Explaining Mind Wandering Reports

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Abstract

Mind wandering refers to a reallocation of attentional resources away from what has been explicitly identified as the primary task towards some other point of focus. Experimental work investigating mind wandering relies extensively on self-report as the primary means of measuring mental state (e.g. to what extent one is focussed on a given task). However, little is known about how mind wandering reports are formed. The assumption is that participants can simply report whether or not they are experiencing mind wandering when probed, though various lines of evidence suggest this may be an oversimplification. This dissertation advances a basic theoretical framework to explain how mind wandering reports are formed. The results of Experiment 1 supported the hypothesis that mind wandering reports are shaped by perception of performance. Experiment 2 demonstrated a biasing effect on reports of the framing of the concept of mind wandering in the initial experimental instructions. Experiment 3 revealed various individual differences in what information participants reported considering while forming reports, as well as some implied differences in cognitive control. Taken together, these results support a model in which participants consider various sources of information to guide the construction of mind wandering reports. Implications for the use of reports as a means to measure mind wandering are discussed. Additional implication for various theoretical constructs relevant to mind wandering are also discussed. These include working memory, meta-awareness, and mindfulness. A research program of sorts is also outlined to enhance the basic framework presented here, with productive future directions, including several novel hypotheses and relevant predictions.

Keywords: mind wandering, self-report

Preface

This thesis is an original work by James Farley. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board: Project Name "Mind Wandering & Self-Report", ID Pro00043241, 2015 04 27, and "Mind wandering self-reports and plasticity", ID Pro00059905, 2017 12 19.

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Introduction

The term 'mind wandering' refers to a phenomenon that is highly familiar to the average person. As examples of this mental state, consider a viewer watching a movie who unintentionally starts thinking about an outstanding email they need to reply, or a student half-heartedly listening to a lecture while intentionally directing most of their thoughts towards their plans for the weekend. Similarly, imagine a commuter skimming a newspaper in a busy train station who may finish an article only to realize they have little idea what they just read. Or perhaps the reader of a lengthy research document who has already succumbed to this familiar fate before even finishing the first paragraph. A common element in these examples is a disruption of attentional engagement with what may be defined as the primary task at hand.

This dissertation presents a framework to explain how mind-wandering probe responses are developed. The first experiment manipulated feedback about task performance to test the hypothesis that perception of performance would affect reporting behaviour. Overestimating performance and receiving feedback that converges with that interpretation was associated with reporting greater focus. Underestimating the same, along with feedback corroborating that level of performance, was associated with reports indicating reduced focus. The second experiment manipulated the presentation of various examples of common benefits or costs of mind wandering following the initial instructions. This influenced reporting behaviour during the first block of trials, which was interpreted as reflecting a change in expectations about that mental state. The third experiment produced descriptive data related to what participants reported considering while forming their reports. Cluster analyses revealed two distinct groups which differed in the extent of information reported, as well as tendency to report considering task-related thought. Various associated group differences in self-reported behaviour were found to be consistent with a hypothesized underlying differences in cognitive control.

Experimental interest in mind wandering has increased dramatically in the last decade or so, cutting across different areas of psychology and associated disciplines (Callard, Smallwood, Golchert, & Margulies, 2013). This interest has a lot to do with the ubiquity with which mind wandering is typically reported in both laboratory (Smallwood & Schooler, 2006) and everyday contexts (Kane, Brown, McVay, Silvia, Myin-Germeys, & Kwapil, 2007; McVay, Kane, & Kwapil, 2009; Killingsworth & Gilbert, 2010). That frequency, as well as a broad range of potential costs and benefits (Mooneyham & Schooler, 2013; Schooler, Mrazek, Franklin, Baird, Mooneyham, Zedelius, & Broadway, 2014), implies a relevance to many aspects of our everyday lives. While the average person can easily identify with this state as a common experience they are familiar with, the covert nature of mind wandering poses particular challenges for reliable and accurate measurement in experimental contexts.

The primary measurement tool used in mind wandering experiments is self-report, typically applied in what is referred to as an 'experience-sampling paradigm.' This entails having participants complete some task while being periodically interrupted to self report their mental state in the 'probe-caught' method (Smallwood & Schooler, 2006; Smallwood & Schooler, 2015), simply reporting whenever they become aware that their mind has wandered in the 'self-caught' method (Reichle, Reineberg, & Schooler, 2010; Sayette, Schooler, & Reichle, 2010), or some combination of the two. Reports are most often made in a dichotomized form ('mind wandering' or 'on task'), though continuous or near-continuous forms are also sometimes used (Dixon & Bortolussi, 2013; Dixon & Li, 2013). Other forms of reports have also been used in experience-sampling paradigms, including likert-type (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013;

Birnie, Smallwood, Reay, & Riby, 2015) and various categorical (mind wandering with or without awareness; Smallwood, McSpadden, & Schooler, 2008, spontaneous vs. intentional mind wandering; Seli, Risko, & Smilek, 2016).

Analysis of mind wandering data typically involves comparing behavioural or physiological measures associated with intervals of time coinciding closely with mind wandering reports against those indicating otherwise, allowing various kinds of inferences to be made about how mind wandering is related to theoretically interesting concepts (Schooler & Smallwood, 2006; Smallwood & Schooler, 2015). For example, reports of mind wandering while reading are often associated with comprehension deficits. Furthermore, this may be particularly true if such reports coincide closely in time with the presentation of critical information necessary for maintaining an adequate situation model that can support drawing relevant inferences (Smallwood, McSpadden, & Schooler, 2008).

Issues related to control and measurement were among the earliest methodological challenges faced by consciousness researchers. The hardline behaviourist perspective that came to dominate by about the middle of the twentieth century regarded unobservable mental processes as inherently problematic as constituents of empirical frameworks. This approach continued to influence the experimental landscape for decades (Skinner, 1985). Serving as somewhat of a counterpoint to that perspective, explanatory theories about mental processes developed using the rigour of the scientific method began to proliferate throughout the second half of the twentieth century with much success. Many of these early successes in the cognitive field were grounded in inferences about mental processes based on carefully controlled direct manipulation of the phenomena of interest. For example, as early as the 19th century, mental chronometry offered a way to infer the amount of time it takes for simple kinds of perceptual judgments to be made by manipulating task requirements and measuring the accompanying changes in response time (Donders, 1969).

In contrast to the example just raised, mind wandering is not something that can be reliably manipulated in the laboratory, and as such is not something that researchers could be said to have direct experimental control over (although attempts at doing so using transcranial magnetic stimulation, manipulating task demands, or the personal relevance of stimuli have yielded moderate success; Axelrod, Rees, Lavidor, & Bar, 2015; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; McVay & Kane, 2013). This lack of direct control complicates the process of drawing causal inferences using the approaches traditionally favoured in experimental work. The ubiquity of which mind wandering occurs somewhat mitigates this because simply allowing it to vary freely in the laboratory can often yield good insights into many theoretically relevant mechanisms, particularly when used in conjunction with careful manipulation of other pertinent factors. The greater obstacle for consciousness researchers in general, and mind wandering in particular, arguably followed from a reliance on self report as the primary means of measurement.

In this introduction, I will first discuss some general concerns about the validity of self-report measures and then describe some of the successful benchmark findings using self report to study mind wandering. I will then turn to some of the problems of instead using indirect correlates of mind wandering as indicators. Following this discussion, I will provide some comments on an explanatory framework for understanding self-report measures of mind wandering. Finally, I will describe the letter-detection task used in the present experiments and some of the previous research using this paradigm.

Concerns Regarding the Validity of Self Report

Self report was regarded wth great caution throughout much of the twentieth century and concerns about subjectivity and reactivity coloured attitudes towards their suitability for empirical work. Nisbet and Wilson (1977) argued that experimental participants base self reports on their own implicitly held theories about the causes of their cognitions and behaviours, and are therefore generally unable to inform on them with the degree of accuracy required for empirical work. They argued for a distinction between process and product, with the understanding that participants can merely report the products of their cognitive system (i.e. representations they have conscious access to), and are unable to report on the processes that produced them with any kind of specificity.

The position of Nisbet and Wilson (1977) focussed on whether participants can comment authoritatively about their cognition in an explanatory way, not simply whether they can report on the contents of their consciousness (i.e. meta-awareness). Using their terminology, responding to mind wandering probes may be more akin to reporting on a product rather than a process, which would seem to disarm the main thrust of their argument. Furthermore, Nisbet and Wilson acknowledge experimental participants can accurately report on their own cognitive processes under certain conditions, such as when influential stimuli are salient, and/or when the report is given immediately following the mental process being reported on occurs. Mind wandering episodes are often described as salient anecdotally, and presumably wouldn't capture attention as much as they do if they weren't, and reports are also typically provided concurrently (though retrospective forms have been used: Barron, Riby, Greer, & Smallwood, 2011; Smallwood, Brown, Baird, Mrazek, Franklin, & Schooler, 2012). Such distinctions should go some way towards alleviating these particular concerns within experience-sampling paradigms.

White (1980) disagreed with Nisbet and Wilson (1977), arguing that their distinction between process and product was not sufficiently defined to be falsifiable. With regard to some of the examples used to support their own argument, White also suggested the paradigm used by Nisbet and Wilson had limited generalizability. He felt this was particularly true because the information participants were asked to report was not something they would have been expected to pay attention to (since the task did not require this), and would therefore have been unlikely to encode it in the first place. White provided a series of methodological recommendations for the productive use of verbal reports in experimental work, many of which are consistent with the application of probes in experience-sampling paradigms. Mind wandering reports are not generally regarded as being effortful, for example, nor do they typically depend heavily on memory.

Ericsson and Simon (1980) argued that verbal reports are a form of data like any other, with the same necessary considerations and limitations inherent to all data. Rather than necessarily revealing anything explicitly, they argued that verbal reports require work to understand and derive meaning or insight from, an "explication of the mechanisms by which the report was generated" (p. 1). Illustrating this point, they propose an argument put forth by Verplanck (1962) against the validity of self-reports was based on apparent inconsistencies between reports and behaviour that was actually the result of inadequate analysis. Inherent to this effort to thoroughly understand what meaning can be extracted from self-report data is an appreciation of the limits to what experimental participants have access to clear representations of, which should frame how responses are interpreted during analysis. For example, if asked to report information participants cannot specifically remember and/or never attended to in the first place, they may simply respond by making an inference (even without being aware that this is what they're doing). In this situation, understanding that participants cannot always provide accurate reports contextualizes what can be gleaned from them. This is not dissimilar from the noise inherent to any data, and it would therefore seem a disproportionate reaction to discount all mind wandering self-reports for that reason alone. Furthermore, that apparent lack of accuracy can actually be informative for theory building in certain situations, as demonstrated by the following example from the mind wandering literature.

Instances in which experimental participants lack meta-awareness of mind wandering is the sort of limitation that Ericsson and Simon (1980) would say constitutes a representation that was never directly 'heeded,' and thus would be unlikely to be accurately reported on. Interestingly, although inaccurate in a sense, reports associated with a lack of awareness have proven to inform our understanding of the underlying neurology driving mind wandering. Christoff, Gordon, Smallwood, Smith, and Schooler (2009) found a certain proportion of reports were associated with indications that participants may have been mind wandering without awareness. These induced explicit reports that one was mind wandering without awareness (until they were probed), as well as 'on-task' responses accompanied by behavioural errors and patterns of particularly robust neural activation of the executive and default-mode-network. These results have enriched our understanding of how mind wandering and meta-awareness relate to neural function, something that may not have materialized if reports that could be considered 'inaccurate' were never recorded in the first place. This idea that what could be regarded as error (in reports) may actually contain valuable information is similar to one advanced by Fisher and Katz (2000) which suggested that inter-subject variance in a social desirability bias may be estimated based on error in responses.

In addition to the question of whether experimental participants can accurately identify and report on whatever their mental state might be at a given point in time, another major concern related to the experimental use of self-reports is the potential for reactivity. Reactivity is a commonly encountered experimental confound in which an unintentional influence results from some idiosyncratic aspect of the experimental design, rather than something of direct theoretical interest intended to be the focus of investigation. For example, Russo, Johnson, and Stephens (1989) reported changes to behaviour in the form of diminished accuracy and slowed response times resulting from the use of think aloud protocols. According to this argument reactivity can essentially contaminate data by changing the nature of what is observed.

Ericsson and Simon (1998) argued that the potential impact of think-aloud protocols upon behaviour varies as a function of the specifics of the experimental design. Rather than broadly discounting their use in all experimental contexts, they argued that a more productive position is to simply focus on what experimental circumstances are most likely to lead to data that is minimally affected by reactivity. This general philosophy seems appropriate to apply towards experience-sampling paradigms. As a point of comparison, while these paradigms share the common element of relying on self-reporting as a primary tool of measurement, they also differ from think-aloud protocols in substantive ways. One of these ways is the fact that reports in experience-sampling paradigms are accompanied by any kind of explanation, justification, or (usually) any other kind of elaboration which is one factor that Ericsson and Simon argued should render effects of reactivity less likely.

The mere act of verbalizing certain kinds of mental representations has been shown to have a potentially distorting effect on their fidelity. One such example is verbal overshadowing in which producing verbal descriptions of sensory-based representations can impair subsequent recognition (Melcher & Schooler, 1996). Sensory-based representations, such as an indistinct buzzing barely audible in the background, may reach awareness yet wouldn't typically be considered to constitute a mind-wandering episode (indeed, if this was the case then researchers might never record any 'on-task' responses from experimental participants in an fMRI scanner!). However, it is conceivable that being able to recall some irrelevant representations might be more likely to be interpreted as evidence for mind wandering if a probe promotes more focussed introspection about the contents of one's thoughts (e.g., 'I guess I was thinking about that noise in the background; maybe that means I was mind wandering?').

Applying the line of thinking that reactivity effects are not inevitable but rather largely determined by the specifics of the experimental design employed (Ericsson & Simon, 1998), Ericsson (2002) argued that verbal overshadowing results from very specific instructions to participants that direct and constrain encoding in a maladaptive way, rather than necessarily being inherent to verbalizing sensory-based representations. Because instructions for experience-sampling paradigms do not typically constrain reports, they should be unlikely to create similar problems. (On the other hand, it could be argued that presenting only two response options is a constraint.) Also, consider that verbal memory has been argued to have privileged access to cognitive resources that mind wandering competes for (Bastian, Lerique, Adam, Franklin, Schooler, & Sackur, 2017). This implies the contents of such episodes may generally be less likely to be susceptible to verbal overshadowing simply because they are more likely to be encoded in a semantic form in the first place. This also raises questions about the relative proportion of mind wandering associated with semantic content, as well as other types of content (e.g., imagistic).

One concern about reactivity which may be particularly relevant for experience sampling is the possibility that periodically interrupting participants with probes may affect their attention throughout the experiment. This could decrease mind wandering if probes serve as a reminder of an expectation that participants should be focussing sustained attention on the experimental task, assuming they possess the cognitive control required to modulate their level of mind wandering in step with perceived task demands (which has been demonstrated to occur in some contexts by Seli, Cheyne, Purdon, & Smilek, 2015). On the other hand, if the probes serve as this kind of intermittent reminder and participants perceive evidence for their own mind wandering as a failure of self-control, this may actually have the effect of increasing mind wandering if they begin ruminating about this. This could be similar to the increase in mind-wandering behaviour that has been linked to stereotype threat, which involves ruminating about some recently activated expectation of failure contingent on some aspect of one's identity (Mrazek, Chin, Schmader, Hartson, Smallwood, & Schooler, 2011; Schuster, Martiny, & Schmader, 2015). Similarly, it is conceivable that the added task demand of continually monitoring one's thoughts in self-caught paradigms could potentially increase mind wandering. These sort of paradoxical effects are sometimes observed in the context of thought suppression and so-called 'ironic mental processes,' in which efforts to avoid thinking about certain things actually leads to increased thoughts related to those very ideas (Wegner, 1997; Wenzlaff & Wegner, 2000). Although this is difficult to conclusively rule out, several lines of evidence are inconsistent with that proposition. These will be discussed in turn.

Schooler, Reichle, and Halpern (2004) found evidence that the added task demands associated with self-monitoring using the self-caught method did not increase the incidence of mind wandering reported (relative to a condition which relied exclusively on the probe-caught method). The question of how to go about determining whether using probes affects mind wandering behaviour is less straightforward simply because a viable standalone alternative to measurement is not apparent. The probe-caught method does generally result in 'catching' more episodes of mind wandering than occurs with the self-caught method (Schooler, Reichle, & Halpern, 2004; Sayette, Reichle, & Schooler 2009; Sayette, Schooler, & Reichle; 2010). However, some proportion of this is presumably attributable to catching episodes that would not otherwise reach awareness (and therefore would not be reported using the self-caught method). The fact that this increase in reports produced using probes (relative to self-caught) is further increased by alcohol consumption and nicotine withdrawal seem to support an explanation grounded in changes in monitoring behaviour (Sayette, Reichle, & Schooler 2009; Sayette, Schooler, & Reichle; 2010).

Lending additional insight into this issue, Varao-Sousa and Kingstone (2018) compared mind wandering rates in a classroom setting relying only on self-caught reports to a comparable context in which both the self-caught method and probes are used. They concluded that reported rates of mind wandering were unaffected by the introduction of probes, providing no evidence that they inflate the reported frequency of mind wandering. Also consistent with the proposition that probing does not alter mind wandering behaviour is the observation that trait level mind wandering, as measured using a validated questionnaire (the 'MWQ'), is correlated with rates produced using probes (Mrazek, Phillips, Franklin, Broadway, & Schooler, 2013). It is worth considering that, even if probing alters overall rates of mind wandering, that does not necessarily mean observations related to how various behaviours and processes change as a function of mental state are completely uninformative. A parallel to this line of thinking can be seen with mood induction experiments which artificially attempt to change affective states yet remain relatively unconcerned with how an induced mood may be different than a spontaneously occurring one. While there are presumably some differences, there may be no particular reason to think effects related to the former would not generalize to the latter. The preceding discussion has touched on various factors which are important to consider when undertaking empirical work that relies on self-report, including validity and reactivity. However, any compelling argument for the experimental utility of self-reports hinges on their potential to generate new knowledge within a scientific framework. It is towards that focus which this dissertation now turns.

Early Successes in the Empirical Study of Mind Wandering

All of the aforementioned theoretical concerns aside, some initial steps taken in the 1960's demonstrated that cognitive experiments relying on self-report for measurement can yield theoretically interesting results. Representing an early attempt to examine physiological correlates of off-task thought, Antrobus, Antrobus, and Singer, (1964) examined eye-movements during daydreaming. Antrobus et al. (1966) demonstrated changes in frequency of self-reported task-unrelated thoughts during a signal detection task resultant of manipulating task-related financial incentives, the presence of distressing stimuli, and target frequency. Building on the latter of these results, and consistent with predictions derived from information theory, Antrobus et al. (1968) showed that the majority of the variance in frequency of task-unrelated thoughts could be predicted by changes in the rate of information presentation.

The relationship between daydreaming and various kinds of personality and cognitive factors were explored in Singer and Antrobus (1963). Foreshadowing some of the current work being undertaken relating mind wandering to various clinical populations (OCD: Seli, Risko, Purdon, & Smilek, 2017; depression: Smallwood, O'Connor, Sudbery, & Obonsawin, 2007; Deng, Li, & Tang, 2014; ADHD: Seli, Smallwood, Cheyne, & Smilek, 2015), Starker & Singer (1975) and Golding and Singer (1983) documented a relationship between depression and daydreaming. The various dimensions of thought that could be said to constitute daydreaming were delineated in Klinger (1979), while Klinger (1978) discussed the flow of consciousness (another early theme of investigation that continues to shape mind wandering research today: Smallwood 2103a; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). Klinger, Barta, and Maxeiner, (1980) tested the prediction that daydreaming content would be based on 'current concerns', predicting the relative frequency of particular kinds of off-task thoughts reported would be related to what carries personal significance for the individual in their current time and place. This laid the foundation for one of the earliest explanatory theories applied towards mind wandering behaviour.

Generally replicating Antrobus et al. (1966) and Antrobus (1968), Giambra (1995) found task-unrelated imagery and thought are sensitive to information demands and increase as target frequency decreases. Importantly, Giambra also demonstrated that frequency of task-unrelated imagery and thought have high test-retest reliability. Giambra (1989) began a productive line of inquiry into how aging changes task-unrelated thought (which continues to find much interest today: Carriere, Cheyne, Solman, & Smilek, 2010; Jackson & Balota, 2012; McVay, Meier, Touron, & Kane, 2013; Maillet & Schacter, 2016). Addressing this topic from a systems perspective, and potentially speaking to why task demands seem to be closely related to off-task thoughts, Teasdale et al. (1995) showed stimulus independent thought is dependent on different components of working memory, including the central executive.

All taken together, while experimental work aimed at understanding consciousness poses particular methodological challenges, the early successes discussed above framed the potential for the scientific study of consciousness. Converging results across studies, which themselves conformed to predictions based on plausible theoretically driven mechanisms, demonstrated that self-reports could be a reliable and valid method for measuring mind-wandering behaviour in the interest of developing explanatory theoretical frameworks. Many of these early lines of work have foci which remain targets for contemporary mind wandering research efforts today. These include effects of task demands, aging, changes across development, and relationships with clinical populations.

Problems With Relying on Correlates

The previous section demonstrated that self-report can be used to measure mind wandering in experimental contexts for the purpose of testing and refining scientific theories. However, having the ability to measure mind wandering using a valid and reliable correlate could entail some benefits relative to relying exclusively on self report. For example, this could minimize possible confounds related to meta-awareness and reactivity. However, virtually all mind-wandering experiments to date have relied on self report as the primary means of measurement (Schooler & Smallwood, 2006; Smallwood & Schooler, 2015). In part, this probably relates to the fact that experience-sampling paradigms have proven relatively productive, and consequently there hasn't been a pressing need for an alternative. However, a more complicated reason relates to difficulties in relying on correlates as suitable all-purpose replacements.

Various correlates of mind wandering have been reported, including behavioural (performance: Randall, Oswald, & Beier, 2013; reaction time: Franklin, Smallwood, & Schooler, 2011, McVay & Kane, 2012; eye blinks: Smilek, Carriere, & Cheyne, 2010), neurological (default-mode-network activation: Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; reduced P300 ERP component: Smallwood, Beach, Schooler, & Handy, 2008; reduced N1/P1 ERP component: Kam, Dao, Farley, Fitzpatrick, Smallwood, Schooler, & Handy, 2011), and physiological (pupil dilation: Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013). Changes in task-specific behaviour have also been associated with mind wandering, which could (in theory) be used to identify those periods, such as changes in eye movements (Schooler, Reichle, & Halpern, 2014), increased fixation duration in reading and scene viewing (Foulsham, Farley, & Kingstone, 2013; Krasich, Mcmanus, Hutt, Faber, Mello, & Brockmole, 2018) or failing to correctly inhibit a prepotent response in the sustained attention to response task (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997).

While a relationship between performance and mind wandering was frequently reported across a meta-analysis of 88 studies (Randall, Oswald, & Beier, 2013), these were not always found to be closely related. For example, the probability that mind wandering affects performance in a given task is contingent on how cognitively demanding the task is (Smallwood & Schooler, 2006), and some tasks do not seem to demonstrate a relationship between mind wandering and performance at all (Smallwood, Obonsawin, & Heim, 2003). It has even been proposed that performance may actually benefit from mind wandering in particular kinds of situations, such as creative tasks involving incubation (Baird, Smallwood, Mrazek, Kam, Franklin, & Schooler, 2012), situations that benefit from dishabituation (Mooneyham & Schooler, 2016), or (potentially) some kinds of implicit learning (Franklin, Smallwood, Zedelius, Broadway, & Schooler, 2015).

As was the case with performance, the nature of the relationship observed between mind wandering and reading time (if any) also varies across studies. The effects related to reading time could be expected to differ depending on the specifics of the task, though there are even conflicting results reported within similar paradigms. For example, while some reading experiments report a positive relationship between mind wandering and reading time (Reichle, Reineberg, & Schooler, 2010; Feng, D'Mello, & Graesser, 2013; Foulsham, Farley, & Kingstone, 2013), some report no relationship (Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013;

Smilek, Carriere, & Cheyne, 2010), while others report a negative relationship (Franklin, Smallwood, & Schooler, 2011). Apparently contradictory results have also been reported for changes in pupil dilation associated with mind wandering. Increases in pupil size have been associated with both mind-wandering (Smallwood, Brown, Tipper, Giesbrecht, Franklin, Mrazek, & Schooler, 2011) and on-task mental states (Grandchamp, Braboszcz, & Delorme, 2014). If we assume deep engagement/interest with some kind of content is necessary for pupil dilation, this offers one possible solution to the apparent discrepancy. It may be the case that mind-wandering episodes which could be described as relatively 'vacant' lapses are less likely to be associated with pupil dilation as compared to a rich daydreaming experience.

Further complicating the question of how performance may relate to mind wandering in a broadly generalizable way, behavioural variability has been proposed as a marker of mind wandering (Seli, Cheyne, & Smilek, 2013). This implies that a simple increase or decrease in a given correlate that varies in step with mind wandering may be an overly simplistic expectation. With respect to reaction time, the direction of change in average response time resulting from mind wandering may be contingent upon the extent of attentional decoupling from the primary task at hand. For example, someone who is continuing to engage in some task-related processing mixed with task-related processing (i.e. mind wandering a little bit) may slow down and essentially engage in a form of task switching. However, if someone is in a deeply enough decoupled state then they may begin pressing buttons in an absent-minded fashion with little to no task-related processing taking place whatsoever, to the extent that this may be accompanied by feelings of lack of agency (as some phenomenological reports indicate participants experience during the sustained attention to response task (SART): Cheyne, Carriere, & Smilek, 2009).

There has been considerable interest in understanding the neural correlates of mind wandering in recent years. One such line of inquiry began with the discovery of a network of brain regions that become active while participants are ostensibly at rest, known as the default-mode network (Raichle et al., 2001; Greicius, Krasnow, Reiss, & Menon, 2003; Greicius & Menon, 2004; Greicius, Srivastava, Reiss, & Menon, 2004). A number of studies have since clarified the role of this network in mind wandering (Mason et al 2007; Buckner, Andrews-Hanna, & Schacter, 2008; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). Differences in the amplitude of ERPs have also been reported during periods of mind wandering (P300, Smallwood, Beach, Schooler, & Handy, 2008; P100 and N100, Kam, Dao, Farley, Fitzpatrick, Smallwood, Schooler, & Handy, 2011), as have changes in phase locking (Baird, Smallwood, Lutz, & Schooler, 2013). One strength of investigating neural correlates of mind wandering has related to their use in validating reports through a process known as triangulation, in which self-reports and neural correlates are compared with other objective correlates expected to vary with mind wandering (Smallwood & Schooler, 2015).

As with other kinds of objective measures, relying on neural correlates for measurement is not free from complication. The default-mode network demonstrates spontaneous fluctuations that are not thought to have anything to do with mind wandering, for example (Kucyi, Esterman, Riley, & Valera, 2016). Furthermore, even if some neural correlate was a perfect index of mind wandering, various limitations inherent to using imaging technology would presumably constrain their widespread use as an all-purpose measurement tool. These include constraints related to experimental design (e.g., timing stimuli presentations using ERPs), participants (e.g., exclusionary criteria for fMRI: metal in body, difficulty remaining still, etc.), or the equipment itself (e.g., cost).

Developing an Explanatory Framework

The work described above demonstrates how studying objective correlates of mind wandering has proven a productive avenue of research and will likely continue to be so for the foreseeable future. However, correlates also appear unlikely to provide a viable all-purpose replacement for self reports as a primary means of measurement in the near future. In part, this has to do with a lack of a consensus with respect to which correlates are consistently related to mind wandering, as well as how exactly they are related (i.e. does reaction time speed up or slow down while mind wandering?). Part of this discrepancy may also relate to variability in how correlates are associated with mind-wandering behaviour across different tasks and contexts, which introduces a further complication.

Another layer of complexity that a thorough understanding of correlates would have to overcome to seriously contend with self report as a measurement replacement is the gradually increasing understanding of the complexity and heterogeneity associated with mind wandering. One line of evidence for this heterogeneity comes from inter-individual differences in default-mode network functional connectivity related to dimensions of the mind wandering experience involving positive habitual thoughts and spontaneous task-unrelated thought (Wang, Poerio, Murphy, Bzdok, Jefferies, & Smallwood, 2018). Various dissociations have also been reported that relate to differences between deliberate and spontaneous mind wandering (Seli, Carriere, & Smilek, 2015). One implication of the existence of these dissociations is that the interpretation of mental state could differ in some situations depending on which correlate was used.

There have also been some distinctions between which theoretically relevant constructs are linked to particular types of mind wandering. An example of this is that feelings of alertness are more closely related to spontaneous mind wandering, whereas motivation is more closely linked with intentional mind wandering (Robinson & Unsworth, 2017). These kinds dissociations lend further support to the idea that there are meaningful distinctions cutting across what can be conceived of as different 'types' of mind wandering. This emerging view of mind wandering as a complex and heterogeneous construct is another reason why relying on a single correlate to index overall levels of mind wandering may not be a realistic prospect.

Reflecting a similar spirit of heterogeneity, Smallwood and Andrews-Hannah (2013) argued that specifics related to the task one is engaged with largely determine the probable costs or benefits that manifest during mind wandering ('context regulation hypothesis'). For example, mind wandering could be expected to be more likely to detrimentally affect comprehension of a lecture than enjoyment of musical improvisation. Smallwood and Andrews-Hannah (2013) also explained how specifics related to the content of the mind wandering may constrain the likely associated outcomes. As an example of the potential influence of content, compare the unpleasant effects of mind wandering associated with dysphoria (Smallwood, O'Connor, Sudbery, & Obonsawin, 2007) to the mood lift that can accompany a pleasant off-task thought (Franklin, Mrazek, Anderson, Smallwood, Kingstone, & Schooler, 2013).

Variability within whatever relationships exist between various correlates and mind wandering might also be expected. For example, decreased physiological indicators of arousal may accompany mind wandering episodes in which neither task-unrelated nor task-related thoughts are particularly developed ('spaced-out'). This may contrast with a mind wandering episode in which rich imagery is processed in relation to a more aggressively pursued line of off-task thinking ('daydreaming') in where there may exist indicators of relatively increased physiological arousal. In the latter case, relying on a method of measurement like self report which indexes a 'superordinate' category (e.g., overall levels of any kind of mind wandering) could be advantageous relative to relying on a single physiological correlate that may exhibit different relationships with different kinds of mind wandering (assuming that superordinate category of overall mind wandering was most relevant to the research question being investigated).

It would be possible to build more complex detection models that delineate different kinds of mind wandering based on these kinds of nuanced distinctions (e.g., correlates of intentional vs. spontaneous mind wandering). Inferences about mental state could even be made based on the measurement of some combination of correlates, potentially leveraging machine learning (as has been attempted with some success: Bixler & D'Mello, 2014; Mills, Bixler, Wang, & D'Mello, 2016; Mills, Dame, & Mello, 2015). More elaborate detection models could potentially even be calibrated to the idiosyncratic 'tells' specific to an individual. However, given the current state of our understanding of how various correlates relate to mind wandering, such detection models would not be expected to replace self reports as the primary measurement tool anytime soon. Even with the great potential offered by these kinds of detection models, completing the necessary foundational work to get to a point where they are viable will likely require considerably more basic research relying on self report to measure mind wandering. If anything, this line of thinking provides further motivation for more fully understanding the processes supporting the development of mind-wandering self reports in the service of disentangling these relationships.

Given the relationship of necessity between self reports and mind wandering experimentation just outlined, there is an argument to be made that understanding as much as possible about the various factors that affect self report is an important research goal. This is because using self reports in research as effectively as possible necessitates a thorough understanding of any effects which may enhance or confound the measurements they produce (Ericsson & Simon, 1998). One basic example would be understanding whether there are boundary conditions under which reporting people are able to produce accurate measurement. Meta-awareness, or the awareness of the contents of one's thoughts, is the most commonly discussed example of a factor understood to affect mind wandering reporting behaviour (Schooler, 2002). The common understanding of this is that experimental participants don't always realize when their minds have wandered, and they therefore sometimes fail to provide an accurate report (Schooler, Smallwood, Christoff, Handy, Reichle, & Sayette, 2011). Understanding these potentially confounding effects related to meta-awareness also encourages researchers to consider other converging indicators to infer effects which may otherwise be obscured if relying on reports alone (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009).

Along similar lines, some factors have been reported to produce changes in reporting behaviour independent of any evidence for accompanying changes in mental state. These include priming the concept of honesty (Vinski & Watter, 2012), manipulating criterion to produce more or less frequent reports (Bastian, Valentin, & Sackur, 2014), and manipulating probe frequency to increase the probability of a mind-wandering response (Seli, Carriere, Levene, & Smilek, 2013). All of these factors which can interact with reports implies a methodological need to understand the underlying processes which support their development as completely as possible. More generally, these kinds of effects also suggest a more complex underlying process driving reports than is currently accounted for in the literature. This further underscores the utility in developing a more complete understanding of how reports are formed, further motivating this pursuit as a productive research direction. To date there would seem to be no consensus for a clearly operationalized causal mechanism that explains how reports are formed in general, nor any that are well suited to account for the various instances in which reporting behaviour seems to change independent of any evidence for changes in actual mind-wandering behaviour.

Finally, developing an explanatory framework that helps researchers understand how participants introspect about their own mind wandering may also confer practical benefits, such as developing methods to improve skills associated with meta-awareness and cognitive control. There is currently a great deal of interest in various interventions that might reduce mind wandering, such as mindfulness training (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Morrison, Goolsarran, Rogers, & Jha, 2014). One promising target for mitigating the negative consequences of mind wandering could be to train people to emulate things which individuals that are more successful in producing accurate reports, and or exerting greater attention control, tend to do. This may involve more closely attending to particular kinds of information which may be more reliable indicators of mental state than others. Understanding the full range of information that people may consider when introspecting about their mental state, as well as differences in the associated relative successes in both identifying and maintaining task focus when attending to these various sources of information, should assist with this endeavour.

Letter Detection and the Missing-Letter Effect

The paradigm used in the experiments reported throughout this dissertation builds on a frequently used approach to study mind wandering in which a reading for comprehension task is used in conjunction with experience sampling (Dixon & Bortolussi, 2103; Feng, D'Mello, & Graesser, 2013; Franklin, Broadway, Mrazek, Smallwood, & Schooler, 2013; Franklin, Smallwood, & Schooler, 2011; Schooler, Reichle, & Halpern, 2004; Smallwood, McSpadden, & Schooler, 2008; Reichle, Reineberg, & Schooler, 2010). Following the general design used in Dixon and Li (2013), participants simultaneously read three stories for comprehension while also performing a letter-detection task (monitoring the text for occurrences of the letter 'e') and occasionally responding to mental-state probes. This design could be described as a dual-task experience-sampling paradigm.

The missing-letter effect refers to the higher rates of errors of omission (in which a target letter is missed, e.g., not noticing an 'e' in 'the') that are commonly observed for function words. While function words tend to occur with a higher frequency than content, and thus these factors covary, frequency has been shown to make independent contributions to the missing-letter effect above and beyond word type (Klein & Saint-Aubin, 2016). The missing-letter effect was originally reported in Corcoran (1966), who suggested that it may be partly due to the greater probability of skipping function words during reading.

One early theoretical account of the missing-letter effect focussed on unitization. According to this view, words that are more familiar (such as high frequency words) are more likely to be recognized as complete orthographic units before their constituent letters are fully processed. Given the hierarchical nature of textual processing, processing at the subordinate level of letter identification is assumed to terminate early because it is not necessary to proceed with word identification, thus accounting for failures to identify target letters (Healy, 1994). The role of parafoveal processing has also been proposed to be a factor in the missing-letter effect for similar reasons. Although the constituent letters of words viewed in parafoveal regions are not individually processed due to limitation on resolution, recognition of more familiar words (as whole units) can still occur in that context (Hadley & Healy, 1991). Thus, highly familiar words may not be foveated because it is not always necessary to identify them, and in those instances their letters are not individually processed. Generally related to both of these ideas, the processing time hypothesis postulates that the missing-letter effect is related to the amount of time spent processing a given word (Moravcsik & Healy, 1995).

In contrast to the more bottom-up nature of the theories just described, the structural account of the missing-letter effect proposes a top-down explanation invoking the idea that reading behaviour is influenced by a mental representation of how meaning is expected to be structured in upcoming portions of a text. Function words assist the reader with acting on these expectations by directing attention to content words for the purpose of integrating information about the relevant representations. These words therefore receive comparatively less processing given their relative importance/salience and are more likely to be associated with errors of omission for this reason (Koriat & Greenberg, 1994). Saint-Aubin and Klein (2001) suggested that both bottom-up elements found in the unitization account and top-down ones found in the structural account could be relevant to the missing-letter effect, and Greenberg, Healy, Koriat, and Kreiner (2004) proposed the guidance-organization ('GO') model as a sort of amalgamation between these two general accounts. However, Roy-Charland, Saint-Aubin, Klein, and Lawrence (2007) reported reaction time results which they interpreted as inconsistent with a key prediction made by the GO model. They proposed the attentional-disengagement model to account for their results (Roy-Charland, Saint-Aubin, Klein, & Lawrence, 2007; Klein & Saint-Aubin, 2016). This model maintains the interruption assumption, which states that successful identification at the word level interrupts processing at the (subordinate) letter level, while rejecting the independence assumption which assumes no further letter processing occurs once processing at the letter level is interrupted.

The missing-letter effect has been primarily studied using pen and paper methods. This raises the possibility that any results obtained using a computer-based paradigm may be difficult to reconcile with prior work. However, Saint-Aubin and Klein (2004) found similar results when comparing results produced with a pen and paper version to those using a computer-based rapid-serial-visual presentation (RSVP) paradigm. The paradigm used in the present work involves the sequential presentation of individual words, which seems intermediate between traditional pen-and-paper methods (whole paragraphs presented simultaneously) and RSVP (individual letters). Irrespective of whether an overall effect is obtained, the presentation style could be expected to sometimes constrain what contributions are possible. For example, as pointed out by Dixon and Li (2013), a word-by-word presentation would seem to reduce/eliminate contributions to the missing-letter effect more directly related to eye movements (e.g. parafoveal processing account). Dixon and Li (2013) also reported a typical missing-letter effect using a similar word-by-word presentation method as in the present work.

The accounts of the missing-letter effect presented above generate some predictions about how it might be affected by mind wandering. Before evaluating those predictions, it is worth reviewing the findings from one other previously published study looking at how mind wandering affects letter detection. Dixon and Li (2013) reported that letter detection became more error prone in general prior to reports of mind wandering, yet found no evidence that task focus interacts with the missing-letter effect. This suggests that the typical range of variation in resource allocation associated with differences in reported task focus affects the overall efficiency of letter detection but doesn't alter other relevant processes that may be more proximally related to the missing-letter effect itself. Dixon and Li interpreted their results as consistent with the unitization account of the missing letter effect, in agreement with other findings showing that words presented within scrambled sentences still produced the usual effect (Healy, 1976).

Moderate levels of mind wandering during reading may be more likely to create problems related to insufficient top-down processing in the long run based on the cascade model of inattention (Smallwood, 2011). This is because momentary lapses in attention can have enduring and cumulative impacts on comprehension later on, whereas inadequate bottom-up processing in one paragraph shouldn't substantially affect subsequent word identification in another sentence (aside from some minor effects, e.g. animals words might be identified more quickly following a paragraph about a zoo). Additionally, while some elements of bottom-up processing may break down when attention becomes strongly decoupled, it seems unlikely that processing at the word (and by extension, letter) level would cease entirely under typical circumstances. One line of support for that assumption is the wealth of effects related to the automaticity of word reading (Stroop, 1935).

Albeit somewhat of an oversimplification, various mechanisms hypothesized to be driving the missing-letter effect could be categorized as falling predominantly on either the bottom-up or top-down ends of the perception spectrum. Building on the premise that moderate levels of mind wandering may be more likely to affect top-down processing during reading, studying the missing-letter effect using an experience-sampling paradigm may allow for inferences about the relative balance of top-down and bottom-up contributions to this effect. If top-down mechanisms are making substantial contributions to the missing-letter effect, and these are more affected when mind wandering, then an interaction might be apparent.

In addition to possibly speaking to a better understanding of the underlying processes associated with typical reading behaviour and/or mind wandering, the missing-letter effect could have some utility as a non-invasive method for delineating mental state. Sensitivity to the missing-letter effect has already been explored as a diagnostic for level of reading proficiency, with a larger magnitude of effect being associated with more highly developed reading skills (Saint-Aubin & Klein, 2008). If the magnitude of the missing-letter effect was found to be a reliable way to index periods of time in which attention has lapsed, this would entail certain advantages over existing methods (e.g., not interrupting participants during experimental tasks, avoiding issues surrounding meta-awareness and validity, circumventing biases that may affect reporting behaviour). Furthermore, while probe responses reflect discreet points in time, the missing-letter effect could be used to more precisely track the time course of mind wandering behaviour in various ways (e.g., average duration of episodes, relationship between duration and reported intensity and/or behavioural changes, individual difference in these factors).

Because there was no reason to think any of the differences across experiments would have any systematic effect on letter detection, data from all three experiments will be collapsed across into a single sample. These results will be presented just prior to the general discussion section in this dissertation. Although Dixon and Li (2013) failed to find any meaningful interaction between mind wandering and the missing-letter effect, the power advantage associated with the larger sample size used in the present work increase the motivation for attempting to replicate their result here.

Overview of Experiments

The three experiments presented in this dissertation collectively support a theoretical framework that begins to explain how experimental participants form responses to mind wandering probes. The general discussion then synthesizes some of these ideas and builds on them, exploring reinterpretations, implications, and productive future directions for mind wandering research. Experiment 1 examined the possible influence of perception of task performance on mind wandering reports. The robust relationship typically found between performance and mind wandering reports (Randall, Oswald, & Beier, 2013) is generally assumed to occur because participants perform worse as a direct consequence of mind wandering. Another possibility is that some people may be implicitly aware of this relationship and use it as a source of information to base inferences related to mental state. In other words, someone might notice that they are performing poorly and on that basis infer that they might be mind wandering. This would be consistent with the idea of an inferential process driving self reports advanced by Nisbet and Wilson (1977). Among other reasons, this is of theoretical interest because a close correspondence between performance and reports is frequently taken as validating the latter. Among other things, evidence found to support my hypothesis implies a potentially important confound in the literature.

The original motivation for Experiment 2 was to test whether differences in attitudes and related expectations about mind wandering would affect reporting behaviour. It was hypothesized that introducing mind wandering as a strictly negative phenomenon at the beginning of the experiment would make participants more hesitant to report that state. Introducing mind wandering in a more positive way by providing examples of possible benefits was predicted to have the opposite effect. Contrary to expectations, contextualizing mind wandering with negative consequences inflated the relative frequency of those reports early on in the experiment. This occurred independent of any clear evidence for an accompanying behavioural change, suggesting the manipulation changed reporting behaviour rather than mind wandering behaviour. This also implies that people may be more sensitive to contextualizing information presented at the beginning of experiments than is typically understood, raising cautions about the wide ranging differences in how this is done across studies.

Experiment 3 was intended to produce data that would assist with understanding the breadth of information participants rely on when forming reports. A secondary motivation was to find converting support for my interpretation of Experiment 1. Building on work aimed at better understanding the nature of the contents of mind wandering episodes (temporal focus, Smallwood, Nind, & O'Connor, 2009; categorization of different kinds of common foci, Stawarczyk, Cassol, & D'Argembeau, 2013, etc.), this descriptive approach was extended to characterize what kinds of information people are consciously aware of considering while responding to mind wandering probes. The results support the claim that there is some individual difference in how reports are developed, including variability in the use of information related to perception of performance.

Experiment 1

A dual-task paradigm was used in which participants read three stories for comprehension, presented one word at a time on a monitor, while simultaneously providing a response to indicate whether or not each word contained at least one letter 'e.' Every story was interrupted at three pseudo-randomly timed points (the 'probe'), at which point participants estimated both their average (per word) reading speed and mean letter-detection accuracy since the last probe (or beginning of experiment), then received feedback related to these two measures. Critically, the letter-detection accuracy feedback was manipulated such that it sometimes indicated scores reflecting greater or less than actual levels of performance. Participants then responded to two self-report probes on the level of focus they attributed to each aspect of the dual-task (letter detection and comprehension). After reading all three stories, participants answered a block of comprehension questions.

The letter-detection probe responses were the focus for testing my hypothesis. The use of two probes is not typical in mind wandering experiments, though the dual-task nature was expected to afford an intuitive interpretation of the 'on task/focus' framing used for the probes in this experiment (i.e., extent of engagement with the letter detection and comprehension aspects of the task). Conversely, it is not clear how one would interpret independent probes framed as extent of 'mind wandering' associated with each aspect. Previous work using a similar dual-task paradigm found responses across two probes to be relatively independent (Dixon & Li, 2013).

This experiment tested the hypothesis that perception of task performance influences mind-wandering reports. Time-on task and actual performance are two factors expected to explain some variance in probe response for reasons not directly related to my hypothesis. Controlling for these factors within my modelling therefore allows for a more sensitive test of my hypothesis. Time-on-task refers to the tendency for reports of mind wandering to increase across the duration of experiments (Farley, Risko, & Kingstone, 2013). This is similar to the vigilance decrement (Grier, Warm, Dember, Matthews, Galinsky, Szalma, & Parasuraman, 2003). Controlling for time-on-task can generally be accomplished by modelling an additive effect of block.

Actual performance is often found to decline during periods of time in which mind wandering has been reported (Randall, Oswald, & Beier, 2013). The typical explanation for this relationship invokes references to differences in the extent of attentional engagement, and accompanying allocation of cognitive resources, towards an experimental task. Because mind wandering is generally expected to impair performance, seeing such detriments associated with intervals of time in which this state has been reported is sometimes taken as validation that the reports were accurate. Given my hypothesis, it makes sense to try to control for variance related to resource allocation when modelling probe response to more precisely assess the influence of perception of performance. However, it is not clear how to partition contributions to probe response related more proximally to perception of performance, from those other more general effects also related to actual performance (e.g., resource allocation). Variance associated with both kinds of contributions should be subsumed by actual performance and distinguishing between those sources therefore presents a challenge for my experimental design. My solution involves recording performance estimates and taking the deviation of those from actual performance as a conservative estimate of variance associated with perception that has been dissociated from actual performance, while controlling for contributions related to resource allocation using actual performance.

When interpreting these results it will be important to assess the evidence the manipulation affected reporting behaviour, rather than actual mind-wandering behaviour. In addition to looking for obvious differences in mean performance and response time, response-time variability may be another useful diagnostic for gauging that evidence. While response time can prove a useful diagnostic for inferring changes in mental state, there remains ambiguity about how it is affected by mind wandering. Mind wandering has sometimes been associated with reports of both longer mean response times (Reichle, Reineberg, & Schooler, 2010; Feng, D'Mello, & Graesser, 2013; Foulsham, Farley, & Kingstone, 2013), and shorter (Franklin, Smallwood, & Schooler, 2011). Given this, variability in response time has been suggested as a more robust diagnostic measure for inferring mind wandering. This is consistent with suggestions that general behavioural variability may be useful as an index of mind wandering (Seli, Cheyne, & Smilek, 2013). The response time variability coefficient is a measure that has been used to make such inferences in prior research (Carriere, Cheyne, Solman, & Smilek; Bastian & Sackur, 2013). The variability coefficient is the standard deviation of reading time divided by the mean. This measure will be assessed in my analyses.

Models were compared using likelihood ratios that describe how likely the data were given the best fit of one model relative to another. The likelihood ratios were adjusted for the varying number of parameters based on the Akaike Information Criterion (Akaike, 1973; Glover & Dixon, 2004). The symbol λ_{adj} is used to indicate such adjusted likelihood ratios. As a point of comparison, a significance level of .05 corresponds approximately to an adjusted likelihood ratio of 3 in typical hypothesis testing scenarios. The program lme4 (Bates, Maechler, Bolker, & Walker, 2015) was used to fit liner mixed effect models in the R statistics environment (R Core Team, 2012) for model comparisons.

Method

Design. The independent variable of feedback condition was manipulated within participants across three levels. Every participant read one story in each of the three feedback conditions: increase, decrease, and control. Stories were divided into three sections, each of which ended with a probe break. Assignment of stories to conditions, as well as order of condition presentation, was counter-balanced across participants.

The dependent variables of primary interest were letter-detection task-focus self report and score estimate. A second probe response related to comprehension task-focus was also recorded.

Feedback manipulation. Accuracy was determined by dividing the number of words for which a correct response was given by the total number of words presented. In the control condition, the feedback presented was based on actual performance. The values used for the feedback presented in the decease and increase condition were calculated as follows: The participant's actual score (expressed as a percentage of correct responses) was converted into logits, one logit was added or subtracted (respectively), then this value was converted back into a percentage. The experiment was programmed not to increase the score above 99%. This was done with the expectation that most people will make at least one mistake and therefore feedback indicating perfect accuracy would be likely to arouse suspicion. The choice for a one percentage point cutoff from perfect performance was based on pilot data.

Performing the manipulation calculations in the logit space was expected to produce a more effective distribution of modified scores than would have been possible in the proportion space. The way this was applied produces larger average changes in the decrease condition, as compared to the increase condition (at least when performance is above 50%). This was considered useful on account of the expectation that there could be a tolerance for larger magnitudes of score manipulation in the decrease condition (i.e. while still seeming believable). The basis for this expectation was that participants might rely on an anchoring heuristic to estimate their score (Tversky & Kahneman, 1974). Given the relatively high average level of performance, a plausible estimation strategy would be to approximate the number of errors made and subtract that from an ideal level of performance (i.e. 100%). If such a strategy was employed, manipulated scores may arouse more suspicious as they approach ceiling performance on account of more readily available evidence to the contrary (e.g. receiving feedback indicating 99% accuracy but remembering making more than one mistake over the last 100 trials).

Participants. Thirty-four subjects from the University of Alberta undergraduate psychology human subject pool participated in this study in exchange for course credit. Two participants were excluded from the analysis for failing to provide any responses.

Materials. Three short stories taken from Grimm's fairy tales were used as stimuli (Grimm & Grimm, 2013): 'The Seven Ravens', 'The Turnip', 'The Mouse the Bird and the Sausage'. The stories ranged from 710-1154 words, with a mean length of 958 words (SD = 226.52).

Apparatus. All stories were presented on 51 cm iMac computer. Words were centred, presented in 12-point Times font, and viewed at a distance of approximately 50 cm under normal room illumination.

Procedure. Subjects read three stories presented one word at a time. Each word remained on-screen until a response was made. Subjects were instructed to press the 'e' key if the current word contained at least one letter 'e,' or otherwise press the space bar. The stories were divided into three sections, each of which was associated with a pseudo-randomly timed probe break which interrupted the dual-task. At each probe break, subjects 1) estimated their mean per word-reading speed in ms and letter-detection accuracy as a percentage of correctly responded to words, 2) were then presented with feedback they were told reflected the actual values related to their estimates, and finally 3) self reported the level of focus they attributed to each task (letter detection and reading for comprehension). The self-reports were phrased as follows: "Please Respond to the Statement *My attention is fully focused on the letter-detection task*" and "Please Respond to the Statement *My attention is fully focused on the comprehension task*", respectively. Responses ranged from 1-7, associated with the following verbal labels: "Strongly disagree," "Somewhat disagree," "Slightly disagree," "Neither agree nor disagree," "Slightly agree," "Somewhat agree," "Strongly agree." After reading all three stories, subjects completed a block of comprehension questions. Each story section was associated with two multiple choice comprehension questions. Finally, participants completed a series of questions designed to gauge how believable they perceived the presented feedback to be.

Following completion of the experiment, participants also answered a series of defunnelling questions. These were aimed at gauging the level of skepticism that the feedback presented may have been regarded with, as well as retrospective impressions of how the feedback may have affected one's probe responses. Response were made using a Likert-type scale of 1-7, ranging from strongly disagree to strongly agree, similar to the one used for probe responses. The questions are presented below:

Q1: "The accuracy estimates provided throughout the experiment affected the way I perceived my attentional state"

Q2: "I was surprised by the accuracy feedback for at least one story"

Q3: "I thought the accuracy feedback may have been incorrect for at least one story"

Results

The first experiment tested the hypothesis that manipulating feedback related to performance in the letter-detection task would affect mind-wandering reports. Evidence in favour of this proposition would support the idea that perception of task performance shapes the development of such reports.

Table 1 presents mean response to the letter-detection probe question ("Please Respond to the Statement *My attention is fully focused on the letter-detection task").* These values are split by block and letter-detection performance (based on a median split of mean letter-detection accuracy). A typical 'time-on-task' effect is apparent, in which reported task focus diminishes across the duration of the experiment. They also show the expected positive relationship between task focus and performance. As mentioned in the introduction to this experiment, time-on-task and performance were expected to vary with probe response for reasons not directly related to my hypothesis. Confirming that such general relationships are indeed apparent in these data lends further support to the idea that controlling for these these two factors during modelling may assist with gauging the evidence for my hypothesis by affording a more sensitive test of it. Table 2 shows mean letter-detection probe response by estimate accuracy. This table demonstrates that overestimating performance is associated with probe responses endorsing greater focus, as compared to responses in which performance was underestimated.

Figure 1 plots the mean responses to the letter-detection probe question across conditions, contingent on whether letter-detection performance was underestimated or overestimated. An interaction between the effect of the manipulation and letter-detection score estimates is apparent in Figure 1. Participants who underestimated their score during the decrease condition reported a lower mean level of focus, while the opposite was true for those who overestimated their score during the increase condition.

Table 1

Mean Letter-detection Probe Response Split by Block and Letter-detection Accuracy Median Split (and Standard Error)

Block	Accuracy	Probe Response
1	Low	5.06 (0.13)
1	High	5.68 (0.11)
2	Low	4.51 (0.11)
2	High	5.13 (0.13)
3	Low	4.27 (0.12)
3	High	4.89 (0.13)

Table 2

Mean Probe Response by Estimate Accuracy (and Standard Error)

Condition	Letter Task
Overestimate Performance	5.84 (0.10)
Underestimate Performance	5.44 (0.10)

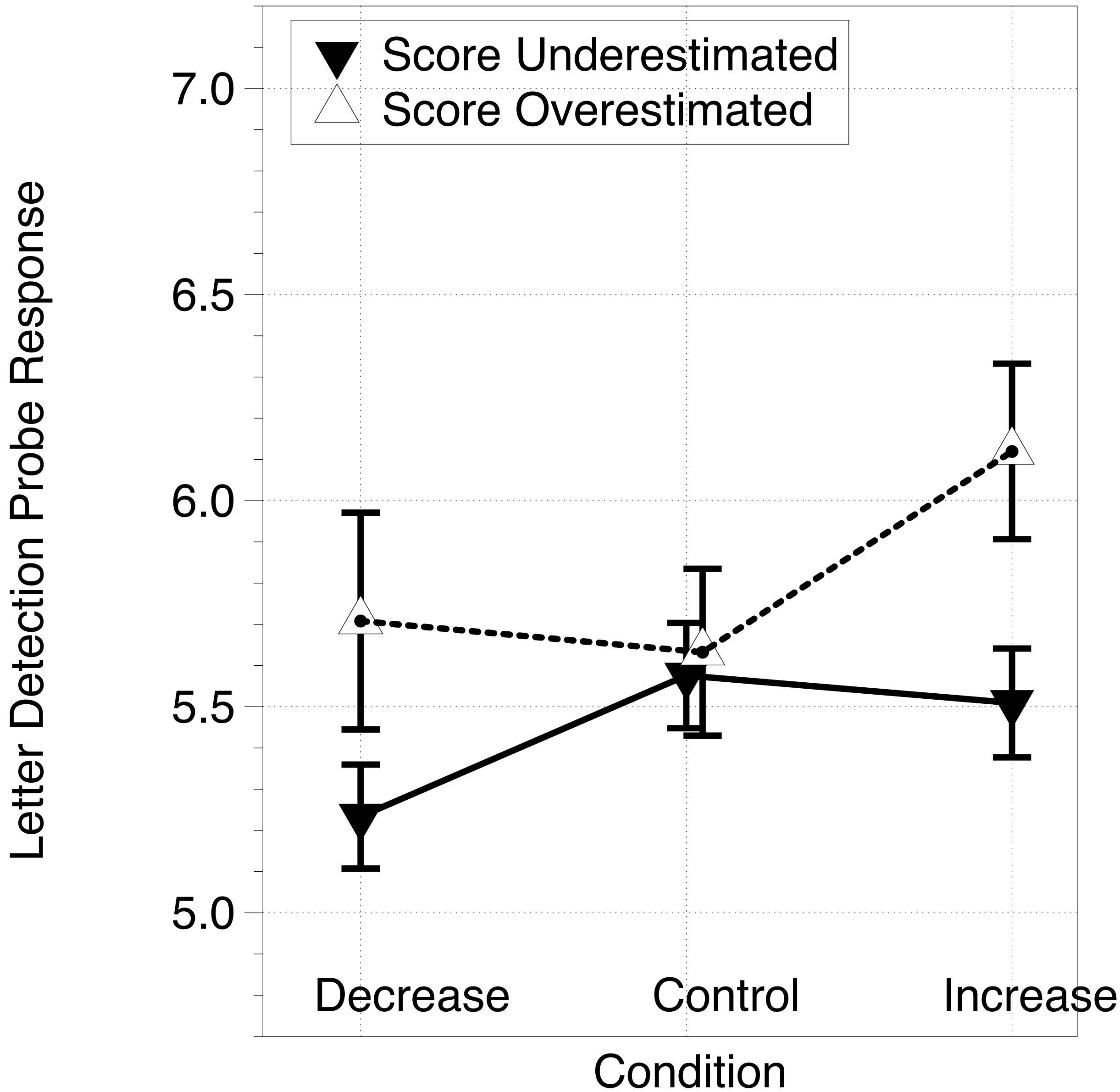

Figure 1. Mean probe response by condition and letter-detection performance estimate accuracy (overestimated or underestimated), with standard error.

The next step in the analysis involved modelling competing theoretical accounts of these data to ascertain the relative strength of the evidence for each. Factors related to time-on-task and actual performance will first be included in the models to account for as much variance as possible in probe response that is not expected to directly relate to perception of performance. This should allow for a more sensitive test of my hypothesis. Models embodying effects related to the manipulation and performance estimates will then be considered.

Controlling for time-on-task and performance. A model using a single predictor related to time-on-task to predict probe response ('block') was much better than a null model (λ_{adj} > 1000). This presumably reflects the expected decline of task focus across the duration of the experiment which is frequently reported in the mind wandering literature, a trend that is apparent across blocks in Table 1. Adding letter-detection score as a second predictor improved greatly upon the simple time-on-task model (λ_{adj} > 1000). Using both of these predictors was also better than just using letter-detection score as the sole predictor (λ_{adj} = 158.84). As expected, better performance was associated with probe responses indicating greater focus (Table 1). The modelling has thus far demonstrated strong evidence for a positive relationship between probe response and actual letter-detection performance in these data, along with a negative relationship between probe response and time-on-task. Each of these factors was expected to vary for reasons not directly related to my hypothesis. The next step in the modelling involved more directly assessing the evidence for my hypothesis by testing whether factors related to variance in perception of performance can explain additional variance in probe response (i.e., above and beyond time-on-task and actual performance). My preferred model is presented here, which is based on simple effects.

Probe response, simple effects model. A three-level factor was constructed which denotes whether a given probe is associated with 1) underestimating score in the decrease condition, 2) overestimating score in the increase condition, or 3) neither of the above joint conditionals being satisfied. These first two sets of circumstances were the contexts predicted to show the largest decrease and increase in mind wandering response, respectively. A model adding this three-level factor as a third predictor (in addition to block and score) was much better than the the simpler alternative using just block and score ($\lambda_{adj} = 69.45$). This effect is clear in Figure 1, in which the probe responses were lower in the underestimated score/decrease condition, higher in the overestimated score/increase condition, and approximately equal in the other conditions.

Inferring changes in mind-wandering behaviour. The preceding analysis focussed on modelling the relationship between perception of performance and probe response. An important consideration for my interpretation is whether there is any indication that the feedback manipulation may have affected actual levels of mind wandering, rather than simply changes in reporting behaviour. This is important to consider because changes in perception of focus could be confounded with actual changes in focus. For example, receiving feedback indicating worse (or better) than actual performance may affect motivation levels, which could then more directly affect mind wandering behaviour (Unsworth & McMillan, 2013; Seli, Schacter, Risko, & Smilek, 2017). The approach taken to address that possibility here was based on assessing whether there were any obvious differences across conditions apparent in behavioural measures that have been previously associated with mind wandering behaviour. These measures include actual performance, mean response time, and response time variability.

The performance-based analyses are not presented in full for the sake of brevity. However, it can be said that no strong evidence was found to undermine the main interpretation applied towards these data in the preceding section. Overall performance as a function of the most recent instance of feedback condition is shown in the Appendix 2 (Table A1). These means suggest that letter-detection performance may have been slightly better following an instance of feedback in both the decrease and increase condition. A similar trend for better performance in the decrease condition seems evident for comprehension score.

Means related to response time variability show no clear variation across conditions (Table A2).

Probe response and score estimate error. Another question of theoretical interest is how mind wandering might affect the accuracy of the score estimates produced by participants. This could speak to changes in performance monitoring that accompany fluctuations in task focus. Deviation of score estimate from actual performance is a simple way to index accuracy of those estimates. A measure of that nature will be referred to as 'estimate error'.

The values associated with estimate error reflect whether performance is underestimated or overestimated (indicated by sign, negative or positive), as well as the accuracy with which the estimate was made (indicated by the absolute numeric value). These values therefore speak to both the direction and amount of error in those estimates, which may be informative for different reasons. Independent of whatever effect the feedback manipulation has, a related prediction follows from my hypothesis about perception of performance shaping reports. That is, overestimating or underestimating letter-detection performance should be associated with reports indicative of more/less focus (respectively). Along somewhat different lines, the absolute value of the estimate error should reflect how accurately performance was estimated. This absolute value is expected to relate more directly to resource allocation, rather than reporting behaviour (as was suggested for the direction of error). If performance is tracked better during periods associated with greater focus, average estimate error should get smaller as reported task focus increases.

Table 3 shows mean response to the focus probe question as a function of whether score was underestimated or overestimated. Table 4 shows that same mean response but now as a function of whether the absolute value of the estimate was relatively small or large (based on a median split of all estimate errors, across all subjects). These mean probe values conform to predictions. Participants who overestimated their performance reported a higher average level of task focus than those who underestimated it. Reporting a higher level of focus was also associated with smaller estimate error (i.e. more accurate estimates). This is suggestive of two somewhat separable sources of variance subsumed by estimate error.

The following model comparisons support this interpretation. Using probe response as the sole predictor to model estimate error is better than a null model ($\lambda_{adj} = 4.57$). The same is true when trying to predict a dependent measure reflecting only the absolute value of estimate error (i.e. no +/- sign), $\lambda_{adj} = 6.63$. While each of these forms of estimate error (i.e. with and without the sign) are better predictors of probe responses than chance, they share different relationships with probe response. As was apparent in Tables 3 and 4, reports of greater focus are associated with both positive error values, as well as smaller error values.

Another way to quantify the strength of the evidence for these kinds of relationships is to try adding these predictors to models already controlling for time-on-task and performance. Compared to a base model consisting of just block and score, adding a third predictor related to estimate error now produces a very large improvement ($\lambda_{adj} > 1000$). Returning to that base model as the point of comparison (two predictors: block and score), adding a third predictor reflecting just the absolute value of estimate error (i.e. no +/- sign) also produces an improvement, though not quite as large (λ_{adj} = 199.79). This demonstrates that each of these predictors can explain variance in probe response above and beyond that accounted for by time-on-task and performance. In addition, a predictor embodying the sign of the estimate error explains even more variance than just the absolute magnitude of the estimate error by itself.

Finally, a model using block, score, and estimate error was better than one using those three predictors plus a fourth reflecting just the absolute value of estimate error (λ_{adj} = 2.15). This is presumably because information related to the absolute deviation of the score estimate is already contained within the (signed version of the) estimate error predictor (and thus, redundant). Nevertheless, the fact that the simper model is only slightly better is informative given this apparent redundancy. All taken together, this modelling is consistent with somewhat dissociable sources of variance embodied within estimate error: one related to direction, the other related to magnitude.

Table 3

Mean Probe Response by Estimate Signed Accuracy Error (and Standard Error)

Estimate Accuracy Error	Probe Response
Overestimate	5.84 (0.10)
Underestimate	5.44 (0.10)

Table 4

Mean Probe Response by Absolute Estimate Accuracy (and Standard Error)

Absolute Estimate Accuracy Error	Probe Response
High	5.30 (0.08)
Low	5.73 (0.08)

Defunnelling questions. Mean responses to the three defunnelling questions presented at the end of the experiment are shown in Table 5. The first item gauges whether participants endorse the idea that perception of their own performance influenced how focussed they felt they were. The mean value associated with that item equates to the verbal label 'somewhat agree.' While this does not provide the basis for a very compelling argument in and of itself, it is consistent with my other interpretations of these data. That is, participants seem to generally agree perception of performance contributed to their overall impressions of task focus.

The next two statements assess the degree of skepticism reported towards the veracity of feedback presented. Although the retrospective form does not speak to possible changes throughout the course of the experiment, the mean values in Table 6 do suggest that (at least by the end of the experiment) some suspicion had developed regarding the accuracy of the feedback.

Table 5

Mean Responses to Defunnelling Questions (and Standard Error).

Question	**Mean Response (and Standard Deviation)**
The accuracy estimates provided throughout the experiment affected the way I perceived my attentional state.	5.06 (1.54)
I was surprised by the accuracy feedback for at least one story.	5.84 (1.74)
I thought the accuracy feedback may have been incorrect for at least one story.	5.78 (1.79)

Discussion

This experiment tested the hypothesis that perception of performance would influence how people estimate their own relative level of task focus. Participants periodically estimated their letter-detection score, were shown feedback related to their performance, and then responded to a mind-wandering probe. Critical for testing my hypothesis, the feedback was sometimes manipulated to reflect either better or worse than actual performance. As was apparent in Figure 1, participants who underestimated their performance in the decrease condition reported lower levels of focus, while those who overestimated performance in the increase condition reported higher levels of focus. A parsimonious interpretation of this interaction is that it defines the boundary conditions under which the manipulation affected probe response: Instances of feedback in the same direction as a preexisting bias in perception of performance already held by the participant (e.g., feedback indicating worse than actual performance after it had just been underestimated) led to changes in reported focus. The degree of consistency between a given score estimate and an associated instance of manipulated feedback may have constrained whether the latter was likely to be perceived as credible, which would be a foreseeable contingency on whether or not it influenced reporting behaviour. These results provide evidence for a cognitive mechanism associated with the development of mind-wandering reports involving a judgment about task performance.

The outline for the balance of this discussion is as follows. Challenges associated with the paradigm will first be addressed. These primarily relate to balancing believability of the manipulation with noticeability, as well as modelling variance in probe response in a way that does not confound effects related to perception of performance with those more directly related to resource allocation. This latter problem was related to the expectation that variance attributable more proximally to each of these theoretically distinct sources would be subsumed by a single measure indexing actual performance. Limitations, potential confounds, and considerations relevant for better understanding the relationship between mind wandering and performance monitoring are then evaluated. Finally, some particularly important theoretical implications that follow from my interpretation of these data pertaining to working memory and validating reports will be presented.

Challenges. Effectively manipulating perception of performance presented a major challenge to testing my hypothesis. Assuming my interpretation is correct, the interaction apparent between condition and score estimate in Figure 1 highlights the importance of believability in mediating the effect of the manipulation. Unlike a more robust effect associated with less variability (e.g., priming), the manipulation may have only successfully convinced participants that the feedback presented was accurate on some proportion of trials. This could help explain why clear evidence for an overall effect of the manipulation was not obtained.

One element of the design intended to promote believability of the manipulated feedback was the choice of the task itself. As discussed in the introduction, letter-detection experiments frequently report a missing-letter effect in which target letters are more likely to be missed when appearing in function words (Klein & Saint-Aubin, 2016). While it is not clear what level of awareness is typically associated with these kinds of errors, the highly automatic nature of processing thought to underpin them (see the literature review on page 24-30 for more info), coupled with the additional processing demands inherent to the dual-task used here, means they probably aren't particularly salient and may therefore typically go unnoticed. Participants who monitor their performance more diligently may occasionally notice these errors after the fact, which could lead to some awareness of how easy it is to make mistakes in this paradigm. Even if some participants never notice their errors, the demands associated with the dual-task design could tax cognitive resources to an extent that effective performance tracking may not be easily accomplished in general (i.e., not just function words). Both of these factors should generally promote greater uncertainty about relative levels of performance, encouraging a greater reliance on deferring to feedback for gauging performance.

As a point of comparison, consider that participants often report being aware of errors made within the SART paradigm shortly after, or even while, making them (Cheyne, Carriere, & Smilek, 2009). The task demands and stimuli are comparatively impoverished in the SART paradigm, meaning the stimuli themselves are essentially the only task-related information available for processing. This presumably increases the salience of any errors that are made, allowing for more accurate performance tracking, and therefore promoting encourage greater skepticism towards manipulated SART feedback. Importantly, none of these factors coerce participants to apply performance-based information to the development of their probe responses. Rather, these factors may simply predispose them to more heavily defer to whatever feedback is presented when judging performance, for whatever purposes they deem fit.

Another major challenge associated with testing my hypothesis involves distinguishing between multiple potential sources of variance in probe response that might be theoretically distinct yet nevertheless all be subsumed by a single measure related to actual performance. For modelling purposes, my design had to disentangle two potentially confounded effects on probe response associated with performance. This included an expected source of variance more proximally linked to resource allocation on the one hand, which should be related to actual performance. On the other hand, as per my hypothesis, another source of variance linking perception of performance with reporting behaviour should also be generally related to actual performance (i.e. perceiving oneself to be performing well would of course be expected to relate to actually doing well). This confound has the potential to effectively mask evidence for my hypothesis by confounding explanations related to resource allocation with those related to reporting behaviour. The conventional explanation for variance in probe response explained by actual performance invokes references to resource allocation. It is expected that participants whose attention is more closely coupled to an experimental task will perform better due to the additional resources allocated towards the task, while their probe responses will likewise reflect that same greater attentional investment. In this way, performance is indirectly linked to the probe response but not considered a causal factor. However, if my hypothesis is correct, then perception of performance may be more directly (i.e., causally) linked to probe responses.

My solution to the problem of partitioning distinct sources of variance in probe response that are associated with performance involves both manipulating feedback and recording score estimates. The latter afforded a conservative estimate of contributions to probe response from perception of performance, operationalized as deviation of score estimate from actual performance. Importantly, this predictor would not be expected to explain substantial variance in probe response attributable to resource allocation. Score estimate error can therefore be taken as a conservative estimate for contributions related to perception of performance that have been isolated from those related to resource allocation. At the same time, this is only partially effective because any predictor based on actual performance is likely confounding contributions related to resource allocation with those from perception of performance (assuming my hypothesis is correct). In a sense, the fact that this conservative estimate yielded good evidence in favour of my hypothesis is encouraging. However, the fact that it may well be underestimating the true extent of such effects could be considered a limitation of my study.

To help demonstrate why the measure designated as indexing variance in perception of performance in my modelling may be underestimating the totality of all such perception-based contributions to probe response (because some are 'soaked up' by the predictor tied to actual performance), consider the following situation. A participant correctly estimates their mean score to be exactly 92% and then infers a high level of relative focus based, at least in part, on that impression. The way the modelling is structured in my analyses, variance related to perception of performance would be entirely subsumed by the predictor associated with actual performance (i.e. the predictor that indexes actual performance). Conversely, the predictor related to perception of performance would have a value of zero for that instance (because the deviation of score estimate from actual score would be zero). My preferred model would therefore not attribute any variance whatsoever to the sole predictor in the model used to index variation in perception of performance. In other words, a predictor related to score estimate error should be driven (at least almost) entirely by variance in perception, and therefore have no confounded contributions from resource allocation. However, the variance in probe response related to actual performance is still potentially confounding effects attributable to resource allocation with those related to perception of performance.

Framing the preceding example more optimistically, the fact that a conservative estimate related to perception-based contributions still produced clear evidence for my hypothesis implies the effect observed may simply be 'the tip of the iceberg,' reflecting a much more robust effect than is apparent in these data. Further disentangling potentially independent sources of variance in probe response associated with actual performance (e.g., contributions related to perception and reporting purposes vs. those related to resource allocation) presents a formidable experimental challenge to which a solution is not immediately apparent.

Another limitation of this study relates to the possibility of individual difference in how probe responses are developed. It may have been the case that various participants considered different kinds of information than others while forming their reports. If some participants relied on performance-based information to construct their reports and others did not, or even if there was variation in how this information was weighed, that could further 'wash out' overall estimates of the effect (independent of the constraints related to believability discussed above). While these data cannot speak to that issue directly, the results of Experiment 3 produced evidence consistent with this conjecture. As with the other limitation just discussed, the fact that reliable effects were still observed in the face of this potential additional source of unaccounted for variability suggests contributions related to perception of performance might be effectively underestimated (at least in so far as individuals who do consider that information, if the models are averaging across participants with different reporting styles).

Also note that impressions of performance related to the other half of the dual-task (i.e. comprehension) would be hypothesized to be making similar contributions to probe response that are not accounted for in my modelling. A follow-up study could manipulate estimates and feedback related to both letter-detection and comprehension performance in a similar paradigm to ascertain whether perceptions of performance across both aspects of the dual-task make similar contributions to probe response(s).

Alternative explanations. Several possible alternative explanations should be considered in interpreting these results. One such example relates to the possibility that the manipulation could have affected actual mind wandering behaviour, rather than simply reporting behaviour. Although distinguishing between effects on probe response related to actual changes in mental state from those more directly related to reporting behaviour is challenging, several lines of investigation failed to produce any compelling evidence for an explanation of that nature. This included no clear differences across conditions that would be expected if actual levels of mind wandering varied in terms of measures commonly associated with that behaviour in the literature (performance, mean response time, and response time variability).

Further, the interpretation of any change in performance observed across conditions depends upon the direction of change. Lower levels of focus were reported in the decrease condition (Figure 1). Although finding worse performance in that condition could be consistent with the idea that the manipulation reduced actual levels of focus (rather than just perception of focus), the fact that the change in performance is actually in the opposite direction is not. If anything, better performance in the decrease condition might suggest two somewhat independent effects of the manipulation: one increasing actual focus (reflected in the better performance), and another decreasing perception of focus (embodied in the probe response). That said, the difference in performance is not huge. Also recall that the modelling in the previous section produced good evidence for variance in probe response related to perception of performance while controlling for actual performance. This indicates that there is evidence for an effect on perception of task focus related to perception of performance, independent of whatever effect on actual performance may also exist. Thus, evidence for changes in performance do not necessarily imply an interpretation that is mutually exclusive with one in which perception of performance also affects probe response.

As alluded to earlier on in this discussion, another potential explanation involves the possibility that effects related to the manipulation are products of participants 'saving face.' Saving face can be operationalized as incurring some cost for the benefit of minimizing feelings of embarrassment (Brockner, Rubin, & Lang, 1981). Previous work has demonstrated that priming the concept of honesty can improve the correspondence between performance and mind wandering reports (Vinski & Watter, 2012), which the authors interpreted as implicating an association between honesty and accuracy of reports. In the context of the present study, participants could have conceivably elected to incur the moral cost of behaving dishonestly by reporting higher levels of mind wandering than they felt were accurate to reduce feelings of embarrassment related to being told they were performing worse than predicted. This could be done in the service of mitigating any sense of embarrassment felt personally (i.e., independent of being contingent on others being aware of it). Additionally, while a researcher was not in the immediate presence of the participants, an 'implied social presence' can also affect behaviour in ways that are consistent with social expectations (Risko & Kingstone, 2011) which could introduce greater social pressures relevant for motivating one to save face.

A similar yet somewhat distinct alternative to the idea of saving face is that participants may have responded to the probes in such a way as to reduce cognitive dissonance (Festinger, 1962). This would involve adjusting the perception of one's own level of focus to account for feedback indicating lower than expected performance. All that said, the interaction in Figure 1 is at odds with explanations of that nature because it is not clear why participants would only report lower levels of focus in the decrease condition if they had also underestimated their score in the first place. This applies regardless of whether processes associated with saving face or cognitive dissonance were involved. Furthermore, it is not clear why there would be a comparable effect in the increase condition for an explanation invoking saving face, in which feedback indicating better than actual performance is associated with reports endorsing higher levels of task focus. All taken together then, these ideas are not parsimonious explanations for the effects observed.

Another potential explanation relates to the fixed order of the probe break sequence. Participants always provided estimates before seeing feedback and then responded to the focus probe question, and this was not counter-balanced. This fixed ordering was necessary because performance estimates wouldn't be meaningful if made after related feedback had just been provided, as well as the fact that gauging a casual relationship between the manipulation and the probe response logically requires the latter to follow the former. However, generating the estimates and/or interpreting feedback just prior to responding to probes may have biased participants in what they considered by drawing attention to performance-based information. This information may have remained in working memory, which could have affected probe responses more than would otherwise be the case. This raises the possibility that contributions related to demand characteristics (Orne, 1962), general priming effects, or an availability bias of sorts (Tversky & Kahneman, 1973) could be confounding the relationship observed between probe response and the manipulated feedback. Several considerations help mitigate these risks, which will be considered in turn.

To begin with, it would not necessarily be immediately obvious to participants what hypothesis is being testing. This bears on the possibility of demand characteristics because interpreting the presence of feedback as implying an expectation it will affect reports cannot be assumed. From the perspective of the average naive participant, a hypothesis involving performance tracking could be just as plausible as any other. For example, an obvious purpose for showing feedback related to letter-detection scores could be simply to help participants become accustomed to estimating their performance.

Participants also estimated (and were given feedback related to) average per word reading times, which was intentionally included as a foil that had the potential to introduce other information that could compete for attention with performance-based representations. If explanations related to demand characteristics, priming or an availability bias were correct, a similar bias could be expected between the response time-based information and reports. For example, participants might assume reading slower is indicative of less task focus and report accordingly (and/or feel embarrassed and attempt to report in a way that saves face, etc.). The fact that no such relationship between probe response and response time estimates was found lends no support to this idea.

The ongoing comprehension demands of concurrently encoding the details of the story world in preparation for the comprehension test would also compete for limited cognitive resources. The same would also be true for the generally demanding nature of the dual-task aspect of the experiment itself. This should all tax the pool of cognitive resources to a point where the availability of residual resources could be in short supply, presumably diminishing (out of necessity) the likelihood of any additional processing of information related to non-essential task demands.

Along similar lines, the notion of the ‘path of least resistance’ casts further doubt on the proposition that the use of estimates and feedback seriously threaten the internal validity of the experiment. This is because even if participants inferred that they were expected to somehow integrate performance-based information into their reports, it is not immediately obvious how to go about doing so. Deciding exactly how to go about integrating such information into reports, particularly in a forced manner, would require additional effort and cognitive resources. People tend to go about making decisions using information that is easily accessible, leading to favouring simpler decision making processes over ones that involve extra work that is seen as strictly speaking unnecessary (Shah & Oppenheimer, 2008; Shah & Oppenheimer, 2009). While it is true that the feedback provided makes the performance-based information easily accessible, it is not clear from the experimental design alone how to go about integrating that information into reports. So although a general relationship may be intuited (negative correlation between mind wandering and performance), mapping response options onto performance ranges still entails additional effort. The idea that the average participant would consider information that they didn't need to purely because of a perceived expectation on the part of the experimenter, particularly in a situation where the explicit task demands are already relatively onerous, is inconsistent with these ideas. Even if someone was unsure how to respond, there was no constraint on responding in a highly subjective way (a 'gut' reaction), including no reason to think there were any expectations that explaining or defending the report would be necessary. That said, if someone has preconceived ideas, experience, and/or heuristics relating different relative levels of performance to mind wandering, then using performance-related information while responding to the probe could be relatively natural. While not completely eliminating the risks of contributions from demand characteristics, priming effects, or an availability bias, the reasons outlined above collectively suggest these sort of explanations are unlikely to entirely account for the effects observed here.

Relationship between performance monitoring and mind wandering. These data also speak to the relationship between performance monitoring and mind wandering behaviour. Performance monitoring serves the adaptive function of evaluating goal-directed behaviour and is required to maintain adequate cognitive control in many contexts. A robust literature on the underlying neurophysiological processes underpinning performance monitoring demonstrates that humans have a well developed system for error monitoring, which is understood to play a key role in various kinds of learning (Holroyd & Coles, 2002). This activity is thought to be reflected in the error related negativity ERP component, which has been proposed to facilitate error detection by way of monitoring response competition (Yeung, Botvinick, & Cohen, 2004). Systems implicated in supporting the online evaluation of performance included the prefrontal cortex (Ridderinkhof, Van Den Wildenberg, Segalowitz, & Carter, 2004), anterior cingulate (Carter, Braver, Barch, Botvinick, Noll, & Cohen, 1998; Scheffers & Coles, 2000), habenular complex (Ullsperger & Cramon, 2003), and the supplementary eye field (Stuphorn, Taylor, & Schall, 2000).

The executive control network is generally regarded as being important for performance monitoring (Ridderinkhof, Wildenberg, Segalowitz, & Carter, 2004). Christoff, Gordon, Smallwood, Smith, and Schooler (2009) showed that mind wandering behaviour not only recruits the default network but also some regions associated with executive control. Activation of these networks was found to be greatest during periods presumed to be associated with relatively deep levels of mind wandering. This suggests that there may be some tradeoff between performance monitoring and mind wandering (i.e., it could be difficult to do both at once). If so, this might elucidate a mechanism by which an off-task train of thought might be likely to be perpetuated (an attenuation of performance monitoring that might otherwise contribute to the off-task episode reaching awareness and then potentially being terminated more quickie). Thinking more generally about this in the context of traditional resource-based models, the basic proposition that cognitive and/or neural resources which could otherwise go towards supporting good performance in the primary task (including due to contributions related to adequate monitoring) are directed elsewhere leads to predictions that some inherent tradeoff may exist between performance monitoring and pursuing an off-task line of thinking.

Several lines of behavioural evidence similarly suggest a tendency for a tradeoff between mind wandering and performance monitoring. The more detailed encoding found to take place during periods associated with greater levels of task focus (Smallwood, Baracaia, Lowe, & Obonsawin, 2003) could make errors more likely to be noticed in that context. If so, less effective performance monitoring while mind wandering might be expected. The idea that mind wandering impairs performance monitoring also agrees with a similar interpretation of results from a continuous tracing task (Kam, Dao, Blinn, Krigolson, Boyd, & Handy, 2012). This is also generally consistent with the idea that evaluative processes supporting good comprehension might break down and/or cease during periods of mindless reading (Reichle, Reineberg, & Schooler, 2010).

The preceding paragraphs have briefly described what performance monitoring is, as well as how it might be affected by mind wandering. Although not the intention for Experiment 1, these data can be used to test the hypothesis that mind wandering impairs performance monitoring by checking whether estimates become less accurate as greater degrees of that behaviour are reported. However, relative differences in task focus might predict how accurately participants can estimate their letter-detection score for reasons not directly related to performance monitoring. As expected, reports indicating greater levels of focus were associated with better performance in these data. Given the potential for an anchoring heuristic to be employed in this task (if estimating score based on counting number of errors), better performance may simply be easier to estimate. Thus, if greater focus is associated with better performance, and better performance is easier to estimate in this task, then participants with better focus may also make more accuracy estimates for reasons that have nothing to do with changes in performance monitoring.

The above consideration not withstanding, recall that the models presented in the results section demonstrated apparent contributions to probe response relating to somewhat dissociable sources of variance. The direction score estimates erred was interpreted as one source (i.e. overestimated or underestimated, relating to perception of performance affecting reporting behaviour) and the absolute value of the deviation of score estimates from actual performance another (interpreted as more proximally relating to efficacy of performance monitoring). The means associated with a model using a predictor related to the absolute value of the deviation of score estimate from actual performance showed that probe responses indicative of less focus were associated with larger average score estimate error (i.e. were less accurate). This is consistent with the idea that mind wandering impairs performance monitoring.

Implications. Various theoretical implications emerge from my interpretation of these results. To begin with, the preceding discussion about performance monitoring suggests relative deficiencies in such behaviour may compound problems arising from mind wandering. If an awareness of performance decrements contributes to the perception that one's mind has wandered, that suggests engaging in more regular and accurate performance monitoring should provide a greater probability of more quickly gaining awareness that one's attention has lapsed, and therefore (assuming attention is successfully refocused) also reduce the probability of serious consequences of mind wandering manifesting. It follows that mind wandering episodes might be more likely to reach meta-awareness if the frequency of any provided feedback is increased (and vice versa). This would seem to fit reasonably well with one possible explanation as to why interpolated memory tests were found to reduce mind wandering (Szpunar, Khan, & Schacter, 2013). An elevated rate of feedback might also increase motivation, which could somewhat independently reduce mind wandering (Seli, Schacter, Risko, & Smilek, 2017). Some tasks may also lend themselves to 'gamification', which could further enhance any associated motivating effects of feedback. This general idea also has implications for tasks that become automatized and do not require focussed attention for good performance. Mind wandering episodes that occur in those contexts might be less likely to reach meta-awareness on the basis of a performance-based heuristic (if performance in those tasks is less likely to be negatively impacted by mind wandering on account of automatization rendering focussed attention unnecessary for good performance).

Building on the idea that feedback can be incorporated into a task in such a way as to benefit meta-awareness, consider how a similar idea might be applied to interventions aimed at assisting populations that struggle with a lifelong pattern of chronic attentional lapses encountered in everyday life. If paying attention to one's own performance can be a useful cue for increasing meta-awareness of these lapses then people who belong to a demographic for which the preceding description is particularly applicable might benefit from a form of training built on enhancing performance monitoring. This could amount to helping them devise better strategies for continually and more accurately reappraising their performance as a heuristic that would allow them to more rapidly detect when their mind has wandered, providing a cue to refocus attention on a primary task. One potential stumbling block for such training would be unintentionally promoting 'task-related interference', stereotype-threat, and/or ironic suppression-like effects (McVay, Meier, Touron,& Kane, 2013; Stawarczyk, Majerus, Van der Linden, & D'Argembeau, 2012; Mrazek, Chin, Schmader, Hartson, Smallwood, & Schooler, 2011; Schuster, Martiny, & Schmader, 2015; Wegner, 1997; Wenzlaff & Wegner, 2000).

Another implication that follows from the interpretation of my results is that it provides a plausible mechanism which might contribute to the tendency of individuals with higher relative working memory capacities to report lower average levels of mind wandering (McVay & Kane, 2009). This robust association between working memory and mind wandering has been explained in various ways, including with reference to constructs that are highly correlated with working memory (i.e., differences in cognitive control, available resources, inhibition, distractibility, etc.). However, one alternative possibility follows from a tendency for individuals with higher working memory capacities to be more likely to demonstrate good performance (which could be expected for various kinds of tasks). They may then infer strong task focus based on that good performance, independent of their actual levels of mind wandering. This would effectively amount to confounding actual levels of mind wandering with performance for individuals with higher working memory capacities, assuming a similar heuristic is at play as has been applied to my interpretation of the results from Experiment 1. This idea that the contents of working memory might influence not only what could be conceived of as actual task focus, but rather perception of task focus, is consistent with a proposition made by Dixon and Bortolussi (2013) (and Dixon & Li, 2013) that probes are formed based on the retrospective assessment of the contents of working memory. Ideas related to the relationship between working memory and mind wandering will be further pursued in the general discussion.

One potentially critical methodological implication of these results is that it may not always be defensible to rely on performance as a means to validate mind wandering reports. As this kind of approach is sometimes taken in the mind wandering literature, the interpretation advanced here raises cautions about the extent to which it can be relied upon. The modelling described above does not suggest that actual task performance explains no variance associated with self-reports for reasons related to resource allocation (which could be a defensible rationale for looking to performance as a means to validate reports). Rather, that some of the variance associated with changes in performance may be related to reports due to the explicit (or perhaps sometimes implicit) use of perception-based information to derive them in the first place. Estimating the relative proportion of variance associated with these distinct sources could help clarify the parameters under which it is reasonable to use performance to validate reports.

A final methodological note relates to the use of two probes to measure task focus across different aspects of a dual-task. As was the case in Dixon and Li (2013), the use of two probes to index separable elements of a dual-task were found to produce responses that were relatively independent. It may also be the case that using multiple probes to assess how task focus is distributed across various dimensions of a relatively complex task may provide experimental benefits in certain situations, such as affording more sensitive tests of particular hypotheses. For example, evidence for the modest effects related to perception of performance observed may have been less likely to be obtained if a single common probe was used, assuming that would have effectively diluted the impact of the manipulation on probe response (by collapsing across aspects of the dual-task). Multiple probes might also allow for easier tracking of trade-offs. It could also offer a potentially more ecologically valid way of conceptualizing how task focus is compartmentalized across different aspects of certain complex tasks. For example, it might be useful to think of some tasks as having separate components associated with dissociable levels of attentional resources allocated towards them rather than necessarily always having a singular level of attention that is uniformly distributed. For example, attending more closely to one element that is expected to change in the near future, while more intermittently monitoring a second element for which there is no reason to expect imminent change. If so, the use of two probes could prove informative for testing certain predictions. These general ideas suggest that there may be various theoretically motivated reasons for considering the use of multiple probes to gauge mind wandering and/or focus in some contexts, rather than the traditional use of a single general probe.

The results of Experiment 1 support my hypothesis that perception of performance affects the development of mind-wandering reports. Two particularly theoretically important implications follow from the interpretation of my results. Firstly, among other things, one source of information that people rely on to make inferences about their relative level of task focus is perception of performance. This speaks to a cognitive mechanism associated with the development of mind-wandering reports. Secondly, validating reports based on performance risks misunderstanding the relationship between performance and probe response.

Experiment 2

The starting point for the second experiment was the question of whether people may be differentially willing to report mind wandering contingent on various idiosyncratic differences, such as attitudes, beliefs, and personal experience with the phenomenon. One prediction was that people who regard mind wandering less favourably (e.g., consider it a serious problem with few or no benefits) may be more hesitant to identify their own behaviour as meeting this description, reflected in a reduction in such reports. To test this hypothesis, I attempted to draw attention towards possible negative or positive consequences of mind wandering that were provided after a relatively neutral initial definition provided in the instructions. I predicted that contextualizing mind wandering as involving possible costs would make participants more hesitant to identify their own mental state in those terms and therefore report it to a lesser degree. Conversely, the opposite was predicted in the positive condition.

The paradigm used in the second experiment was the same as that described for Experiment 1, although without any estimates or feedback. A manipulation was also added that changed how mind wandering was contextualized during the presentation of the instructions for the experiment. In the negative condition, examples of possible negative consequences of mind wandering were listed after the initial instructions. In the positive condition, examples of possible positive consequences of mind wandering were listed after the initial instructions. In the control condition, no examples of consequence of mind wandering were mentioned following the initial instructions.

Method

Design. The independent variable of instruction condition was manipulated between subjects across three levels. Subjects were randomly assigned to either the control condition, the positive condition, or the negative condition. Assignment of stories to conditions, as well as order of story presentations, was counter-balanced across subjects. The dependent variables were the same as in the first experiment.

Participants. Fifty-six subjects participated in this study in exchange for course credit. One subject was excluded on account of their behaviour leading to chance levels of performance.

Materials. Stories ranged from 710-1154 words, with a mean length of 958 words (SD = 226.52). In all three conditions, the following neutral definition of mind wandering was displayed at the beginning of the experiment:

> We are interested in studying mind wandering, or 'task-unrelated thought'. This term refers to thinking about content that is not directly related to the current task being undertaken (e.g. thinking about plans for the evening while listening to a lecture). You will occasionally be asked to report to what extent you were mind wandering just prior to being asked, using a scale of 1-7.

No further context was provided in the control condition before the experiment began. Participants in the negative condition began the experiment after reading the following message:

> Mind wandering can have negative consequences. These involve comprehension deficits related to recognition and/or recall of material, difficulties in making inferences related to material, and insufficient depth of processing to produce fully developed representations. There are associations between mind wandering and GRE scores.

In the positive condition, participants began the experiment after reading this message:

> Mind wandering can have positive benefits. These involve enhanced mood, insight and problem solving. Other benefits relate to taking a mental break, as well as planning for the future. There are associations between mind wandering and creativity.

Apparatus. All stories were presented on 51 cm iMac computer. Sentences were centred, presented in 12-point Times font, and viewed at a distance of approximately 50 cm under normal room illumination.

Procedure. The procedure was the same as that used in the first experiment except that no estimates or feedback were provided, and only a single self-report measure of task focus on the experiment as a whole was collected. The rationale for including two independent self-reports in Experiment 1 (associated with different aspects of the dual-task) was to more directly link reports to the manipulated feedback and accuracy estimates. As this logic did not apply here, a single self-report measure was used in Experiment 2 for the sake of simplicity. This consisted of a self-report probe phrased as follows: "Please Respond to the Statement 'I was mind wandering just prior to this screen appearing.'" As with Experiment 1, responses again ranged from 1-7, associated with the verbal labels: "Strongly disagree," "Somewhat disagree," "Slightly disagree," "Neither agree nor disagree," "Slightly agree," "Somewhat agree," and "Strongly agree."

As with the first experiment, participants completed a block of comprehension questions after finishing the reading portion of the experiment. After answering the comprehension questions, they also responded to several questions designed to assess attitudes about mind wandering. They used the same seven-point likert scale as was used for the mind wandering self report (using the same verbal labels) to answer five questions that were phrased as follows:

Q1. I usually experience some positive effects of mind wandering during my everyday life

Q2. I experienced some positive effects of mind wandering during this experiment

Q3. I usually experience some negative effects of mind wandering during my everyday life

Q4. I experienced some negative effects of mind wandering during this experiment

Q5. I consider it important to always limit mind wandering as much as possible

These questions were designed to roughly index general attitudes related to experiences of mind wandering, framed in the context of either a recent (Q2, Q4) or more general (Q1, Q3, Q5) history of the reporting subjects. These were intended to evaluate whether there was an overall effect of general attitudes on frequency of mind wandering reports, as well as whether assignment of condition affected their perception of recent mind-wandering experiences.

Results

This experiment tested the hypothesis that the way the concept of mind wandering was introduced in the instructions presented at the beginning of the experiment would affect probe responses. It was expected that describing negative consequence of mind wandering would make participants less comfortable identifying that state, resulting in reductions of such reports. Conversely, it was expected that describing benefits of mind wandering would make participants feel more comfortable reporting that state and therefore result in reporting higher rates of it.

Figure 2 presents mean probe response by block and condition. Contrary to my predictions, there was little evidence of changes in reported rates of mind wandering throughout the experiment in either the negative or positive condition. However, some effect of the manipulation seems apparent in the first block of the negative condition. Rather than reporting decreased rates of mind wandering as predicted, participants reported higher rates of mind wandering in the first block of the negative condition.

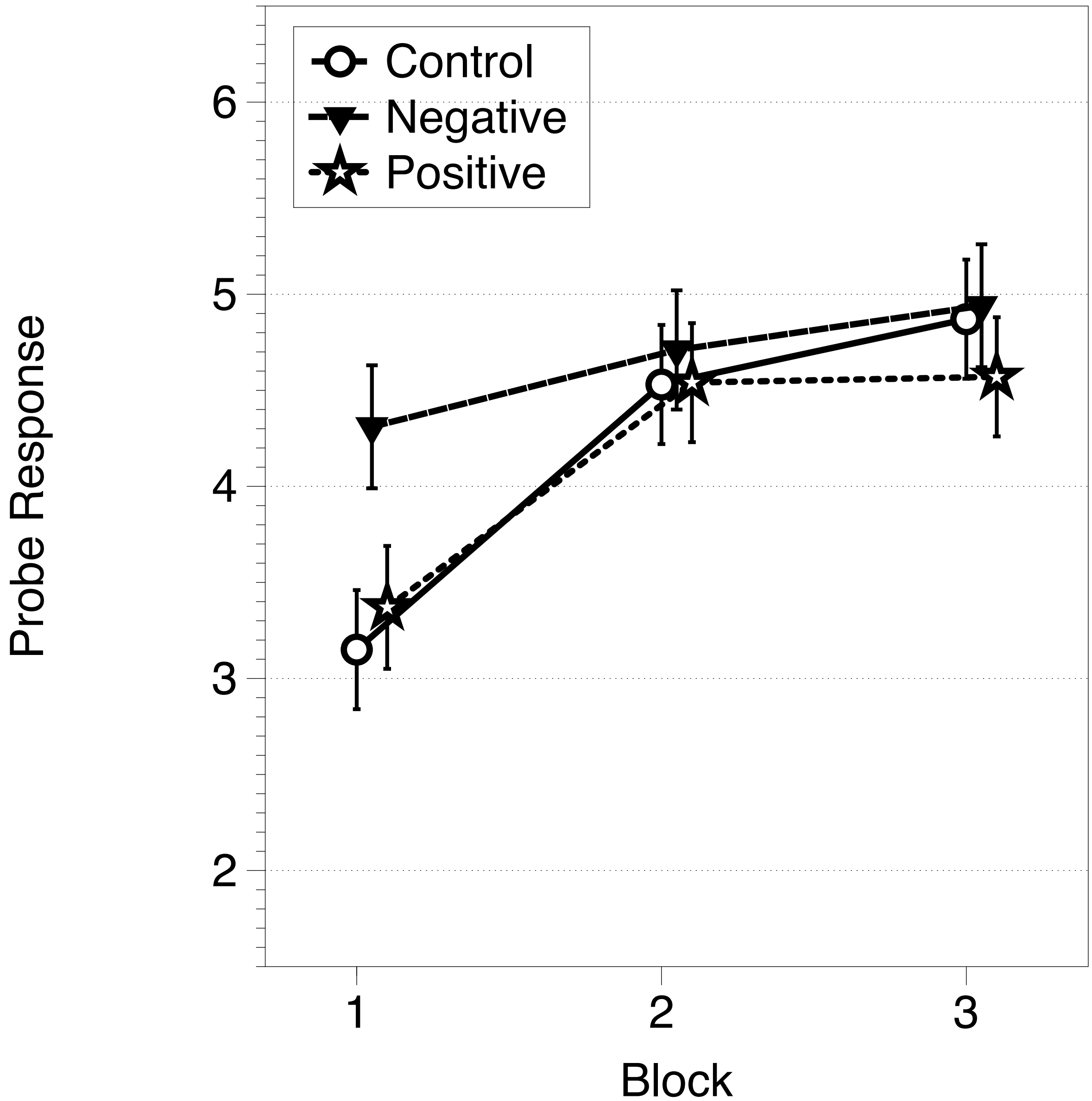

Figure 2. Mean probe response by condition.

As with the first experiment, analyses relied on linear mixed effect models embodying different theoretical interpretations. These are then compared using likelihood ratios to quantify the strength of the evidence for each. The first step in the modelling began by predicting probe response as a function of time-on-task (block) and letter-detection performance. As with the previous experiment, accounting for as much variance as possible that is not expected to directly relate to my hypothesis should allow for a more sensitive test of my manipulation.

Probe response. Figure 2 clearly suggests an effect constrained to the first block of the experiment. A focussed approach to modelling would therefore be to only consider data associated with that first block. Although this constitutes a post-hoc approach to the analysis, concentrating on that block can be argued to be defensible given the experimental design (i.e., in which the manipulation is constrained to the very beginning of the experiment). The following model comparisons were based on data from the first block. Condition is a better predictor of probe response than a null model, though only marginally so ($\lambda_{adj} = 2.65$). A factor was constructed which embodied a contrast between the negative condition and the other two conditions. A model using this contrast to predict probe response was better than a null model ($\lambda_{adj} = 6.67$).

Defunnelling questions. As explained in the method section, several exploratory questions were included at the end of the experiment to assess attitudes about mind wandering. No overall relationship was found between any of the five attitude-related responses and mean probe response throughout the experiment. This therefore produced no evidence to support the idea that perceiving mind wandering as being associated with more negative (or positive) experiences in everyday life affects the frequency with which it is reported during experiments. However, the means suggested a possible effect of condition on responses to the question, “I experienced some negative effects of mind wandering during this experiment." Participants in the positive condition reported less agreement about effects of that description than the control, while those in the negative condition reported greater agreement than controls (Table 6). The elevated perception of negative effects of mind wandering during the experiment in the negative condition would be consistent with the interpretation that the instruction manipulation encouraged participants to attend to difficulties with performance to infer mind wandering. To quantify the strength of the evidence for a clear difference in mean response values across condition, a general linear model was constructed to predict the response to defunnelling question #4. A model predicting this response based on condition was better than a null model (λ_{adj} = 6.23). This supports the idea that participants in those conditions (for whatever reason) noticed more or less negative consequences of mind wandering, depending on the examples presented along with the initial instructions. Although somewhat indirect, this could be taken as a form of a manipulation check in so far as it seemed to affect how they perceived their own mind-wandering behaviour.

Table 6

Mean Response to Defunnelling Question 4 (and Standard Error).

Condition	Mean Response (1-7)
Negative	4.75 (0.12)
Control	4.18 (0.12)
Positive	2.75 (0.06)

Discussion

This pattern of results obtained in the second experiment was not what was predicted. It was expected that the negative and positive condition would produce decreased and increased frequencies of mind wandering reports (respectively) relative to control. This was based on the rationale that information contextualizing mind wandering at the beginning of the experiment by associating it with either possible benefits or costs would make participants feel more or less comfortable reporting it. Contrary to predictions, reports of mind wandering were actually elevated in the first block of the negative condition, while reports in the positive condition were comparable to control.

One possible explanation for why the manipulation could have changed reporting behaviour is that participants may have begun the experiment holding the examples of possible consequences of mind wandering in working memory to help them make sense of how to interpret and report their own mental state. The effect obtained in the first block represents three probe breaks. Across this interval, the task of encoding content related to the comprehension task would have competed with the contextualizing information (i.e. the manipulation) and could have therefore gradually displaced it from working memory. If so, this would likely result in a similar pattern of any discernible effect attributable to the manipulation essentially tapering off as the experiment progressed as to what was observed. It also seems reasonable to expect that participants might develop their own ideas about how best to gauge their mental state as they become more familiar with the experience-sampling paradigm. This could also manifest as a diminishing effect of the manipulation across time. This might also speak to the idea that there are practice effects associated with reporting behaviour.

The main finding from Experiment 1 might also afford some insight into the elevated reports in the negative condition. The relationship between variables associated with perception of task performance and mind wandering reports in that experiment suggests that people are sensitive to indications of the former when developing the latter. A similar mechanism may be at play in the negative condition of the second experiment. By drawing attention to the possibility that mind wandering can lead to performance detriments, this may have resulted in participants being more likely to infer their attention had lapsed if/when they noticed letter-detection response errors or comprehension difficulties. Participants in the negative condition reported perceiving more negative effects of mind wandering during the experiment than the other two groups, while those in the positive condition reported perceiving less. This would be consistent with the interpretation that reports in the first block of the negative condition were elevated because the manipulation encouraged them to attend more closely to indicators of negative consequences that were then used to help infer mental state. Among other things, this may also reflect a representativeness bias (Kahneman & Tversky, 1972). Given that the manipulated examples provided at the beginning of the experiment emphasized either benefits or consequences of mind wandering, participants may have used this as a sort of template to gauge what level of mind wandering to report. This contextualizing information may have also produced an availability bias of sorts (Tversky & Kahneman, 1973), in which possible benefits or consequences were recalled more easily when introspecting about mind wandering.

If the above interpretation about the manipulation changing the nature of the information that participants relied on when forming reports is correct, one question that follows is why no change in reports was observed in the positive condition. One simple explanation for that difference could be that negative consequences of mind wandering are more likely to manifest than benefits in the current paradigm, given the particular task demands involved. It could also be the case that, generally speaking, the potential for positive consequences of mind wandering manifesting might be less directly related to the task itself (as compared to negative consequences). Examples of such seemingly task-unrelated benefits include a mood lift because you were thinking about something off-task that interests you (Franklin, Mrazek, Anderson, Smallwood, Kingstone, Schooler, 2013) or a serendipitous insight into some problem you've recently encountered elsewhere (Baird, Smallwood, Mrazek, Kam, Franklin, & Schooler, 2013). Conversely, the probability of negative consequences of mind wandering manifesting could be more contingent on the specifics of the task at hand. One's chances of having positive benefits follow from mind wandering might therefore remain relatively invariant (and perhaps relatively low) across tasks, while paradigms like the one used throughout this dissertation might more readily promote negative consequences of mind wandering. This relative balance of costs and benefits, and how those change across tasks and contexts, could be a good target for future work.

These ideas are broadly consistent with the context regulation hypothesis which predicts the likelihood of particular consequences of mind wandering (e.g., benefits vs. costs) are going to be strongly related to, among other things, the task context in which individuals find themselves when it occurs (Smallwood & Andrews-Hannah, 2013). So, according to this kind of explanation, participants noticing negative or positive effects may have been more likely to infer that they had mind-wandered in each respective condition for similar reasons (i.e., related to the specifics of whichever contextualizing examples they saw). However, evidence consistent with the information related to negative consequences may have simply been more likely to manifest here, which could account for why clear evidence for the effect was only found in that condition.

As was the case with the first experiment, interpreting the nature of the effect of condition depends on determining whether the manipulation affected actual rates of mind wandering, reporting behaviour, or both. One possible reason why actual rates of mind wandering rates could have increased in the negative condition is the idea of 'stereotype threat,' in which expectations about negative consequences of mind wandering can lead one to essentially mind-wander about the negative consequences of mind wandering (Mrazek, Chin, Schmader, Hartson, Smallwood, & Schooler, 2011; Schuster, Martiny, & Schmader, 2015). This could be considered similar to a proposed category of off-task thought known as 'task-related inference,' in which concerns about current/recent performance have a cascading negative effect on subsequent performance (McVay, Meier, Touron, & Kane, 2013; Stawarczyk, Majerus, Van der Linden, & D'Argembeau, 2012).

As before, although it is not a given that the dependent measures used here would necessarily be sensitive enough to detect any such changes, some accompanying behavioural change would be expected if the manipulation increased actual mind wandering in the present experiment. No clear changes were observed for measures of performance, mean response time, or response time variability. These are shown in the Appendix 3 (Tables A3 and A4). So while this alternative cannot be conclusively ruled out, the balance of evidence points towards contributions related to changes in reporting behaviour in the first block of the negative condition, rather than differences in actual levels of mind wandering.

Implications. The interpretation applied here hints at a possible individual difference that could be relevant for understanding how people go about monitoring and evaluating mind wandering. Assuming enough variability, expectations for particular kinds of consequences developed over a lifetime of mind wandering could predispose some people to pay attention to different kinds of information than others while assessing their own relative levels of task focus. Consider that someone who chronically experiences problems inhibiting and/or terminating off-task thoughts may be more likely to commonly experience deleterious consequences of mind wandering than the average person and may therefore be more likely to associate the concept of mind wandering with consequences of that nature. Accordingly, they may rely on certain kinds of cues more than others would when making judgments about their level of focus (e.g., noticing a performance error). In contrast, someone who exhibits excellent control over their mind wandering and is able to curtail it whenever they choose may be more likely to associate mind wandering with positive effects and may accordingly be more likely to rely on information consistent with those experiences to infer mental state. This possible individual difference in monitoring/evaluating behaviour could be an adaptive strategy to better regulate mind wandering by focussing on the kind of consequences that are most likely to occur for an individual.

Building on the idea in the preceding paragraph, this sort of process could also be expected to drive some individual difference in attitudes held about mind wandering. For example, consider the previous example of someone with comparatively weaker control who might run into more problems as a result of mind wandering in their daily lives. This might not only predispose them to pay attention to particular kinds of indications based on expectations (e.g. negative consequences), yet also promote the development of a more negative attitude towards it. Through that lens then, the manipulation might be thought of as having effectively induced a more negative or positive set of expectations and/or attitude towards mind wandering in the short term. This distinction between short and long-term changes in attitudes might be comparable to the difference between a state and trait variable.

This line of thinking generates a set of related predictions that will be revisited later in this dissertation ('the familiarity hypothesis'). It essentially consists of three related predictions. Firstly, people who have better cognitive control should experience fewer negative consequences of mind wandering, and more positive ones (and vice versa). Secondly, this distinction should change what information people attend to while deliberating about their own mental state. This has clear implications for reporting behaviour. Thirdly, on account of the first two predictions, people with relatively weaker cognitive control should develop more negative attitudes about mind wandering.

An alternative interpretation of a recent study using a sample of children follows from my 'familiarity hypothesis' outlined above. Zhang, Song, Ye, and Wang (2015) found children in their study with more positive attitudes towards mind wandering did not produce reports that corresponded as closely with their performance as children who reported holding a more negative attitude. The authors interpreted this difference as reflecting inaccurate reports in the group with the positive attitudes due to a bias they hold. However, the proposition outlined in the preceding paragraph offers an alternative explanation. It is possible the children who seldom experience negative consequences of mind wandering don't infer such lapses based on performance errors because they don't experience them as a consequence of mind wandering frequently enough to develop an association. Rather, they may attempt to infer mind wandering based on the same positive outcomes that drove their divergence in attitude in the first place (e.g., identifying one's own mind wandering after gaining awareness of having a creative insight into something unrelated to the primary task). If this were true, and if the children who commonly experience negative effects of mind wandering have a tendency to likewise rely on cues they more commonly experience concurrently with mind wandering (such as performance errors), then the pattern of results obtained by Zhang et al. (2015) may be due to reasons that have nothing to do with group differences in validity. As a middle ground alternative, the reports provided by the group with the positive associations may be slightly less valid than their counterparts with differing attitudes simply because they aren't utilizing what could be an informative cue to gauge their mental state (performance lapses). If my interpretation is correct, then changes in reporting behaviour related to attitudes may already be apparent at a relatively young age.

Another implication of my interpretation of these results is that definitions of mind wandering presented at the beginning of experiments can affect how people introspect about their mental state and respond to associated probes. This includes any contextualizing examples that may be provided. Instructions which introduce the concept of mind wandering can differ considerably across studies, and this could represent a seldom accounted for source of variance in probe responses. In particular, these instructions often attempt to reassure participants that it is perfectly acceptable to report mind wandering, and indeed that it is expected to occur relatively frequently based on prior work. This may result in an inflated frequency of reports to match expectations in some situations. My interpretation also finds some precedent with results reported by LeFevre and Dixon (1986) in which misleading examples provided in conjunction with experimental instructions distorted the manner in which participants responded to the task. This even occurred at the expense of following ostensibly correct information provided in the body of the instructions themselves that nevertheless conflicted with the examples provided.

The fact that suggesting to participants that mind wandering is more or less frequent in the general population can change reports also demonstrates a sensitivity to expectations related to the way the topic is introduced to experimental participants (Bastian, Valentinm, & Sackur, 2014). Those authors interpreted this effect as reflecting a change in the threshold which participants felt they needed to meet in order to report mind wandering. This raises another possible interpretation of the results from the second experiment: warning participants about costs associated with mind wandering may lead to the perception that it is a more problematic phenomenon, at least as compared to the information presented in the control and positive conditions. This may have implied an urgency in identifying mind wandering as soon as possible after it happens (so as to refocus attention on the primary task), which could have resulted in a criterion shift similar to that interpreted in Bastian, Valentin, and Sackur (2014). If participants decide that the problematic consequences of mind wandering means the cost of a miss outweighs that of a false alarm, this would be expected to produce such a change in criterion. Attempting to better understand variance in reporting behaviour relate to these kinds of factors using a signal detection theory framework could be a productive direction for future work (Macmillan, 2002).

In summary, although not matching predictions, the results of the second experiment provide additional insight into factors relevant for understanding variation in reporting behaviour. Elevated reports of mind wandering in the first block of the negative condition demonstrate an apparent effect on reporting behaviour related to what information is attended to. This interpretation is consistent with the defunelling questionnaire results for that condition, endorsing the impression that more negative effects of mind wandering were noticed throughout the experiment. Furthermore, the transient nature of the effect of the manipulations suggests that reporting behaviour is dynamic and amenable to recent experience. This last idea hints at the possibility that day-to-day experiences with mind wandering could modify how people go about evaluating their own level of relative focus. If so, this may be one influential factor in predicting different styles of reporting behaviour.

Experiment 3

The first experiment produced evidence that perception of task performance is something participants consider when self reporting mind wandering. My interpretation of the second experiment was suggestive of a similar sort of inferential process in which the manipulation applied in the negative condition directed attention towards indicators of performance difficulties attributable to mind wandering and resulted in an inflated frequency of such reports in the first block. The intention for the third experiment was to further examine what kinds of information participants rely on when introspecting about mental state. Based on the previous results, I predicted that some participants would endorse the idea that perception of performance is one heuristic employed when self reporting. I also predicted that other factors unrelated to perception of task performance may also be reported as additional sources of information participants considered when forming their reports. The third experiment was therefore designed to follow up on the previous two experiments, as well as extend these results by examining other potential sources of information which participants rely on when self-reporting mental state.

A modified version of the same paradigm used in the previous two experiments was again used here (albeit without the instruction manipulation or estimates/feedback component). In addition, participants in the third experiment also completed a descriptive inventory at every probe break. This consisted of completing a pen and paper-based checklist in which participants endorsed any number of 18 descriptions that may correspond to specific kinds of thoughts they had when responding to the probe. Items were mostly split between two broad categories: the first seven related to task-related thoughts and items 8-16 to task-unrelated thoughts. The 17th item conveyed uncertainty about having a clear idea as to why the probe response that was selected was made. The 18th item reflected an 'other' category, in which an open-ended written description could be provided. At each probe break, participants first reported their probe response, then completed their descriptive inventory. Participants also provided a confidence rating related to the self-report process before returning to the story.

Method

Design. There were no manipulations in this third experiment. The dependent variables were the same as in the first two experiments, along with a cluster of items related to a descriptive inventory which subjects now completed during the probe break, and a self-reported confidence rating. These new measures are described in the procedure. Assignment of stories to conditions, as well as order of story presentations, was counter balanced across participants.

Participants. Forty-nine subjects participated in this study in exchange for course credit.

Materials. The stimuli used were three short stories taken from Grimm's fairy tales. Stories ranged from 710-1154 words, with a mean length of 958 words (SD = 226.52).

Participants also completed several questionnaires related to mind wandering approximately six months prior to participating in this experiment (referred to as 'Mass Testing' in the Discussion section). These included a validated questionnaire to measure overall propensity for spontaneous and deliberate mind wandering, as well as everyday cognitive errors (Carriere, Seli, & Smilek, 2013). A version of the 'Attentional Control: Distraction and Attentional Control: Shifting Scales' (Derryberry & Reed, 2002), modified by Carriere, Seli, and Smilek (2013), was also used as an index of general attentional functioning. Additionally, five exploratory questions about attitudes towards mind wandering were also included. These were written by the author of this dissertation and have not been validated. All questionnaires are presented in the appendix.

Five exploratory questions about attitudes towards mind wandering were also included. These were written by the author of this dissertation and have not been validated. All questionnaires are presented in the appendix.

Apparatus. All stories were presented on 51 cm iMac computer. Sentences were centred, presented in 12-point Times font, and viewed at a distance of approximately 50 cm under normal room illumination.

Procedure. The procedure was the same as used in Experiment 2, with the additions of the descriptive inventory and confidence ratings. Participants were instructed to record these measures every probe break, after responding to the probe question. The descriptive inventory (shown in Table 7) responses were recorded by marking the box(es) adjacent to any/all items corresponding to thoughts that participants may have had while determining their response to the mind wandering probe question. Confidence ratings were described as a general sense of confidence in their overall report (probe response and inventory items selected, all taken together). These were provided on a Likert-type scale of 1-7.

Table 7

Probe Response Inventory Items

"I thought I was on-task because…" (category label on inventory)

1. I was thinking about a character or place in the story
2. I was visualizing something from the story
3. I was thinking about the sequence of events in the story
4. I was thinking about whether I was fully comprehending the story
5. I remember making one/more correct responses recently (letter-detection task)
6. I remember one/more word(s) that were presented recently

I thought I was off-task because… (category label on inventory)

7. I was visualizing something task irrelevant
8. I was 'talking to myself' about something task-irrelevant
9. I was thinking about something task-irrelevant that happened to me in the past
10. I was thinking about/planning for something in the future that is task-irrelevant
11. I was thinking about something task-irrelevant in my environment (noise, etc.)
12. I do not remember thinking about anything specific
13. I felt like I was mindlessly going through the experiment without fully processing what I was reading (on 'autopilot')
14. I remember making one/more incorrect responses recently (letter-detection task)
15. I do not remember one/more word(s) that were presented recently

Other (category label on inventory)

16. I'm not really sure why I made the self-report that I did.
17. Other, please specify _____

Results

The primary goal of Experiment 3 was to produce descriptive data related to how individuals introspect about their own relative level of mind wandering. The inventory item response distribution shown in Figure 3 provides a general impression of the range of information participants reported considering while responding to mind wandering probes. While some items correspond to things that were rarely reported, on average about half of the 17 items were responded to affirmatively at least a couple of times per experimental session. This indicates that some participants, at least some of the time, consider a range of information while forming mind wandering reports. The correlation matrix for the inventory items is shown in Table 8.

Item #/Contents	Omit
1. I was thinking about a character, place or event in the story	
2. I was visualizing something from the story	
3. I was thinking about the sequence of events in the story	
4. I was thinking about whether I was fully comprehending the story	
5. I remember making one/more correct responses recently (letter detection task)	
6. I remember one/more word(s) that were presented recently (letter detection task)	***
7. I was visualizing something task-irrelevant	
8. I was 'talking to myself' about something task-irrelevant	
9. I was thinking about something task-irrelevant that happened to me in the past	
10. I was thinking about/planning for something in the future that is task-irrelevant	
11. I was thinking about something task-irrelevant in my environment (noise, etc.)	
12. I do not remember thinking about anything specific	
13. I felt like I was mindlessly going through the experiment without fully processing	***
14. I remember making one/more incorrect responses recently (letter detection task)	
15. I do not remember which words were presented recently (letter detection task)	***
16. I'm not sure why I made the self-report that I did	***
17. Other (please specify below, corresponding to the correct self-report #)	***

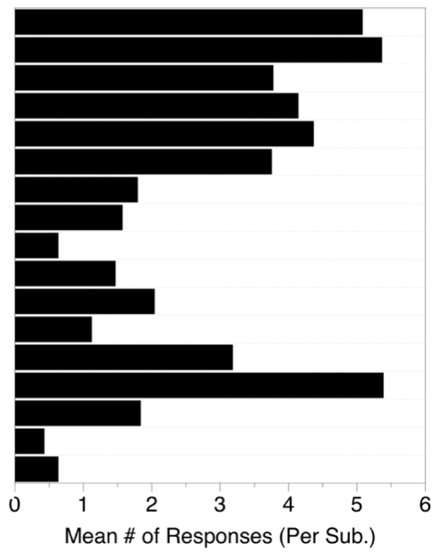

Figure 3. Inventory item response count.

Table 8

Table 8
Correlation of Inventory Items Across Participants

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Thinking about a character	1.000	0.826	0.620	0.641	0.537	0.678	0.132	0.167	0.017	0.215	0.183	-0.085	-0.360	0.424	-0.016	0.050	0.106
2. Visualizing something	0.826	1.000	0.694	0.594	0.593	0.711	0.166	0.258	0.168	0.266	0.203	0.028	-0.237	0.499	-0.084	-0.014	0.024
3. Thinking about sequence	0.620	0.694	1.000	0.643	0.609	0.676	0.193	0.234	-0.015	0.240	0.233	0.011	-0.023	0.536	0.037	0.004	0.029
4. Thinking about comprehending	0.641	0.594	0.643	1.000	0.424	0.526	0.328	0.214	-0.106	0.180	0.232	-0.070	0.045	0.354	0.203	0.029	-0.073
5. Remembering correct responses	0.537	0.593	0.609	0.424	1.000	0.812	0.237	0.288	0.084	0.328	0.362	0.076	-0.105	0.597	0.171	0.024	0.062
6. Remembering words	0.678	0.711	0.676	0.526	0.812	1.000	0.125	0.136	0.004	0.251	0.364	0.102	-0.092	0.543	0.113	0.072	0.152
7. Irrelevant visualizing	0.132	0.166	0.193	0.328	0.237	0.125	1.000	0.455	0.398	0.445	0.415	-0.076	0.327	0.274	0.320	0.161	-0.110
8. Talking to myself	0.167	0.258	0.234	0.214	0.288	0.136	0.455	1.000	0.179	0.350	0.159	-0.082	0.036	0.233	0.029	-0.065	-0.097
9. Thinking about past	0.017	0.168	-0.015	-0.106	0.084	0.004	0.398	0.179	1.000	0.319	-0.012	0.041	0.226	0.115	0.164	0.043	-0.058
10. Planning for the future	0.215	0.266	0.240	0.180	0.328	0.251	0.445	0.350	0.319	1.000	0.235	0.090	0.219	0.253	0.359	-0.072	-0.042
11. Thinking about environment	0.183	0.203	0.233	0.232	0.362	0.364	0.415	0.159	-0.012	0.235	1.000	-0.057	0.164	0.439	0.411	0.032	0.029
12. Nothing specific	-0.085	0.028	0.011	-0.070	0.076	0.102	-0.076	-0.082	0.041	0.090	-0.057	1.000	0.117	0.190	0.055	0.025	-0.060
13. Performing mindlessly	-0.360	-0.237	-0.023	0.045	-0.105	-0.092	0.327	0.036	0.226	0.219	0.164	0.117	1.000	0.220	0.257	-0.143	-0.055
14. Remembering errors	0.424	0.499	0.536	0.354	0.597	0.543	0.274	0.233	0.115	0.253	0.439	0.190	0.220	1.000	0.258	-0.126	-0.046
15. Don't remember words	-0.016	-0.084	0.037	0.203	0.171	0.113	0.320	0.029	0.164	0.359	0.411	0.055	0.257	0.258	1.000	-0.180	-0.006
16. Not sure	0.050	-0.014	0.004	0.029	0.024	0.072	0.161	-0.065	0.043	-0.072	0.032	0.025	-0.143	-0.126	-0.180	1.000	0.327
17. Other	0.106	0.024	0.029	-0.073	0.062	0.152	-0.110	-0.097	-0.058	-0.042	0.029	-0.060	-0.055	-0.046	-0.006	0.327	1.000

Confirmatory factor analysis. Confirmatory factor analysis were used to validate an underlying latent variable structure for the inventory items. The program 'lavaan' (Rosseel, 2012) was used in the R statistics environment for this purpose. Models for various plausible latent variable structures were evaluated using comparative fit indices. A comparative fit index > 0.9 has been conventionally considered to reflect an adequate fit, though a value > 0.95 has been more recently argued to be a more appropriate cutoff (Hu & Bentler, 1999). The a priori structure for how these items relate to each other spans five categories that subsume the individual item responses: story comprehension (items #1-4), letter detection (#5, 6, 14 and 15), task-unrelated thought (#7-11), subjective sense of disengagement (#12 and #13), and other (#16 and #17). Another way to think about this structure is that the letter detection and comprehension categories (#1-6,14-15) all refer to task-related kinds of processing and the rest (items 7-13) refer to items associated with task-unrelated processing (including subjective feelings of disengagement). Note that items 16 ('I'm not sure why I made the self-report that I did') and 17 ('other, please specify') distinguish themselves from the rest of the inventory items in that they are non-specific. It is therefore not clear how they might relate to the rest of the inventory items within a latent variable structure. They were seldom used by participants and exploratory analyses indicated their inclusion in various models consistently reduced the comparative fit index. Items 16 and 17 were therefore omitted from the confirmatory factor analyses presented below, leaving four latent variables.

Although plausible, the a priori latent variable structure described above yielded a less than acceptable comparative fit index ($CFI = 0.86$). The z values associated with each item indicated that items 13 ("I felt like I was mindlessly going through the experiment"; $z = 0.12$) and 15 ("I do not remember one/more word(s) that were presented recently"; $z = 0.99$) did not contribute clear improvements to the fit (i.e., explained little variance). Item 13 had been placed in the disengagement category, while item 15 was included in the letter-detection category. Removing these two items increased the comparative fit index to a level deemed acceptable by Hu and Bentler (1999). Exploratory analyses revealed that also removing item 6 ('I do not remember which words were presented recently') produced a further improvement to the comparative fix index (*CFI* = 0.98). A latent variable structure largely conforming to the a priori form initially laid out, though omitting items 6, 13, and 15, was therefore used for subsequent modelling. Figure 4 shows a description of the latent variable model.

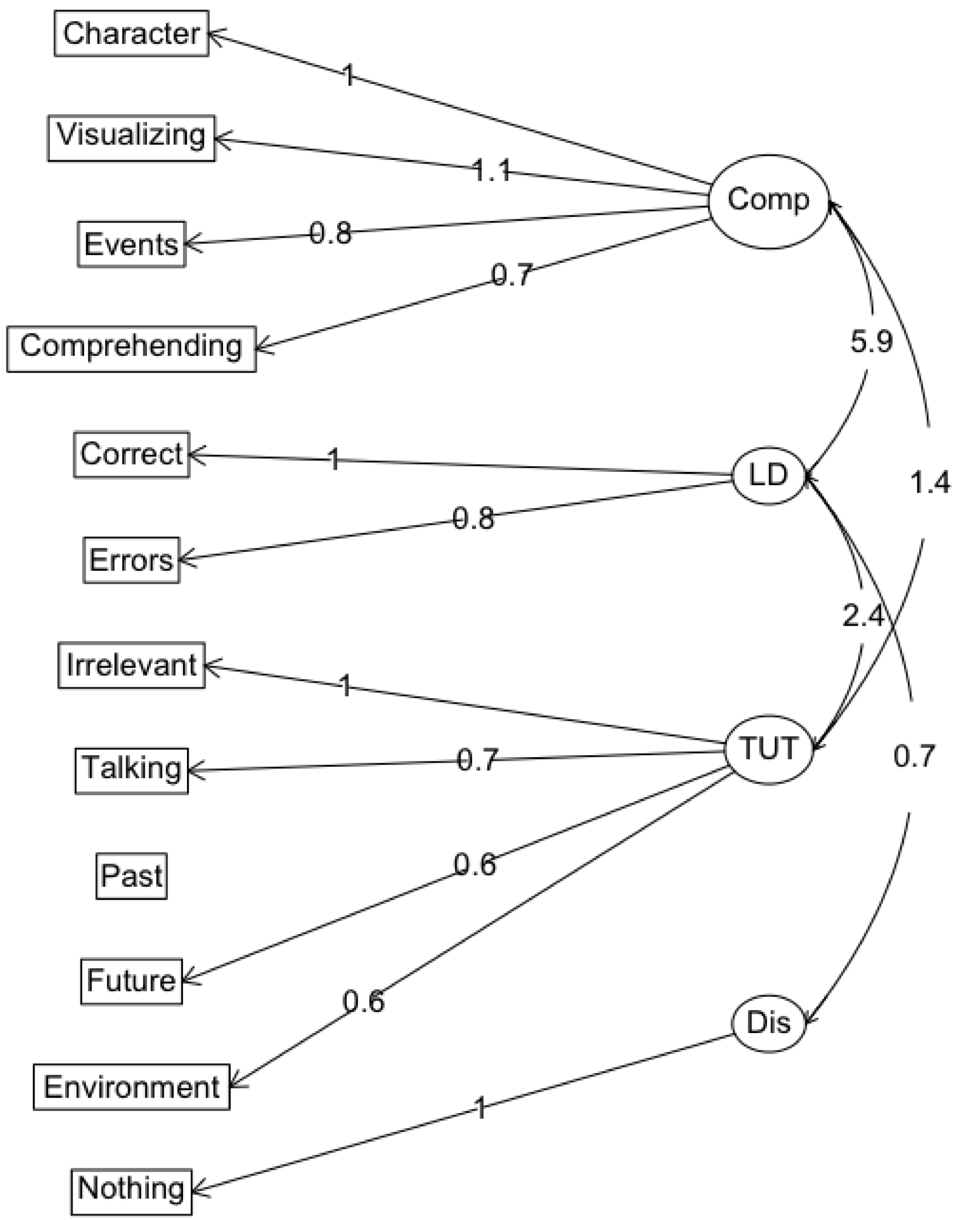

Figure 4. Confirmatory factor analysis model, showing latent variable weights and covariances between latent variables. (The weight for the “Past” item was small, 0.25.)

Hierarchical cluster analysis. Having established a defensible latent variable structure, the next step was to assess whether any overall group differences were apparent in these data. Latent variable scores were calculated for each participant across the entire experiment and these data were then assessed using hierarchical cluster analysis (for more info see Romesburg, 2004). Two clearly distinct groups emerged from this analysis (N = 31 and 18). The existence of two clearly distinct groups is apparent in the dendrogram (Figure 5). This dendrogram was drawn using a program written for the R statistics environment by Francois (2006).

Mean latent variable scores by these two groups are shown in Figure 6. On average, one of the groups reported more inventory responses per probe than the other. These groups will herein be referred to as the high and low-information groups. This tendency for the high-information group to report more items is apparent in Figure 6. On average, the first group responded to 6.65 items per self-report, while the equivalent value for the second group was 2.64. Other group differences are shown in Appendix 4 (Table A5).

The latent variable scores indicate the tendency to report inventory items associated with a particular latent variable. Although participants were always supposed to indicate at least one item per probe (even if it was the relatively uninformative item 16: 'I'm not sure why I made the self-report that I did'), variability in the number of responses provided should yield some insight into variation in the breadth of information considered while participants formed their report. Because there were various item responses related to both task-related and task-unrelated processes, number of item responses wasn't expected to distinguish participants based on extent of mind wandering.

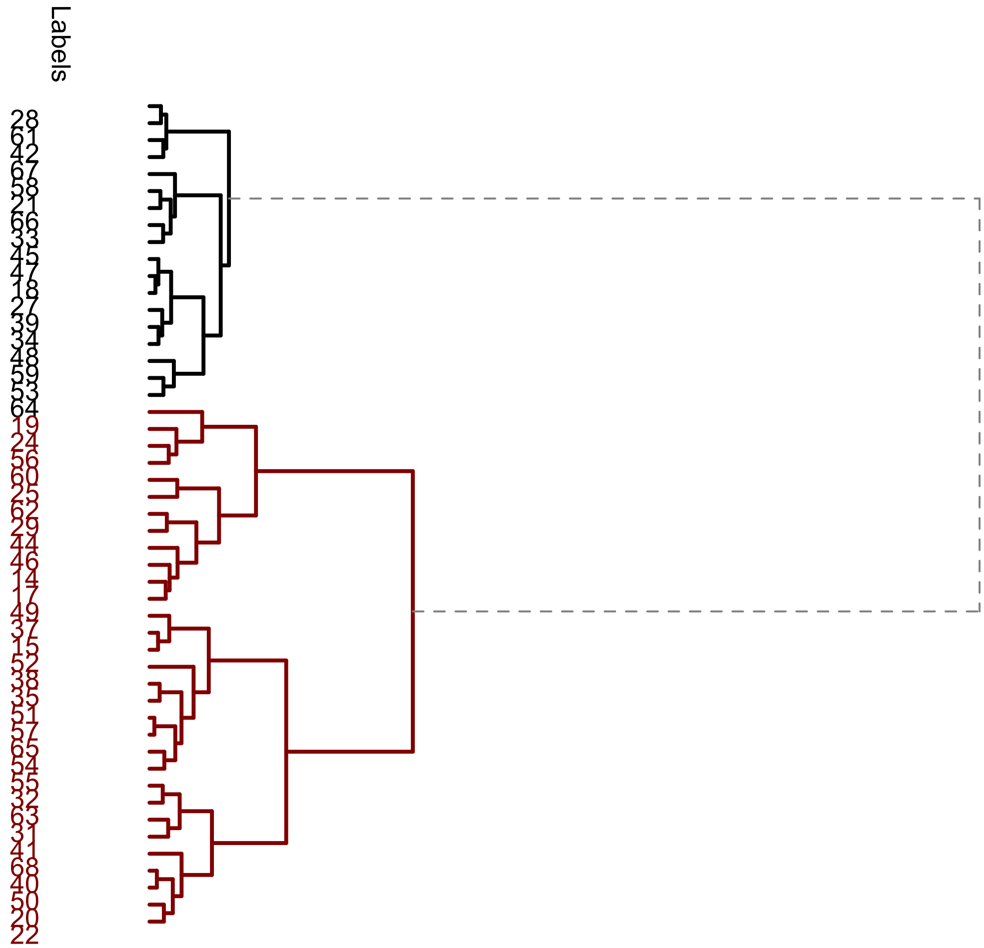

Figure 5. Cluster analysis dendrogram.

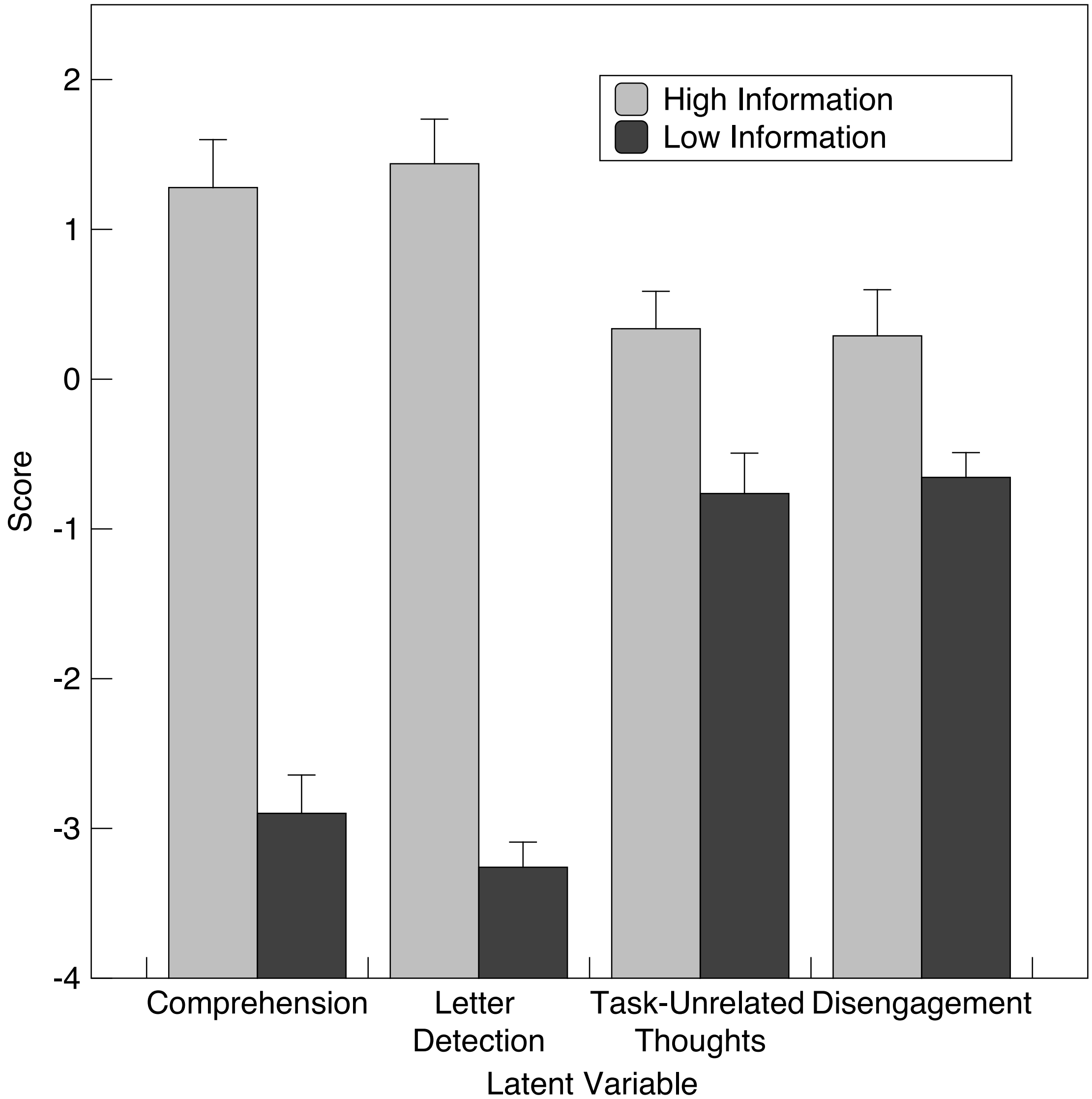

Figure 6. Mean latent variable scores (and standard errors) by group.

The high-information group had higher mean values associated with all four latent variables. While mean levels of task-unrelated thought and disengagement are relatively close in both groups, the two other latent variable means show considerably greater separation. Both of these variables, comprehension and letter detection, are related to what could be considered task-related thought. So, in addition to simply reporting more items, another way to characterize the difference between groups is that the high-information group frequently reported considering task-related thought while responding to probes, whereas the low-info group rarely did so.

Discussion

Experiment 3 provided additional insight into the underlying mechanisms driving the construction of mind wandering reports. The overall pattern of results indicates that participants endorse the idea that their reports are shaped by a range of information. Consistent with the interpretation applied towards the results of Experiment 1 and 2, it also provides converging support for the proposition that perception of performance is a factor considered by some participants while making inferences about their mental state.

A confirmatory factor analysis validated a latent variable structure for the inventory response data. This distinguished between four latent variables: task-unrelated thought, subjective sense of disengagement, story comprehension, letter detection. One basic interpretation of this result would be that some participants are reporting considering task-related information associated with the dual-task, as well as task-unrelated representations. Because many of these items relate to performance, this is consistent with the idea that (at least some) participants are considering information related to perception of performance.

Cluster analyses revealed two clearly distinct groups. One group reported a higher average number of inventory response items while forming reports (referred to as the 'high' information group, in contrast to the 'low'). This could be interpreted as indicative of a tendency to consider more information while developing reports, as compared to those in the other group. Both groups reported a similar tendency towards the task-unrelated thought latent variable, while the high-information group had a much higher tendency to also report considering the latent variables associated with task-related thought.

The design of Experiment 3 did not take into account the rationale for why participants considered the information they did while responding to probes. Any explanations for the group difference in tendency to report thinking about task-related information therefore remains speculative. Participants in the low-information group may not have thought that information was relevant to consider, a strategic difference. While this possibility cannot be ruled out, there is also no evidence to support that conjecture. On the other hand, there does seem to be some correlational evidence consistent with another possibility related to a more fundamental group difference in cognitive control. My hypothesis is that participants in the high-information group had higher average levels of cognitive control which allowed them to more effectively monitor and/or integrate performance-based information into their reports. This made them more likely to rely on that information while introspecting about their relative level of mind wandering. Before discussing the correlational evidence consistent with this hypothesis, some consideration is given to why a general relationship between cognitive control and the nature and/or breadth of information considered while responding to mind wandering probes might be expected.

To begin with, participants with better cognitive control should be more likely to be able to adequately perform a demanding task without entirely depleting their pool of cognitive resources, meaning they should be more likely to have residual resources available to devote to performance monitoring if they so choose. Consider also the highly correlated nature of constructs such as cognitive control and cognitive capacity (Engle & Kane, 2004; Engle, 2010). Given that people with greater control also tend to have greater capacities, this should make tracking and aggregating performance trends over many trials easier to do. Of course, this doesn't necessarily mean that they will (although associations of this nature have been reported: Welhaf et al., 2018) but would merely seem to satisfy the sufficient conditions for doing so if they were so inclined. The higher average number of response items reported by the high-information group seems consistent with the idea that they might enjoy a relative control and/or capacity advantage over the other.

Conversely, if merely keeping up with the primary task demands was perceived as sufficiently challenging in and of itself (as might be expected for individuals with relatively weaker control), it could be strategic to prioritize engaging in monitoring performance to a lesser extent. This is because performance tracking presumably requires cognitive resources that could otherwise be allocated towards more fundamental aspects of the primary task to more directly support better performance. Furthermore, how to go about integrating performance-based information into mind wandering reports is not immediately obvious and would be expected to also require additional cognitive resources to deliberate about. For both of these reasons, participants with relatively weaker cognitive control could be more likely to adopt a strategy in which less of an emphasis is placed on performance tracking.

All taken together then, these ideas contribute to a general expectation that individual differences in cognitive control and/or capacity might lead to differences in reporting behaviour. The hypothesis that differences in cognitive control might predict differences in tendency to consider performance-based information while reporting mind wandering should be straightforward to test in a future study. Although direct measures of cognitive control were not taken in the present study, several measures expected to be associated with that construct were collected. While it is true that the measures being used to make inferences about cognitive control are more indirect than would be typical for experimental work, the multiple converging predictions that are met form the basis for a reasonable argument.

At the beginning of the school year in which the data for Experiment 3 was collected, all undergraduate students in the Department of Psychology subject pool at the University of

Alberta were invited to complete a series of questionnaires aggregated into a single survey for course credit (referred to herein as 'mass testing'). One intention for these archival measures was to provide covariates of potential interest for future experiments planned by researchers in that department for the upcoming year. Recall that one of the predictions related to the 'familiarity hypothesis' outlined in the Discussion section for Experiment 2 was that people with better cognitive control should experience fewer negative consequences of mind wandering in everyday life. For reasons that will be discussed shortly, there is also reason to think that people with better cognitive control may engage in less spontaneous mind wandering, and possibly more deliberate. Measures related to spontaneous and deliberate mind wandering, as well as those related to everyday cognitive errors, might therefore be useful as a proxy for estimating cognitive control.

Recent work has started to articulate some of the meaningful distinctions between spontaneous and deliberate mind wandering. One such difference relates to the idea that some people are better able to intentionally shift their attention as needed, allowing them to engage in deliberate mind wandering when task demands are low, then quickly reallocate a greater attentional investment when task demands dictate a need to do so (Levinson, Smallwood, & Davidson, 2012; Seli, Risko, & Smilek, 2016). It may be the case that engaging in more spontaneous mind wandering is associated with relatively impoverished cognitive control (on average, all things being equal), with the opposite being true of intentional. If so, this suggests that differences in self-reported intentional and spontaneous mind wandering may have some utility as crude measures of relative cognitive control. Results from a recent fMRI study lend credence to this idea by more directly linking tendency to engage in these kinds of mind wandering and cognitive control (Golchert et al., 2017). Reporting high levels of intentional mind wandering was associated with increased cortical thickness in default-mode and fronto-parietal networks, including some involved in cognitive control. Reporting higher levels of spontaneous mind wandering was also found to be correlated with cortical thinning in parietal and temporal regions.

Evidence for a relationship between different types of mind wandering and variation in cognitive control generates some predictions. If the groups identified by the cluster analysis differed in their average level of cognitive control, then the relative balance of reported spontaneous and deliberate mind wandering might also be predicted to vary in line with the findings discussed above. Individuals in the high-information group reported lower average levels of spontaneous mind wandering relative to the low-information group, as well as higher levels of deliberate mind wandering (Table A6 in Appendix 4: Spontaneous MW and Deliberate MW).

Also recall the familiarity hypothesis advanced in the Discussion section for Experiment 2. This consisted of various predictions related to how variation in cognitive control may affect the way mind wandering is typically experienced and evaluated. Two of the predictions made were that people with better control should 1) experience less frequent negative consequences of mind wandering in everyday life, and 2) hold less negative attitudes towards that mental state (as a result of experiencing less frequent negative consequences).

Table A6 demonstrates that participants in the low-information group do indeed report more frequent consequences related to attentional lapses (Appendix 4: ARCES). As is evident in Table A7, there also appear to be some differences in mean responses to the exploratory questions about attitudes held toward mind wandering. The low-information group more strongly agreed with the statement “I typically consider instances of mind wandering to reflect a failure of attention”, as well as less strongly agreed that they “regularly experience mind wandering episodes which I consider to positively impact my everyday life (e.g. helps me plan for the future, provides insight into problems I've been thinking about, improves my mood, etc.)". Both of these ostensible differences in attitude may be predicted on the basis of having less effective cognitive control, as per the familiarity hypothesis. While merely correlational, these results all seem broadly consistent with the suggestion that the high-information group enjoyed better average cognitive control.

Note that there appeared to be no difference in self-reported distractibility across groups, while the low-information group actually reported having less difficulty shifting attention, on average (Table A6 in Appendix 4: Shifting and Distractability). This is one relationship that does not conform to what would be expected if that group had worse cognitive control. However, one possibility is that the low-information group might lack awareness of how effectively they are able to shift their attention and therefore provide related judgments that are not particularly accurate. Regardless, while that measure does not support my hypothesis, the balance of group differences apparent in this mass testing dataset are consistent with what would be expected if average levels of cognitive control differed across groups.

Further converging evidence for some of the ideas touched on above may be found by examining the overall general relationships embodied within the complete 'mass-testing dataset' (i.e. consisting of responses from all 1517 participants who completed that survey at the beginning of the semester, not just those that participated in Experiment 3). Evidence for particular kinds of overall relationships permeating that dataset as a whole could go some way towards building further support for these ideas. The large sample size should provide excellent power to this end.

Based on the work described above, a given individual's tendency to spontaneously mind wander, as well as frequency of experiencing everyday cognitive errors, should both be negatively related to cognitive control. On the other hand, a tendency to deliberately mind wander would be predicted to be positively related to cognitive control (or perhaps not at all). The overall correlations between mass testing variables provide some support for these ideas (see Table A8 in Appendix 4). As predicted, the tendency for both spontaneous mind wandering and experiencing cognitive errors in everyday life share very similar relationships with the reported negative consequences of mind wandering, with correlations of .35 and .47. In contrast, the tendency to deliberately mind wandering shows somewhat different relationships, with a correlation of .45 with reported positive consequences. These results are consistent with the first two measures being negatively related to cognitive control and with the tendency to deliberately mind wander being positively related to cognitive control.

In summary, the results of Experiment 3 support the idea that people consider a range of information when introspecting about their own mental state (including performance-based information). Some potentially important individual differences were apparent in what information was reported to be considered, including a greater tendency towards task-related thought to guide reports. Correlational evidence was also found that is consistent with the hypothesis that the groups identified by the cluster analysis differed in average level of cognitive control.

Missing Letter Effect

As discussed in the introduction, the letter-detection aspect of the dual-task was of theoretical interest for reasons unrelated to my hypotheses about reporting behaviour. Recall that the missing-letter effect refers to a well-established tendency for target letters contained in high-frequency function words to be more likely to be missed during letter detection. These data can be used to address the question of whether this effect is still observed during periods of mind wandering and, if so, whether that changes how it manifests. In addition to potentially understanding the processes supporting reading more generally, the possibility that the missing-letter effect could be used as a covert indicator of mind wandering provides further motivation for the following analysis.

The differences across the three experiments reported in this dissertation were not expected to have any particular relevance for either letter detection or the missing letter effect, so data associated with the letter-detection aspect of the dual-task was collapsed across for all three experiments to maximize power. This produced a single sample of 144 participants. As outlined in the introduction, finding evidence for an interaction between the missing-letter effect and mind wandering could be consistent with accounts of that effect involving substantial contributions from top-down mechanisms and/or processes related to lexical access. Although Dixon and Li (2013) found a missing-letter effect associated with periods in which mind wandering had been reported, they found no evidence for an interaction with task focus. However, the present sample is several times larger than the one the aforementioned authors used. This will provide a more powerful test for evidence of any interaction between the missing-letter effect and task focus.

Linear mixed-effect models were constructed using the binomial family, similar to the general approach taken in logistic regression. These models use the logit space and therefore avoid some of the problems associated with accuracy analyses dealing in the proportion space. Issues can arise from scaling artifacts that inflate the apparent evidence for effects modelled within the proportion space, such as interactions with various manipulations (Everitt, 2001; Dixon, 2008; Dixon & Li, 2013). A median split (based on all probe responses) dichotomized mental state as on-task or mind wandering. The analyses presented below associate probe responses with all data from a given section of a story (i.e., all trials following the previous probe, up until the current probe). It is not always clear what interval of time to analyze/associate with a given probe response because no information is provided about mental state at that discreet point in time (i.e., if mind was reported, how long did that mental state persist before the probe?). It is not necessarily defensible to simply assume that whatever mental state is reported during a probe would be consistent throughout the entire preceding section. That said, exploratory analyses found similar results when conducting various intervals of time preceding the probe (entire section, half section, x number of trials, etc.). The results reported below pertain to data from the entirety of a section associated with a given probe response.

Results

The results demonstrated the typical missing letter effect: Targets were more likely to be missed in function words (with a detection rate of .908) than in content words (with a detection rate of .926). There was very little difference in accuracy across content and function words when they did not contain the target, e, and the overall false alarm rate was less than .03. More relevant to topics pertaining to this dissertation, Figure 7 shows how the missing-letter effect varied with task focus. This figure is in the logit space, though labels are also shown for the corresponding values in the proportion space. Although there was a drop in letter-detection accuracy for function words regardless of task focus reported, those categorized as mind wandering showed a larger drop in performance for those words than content words.

The evidence for an interaction was strong. The following models all included a random effect of subject. A model consisting of just a fixed effect for word type (function or content) was better than a null model (λ_{adj} = 11.04). A two-factor additive model, including fixed effects for both word type and task focus (on-task or mind wandering) was also better than one using just task focus (λ_{adj} = 9.34) or just word type (λ_{adj} > 1000). Critically, modelling an interaction between task focus and word type was unequivocally better than the additive form of that two-factor model ($\lambda_{adj} > 1000$).

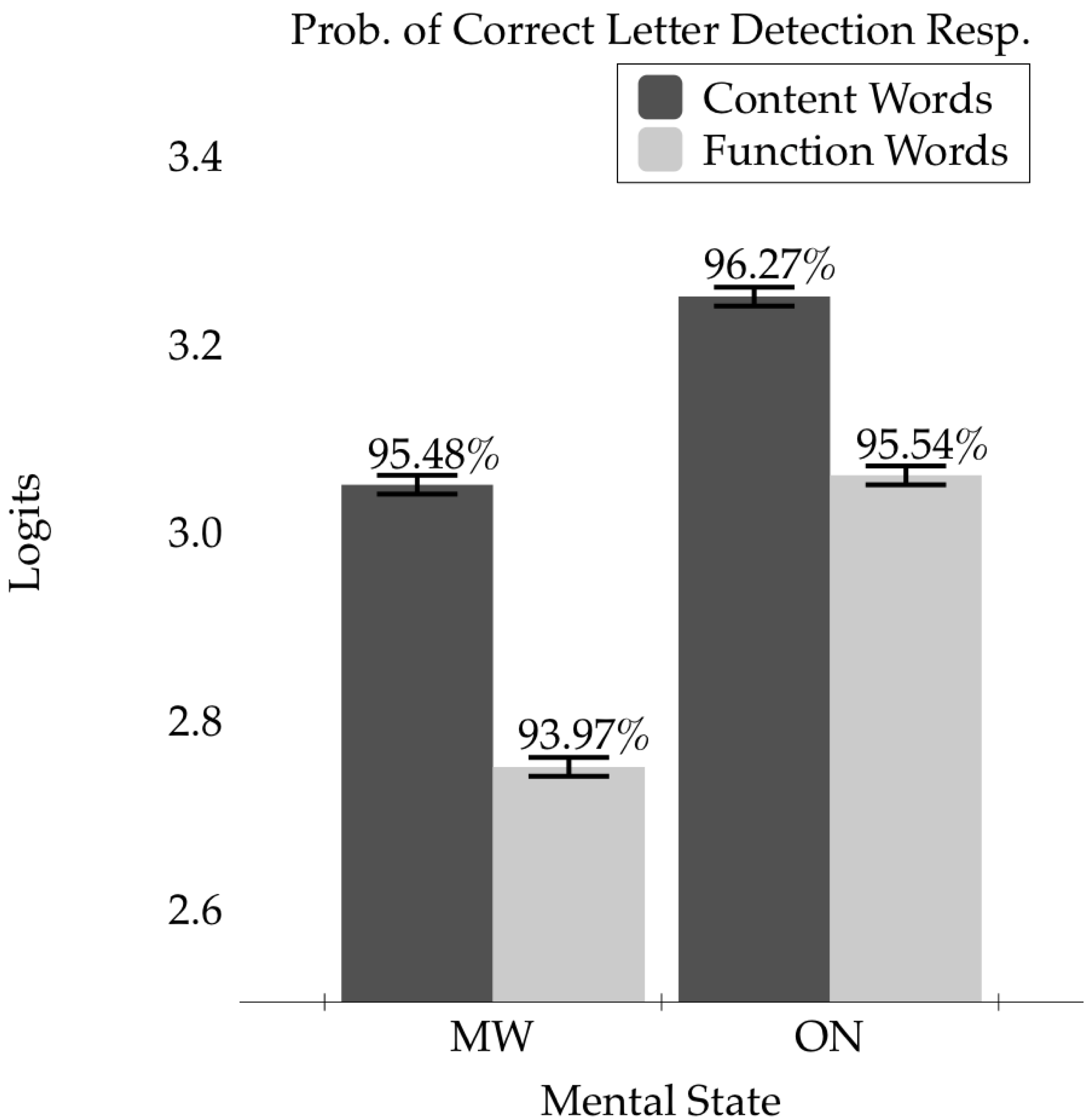

Figure 7. Log odds correct letter-detection response by word type and mental state (derived from a median split of probe response).

Discussion

As expected, participants were less accurate at responding to targets presented in function words as compared to content words. This replicates the typical 'missing letter effect'. Like Dixon and Li (2013), letter detection associated with periods of time for which participants were classified as mind wandering was slightly less accurate yet still demonstrated a typical missing letter effect. However, unlike in the other study, strong evidence for an interaction between the missing-letter effect and task focus was obtained in these data. The much larger sample size and associated increase in power provides a plausible explanation for this discrepancy. While the evidence obtained for an interaction was very strong, the effect itself is rather modest. In absolute terms, the interaction does not amount to a substantial difference in performance (1.5% drop in performance for function words while mind wandering, as compared to about 0.75% when on task). It may therefore be wise not to read too much into the interaction here for that reason. Nevertheless, this result bears on several predictions.

Evidence for an interaction between task focus and the missing-letter effect may be most consistent with the proposition that top-down mechanisms are making substantial contributions to the missing-letter effect. This is based on the logic outlined in the introduction. In brief, prior research linking mind wandering with changes in top-down processing during reading provide plausible candidate mechanisms that may more proximally underlie the change in magnitude of effect observed when mind wandering. While it could be considered a model that falls more on the top-down end of the spectrum, the structuralist account of the missing-letter effect would be expected to be less applicable in this paradigm than in others on account of the word-by-word presentation style used. This would presumably limit the potential for word type to assist with allocating attention while reading. In part, this is because eye-movements become so much less relevant when words are all presented at central fixation. This raises the possibility that some other top-down mechanisms which may not yet be known in the literature could be relevant for understanding the processes underpinning the typical missing-letter effect.

Given that mind wandering has been shown to reduce word frequency effects (Reichle, Reineberg, & Schooler, 2010; Foulsham, Farley, & Kingstone, 2013), possibly by reducing the efficiency of lexical access, this represents another possible mechanism which may factor into a more complete explanation of how variation in task focus influences letter-detection behaviour. Another possible explanation for the observed interaction is a reduction in controlled processing that occurs while mind wandering, which may interact with the greater relative automaticity with which function words are read. Similar to the consistent-mapping condition in Schneider and Shiffrin (1977), it may have been the case that some participants were able to automate the process of searching for the same target letter throughout the course of the experiment. If the missing-letter effect is partly attributable to the greater relative automaticity with which certain words are read, and mind wandering produces a further reduction in the level of cognitive control exerted on a trial-by-trial basis, that might produce the sort of multiplicative effect apparent in Figure 7.

The strong evidence for the interaction between task focus and the missing-letter effect suggests it may indeed hold some promise as a measurement tool. This kind of 'second-order' correlate, based on a calculated effect size rather than a less processed form of data (e.g., overall average response time), could have some advantages when used to infer mental state. Because making inferences about mental state using such second-order correlates relies on catching a much more specific behavioural change, this kind of approach might demonstrate less variability and therefore be more reliable. A viable covert measurement tool to assess mental state could have several advantages over other methods (e.g., probe-caught, self-caught, retrospective reports), as discussed in the introduction to this dissertation. Measuring mental state without interrupting participants with probes could increase ecological validity by minimizing reactivity, while also avoiding certain biases that can affect reporting behaviour and limitations related to meta-awareness. An online measurement such as that could also provide a better understanding of the time-course of mind wandering, for example by examining the average number of consecutive trials meeting the criteria for classifying someone as having that mental state. This could address questions like whether individual difference in propensity for initiating mind wandering episodes is associated with their average duration.

One possible limitation of relying on an interaction with the missing-letter effect to infer mind wandering is that the effect appears relatively modest. While strong evidence was found for an interaction in these data, the fact that previous work with smaller samples failed to find any evidence for an interaction (Dixon & Li, 2013) suggests the success here likely has a lot to do with a sample size that is larger than many researchers would typically collect. This may mean it is not be a robust enough effect for diagnostic purposes in more typical sample sizes. That said, further work would be required to determine the viability of this kind of approach. It might also be the case that several weaker effects assessed in conjunction could produce better results. Various established effects could be further pursued to a similar end. For example, mind wandering has been shown to reduce semantic satiation which can be inferred via changes in priming behaviour (Mooneyham & Schooler, 2016). Detection models could use machine learning to optimize how multiple effects are assessed in conjunction to infer mental state (similar to Bixler & D'Mello, 2014; Mills, Bixler, Wang, & Mello, 2016; Mills, Dame, & Mello, 2015)

General Discussion

The results reported in this dissertation all provide converging support for the proposition that a more nuanced process is involved in introspecting about relative levels of task focus than typically assumed in the mind-wandering literature. Rather than simply reporting whether or not off-task thoughts can be recalled from just prior to the onset of a probe, other influences on reporting behaviour were apparent across three experiments. This was evident from differences in probe responses attributable to what information participants were presented with in Experiment 1 and Experiment 2, as well as differences in what information participants reported attending to while deliberating about reports in Experiment 3. An influence of the perception of performance on reports was central to the interpretation of the results from Experiment 1. A similar interpretation was associated with data from the first block of the 'negative' condition in Experiment 2. Experiment 3 demonstrated individual difference in the patterns of information that were explicitly identified by the participants as having been considered in forming their report, including the use of performance-based information. Some participants consistently reported considering task-unrelated thoughts, some task-related thoughts, and some both.

The interpretations provided for these data suggest a simple theoretical model of how mind-wandering reports are developed. Various sources of information, cues, or heuristics may be considered while deliberating about one's mental state, such as perception of performance and/or awareness of task-unrelated thoughts. This information is then assessed in light of what evidence it provides for a particular mental state (e.g., mind wandering), leading to a probabilistic inference. For example, if someone perceives themselves to be making frequent mistakes in a task for which they would generally expect good performance with a reasonable level of task focus, they may infer their mind had wandered. The idea of an inferential process driving reports is consistent with interpretations applied towards other work undertaken in our lab. For example, as mentioned previously, Dixon and Bortolussi (2013) reported results they interpreted as supporting the idea that participants consider the contents of working memory while responding to mind wandering probes.

Another example of a converging interpretation relates to Ahmed and Dixon (2016). In this study, participants read several stories presented in blocks of text on a monitor. Some conditions involved forced delays of a couple seconds between text presentations during which pictures that were either relevant or irrelevant to the story being read were shown onscreen. The nature of the pictures presented affected how focussed participants reported feeling yet had no apparent effect on their recall of what was read. Displaying pictures that were relevant to the story increased reported focus, while irrelevant pictures had the opposite effect. One plausible interpretation of these results is that the manipulation had an effect on reporting behaviour rather than any direct effect on mind wandering behaviour. If participants searched the contents of working memory while responding to the probes and could recall irrelevant pictures, then this may have led them to report lower levels of focus (and vice versa for relevant pictures), independent of any changes in what might be considered actual levels of task focus.

Prior to collecting data for Experiment 1, results from a pilot experiment also produced some converging evidence for a couple of the ideas discussed throughout this dissertation. Participants were periodically given manipulated feedback about their performance during a SART paradigm (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Although there was no clear evidence for an overall effect of the manipulation, there was some evidence for an interaction of the manipulation with an individual difference measure. Participants on the high end of a median split of a measure indexing mindfulness (the mindfulness awareness attention scale, or MAAS: Brown & Ryan, 2003) showed an effect similar to what was reported in Experiment 1. On blocks in which perfect performance was obtained but the feedback presented indicated that at least one error was made, those participants reported a lower level of task focus (Farley & Dixon, 2014). Observations of similar effects related to perception of performance using a different paradigm increase confidence in the generalizability of the interpretation reported for Experiment 1. Additionally, it also demonstrates an individual difference in the sensitivity and/or use of a particular kind of information similar to what was reported in Experiment 3. The nature of this individual difference also finds some parallel in the high-information group from Experiment 3. Although no measure of mindfulness was directly assessed in that experiment, those participants did trend towards reporting fewer cognitive errors in everyday life. This might be expected if those participants were higher on levels of trait mindfulness. Moore and Malinowski (2009) studied a group of meditators and demonstrated a close relationship between cognitive control and various measures of mindfulness.

This general theoretical account of how reports are generated should serve as a productive starting point for further work considering how people introspect about their own mental state. It also entails some important methodological implications for researching mind wandering in experimental contexts. Given the central role reports play within a measurement capacity in mind wandering research, understanding otherwise unaccounted for sources of variance in those reports represents an important methodological contribution for reasons related to minimizing sources of measurement error. One implication that follows from my work is that relying on a correspondence between performance and probe responses might be problematic as a means to validate reports. Another implication is that contextualizing mind wandering at the beginning of experiments might bias participants to evaluate their own mental state in particular ways. In addition to methodological implications, understanding how people evaluate their level of task focus may also have some practical implications outside of the lab. For example, the individual differences noted in Experiment 3 suggest some important distinctions in how people monitor, and perhaps regulate, their own mind wandering. It may be the case that people who struggle with maintaining task focus in everyday life could benefit from training that attempts to change the way they go about monitoring their mental state so as to allow them to be more proactive in redirecting off-task thought when necessary.

In the remainder of the General Discussion, I will first discuss the implications of the present perspective on several other findings in the literature. Second, I will describe the relationship of the present account to other theoretical constructs pertaining to mind wandering. Finally, I will discuss additional empirical and theoretical work that might be based on the current conclusions.

Reinterpreting Results in the Mind Wandering Literature

One measure of the utility of a theoretical framework is how well it can explain a range of results associated with a particular phenomenon. The model proposed here provides some plausible alternative interpretations for a number of published results. Many of these alternative interpretations hinge on the idea that contributions to probe responses are influenced by evaluating the contents of working (and/or long-term) memory in various ways. In addition to evaluations related to performance, judgments associated with the perception of newly acquired knowledge (e.g., sense of mastery, depth/elaboration, distinctness of representations, etc.) may at times factor into the development of probe responses. The following examples demonstrate some alternative interpretations built on the framework proposed in this dissertation.

Kopp, Mills, and D'Mello (2015) found less mind wandering was reported while watching a short movie if participants had just read a textual adaptation of the same story. These results were interpreted as supporting the idea that familiarity with a story reduced mind wandering. One possible alternative explanation is that having a preexisting situation model (Zwaan & Radvansky, 1998) for the story promoted the sense that participants were more focussed than they actually were. For example, if a crucial piece of information was missed due to an attentional lapse, someone already familiar with the story would be unlikely to experience substantial comprehension difficulties as a consequence because they should be able to essentially fill in that detail based on their previous understanding in a relatively automatic fashion. Assuming an inferential process involving perception of performance was guiding reports along the lines of the interpretation proposed for the results from Experiment 1, participants may have made errors in misinterpreting previous comprehension gains as indicative of present attentional investment in the task. This could be thought of as effectively amounting to a source misattribution error (Loftus & Hoffman, 1989).

A similar inferential process may also be equally applicable as an alternative account for why levels of reported mind-wandering rates have been found to be positively correlated with the difficulty level of a text (Feng, D'Mello, & Graesser, 2013). Part of the theoretical significance of explaining observations of a positive relationship between story difficulty and mind wandering pertains to explaining this ostensible contradiction with a wealth of other findings indicating a robust negative relationship between mind wandering and task difficulty in most other contexts (Randall, Oswald, & Beier, 2013). This kind of relationship would be expected if cognitive control was successfully exerted to modulate mind wandering as an adaptive response to current task demand, which seems to hold true in most other experimental tasks. Conversely, it is not clear why increasing task demands during reading should promote more mind wandering behaviour. Comprehension of a story depends upon the cumulative integration of information that is processed across time, as well as hierarchical processing which depends on subordinate levels (constructing an adequate situation model depends on processing meaning at the sentence level, which itself depends on adequate processing at the word level, etc.). Given this, even relatively minor lapses in attention can aggregate into more meaningful comprehension difficulties throughout a reading (as per the cascade model of inattention; Smallwood, 2011). While this applies generally across difficulty levels, more difficult texts could involve more opportunities for comprehension difficulties. Feng, et al. therefore proposed that it was easier for participants to get 'off track' with difficult texts which could make them less engaging and thus lead to more mind wandering. However, if ease of processing or sense of mastery of material is a source of information participants consider when forming mind wandering reports (perhaps as a proxy for performance), this suggests a different account of the relationship between text difficulty and mind wandering. Increasing difficulty could more directly lead to the perception that one is experiencing a lack of focus, perhaps due to a greater chance of producing evidence indicative of performance difficulties, without it necessarily being true.

Related to the general relationship just described, consider that Forrin, Risko and Smilek (2017) found that (at least some) contributions from effects of story difficulty on reported mind wandering rates were mediated by the presentation style of the material. They initially found marginal comprehension effects and more substantive increases in reported mind wandering for more difficult stories relative to easier ones (as measured by Flesch-Kincaid scores). They interpreted this effect as relating to passage length because it disappeared when the same stories were presented sentence by sentence, rather than page by page. This was further interpreted as indicating that participants preemptively disengage their attention from longer passages in anticipation of them being more demanding. Forrin, Risko and Smilek (2018) also reported similar results for participants exposed to both presentation styles using a within, but not between-subject, passage-length manipulation. They interpreted these results similarly. An alternate interpretation consistent with the ideas presented in this dissertation is that these results reflect effects of passages length on reporting behaviour, rather than effects on actual mind wandering behaviour. This could be consistent with not finding anything more than marginal effects on behaviour (comprehension) in contrast to the much clearer effects on probe responses. Participants might consider how complete they felt that their representation of whatever information was onscreen just prior to being probed. Larger amounts of information could provide more opportunities for memory or comprehension difficulties, as well as the perception of such, including doubt that everything in the most recent ‘chunk’ of content had been reliably committed to memory.

Effects on reporting behaviour related to mastery of material might be evident in some studies looking at how revisiting material affects mind wandering behaviour. Phillips, Mills, D’Mello, and Risko (2016) reported negligible comprehension gains and increases in reported mind wandering when participants reread material, and Martin, Mills, D’Mello, and Risko (2018) reported similar effects associated with rewatching video lectures. While it seems entirely plausible that rereading and/or rewatching material could increase actual levels of mind wandering by reducing engagement (perhaps in part by reducing novelty), there may still be some contributions from these effects that relate more proximally to reporting behaviour. This dissertation has argued that people consider perception of task performance when introspecting about their level of task focus. If one were engaging with a text or video subsequent to their initial exposure, and (despite being fully focussed) consider themselves not to have gleaned any novel knowledge, insight, or meaning, this might lead them to infer their relative level of task focus was lower than it might actually have been (assuming improving understanding is a goal of the reader/viewer). If so, even if actual levels of mind wandering actually do increase somewhat across repetitions of material, that could still result in levels of reported mind wandering being inflated above and beyond actual levels. This also touches on the idea that there may sometimes be effects on both reporting behaviour and actual rates of mind wandering which could sometimes be less than straightforward to disentangle.

Along somewhat similar lines as the previous example, observations that reports of mind wandering decrease while in the region of proximal learning (Xu & Metcalfe, 2016) might have something to do with there being more salient comprehension gains when challenge is closely balanced with accessibility, rather than necessarily just changes to actual levels of mind wandering. An earlier study by those same two authors affords a similar reinterpretation driven by the framework articulated in this dissertation. Metcalfe and Xu (2015) also found rates of reported mind wandering differed as a function of how material was presented. Participants in that experiment studied a number of paintings by various artists, presented in one of two formats. In the massed condition, pieces were grouped together by artist, while multiple works by the same artist were always interleaved with works by other artists in the spaced condition. The main result was an increase in reported mind wandering in the massed condition which they interpreted as evidence that the variety associated with the spaced condition reduced mind wandering by promoting task engagement. An alternative explanation that is more consistent with the framework proposed here involves the possibility that fewer distinct task-related details may be perceived in the massed condition because different paintings by the same artist are often more similar to each other than works by other artists. If so, this could amount to what may seem like a comparatively impoverished amount of task-related information in working memory which could result in judgments of relatively greater mind wandering. In other words, if not much in the way of clearly distinct pieces of information about the material studied can be recalled, a relative lack of task focus may be more likely to be inferred.

Another simple reinterpretation that is broadly consistent with my interpretation of the results from Experiment 2 comes from Sanders, Wang, Schooler and Smallwood (2016), in which initial instructions emphasizing the importance of closely attending to meta-awareness (as compared to emphasizing comprehension of the material being read) resulted in reduced reports of mind wandering reports yet no accompanying behavioural change. The authors interpreted this as a change in mind-wandering behaviour based on priming the concept of meta-awareness. The ideas discussed throughout this paper suggest a general alternative explanation could be that attending to different kinds of information changed reporting behaviour.

One final example of a reinterpretation of prior work comes from what was initially an unexpected trend in a study related to reading, mind wandering, and problem solving (Farley & Dixon, 2013). In this series of experiments, participants read various short mystery stories for which the author had provided particular explicitly defined solutions (not presented to participants during the experiment). The presence of cues designed to draw attention towards solution-relevant pieces of information was manipulated. It was anticipated that the mysteries in cued stories should have been easier to solve than those in stories which contained non-informative filler sentences in place of the informative cues. Although random assignment meant there was no reason to expect any difference in actual rates of mind wandering across cueing condition, a marginal effect of cueing on probe responses was apparent such that participants trended towards reporting lower levels of mind wandering in the cued condition. This relationship disappeared when accounting for actual solution rates (operationalized as being consistent with the explanations explicitly provided by the author). In other words, engaging with a mystery that is easier to solve may have made participants feel more focussed on the text, for reasons that likely related to perception of performance rather than any actual difference in mental state. Once again, an inferential process based on perception of task performance offers a reasonable reinterpretation of these results.

Reinterpreting Theoretical Constructs in the Mind Wandering Literature

The broad relevance of the framework proposed in this dissertation has the potential to enrich understanding of a range of constructs of theoretical importance for mind wandering research. In part, this is because a better understanding of how people think about and report mind wandering should generate implications and predictions for other major concepts in emerging areas of research that could serve as good targets for future work. For example, as was touched upon in the discussion of Experiment 1, the modulating role of working memory is one concept that factors prominently in various frameworks addressing mind-wandering behaviour (McVay & Kane, 2009 ; McVay & Kane, 2010; Kane & McVay, 2012a).

McVay and Kane (2012b) used a latent variable analysis of a battery of working memory, reading comprehension, and attentional control tasks to assess the relationship between working-memory capacity, mind wandering, and performance. They found the expected (positive) relationship between working-memory capacity and reading comprehension was mediated by the effect of mind wandering. This was interpreted as evidence that the kind of difficulties with attentional control which can lead to increased mind wandering were a major contributing factor in understanding the explanatory relationship found between working-memory capacity and reading comprehension. While individuals with higher working-memory capacities tend to report higher levels of task focus, the framework presented in this dissertation suggests some other possibilities. For example, participants with higher working-memory capacities had better reading comprehension for reasons not directly related to mind-wandering behaviour (Daneman & Carpenter, 1980). These participants then somewhat independently inferred greater task focus based on an awareness of their own good performance. Furthermore, having a relatively large working-memory capacity should afford the ability to more easily monitor and integrate information related to perception of performance into reports. While the availability of such resources depends heavily on task demands, residual resources should be more likely to be available for individuals with higher working-memory capacities. Thus, while having a higher working-memory capacity would not necessarily mean that someone would adopt a strategy in which performance-based information is considered while introspecting about mental state, if they are so inclined this should afford a better capability for doing so as compared to someone with a lower capacity. There may also be more incidental processing of performance-based information for individuals with higher working memory capacities, which may then 'contaminate' their report without intention or explicit awareness of this influence.

Also consider the role working memory may play in redirecting mind wandering behaviour once a task-unrelated train of thought has been initiated. Assuming that better performance tracking serves as a cue which can help refocus attention more quickly when it gets off-track, that could also be a mechanism that helps explain the tendency for that population to report less mind wandering which wouldn't necessarily be mutually exclusive with some of the explanations proposed earlier. This could be relevant for disentangling factors which commence, as opposed to perpetuate, an off-task train of thought (cf. Smallwood, 2013a).

Another general possibility is the relationship typically observed between mind wandering and working memory may (at least in part) reflect a bias towards inferring focus based on a greater likelihood of having robust task-related representations to consider as evidence for being on task. It perhaps remains to be seen whether this should be considered entirely distinct from actually being on task, although the effect of similarly robust off-task representations on reporting behaviour in situations in which robust task-related representations are also accessible would seem to be an outstanding empirical question for future research to address. This could be tested by recording open-ended responses indicating all task-related and task-unrelated thoughts one is aware of during a probe and comparing these counts to probe response values.

Consider the following example to illustrate the point that there may be some individual difference in how people interpret the relative balance/proportion of accessible task-related and task-unrelated unrelated representations. Imagine two hypothetical participants for whom we assume comparable mental states. Both are genuinely engaged with an experimental task but are also experiencing plenty of task-unrelated thoughts. Assume the task demands are relatively modest and these task-unrelated thoughts are not having any noticeable impact on performance, which is at a relatively high level for both individuals. If probed, the first of these hypothetical people might consider themselves to be completely on task simply because of having what may be perceived as sufficient task-related representations and are performing well (independent of whether, and if so how many, task-unrelated thoughts may have also been accessible). The second hypothetical person might consider the presence of any task-unrelated thoughts to be an absolute indicator of mind wandering, and therefore provide a response indicative of diminished focus when probed. Relevant to the framework proposed here, this could effectively introduce measurement error into indexing what are comparable mental states.

The present framework may also provide some additional insight into mindfulness. The relationship between mindfulness and mind wandering has become an active area of discussion in the literature (Mrazek, Smallwood, & Schooler, 2012; Schooler, Mrazek, Franklin, Baird, Mooneyham, Zedelius, & Broadway, 2014). Studies examining the effects of mindfulness training on mind-wandering behaviour have been a frequent experimental target in recent years. Some studies fail to find evidence for any change in mind-wandering behaviour following mindfulness interventions (Giannandrea et al., 2018), while others infer such an effect based on a reduction in mind-wandering reports accompanied by improvements in performance (Mrazek, Franklin, Phillips, & Schooler, 2013; Morrison, Goolsarran, Rogers, & Jha, 2014; Zanesco, King, MacLean, Jacobs, Aichele, Wallace, Smallwood, Schooler, & Saron, 2016). As occurs elsewhere in the literature, this pattern of results is sometimes used to justify the inference that changes in mind-wandering behaviour have taken place (rather than just changes in reporting behaviour). However, the ideas advanced in this dissertation raise some cautions about that line of thinking. Perhaps mindfulness training benefits performance for reasons not directly related to mind wandering (improving mood, reducing stress, etc.). For example, certain kinds of mindfulness training have been shown to reduce cortisol secretion in response to stressful events (Tang & Posner, 2009). If effects of this nature are more directly contributing to performance benefits, and people rely on their perception of performance to inform on mental state, then differences in performance that are not driven by changes in mind-wandering behaviour may nevertheless be interpreted as such. Along similar lines, the hypothesis that mindfulness training may enhance working memory function (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010) suggests a similar potential confound if the intervention more directly benefits performance, and performance (or perhaps even just the perception of more robust mental representations) are then used to indirectly infer a change in relative levels of mind wandering experienced by the reporting participant

When changes are observed in reported levels of mind wandering, changes in meta-awareness might sometimes be a more proximal cause than changes in actual mind-wandering behaviour. For example, Axelrod, Rees, Lavidor, and Bar (2015) reported what they interpreted as elevated levels of mind wandering resultant of transcranial magnetic stimulation (TMS) applied to the lateral prefrontal cortex. However, as pointed out by Fox and Christoff (2015), a plausible alternative interpretation of their data is that the TMS manipulation simply increased meta-awareness of mind wandering with actual levels of mind wandering remaining constant. Fox and Christoff (2015) interpreted this as consistent with prior findings that training participants to up-regulate activity in their rostrolateral prefrontal cortex appears to increase meta-awareness (McCaig, Dixon, Keramatian, Liu, & Christoff, 2011), as well as observations that TMS applied to the dorsolateral prefrontal cortex impairs it (Rounis, Maniscalco, Rothwell Passingham, & Lau, 2010). The cautions raised by this dissertation about relying on performance to validate mind-wandering reports notwithstanding, this interpretation would also be consistent with the lack of any observed behavioural change accompanying the increased rates of reported mind wandering in Axelrod et al. (2015). Understanding how exactly mindfulness training might modulate mind-wandering behaviour, including any effects more specifically related to reporting behaviour if applicable, has the potential for contributing to the sort of explanatory framework advanced in this dissertation.

While the literature on meta-awareness has previously related it directly to reporting behaviour (i.e. you can’t accurately self-report a mind wandering state if you aren’t aware of it: Schooler, 2002), this construct may also be a relevant causal factor for understanding mind-wandering behaviour for reasons linking it with intentionality. The decisions we make throughout our daily lives to refocus our attention are presumably sometimes made as a response to noticing that we are not focussed on what we intend to (i.e. mind wandering), meaning they should depend on being aware that we are mind wandering in the first place. Initiating an intentional shift in attentional focus should therefore be contingent on an awareness of one's current attentional state. See Seli, Ralph, Risko, Schooler, Schacter, and Smilek (2017) for a discussion of how intentionality and meta-awareness may be related.

Additional implications that follow from the present work pertain to the content * context regulation hypothesis (Andrews-hanna, Kaiser, Turner, Reineberg, Godinez, Dimidjian, & Banich, 2013). This theory proposes that the nature of the task one is engaged with is an important determinant of what effects are likely to follow from mind wandering in that particular context. An implication of this is that the specifics of a given task should change the probability of various kinds of effects of mind wandering manifesting. In turn, this should then affect the availability of certain kinds of information for any inferential processing that may occur when introspecting about mental state. This was discussed in relation to the interpretation for why the 'negative' condition in Experiment 2 produced a larger increase in mind wandering than the 'positive' condition, in which it was argued that the nature of the task meant lapses in attention were expected to be more likely to produce negative consequences than positive ones. Thus, participants who saw instructions contextualizing mind wandering by relating it to negative consequences were more likely to report experiencing that state in the negative condition. Another implication is that some tasks may lend themselves to the use of certain heuristics better than others. For example, if mind wandering is unlikely to lead to 'mistakes' in creative endeavours (e.g. musical improvisation), noticing errors may not be a viable source of information to rely on when introspecting about mind wandering in those situations. This idea will be returned to briefly in the context of how sense of immersion may affect reporting behaviour.

Further Developing the Theoretical Framework

Design factors. This section outlines arguments for why various factors related to reporting behaviour should be examined in the interest of further refining the basic theoretical framework proposed in this dissertation. Many of these are of methodological interest, and a common theme is a dearth in work focussed on understanding how elements related to the use of probes affect the associated responses that are provided. To begin with, there is considerable variation in the form report responses take (Weinstein, 2017), and the effect this has on reporting behaviour is not clear. For example, the use of dichotomous versus continuous (or near continuous) response scales may be interpreted rather differently. A related question is what statistical advantage, if any, the use of different reporting protocols offer (e.g. does modelling task focus as a continuous variable explain more variance than doing so in a dichotomous form?).

The framing of the probe and response options may also be expected to change reporting behaviour. Effects related to framing have been an active area of study in decision making for some time now (Tversky & Kahneman, 1985) yet have received little attention within mind wandering research. There is at least one reported study providing evidence that mind wandering probe responses are indeed sensitive to framing effects. Weinstein, De Lima, and Van der Zee (2017) found people were more likely to respond with a 'yes' to probe questions framed in a leading way (asking whether they were on task or asking whether they were mind wandering). This amounts to an acquiescence bias (Klayman, 1995). Framing could also introduce bias for individuals that might have particular connotations with the term 'mind wandering', negative, positive, or otherwise (if used in the probe question or instructions). The use of that term to refer to some response option(s) could affect reporting behaviour for that reason.

These data are suitable for a basic test of the hypothesis that the framing of the probe question affected the responses produced. As explained in the introduction to Experiment 1, it made sense to frame that probe question in the context of focus ('My attention is fully focussed on the letter detection/comprehension task') rather than mind wandering, because two independent probes were used. In essence, attributing multiple (potentially different) levels of focus towards separable aspects of a dual-task seems somewhat intuitive, though the same could probably not be said for ascribing multiple levels of mind wandering. There was no particular reason to frame the probe question one way or another in the second and third experiment. These were framed in the context of mind wandering ("Please Respond to the Statement 'I was mind wandering just prior to this screen appearing' "). Given this, mean probe responses for Experiment 1 can be compared to the same for Experiment 2 and 3 to test for the presence of framing effects.

The mean rating in Experiment 1 (and standard error) was 5.01 (0.18); for Experiments 2 and 3, it was 4.24 (0.16) and 3.97 (0.17) respectively. Thus, mean probe response for the second and third experiment hovered around that neutral point, while mean probe response for the first experiment was skewed towards endorsing focus. To quantify the strength of the evidence for a framing effect, a simple linear mixed effects model was constructed that predicted probe response based on a fixed effect of probe framing and a random effect of subject. This amounts to a contrast comparing probe responses in Experiment 1 to the average in the other two experiments. This simple model was far superior to a null model (λ_{adj} = 959.11). This would seem to provide strong evidence for the presence of framing effects on probe response.

These means could be interpreted as implying an acquiescence bias towards the focus framing in Experiment 1, similar to Weinstein, De Lima, and Van der Zee (2017). However, those authors interpreted that bias as affecting both response framings. In my data for Experiment 2 and 3, at least relative to the other response framing, an effect of this nature does not seem apparent for the mind-wandering framing. However, a social-desirability bias interacting with an acquiescence bias might be interpreted for that framing. This would be based on the assumption that participants are inclined to agree with the probe question all things being equal yet also expect that a focused state would be more socially acceptable than a mind-wandering state. If one felt inclined to generally agree with the question and initially considered a '6' ('Somewhat agree') response based on that proposition alone, yet also felt inclined to generally deny mind wandering behaviour and might therefore consider responding with a '2' ('Somewhat disagree'), a simple model that averaged these responses (based on each respective bias) would predict an ambivalent '4' response ('Neither agree nor disagree').

Two more general thoughts emerge from this larger framing discussion. Firstly, although often tacitly assumed, there seems to be a lack of evidence that mind-wandering and on-task states are actually reciprocal concepts. Furthermore, independent of whatever theoretical arguments might be devised to defend or critique that assumption, an important related question is how the average participant interprets the relationship between the two while reporting those states. This means that framing effects could potentially extend beyond simply introducing error into the measurement of the same thing, to potentially measuring two somewhat dissociable constructs. Secondly, a productive research direction for the mind-wandering community would seem to be further considering how some of the many well-documented effects known in the decision-making literature might be influencing probe responses in experience sampling paradigms. In addition to the simple fact that a relatively impoverished amount of published work in that area currently fits such a description, that area would also seem abundant with easily testable predictions. Both of these factors are conducive to good research outcomes.

The timing or relative frequency of probes is another basic element of experience-sampling designs that may bear on best practices for their general use. Given this, it seems particularly surprising there remains so little in the way of supporting evidence to guide these design decisions. Many researchers operate under the reasonable assumption that excessive use of probes would affect behaviour at some point, reducing the potential for generalization, and should therefore be avoided. An extreme example would be an experiment in which probes are so frequent that they serve as a constant reminder to stay focused on the task, producing less mind wandering than would otherwise be the case (i.e., low ecological validity). As far as the author is aware, only one study has evaluated how the relative frequency of probes affects their associated responses to date, with larger intervening intervals seeming to produce responses which more readily endorse a mind wandering state (Seli, Carriere, Levene, & Smilek, 2013). This could be related to the probes acting as reminders to stay on task which somewhat artificially boost task focus. Of course, the threshold for what constitutes ‘too many’ or ‘too frequently’ is an empirical question that remains remains largely unaddressed. The tradeoff inherent to this balance, in which too few probes will not produce enough data points for meaningful analysis, render this outstanding question particularly important from a methodological perspective.

Another open question that may be relevant to understanding how participants introspect about their mental state is whether the underlying mechanisms associated with reporting behaviour differs in probe-caught and self-caught designs. Probe-caught designs involve responding to a probe which asks participants directly to report their mental state at pseudo-random intervals. On the other hand, participants spontaneously report mind wandering whenever they become aware of it in self-caught designs. While a number of papers using the self-caught technique have been published (Reichle, Reineberg, & Schooler, 2010; Sayette, Schooler, & Reichle, 2010; Sayette, Reichle, & Schooler, 2009; Schooler, Reichle, & Halpern, 2014), the vast majority of research undertaken in the last decade or so has relied on some form of probe-caught methodology. This may be in part due to limitations inherent to the self-caught methodology related to meta-awareness (e.g., you can't spontaneously report mind wandering if you aren't aware of it). However, a more thorough understanding of how these design differences might influence behaviour would be worth pursuing. For example, self-caught designs may capture more typical everyday behaviour, and thus could have better ecological validity. This is based on the fact that most real-world tasks don't periodically prompt us to make attentional judgments, which has the potential to disrupt our attention (in one way or another, e.g., by serving as a constant reminder that helps with focus or by increasing the chances of task-related interference). That said, as discussed in greater depth in the introduction to this dissertation, several recent lines of work have produced evidence that reported rates of mind wandering are similar across those two designs (Varao-Sousa & Kingstone, 2018; Mrazek, Phillips, Franklin, Broadway, & Schooler, 2013).

Cues, heuristics, and other sources of information. The present work provides good evidence that perception of performance is one factor that influences the way people introspect about relative levels of focus. Other kinds of information, cues, and/or heuristics might also make similar contributions and guide a broadly similar inferential process. Consistent with that proposition, Experiment 3 found that some people endorse considering other kinds of information while forming those reports, such as task-unrelated thought (the conventional explanation for what drives reports) or subjective feelings of disengagement. A good target for future work is to investigate what other sources are relied upon while developing mind wandering reports.

Potentially relevant to this pursuit, Weinstein and Wilford (2016) looked for evidence that flow could be considered a reciprocal concept to mind wandering by comparing behaviour when reporting a state of flow to reporting being on task. Although their results did not support their hypothesis, the experience of flow does share some superficial resemblance to characteristics associated with the extreme end of on-task behaviour (i.e., highly focussed on something at the expense of other stimuli). So their interpretation notwithstanding, indications of the experience of flow may yet provide evidence for task focus that one considers when making an inference about mental state, at least under certain conditions. Changes in the perception of time is one characteristic that is sometimes associated with flow (Csikszentmihalyi, 1997). One prediction that would be easy is that participants perceiving that time has passed relatively quickly when stopping to think about how to respond to a mental state probe might be more likely to endorse a description ascribing a relatively high degree of focus. A similar heuristic has been demonstrated in relation to changes in the perception of time and associated subjective ratings of enjoyment (Sackett, Meyvis, Converse, & Sackett, 2010). Building on this idea and applying it towards a topic covered previously in this dissertation, evidence that mindfulness meditation can lead to overestimating intervals of time (Kramer, Weger, & Sharma, 2013) suggests yet another possible mechanism that could conceivably explain some contributions of mindfulness-based interventions to changes in reported rates of mind wandering. Along similar lines, subjective impressions of how much one is enjoying themselves might also be used to make inferences about relative levels of mind wandering. Feelings associated with negative affect (such as those generally related to boredom: Eastwood, Frischen, Fenske, & Smilek, 2012) may promote expectations that mind-wandering behaviour may be likely to occur, or have recently occurred, during periods of time closely coinciding with such feelings. On the other end of the spectrum, mood lifts have been identified as one possible benefit of mind wandering (Franklin, Mrazek, Anderson, Smallwood, Kingstone, & Schooler, 2013), suggesting greater enjoyment might actually be associated with off-task thinking in some contexts. Some individual difference across participants might be expected in these kinds of relationships. This is based on the idea that commonly experienced consequences of mind wandering for a given individual would be more likely to become employed as heuristics to infer focus (in line with the 'familiarity hypothesis' discussed elsewhere in this dissertation).

As with flow, another concept that has been proposed to have a reciprocal relationship with mind wandering is mindfulness (Schooler, Mrazek, Franklin, Baird, Mooneyham, Zedelius, & Broadway, 2014). Indications that one is experiencing such a state could therefore be predicted to influence reports. One characteristic that is sometimes associated with mindfulness is focussed attention on sensory experience (how something feels, tastes, etc.). If so, judgments about the relative richness of sensory representations might be relied upon to help guide reports. To test this, it could be possible to manipulate some peripheral aspect of experimental stimuli to be more or less salient (e.g., an audio component played at quieter or louder volumes). If probe responses differed across conditions, yet no other aspect of behaviour was found to differ, that could be consistent with the idea that perception of focus is influenced by judgments about differences in the perceived relative salience of the stimuli. An obvious challenge to this approach would be disentangling mere changes in reporting behaviour resultant of changes in stimuli salience with actual changes in levels of engagement (which a richer sensory component might be expected to do, and has been interpreted to do, in other experience-sampling contexts: Smallwood, 2013b).

The role immersion, engagement, and/or emotionality could play in shaping reporting behaviour is also worth briefly considering. Although these concepts will not be sharply distinguished here and are being used rather loosely and somewhat interchangeably, they are distinct yet demonstrate overlap and are highly correlated in various ways. Ideas related to transportation theory (Green, 2004; Gerrig, 1993) inspire predictions that sense of immersion and/or absorption could shape perceptions of task focus. Two more general implications about reporting behaviour follow from this initial suggestion. Firstly, sense of immersion/absorption might be expected to be a reasonably good heuristic to use when reporting relative levels of focus (at least when conceived of from the perspective of indexing resource allocation). This is because the prospect of someone getting seriously misled about their relative level of focus based on feelings of immersion seems somewhat unlikely, assuming feeling deeply immersed would typically require a commensurate and substantial investment in resource allocation. Other kinds of heuristics might be more likely to produce misleading inferences (e.g., judgments about performance). It therefore follows that some cues may be more reliable than others when used to make inferences about relative levels of task focus. If so, then work aimed at figuring out which cues tend to be relatively accurate and which are more likely to be misleading could be useful (and again, some individual difference would be expected based on 'the familiarity hypothesis' proposed elsewhere in this dissertation).

The second implication that follows from the possibility that sense of immersion may affect reporting behaviour is that the utility of this kind of cue is presumably limited to contexts that have a reasonable capacity for such. In other words, this might not be a useful cue for inferring relative levels of focus during the completion of mundane tasks, or contingent on the specifics of the materials used within a given task (e.g. reading a boring vs. exciting story: Dixon & Bortolussi, 2013). More generally, this suggests that some cues that are relied upon while reporting could be domain-specific whereas others are likely to be more domain-general (e.g., gauging performance).

One plausible heuristic for judging engagement could be trying to recall whether an emotional reaction was produced in response to some recently processed stimuli. This could happen via various mechanisms, and this may or may not lead to reports that are generally consistent with resource allocation. For example, focus may be inferred because recall of something a participant just read is enhanced on account of emotional content, despite the fact that they may have been genuinely zoning out when probed. This last example suggests understanding how emotion affects reports likely requires distinguishing between effects of emotion on attention and memory (Dolcos, LaBar, & Cabeza, 2005) from those that might be more directly influencing reporting behaviour. Related to this possibility, some effects observed in these data seem consistent with the general possibility that the emotionality inherent to the content of the stories being read may have affected reporting behaviour.

Processes supporting lexical access would be expected to generate basic emotional responses to individual words relatively automatically, devoid of any connection to their larger context placed within the story as a whole. Relying on this kind of process should lead to probe responses that are less directly tied to deeper levels of processing and/or more fully developed representations, and this would presumably be a better predictor of actual mind wandering behaviour (at least in the context of measuring resource allocation). This might be especially likely in a word-by-word presentation style, as was used here. For example, someone could stare at the monitor while frequently experiencing relatively intense mind-wandering episodes, never integrating words at the sentence level yet still reading the easily parsed individually presented words in a relatively automatic fashion (cf. Stroop, 1935). This could generate variation in probe responses across stories with lower or higher emotion values based on relatively automatic emotional response generated as a product of activation at the word level of representation. Data produced by a participant using this kind of strategy might therefore imply variation in actual mind-wandering behaviour across stories, yet not actually reflect any substantial variation in resource allocation for that participant. That kind of effect could therefore be said to more directly tied to reporting behaviour than actual mind wandering behaviour.

Lexical co-occurrence models may be a useful tool for quantifying the emotionality inherent to a story for the purposes of testing the hypothesis outlined in the previous paragraph (Lund & Burgess, 1996; Shaoul & Westbury, 2006; Shaoul & Westbury, 2010). These models take input from a very large corpus of texts and computes values reflecting the degree of relatedness between all possible co-occurrences of all possible words in the corpus, represented in a high-dimensional space. These co-occurrence models can then be used to various ends. Westbury, Keith, Briesemeister, Hofmann, and Jacobs (2015) calculated co-occurrence values based on dimensions of valance and arousal for emotional words. These values then formed the basis for a method of quantifying the relative degree of emotionality inherent to the specific words used in a given story. The stories from Grimm's Fairy Tales were assessed and rank ordered based on relative degree of emotional content as determined in this manner.

In order to test the secondary hypothesis that these emotional values would predict differences in reported mind wandering and/or comprehension, the stimuli used for this dissertation consisted of stories judged to have relative differences in emotionality (low, intermediate, and high: Westbury, Keith, Briesemeister, Hofmann, & Jacobs, 2014). As predicted, the high emotion story was associated with the lowest average reported mind wandering values and the best comprehension (Farley & Dixon, 2016). This suggests some effects related to emotionality on either actual mind-wandering behaviour, reporting behaviour, or both. As stated above, one reason why this might constitute an effect on reporting behaviour is because the greater emotionality associated with certain stories may have benefitted memory more directly (Dolcos, LaBar, & Cabeza, 2005). In turn, this may have been used to make inferences about mental state. One way to attempt to get more leverage on these effects could be to run a follow-up study that manipulates the emotionality of the language used in stories while attempting to hold everything else constant (e.g., the situation model). While not in and of itself disentangling the possibility of effects on reporting behaviour versus effects on actual mind-wandering behaviour, that might help distinguish between effects of emotionality on more superordinate representations (e.g., the situation model) from more those tied to subordinate ones (e.g., the word level).

In concluding this section, it can be said that various other sources of information may be hypothesized to influence reporting behaviour beyond perception of performance. As was mentioned at the end of the framing discussion with respect to looking to the decision-making literature for established effects to test, a range of well-studied concepts in cognitive psychology related to processing distinctions offer clear targets for future work. The alternative interpretations provided in this dissertation for Xu and Metcalfe (2014) and Metcalfe and Xu

(2015) suggest sense of mastery might be another relevant factor to consider. Subjective judgments associated with other concepts such as familiarity, disfluency (see Faber, Mills, Kopp, & D'Mello, 2017), and/or extent of elaborative processing likewise suggest additional easily testable hypotheses.

Other factors. Another direction that may be of theoretical value would be to extend the results of the present work towards understanding how people deliberate about the different kinds of mental states that may be considered to fall under the mind-wandering banner. As discussed in the introduction, there is a clear trend in the literature demonstrating the heterogeneity with which the experience of mind wandering can occur. For example, Wang, Poerio, Murphy, Bzdok, Jefferies, and Smallwood (2018) used multi-voxel pattern analysis to identify differences in default-mode connectivity and various dissociable components of off-task thought (e.g., positive habitual thoughts). Other examples of this heterogeneity include differences in the purported causes, correlates, and consequences of various kinds of mind wandering, such as observations that mind wandering with awareness is associated with less intense activation of the default-mode network than without (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009), or predictions that spontaneous mind wandering is more likely to interfere with task demands than intentional mind wandering (Seli, Risko, & Smilek, 2016).

A related set of empirical questions would naturally extend this work on heterogeneity by asking how participants make judgements about these various kinds of distinctions. Consider a situation in which someone decides that they were mind wandering up until just prior to the point that they were probed in an experience-sampling paradigm. While this thought process would rule out an 'on-task' response, some experiments interested in intentionality ask participants to further distinguish between whether their mind wandering was spontaneous or intentional (Seli, Risko, & Smilek, 2016). It is not clear how exactly one would go about deciding whether they were intending to mind wander or not. The fact that future-oriented mind wandering episodes have been reported to be more frequently associated with reports of intentional (as compared to spontaneous) mind wandering (Seli, Ralph, Konishi, Smilek, & Schacter, 2017) suggests one possible heuristic: an inferential process similar to the sort proposed throughout this dissertation. Participants may evaluate the contents of their off-task thoughts and be more likely to infer that they were of an intentional nature if they were associated with a practical purpose that can be easily identified (e.g., planning). Another possibility is that participants may sometimes respond to those intentionality probes in such a way as to save face (Festinger, 1962).

Related to these questions surrounding heterogeneity and how to go about delineating between different kinds of mind wandering, a dialogue is currently unfolding in the literature about how best to define and/or operationalize mind wandering in the first place. Seli et al. (2018a) and Seli et al. (2018b) have suggested that adopting a family-resemblance type approach could have good utility for determining what mental experiences fit the criteria of what should be considered mind wandering. On the other hand, Christoff et al. (2018) argued that a more precise way to operationalize mind wandering is necessary. Among other things, they suggest that the temporal dynamics of mind wandering as a free-flowing and relatively unconstrained form of thought should constitute a necessary characteristic of mental experiences classified as mind wandering.

More directly pertinent to the present work, this discussion about defining and/or operationalizing mind wandering demonstrates an interesting parallel to a problem that a theoretical account of how people introspect about mental state may eventually need to address.

Simply put, if researchers themselves cannot decide what mind wandering is, it seems unreasonable to expect that the general population from which participant samples are drawn would have a clear consensus as to the nature of what constitutes that phenomenon either. This may have implications for an expectation of some individual difference in how mind wandering is conceptualized, and this could also be expected to impact how decisions about self-reporting that mental state are made. At the very least, the results of Experiment 3 establish an initial line of evidence supporting the proposition that there is individual difference in the kinds of information people consider while responding to mind wandering probes.

One additional thought related to this issue of heterogeneity is how that might inform best practices for analyzing mind-wandering data. Without going into too much detail, it can be said that researchers often focus on the variation observed among participants with respect to task focus. In other words, if someone responds to a probe in such a way that indicates they are mind wandering, analyses often directly compare behaviour associated with that response to behaviour associated with different responses generated by different participants. However, another approach is to look at the 'within-subject' variation and more directly compare how participant behaviour differs as a function of their own probe responses (i.e., my mind-wandering responses vs. my on-task responses). Given the variability in how people might go about forming these reports that has been argued throughout this dissertation, relying more heavily on within-subject variation may be a way to minimize some sources of variability that may not always be relevant to the research questions being posed.

Many alternative ways to try to operationalize mind wandering seem plausible. An alternative account to the one proposed by Seli et al. (2018a and 2018b) and Christoff et al. (2018) could be that mind wandering can essentially be conceived of as a time-sharing situation that resembles the experimental context of task switching. According to this view, effects of mind wandering and/or related predictions might be adequately modelled by considering the processing of task-unrelated content as not only siphoning away cognitive resources that could go towards task-related processing but also as incurring other typical kinds of costs associated with task switching (reconfiguring response sets, etc.). Although it is not immediately clear how to do this, evidence supporting that proposition could derive from models demonstrating switch costs resultant of mind wandering commensurate with the frequency with which one is rapidly alternating between the two types of processing (task-related and task-unrelated or, put another way, coupled and uncoupled attention).

It may also be useful to extend the proposed framework towards social cognition. If someone is trying to judge how focussed a conversational partner is, it is not clear exactly how they would go about doing this. Presumably, not unlike when introspecting about one's own mental state, various sources of information may be considered that could lead to probabilistic inferences (e.g. facial expression). Various individual differences, such as those related to social functioning (e.g., autism-spectrum quotient: Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), may predict variance in how well people are able to make those judgments. A better understanding of how these judgments are made has implications for social contexts (e.g. educational instruction) yet also holds the potential to provide some leverage on the processes one goes through while introspecting about their own attention state. For example, participants making judgements about the attentional state of others presented in brief video clips reported making inferences based on the extent of fidgeting apparent (Farley & Kingstone, 2013). Conceivably, similar inferences may be made about the relationship between one's own attentional state and fidgeting behaviour.

Summary and Conclusion

The results presented in this dissertation support a particular theoretical account of how people introspect about and report mind wandering. It would seem that Nisbet and Wilson (1977) were correct in predicting that self reports can be made based on indirect inference. While these data support that basic premise, my interpretations are not consistent with their argument that self-reports are therefore not useful for experimental purposes. Decades of mind-wandering research built on self report has yielded many reliable findings which have gone a long way towards enriching our collective understanding of cognition. This dissertation demonstrates that understanding inferential processes that may be driving some reports informs greatly on various theoretical constructs relevant to mind-wandering behaviour.

Experiment 1 demonstrated that changes in perception of task performance influence experimental participants' perception of their own level of task focus. Participants who thought they were doing worse than they actually were reported lower task focus (implying more mind wandering), while the opposite was true for those participants who overestimated their level of performance. This suggests an inferential process at play, in which participants infer their relative level of task focus based (in part) on how well they think they are performing.

The results from Experiment 2 provided insight into how contextualizing factors, such as the way in which mind wandering is described in the initial experimental instructions, shape the construction of such reports. Participants who read an initial description of mind wandering which emphasized possible negative consequences reported more mind wandering in the beginning of the experiment, as well as the perception that mind wandering had more negatively impacted their session. This patten of results suggests that the contextualizing instructions at the beginning of the experiment changed what information participants considered when forming their reports.

Experiment 3 provided converging support for the proposition that perception of task performance is a factor that some people consider when introspecting about mental state. In addition to being somewhat of a conceptual replication, this also increases confidence in the interpretation of Experiment 1 because the absence of explicit performance-based feedback goes some way towards speaking against the possibility that demand characteristics drove the results. More generally, Experiment 3 also provided good evidence for various individual differences in how participants formed their reports.

Collectively, this dissertation has presented an argument for a simple theoretical account of how people think about, and report, mind wandering. This should go some way towards dispelling the prevailing belief that mind-wandering reports are generated relatively automatically and/or as a direct result of identifying whether or not off-task thoughts can be recalled. In addition to providing evidence that various sources of information are considered when forming mind-wandering reports, a more detailed account of the underlying processes driving these reports should also facilitate a better understanding of how these factors might make contact with other theoretical constructs of interest related to mind-wandering phenomena. These include working memory, meta-awareness, intentionality, and mindfulness. Future work should pursue what other sources of information are considered, and individual differences in how attention is directed to these various sources, as well as the underlying differences that drive the particulars of what is attended to.

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Appendix 1

Mass Testing Questionnaires

Questionnaire #1: ARCES

Instructions: The following statements are about minor mistakes and absent-mindedness everyone notices from time to time, but we have very little information about how common they are. The great majority of time these little foibles are harmless, though they do have serious safety implications in industry and everyday life. We want to know how frequently these sorts of things have happened to you.

Scale: never (1) to very often (5)

1. I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice)

2. I go into a room to do one thing (e.g., brush my teeth) and end up doing something else (e.g., brush my hair)

3. I have lost track of a conversation because I zoned out when someone else was talking

4. I have absent-mindedly placed things in unintended locations (e.g., putting milk in the pantry or sugar in the fridge)

5. I have gone into a room to get something, got distracted, and wondered what I went there for

6. I begin one task and get distracted into doing something else

7. When reading I find that I have read several paragraphs without being able to recall what I read

8. I make mistakes because I am doing one thing and thinking about another

9. I have absent-mindedly mixed up targets of my action (e.g., pouring or putting something into the wrong container)

10. I have to go back to check whether I have done something or not (e.g., turning out lights, locking doors)

11. I have absent-mindedly misplaced frequently used objects, such as keys, pens, glasses, etc.

12. I fail to see what I am looking for even though I am looking right at it

Questionnaire #2: MW-Deliberate

Instructions: For the following statements please select the answer that most accurately reflects your everyday mind wandering.

Scale: almost never (1) to very often (5)

1. I allow my thoughts to wander on purpose
2. I enjoy mind-wandering
3. I allow myself to get absorbed in pleasant fantasy
4. I find mind-wandering is a good way to cope with boredom

Questionnaire #3: MW-Spontaneous

Instructions: For the following statements please select the answer that most accurately reflects your everyday mind wandering.

Scale: almost never (1) to very often (5)

1. I find my thoughts wandering spontaneously
2. When I mind-wander my thoughts tend to be pulled from topic to topic
3. I mind wander even when I'm supposed to be doing something else
4. It feels like I don't have control over when my mind wanders

Questionnaire #4: AC-Distractability

Instructions: For the following statements please select the response that most accurately reflects your everyday attentional control ability.

Scale: almost never (1) to very often (5)

1. I have difficulty concentrating when there is music in the room around me
2. When I am working hard on something, I still get distracted by events around me
3. It's very hard for me to concentrate on a difficult task when there are noises around
4. When I am reading or studying, I am easily distracted if there are people talking in the same room

Questionnaire #5: AC-Shifting

Instructions: For the following statements please select the response that most accurately reflects your everyday attentional control ability.

Scale: almost never (1) to very often (5)

1. I am slow to switch from one task to another

2. It takes me a while to get really involved in a new task
3. It is difficult for me to alternate between two different tasks
4. After being interrupted, I have a hard time shifting my attention back to what I was doing before

Appendix 2

Additional Results from Experiment 1

Table A1

Mean Letter Detection Score by Most Recent Feedback Condition (and Standard Error)

	LD	Comp
Decrease	95.82% (0.35)	63.93% (3.17)
Control	94.59% (0.35)	52.34% (3.15)
Increase	95.83% (0.34)	57.20% (3.09)

Table A2

Mean response time and variability by condition (and Standard Error)

Condition	**Mean Response Time Variability**
Decrease	0.30 (0.01)
Control	0.31 (0.01)
Increase	0.29 (0.01)

Appendix 3

Additional Results from Experiment 2

Table A3

Performance by Condition in Block 1 (and Standard Error)

Condition	Mean Letter Detection Score	Mean Comprehension Score
Control	92.15% (1.27)	72.51% (3.17)
Negative	92.43% (1.28)	67.59% (3.21)
Positive	93.37% (1.28)	76.23% (3.21)

Table A4

Mean Response Time and Variability Coefficient by Condition in Block 1

(and Standard Error)

Condition	**Mean Response Time**	**Coefficient of Variability**
Control	748.27 (44.27)	0.35 (0.02)
Negative	781.21 (44.87)	0.39 (0.02)
Positive	680.03 (44.87)	0.34 (0.02)

Appendix 4

Additional Results from Experiment 3

Table A5

Mean Probe Response, Performance, and Response Time by Group (and Standard Error)

Measure	High-Information Group	Low-Information Group	Standard Error
Probe Response	3.91	3.93	0.18
Letter Detection Score	0.96	0.94	0.01
Comprehension Score	0.74	0.79	0.02
Response Time	706.00	672.00	15.00
Mean # of Response Items Reported	6.65	2.64	0.22
Mean Correlation between Letter-Detection Score and Probe Response	-0.30	-0.20	
Mean Correlation between Comprehension Score and Probe Response	-0.17	-0.10	

Table A6

Mean General Attentional/Cognitive Function Scores

Measure	Low-Information Group Mean	High-Information Group Mean	Standard Error
ARCES	36.54	35.69	0.33
Deliberate MW	13.17	13.74	0.14
Spontaneous MW	12.90	11.69	0.19
Shifting	8.56	9.65	0.17
Distractability	13.40	13.44	0.17

Table A7

Mean Attitudes Towards Mind Wandering Scores

Measure	Low-Info Group	High-Info Group	Standard Error
I regularly experience mind wandering episodes which I consider to negatively impact my everyday life (e.g. interferes with school/work, encourages dwelling on past failures, causes me distress, etc.)	3.72	3.74	0.09
I regularly experience mind wandering episodes which I consider to positively impact my everyday life (e.g. helps me plan for the future, provides insight into problems I've been thinking about, improves my mood, etc.)	4.03	4.24	0.07
I have generally negative associations with mind wandering	2.67	2.61	0.06
I typically consider instances of mind wandering to reflect a failure of attention	4.00	3.48	0.08
I consider it important to limit mind wandering as much as possible	4.28	4.26	0.08

Table A8

Mass Testing Correlations

Question	**ARCES**	**SPON**	**DEL**
I regularly experience mind wandering episodes which I consider to negatively impact my everyday life (e.g. interferes with school/work, encourages dwelling on past failures, causes me distress, etc.)	0.35	0.47	0.11
I regularly experience mind wandering episodes which I consider to positively impact my everyday life (e.g. helps me plan for the future, provides insight into problems I've been thinking about, improves my mood, etc.)	0.10	0.24	0.45
I have generally negative associations with mind wandering	0.19	0.24	-0.23
I typically consider instances of mind wandering to reflect a failure of attention	0.22	0.26	-0.14
I consider it important to limit mind wandering as much as possible	0.11	0.08	-0.28