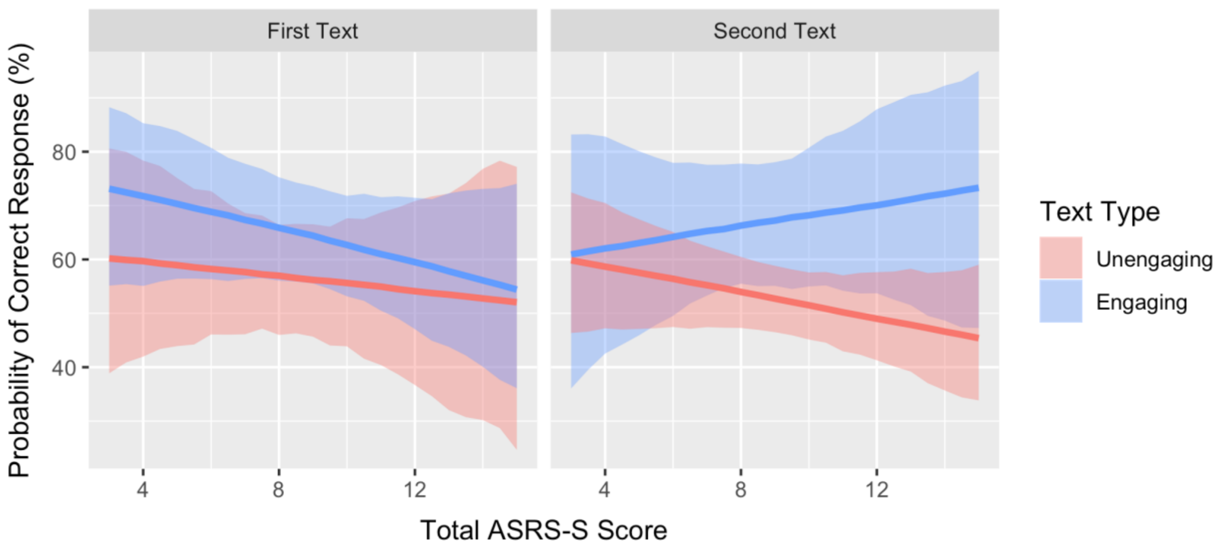

Figure 6. Relationship between total ADHD symptomatology and comprehension question accuracy across text order and text engagingness. Ribbons around regression lines indicate 90% HDIs of the estimates.

An additional model was conducted to determine how general inattentiveness affected reading comprehension, looking at how text engagingness, proportions of “attentive reading” probe responses, text order, and their interactions predicted comprehension accuracy. As illustrated in Figure 7, the results of this model revealed a highly credible main effect of reported attentive reading, with higher rates of attention predicting better quiz performance, $b^* = 0.66$, $HDI_{90\%} = [0.04, 1.29]$, and a weakly credible main effect of text engagingness, with comprehension being higher for more engaging texts, $b^* = -0.63$, $HDI_{90\%} = [-1.33, 0.14]$, $HDI_{60\%}$

= [-0.99, -0.24], but no credible main effect of text order, $b^* = 0.32$, $HDI_{60\%} = [-0.05, 0.69]$.

Additionally, there was a weakly-credible three-way interaction between all three predictors, $b^* = -0.75$, $HDI_{90\%} = [-1.98, 0.56]$, $HDI_{60\%} = [-1.45, -0.14]$. Neither of the second-order interactions were credible.

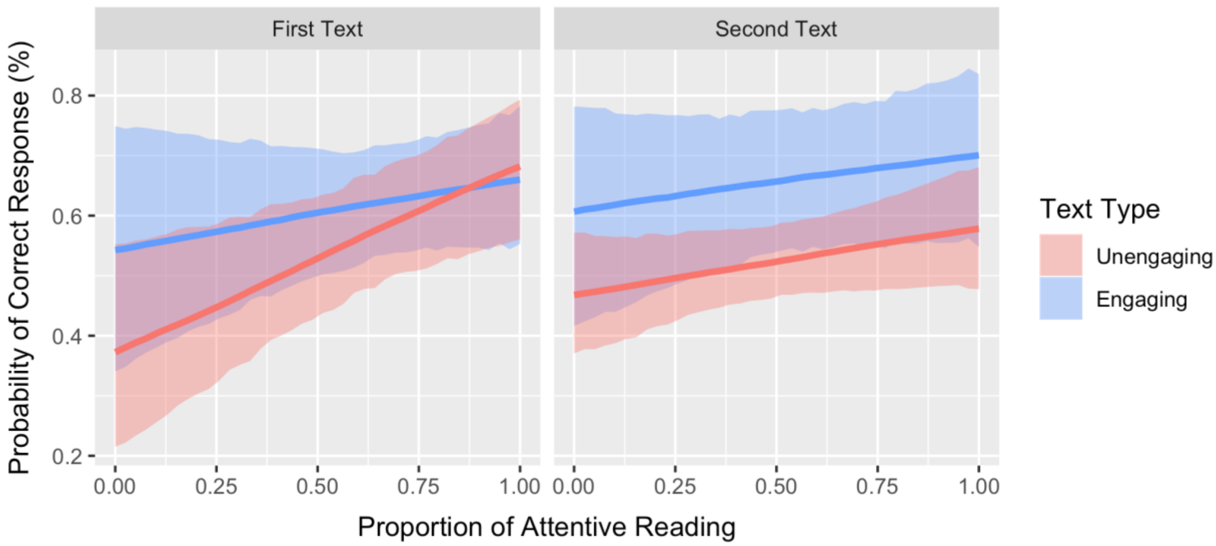

Figure 7. Relationship between proportion of reported attentive reading and comprehension question accuracy across text order and text engagingness. Ribbons around regression lines indicate 90% HDIs of the estimates.

2.4 Discussion

At the outset, we hypothesized that higher ADHD symptomatology would predict higher rates of reported mind-wandering during reading, and that this relationship would be stronger for unengaging texts than relatively engaging ones. Overall, our results provided partial support for this hypothesis. Specifically, as illustrated in Figure 4, higher ADHD symptomatology predicted lower rates of attentive reading, but only for unengaging texts. We likewise found that ADHD symptomatology predicted higher rates of unintentional MW specifically (controlling for other forms of inattention), but only for unengaging texts when those texts were read second, suggesting an effect of time on task. A credible order effect was present in the attentive reading model, with the magnitude of the effect of ADHD symptomatology on attentive reading being stronger for the text that was read second. Together, these effects are suggestive of a strong influence of time on task for people high in ADHD symptoms, particularly when reading unengaging content.

The general observed effects of ADHD symptomatology on mind-wandering are consistent with previous work from Franklin and colleagues (Franklin et al., 2017), who reported that individuals with clinical levels of ADHD symptomatology reported higher rates of MW during reading. Additionally, the increase in inattention over time for participants with higher ADHD symptomatology was likewise observed by Jonkman and colleagues (Jonkman, Markus, Franklin, & van Dalfsen, 2017). However, not all of our results were consistent with this latter study, as we found that the rates of reported inattention for participants with low ADHD symptomatology were not visibly affected by time-on-task or text engagingness. In contrast, Jonkman and colleagues (2017) reported a strong time-on-task effect for participants in their low-ADHD group, such that low-ADHD participants reported much less MW than the high-ADHD group in the first half of their text but reported similar rates of MW in the second half. One possible reason for this difference in results might be the single-word-at-a-time presentation style of Jonkman and colleagues' reading task: if participants' minds wander in a context where they cannot regain their bearings by re-reading a prior sentence or paragraph, this might make it more difficult to re-engage with the text and would thus promote increasing rates of mind-wandering. Presumably, individuals with higher ADHD symptomatology would tend to lose track of the narrative sooner, whereas participants with lower symptomatology may take longer to reach an equivalent level of disengagement.

In support of our other hypotheses, we found that overall rates of attentive reading predicted higher accuracy on the comprehension quiz. This finding is consistent with past research on mind-wandering during reading (e.g. Jonkman et al., 2017; Unsworth & McMillan, 2013; Schooler et al., 2004). In addition, there was a main effect of text engagingness beyond attentiveness alone, suggesting that the comprehension questions for the engaging texts might have been easier overall. Interestingly, the correlation between attentive reading and reading comprehension was strongest for unengaging texts that were read first in the session. This is partially consistent with Jonkman et al. (2017), who found that only mind-wandering in the first half of their text was correlated with overall reading comprehension, and suggests that the benefits of attentive reading on unengaging text comprehension become weaker with increased time on task. However, despite ADHD symptomatology predicting less attentive reading during unengaging texts, and attentive reading predicting better performance on comprehension quizzes, we found no evidence for a corresponding effect of ADHD symptomatology on reading comprehension. This is consistent with Franklin and colleagues (2017), who found no correlation between ADHD symptomatology and reading comprehension, but is at odds with Jonkman and colleagues (2017), who found that individuals in their high ADHD group had lower comprehension. One possible reason for this inconsistency is that Jonkman and colleagues (2017) presented the words of their text one at a time, preventing participants from re-reading text they had initially passed by while mind-wandering, whereas Franklin and colleagues (2017) and the present study displayed full paragraphs of text at a time. Because reflexively re-reading text is a common behaviour during everyday reading and is thought to be important for comprehension (Inhoff, Kim, & Radach, 2019), it is likely that paradigms preventing re-reading would overestimate the real-world costs of mind-wandering on comprehension. However, given the limited statistical power of the present study relative to both previous studies, it is difficult to draw any strong conclusions from our absence of a credible indirect effect of ADHD symptomatology on comprehension.

One notable finding in our results is that text engagingness predicted higher rates of overall attentive reading, but had no credible effect on rates of unintentional mind-wandering. This pattern is generally consistent with Giambra & Grodsky (1989), who found that interest in reading material predicted lower overall rates of mind-wandering but did not find significant effects of text interest on rates of spontaneous or deliberate mind-wandering separately. Looking at raw proportions of responses across engaging and unengaging texts, the inconsistency between the effects of engagingness on attentive reading and unintentional MW appears to be driven by differences in intentional MW, mind-blanking, and external distraction, with rates on all three being considerably higher for unengaging texts. As a consequence, the overall proportion of attentive reading is considerably higher for engaging texts (9.6%), despite rates of unintentional mind-wandering changing relatively little (0.9%).

Another secondary finding of note was that depressive symptoms, as measured via the PHQ, did not predict higher rates of unintentional MW or general inattention during reading. This is in contrast to earlier research, which has found depressive symptoms to predict higher rates of mind-wandering in both lab-based attention tasks (Deng et al., 2014) and everyday life (Seli, Beaty, Marty-Dugas, & Smilek, 2019). One possible reason for the lack of an effect in the current study is the nature of the task itself: given that reading requires a deep level of cognitive engagement to perform successfully (Smallwood et al., 2007), it leaves few resources available for depressive rumination to take hold of one’s thoughts provided that they are able to sustain focus. By contrast, the less-demanding stimulus detection tasks used in prior research do not require the same depth of engagement, thus providing depression-related thoughts more opportunity to intrude. If correct, this theory would support the usefulness of reading tasks in the research of mind-wandering and ADHD, as it suggests that the confound of depression is unlikely to be an issue in this context.

There are some important limitations to the present study. First, because of the interruption of data collection due to COVID-19, we were unable to recruit any participants with high levels of ADHD symptomatology or prior diagnoses of the disorder, limiting our ability to make strong inferences about the magnitudes of effects for people clinically diagnosed with the disorder. However, the presence of credible effects of ADHD symptomatology despite this limited range suggests that our observed effects may be even stronger in a sample that includes high symptomatology participants. An additional consequence of interrupted data collection was that the final sample was small and not properly counterbalanced, preventing the modelling of infrequent thought probe responses such as intentional MW or external distraction and limiting the study's statistical power to separate the effects of text order from the effects of text engagingness. Future research on mind-wandering and ADHD should aim to address these shortcomings, and work to better understand how ADHD and content engagingness interact to alter attention and task performance across different contexts.

Chapter 3: Experiment 1B - Mind-Wandering, Intention, and Effort

In addition to exploring the relationship between ADHD, text engagingness, and the academic costs of mind-wandering, the present study was also designed to study a largely separate, but related, research question. Specifically, we were interested in how mind-wandering relates to self-reported effort to stay focused on the task, and whether using a continuous spectrum of effort ratings might be more practically or theoretically useful than the common binary distinction between “intentional” and “unintentional” MW (Seli, Risko, Smilek, & Schacter, 2016).

A commonly accepted definition of mind-wandering defines it as thought that is both *stimulus-independent* (i.e., unrelated to any current sensory stimuli, such as a nearby conversation or a pain in one’s limb) and *task-unrelated* (i.e., not directly related to any current external task; Smallwood & Schooler, 2015). This definition encompasses situations such as getting lost in one’s memories during an academic lecture, or allowing one’s thoughts to flow freely while on a walk, but excludes situations such as getting distracted from a task by a nearby stimulus (external distraction), or performing mental arithmetic to solve an immediate problem (task-related thought). Importantly, this definition allows for MW to be initiated intentionally as well as unintentionally: for example, someone washing dishes might deliberately choose to engage in task-unrelated, stimulus-independent thought about an upcoming event they need to plan for instead of allocating their full attention to the task at hand.

The distinction between intentional (or “deliberate”) and unintentional (or “spontaneous”) mind-wandering has been a topic of much interest (Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Risko, Smilek, & Schacter, 2016). Given that mind-wandering is most likely to be problematic when it occurs without intention or awareness, researchers who are primarily interested in measuring unintentional MW of this nature must also measure intentional MW to avoid conflating the two (Seli, Risko, & Smilek, 2016). Traditionally, intentional MW has been defined specifically as mind-wandering that occurs as a result of a deliberate, conscious shift of focus towards task-unrelated, stimulus-independent thoughts (Grodsky & Giambra, 1990; Seli, Risko & Smilek, 2016; Robinson & Unsworth, 2018). Intentional mind-wandering is explicitly non-passive under this definition, as people must engage some level of cognitive control to deliberately redirect their focus to something new. As a result of the intentional/unintentional binary distinction, this definition likewise classifies all mind-wandering that occurs in the absence of a conscious, controlled shift of focus to be “unintentional”.

According to the above definitions, the amount of effort that someone puts into staying on-task is irrelevant to whether a mind-wandering occurrence is “intentional” or “unintentional”. Although the prototypical case of unintentional MW is characterized as someone getting lost in thought *despite their best efforts* to stay focused, the traditional definition equally applies to cases where someone’s thoughts drift off-task in the absence of any such effort, as long as the episode of mind-wandering was not *initiated* by a conscious and deliberate shift of focus. This ambiguity raises a philosophical question: if a person makes no effort to suppress irrelevant thoughts and is carried off-task by one, should that mind-wandering truly be considered unintentional? Regardless of the answer, there are practical reasons to be concerned with the amount of effort people put into staying on task. Importantly, if researchers are interested specifically in studying unwanted mind-wandering, it is necessary to distinguish between mind-wandering that people fail to inhibit and mind-wandering that people passively allow to happen. Additionally, participants who passively allow their minds to wander might often report it as “intentional mind-wandering” on multiple choice probes, causing researchers to overestimate the extent to which people make controlled, volitional shifts of focus to task-unrelated imagery and thoughts.

By distinguishing between “unwanted” and “allowed” mind-wandering, the “intentional/unintentional” binary could be expanded into three categories, along the lines of “deliberate”, “allowed”, and “unwanted” mind-wandering. However, if different levels of cognitive effort can be put into maintaining focus, and higher levels of effort are more likely to *prevent* mind-wandering, then the distinction between “allowed” and “unwanted” MW might be better conceptualized as a continuous spectrum. This spectrum of effort would have “allowed” MW at one end, where no effort is put into staying on-task, and “unwanted” MW at the other, where someone is trying their best to stay focused but fails to do so. Given that “deliberate” MW by definition involves an effortful shift of attention away from a task, it would fall outside of this spectrum and be considered its own category.

The purpose of the present study was to evaluate whether the measurement of effort to stay on-task is useful for mind-wandering research and to examine how effort ratings relate to reports of intentional and unintentional MW during a reading task. To accomplish this, each thought probe in the task was immediately followed by an effort probe, asking participants to report on a scale of 0% to 100% the level of effort they had been putting into reading attentively just prior to the thought probe. If participants generally report little-to-no effort following reports of intentional MW and occasionally report unintentional MW in the absence of any effort, this would support the idea that participants correctly report intention based on deliberate initiation and not on effort to stay focused. Conversely, if participants frequently report intentional MW while also putting non-zero effort into staying focused, this would indicate that participants tend to categorize the nature of their mind-wandering based on effort, and would suggest that an effort-based distinction would therefore be practically and theoretically useful. Additionally, if the ranges of reported effort are broad rather than clustered near 0% and 100%, it would support the idea that effort during mind-wandering should be conceptualized and measured as a continuous spectrum rather than a simple dichotomy.

3.2 Results

All analyses for Experiment 1B were conducted on the same dataset as Experiment 1A, using the same analysis tools and inferential framework. As the research questions for this part of the experiment are focused on the relationship between mind-wandering and effort to stay on-task, only data from mind-wandering and effort probes were considered in the following analyses.

As illustrated in Figure 8, all reported instances of intentional mind-wandering were accompanied by non-zero levels of effort to stay on-task, with effort levels for intentional MW responses ranging from to 4.5% to 97.8%. The same was true of effort levels for unintentional MW responses, which ranged from 8.5% to 100.0%. Of all 24 reports of intentional MW across participants, 21 of them (87.5%) were associated with reports of over 20% effort to stay focused on the task.

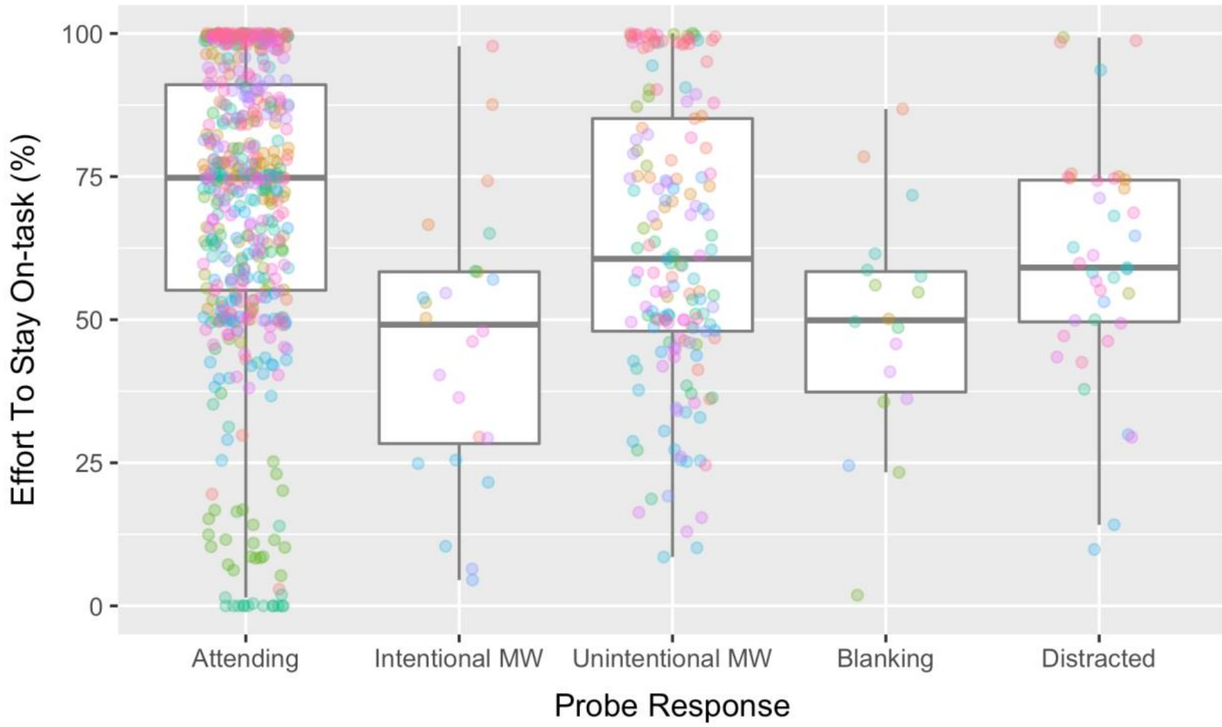

Figure 8. Raw distributions of reported effort levels for each response type, with box plots indicating the median values and interquartile ranges. Scatterplot points are colour-coded by participant: each participant is represented in a unique colour, and multiple instances of the same colour represent separate probe responses from the same participant. This visualizes the extent to which the observed values and ranges are due to individual differences.

The relationship between thought probe responses and reported effort to stay on-task was analyzed using a mixed-effects beta-regression model, the results of which are illustrated in Figure 9. A beta-regression approach was used in place of a traditional linear regression model to better account for the ceiling and floor distortions that can result from the response scale being bounded by 0% and 100% (Cribari-Neto & Zeileis, 2010). Because beta-regression uses a logit link and thus requires all outcome values to be both greater than zero and less than one, effort values were scaled using the formula x' = (x * (N - 1) + 0.5) / N prior to modelling, as recommended by Smithson and Verkuilen (2006).

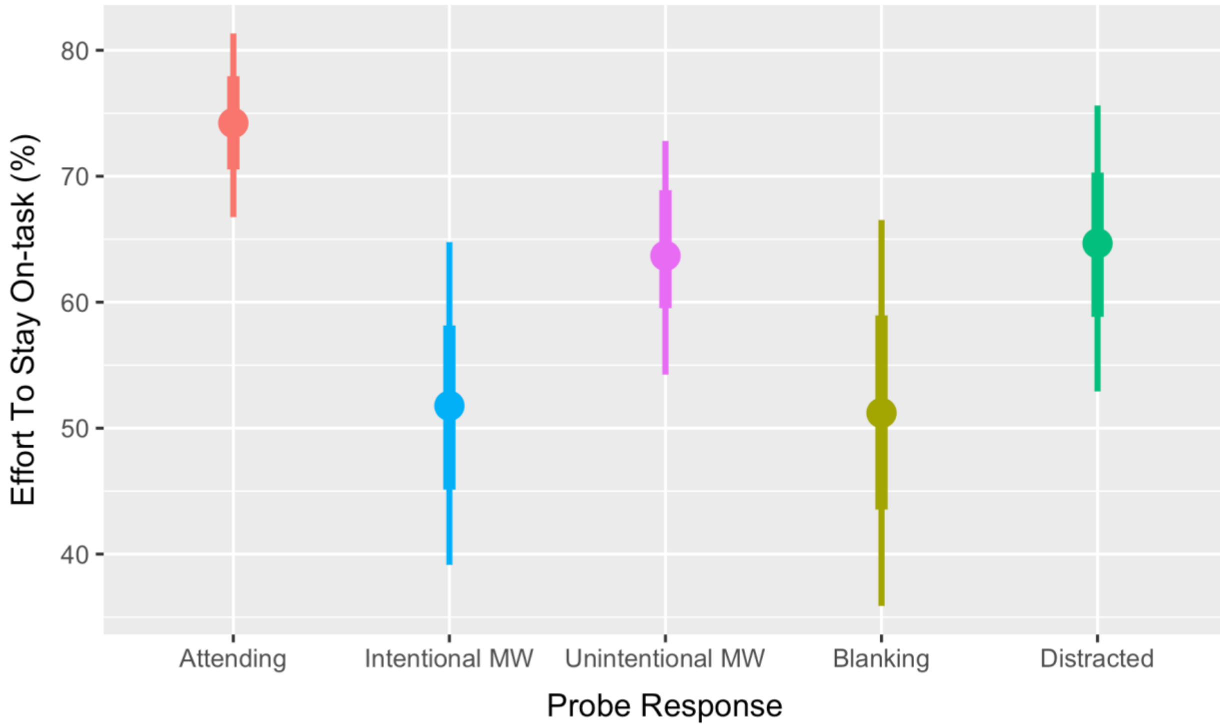

Figure 9. Estimated marginal means of reported effort levels to stay on-task. Thick and thin lines indicate 90% and 60% HDIs, respectively.

Reported effort was highest for attentive reading responses, Mean = 74.2%, $HDI_{90\%}$ = [66.8%, 81.3%], followed by external distraction, Mean = 64.7%, $HDI_{90\%}$ = [52.9%, 75.6%], unintentional MW, Mean = 63.7%, $HDI_{90\%}$ = [54.3%, 72.8%], intentional MW, Mean = 51.8%, $HDI_{90\%}$ = [39.1%, 64.8%], and lastly mind-blanking, Mean = 51.2%, $HDI_{90\%}$ = [35.9%, 66.5%]. Pairwise comparisons between response types revealed that the difference in effort between intentional and unintentional MW was highly credible, Mean = 11.7%, $HDI_{90\%}$ = [2.1%, 21.1%], as was the difference between unintentional MW and attentive reading, Mean = 10.5%, $HDI_{90\%}$ = [6.6%, 14.4%]. Additionally, the difference in effort between unintentional MW and mind-blanking was weakly credible, Mean = 12.4%, $HDI_{90\%}$ = [-0.7%, 24.8%], $HDI_{60\%}$ = [6.5%, 19.3%].

3.3 Discussion

In previous research, "intentional mind-wandering" has been defined as mind-wandering that occurs due to a deliberate and controlled shift of focus away from any current external task (Grodsky & Giambra, 1990; Seli, Risko, Smilek, & Schacter, 2016). By contrast, participants in the present study reported moderate (~50%) levels of effort to stay on-task following reports of intentional MW, and did not report a single instance of intentional MW in the *absence* of any effort to maintain focus. Additionally, intentional MW was associated with lower levels of reported effort than unintentional MW. These findings suggest that, when given a binary choice, participants tend to classify spontaneous mind-wandering that occurs in the absence of strong effort to prevent it as being "intentional", and that MW initiated by a controlled, deliberate shift of focus might not be as common an occurrence as previously thought (at least, not in the context of cognitively-demanding lab tasks). An alternative explanation is that participants were reluctant to admit to zero-to-low levels of effort to stay on-task due to an expectancy bias. That is, when a probe appears asking how much effort was being devoted to the task at hand, participants likely have an expectation that 'zero' is an inappropriate response. If that was the case, participants may have been likely to report moderate effort on the current task even in the face of a deliberate shift of their thoughts to something else. However, given that the popular definition of intentional MW inherently implies zero effort to stay focused on the task, this concern likewise applies to intentional MW as commonly measured.

Moreover, levels of reported effort to stay on-task varied considerably following both intentional and unintentional mind-wandering responses, with considerable overlap among the reported effort levels of the two distinct types of MW. These results suggest that effort to stay on-task cannot be fully inferred from whether a participant reports intentional or unintentional MW, and that the measurement of effort on a spectrum is both theoretically and methodologically useful. If a researcher is interested in mind-wandering that occurs despite a strong effort to suppress it, measuring reported effort directly will allow them to separate truly unwanted mind-wandering from *allowed* mind-wandering with more precision than the common intentional/unintentional binary distinction. If a continuous effort probe is not practical or desirable for a given study, a categorical distinction between "unwanted", "allowed", and "deliberate" mind-wandering may serve a similar purpose. An additional benefit of the proposed unwanted/allowed spectrum is that it is compatible with definitions of mind-wandering other than the one used throughout this thesis. For example, the definition favoured by Christoff and colleagues (Christoff et al., 2018), which argues that unconstrained and free-flowing thought is an essential aspect of mind-wandering, rejects the notion that mind-wandering can be initiated deliberately but is fully compatible with the idea that mind-wandering can be unwanted or allowed to varying degrees.

At the onset, we noted that for effort levels to be worth measuring, reported effort to stay on-task would have to meaningfully affect rates of reported focus. The present results strongly suggest this is the case, with reports of attentive reading being associated with considerably higher levels of reported effort than reports of any form of inattention. These results are consistent with the resource-control account of sustained attention, which proposes that mind-wandering is the default state of the mind and that effort to exert executive control is thus required to inhibit task-unrelated thought and sustain focus (Thompson, Besner, & Smilek, 2015). A potential problem with this inference might be outcome bias, where participants might infer their level of effort from their attentional state instead of reflecting on their actual effort. That is, they may conclude they must have been putting high effort into staying focused when they succeed in doing so, and conversely assume lower effort when a probe catches them being off-task (Head & Helton, 2018). To address this concern, future work on the association between MW and effort could attempt to use task performance measures to better understand their causal relationship.

An important limitation of the current work is that the relationship between intention and effort was only studied within the context of a reading task, which is more cognitively demanding than most common tasks used to study mind-wandering such as the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Tasks that require fewer cognitive resources to perform are likely to promote different levels of effort, and potentially allow for more deliberate, controlled shifts of focus to task-unrelated thought. An additional limitation is the low total number of intentional mind-wandering reports within the current dataset, with only 3.2% of all probes reporting intentional MW. Future research with a larger sample size, or a task in which intentional mind-wandering occurs more often, would prove useful to better understand the relationship between intention and reported effort to stay on-task.

Chapter 4: General Discussion

In Experiment 1A, we examined the practical effects of ADHD symptomatology on mind-wandering during textbook reading, finding that higher symptomatology predicted greater inattention for unengaging (but not engaging) texts, and that this effect was strongest when unengaging texts were read second. These results highlight the unique challenges that adults with higher ADHD symptomatology face in a university environment, even for those who report sub-clinical levels of symptoms. To compensate for this effect, students with moderate-to-high levels of ADHD symptomatology may need to schedule more time for readings from courses that they find unengaging. However, despite finding effects of ADHD symptomatology on attentiveness and effects of attentiveness on reading comprehension, ADHD symptomatology did not predict lower reading comprehension in the present sample. Future research in this area should aim to replicate this lack of effect to determine whether more frequent mind-wandering during reading necessarily comes at a cost for individuals with higher ADHD symptomatology, or whether students with ADHD develop different reading strategies to compensate for their difficulties with sustained attention.

In Experiment 1B, we looked at how effort to stay on-task relates to different attentional states. Our results, which showed that reports of intentional mind-wandering were associated with moderate levels of effort, directly challenge the popular conception that reports of intentional MW indicate deliberate and controlled shifts of focus to off-task imagery and thought. Additionally, the large variation in effort levels we observed within each attentional state highlights the usefulness of continuously measuring effort to stay on-task in order to distinguish between *allowed* and *unwanted* instances of MW. From a theoretical standpoint, the concept of the allowed/unwanted spectrum makes it easier to describe and measure MW that occurs despite strong effort to remain on-task, with the added benefit of being compatible with both common definitions of mind-wandering (Smallwood & Schooler, 2015; Christoff et al., 2018). From a methodological perspective, it allows for fine-grain analysis of the effort put into maintaining focus and provides an additional useful continuous measure for relating to task performance.

Despite their different aims, a consistent theme across both experiments is the examination of mind-wandering and the related mechanisms of sustained attention and effort regulation. In addition, at the time of writing only two studies have been published examining how ADHD symptomatology affects mind-wandering during reading (Jonkman et al., 2017; Franklin et al., 2017), one of which employs a reading task as part of a larger collection of tasks and thus only mentions the effects of ADHD symptomatology on MW during reading in passing (Franklin et al., 2017). Similarly, despite the popularity of the distinction between intentional and unintentional mind-wandering, the direct relationship between perceived effort put into staying on-task and mind-wandering has not been explored in prior work. As future research aims to understand the role of pervasive mind-wandering in ADHD, and cognitive scientists try to better conceptualize and define mind-wandering, the results of this thesis emphasize the usefulness of examining these two understudied areas.

Overall, the results of both lines of research broaden our understanding of the common phenomenon of mind-wandering, exploring both its practical costs for students with higher ADHD symptomatology, as well as working towards a clearer understanding of how to characterize its relationship with intentionality and effort to stay on-task. By developing clear definitions and robust theoretical models of mind-wandering, we can improve the methods and framework with which we can understand its practical costs and benefits in both everyday life and in relation to different pathologies. Conversely, through greater research on mind-wandering in real-world situations, we can identify the areas of our methods and theoretical framework that require the most work and attention. Through these efforts, we can learn how our environments and institutions might be changed to better account for the costs of mind-wandering as well as better utilize its benefits.

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Appendix A - Additional Methods Figures

Figure A.1 depicts a rendered page of text from one of the four textbook excerpts, as rendered and presented to participants during the task. As this figure shows, section headers, paragraph spacing, and the bolding/italicizing of text present in the original textbooks was preserved when adapting the excerpts to be part of the computerized task.

Contract Law

Contracts are frequently used by tourism operators. Common types of contracts include contracts for service, employment agreements, rental agreements, and legal releases (waivers) (Cloutier, 2000). Given the importance of all of these types of agreements, it is vital that operators use documents that are valid and clearly based in contract law. For a contract to be valid and legally enforceable, it must contain all of the following components: an offer and acceptance, consideration, an intent to enter into a legal relationship, and sufficient capacity (understanding) of those involved involved (Longchamps & Wright, 2007). Each of these is described below.

Offer and acceptance means that the "offer" (e.g., a rental car agency will advertise a car for rent) must be clear, unequivocal, and include all of the important and relevant terms in the contract. The acceptance also must be clearly expressed (e.g., the renter agrees to rent the car according to the terms and conditions offered by signing the contract). Once the offer is accepted, it becomes a promise with both parties being bound by the terms of the contract.

Consideration refers to the value that is exchanged between parties in the contract, such as money or services (e.g., the renter pays for use of the rental car). Sometimes consideration is waiving your legal rights for a right to participate in an activity.

An intent to enter into a legal relationship means that the individuals signing are doing so deliberately and understand that if they do not do what they have agreed to do they will be in a breach of their contract.

Capacity refers to the ability of individuals to enter the contract. If a person signing a contract does not have sufficient capacity, the contract will not be binding. The most common reason for not having sufficient capacity is age. In most cases, a person who has not reached the legal age of majority cannot contract with someone else. Other requirements for capacity include having sufficient mental capacity, and being the authorized signatory (the person with the authority to sign on behalf of an organization) (Longchamps & Wright, 2007).

Figure A.1. A page from the Risk Management and Legal Liability text, as presented to participants via the computer screen during the reading task.

Figure A.2 illustrates the appearance and format of the multiple-choice comprehension questions following each text, with navigation buttons on the left and right sides of the screen to navigate between questions, and a translucent rectangle indicating the response the participant is currently hovering their mouse cursor over.

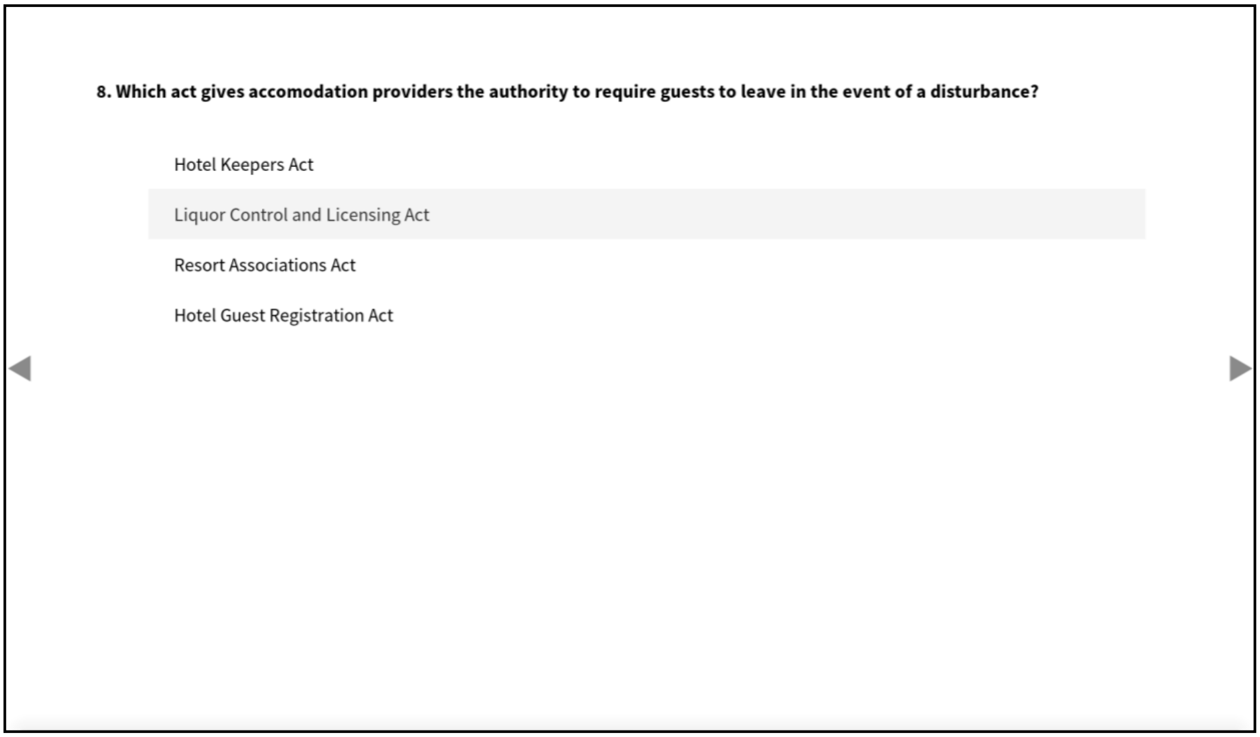

Figure A.2. A comprehension question for the Risk Management and Legal Liability text. The translucent grey rectangle around the second answer indicates that it has been selected by the participant.

The format of the computerized version of the PHQ is illustrated in Figure A.3. Due to space constraints, the eight questions were divided between two pages, with arrow buttons on the sides of the screen allowing navigation between the pages. Additionally, Figure A.4 depicts the appearance and response format of the 5-AFC mind-wandering probes presented intermittently throughout the reading tasks.

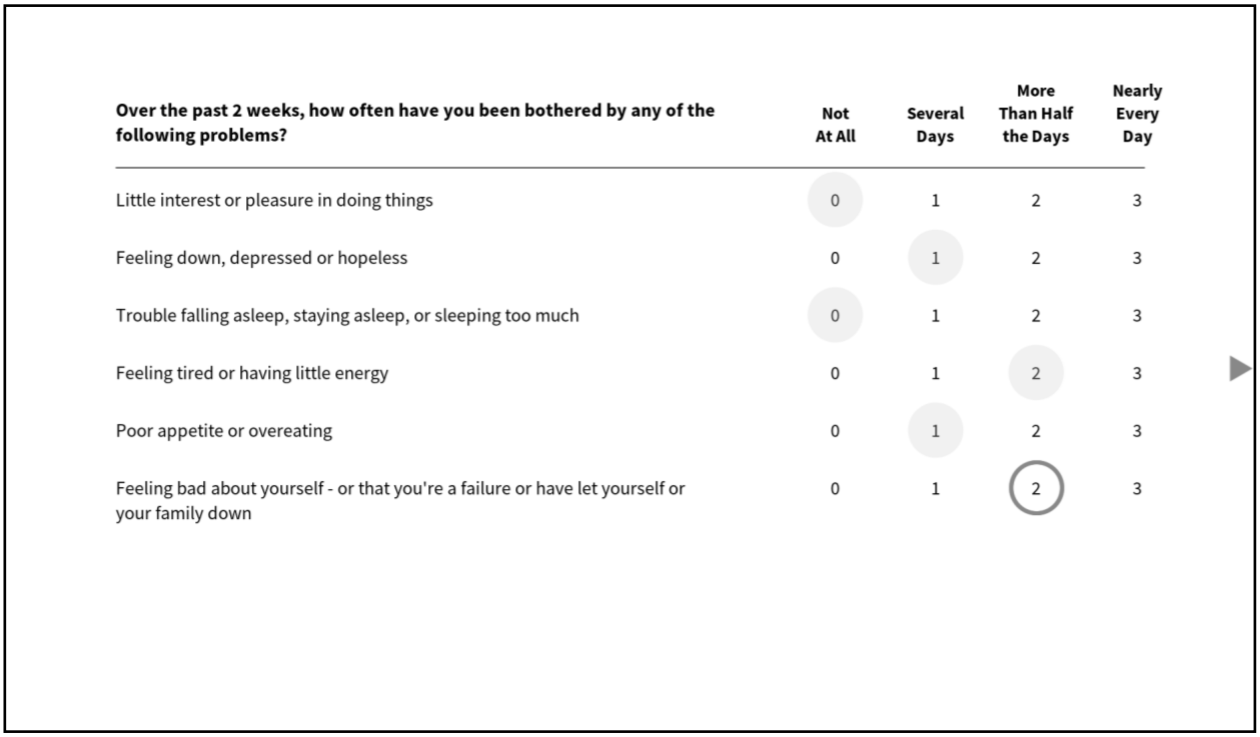

Figure A.3. The first page of the computerized PHQ, showing the first six questions. The translucent grey circles indicate responses that the participant has already made, whereas the solid grey ring indicates the response that the mouse is currently hovering over.

Figure A.4. The mind-wandering component of the intermittent thought probes. The translucent rectangle indicates that the cursor is hovering over the “unintentional MW” response.

Appendix B - Bayesian Model Details

Posterior probability distributions for all reported models were drawn using the default No U-Turn Sampler (NUTS) in RStan 2.18.2, using brms 2.9.0 as a front-end. Weak uninformative priors were used for all parameters, in accordance with the recommendations of McElreath (2020). The sampler ran 4 chains for each model, with each chain collecting 8000 samples from the posterior, 3000 of which were discarded as warm-up samples. This resulted in a total of 20,000 total samples of the posterior for each model in our analysis. Diagnostics on the models revealed that the convergence between chains was adequately high (all R-hats ≈ 1.0), and that the effective sample size for all parameters ($N_{effective}$) was greater than 2000 for all estimated parameters.