An Investigation into the Self-deployment of Attentional Reminders

by

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Author’s Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

Zion Leatham was the primary author of the manuscript, conceived the experimental paradigm for all three experiments in this thesis, and analyzed the data.

Bobby McHardy assisted with the creation of the experimental paradigm for experiments 1 and 2.

Brandon Ralph assisted with the creation of the experimental paradigm for experiment 3.

Jonathan Fugelsang assisted in guiding the research process for experiments 2 and 3, including the creation of the corresponding experimental paradigms, data analysis, and presentation of the findings in written format.

Daniel Smilek guided the research process for all three experiments, including the creation of the experimental paradigms, data analysis, and presentation of the findings in written format.

Abstract

In a series of studies, we sought to determine whether 1) people will self-deploy attentional reminders when asked to complete an attentionally demanding task (Experiment 1 & 2), 2) people modulate the number of attentional reminders they selected depending on the presence or absence of a continuous distraction (Experiment 1 & 2) and 3) if so, do reminders improve performance on the attentionally demanding task (Experiment 1, 2 & 3) . In Experiments 1 and 2 participants were asked to complete an attentionally demanding task (2-back; primary task) and completed the 2-back task on its own (no distraction condition) or while a distracting video was played on the computer screen above the 2-back task stimuli (distraction condition). Critically, participants were given a preview of the 2-back task and the video (if present). After being given a preview of the task, they were asked to set how many (if any) reminders they wanted to receive during the task. We followed this up in Experiment 3, where we removed the choice component. Specifically, in this study, half of the participants received experimenter set attentional reminders (every 2 minutes) while the other half did not receive any reminders. Findings from Experiment 1 and 2 indicated that people will opt to select attentional reminders when asked to complete an attentionally demanding task, however their modulation of the reminders was irrespective of the presence or absence of a distracting video. In addition, the attentional reminders people set did not influence performance on the 2-back task. Experiment 3 demonstrated that people who received experimenter set attentional reminders did not significantly perform better on the 2-back task in the presence of a distracting video. These results suggest that the attentional reminders may influence performance, however their influence might be dependent on the contingent timing of the deployment of the attentional reminders.

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Dedication

To my parents for all their love and support. Thank you for fostering my curiosity, determination, and interest in learning about the world and always pushing me to look beyond what's in front of me. Thank you to my friends who have always readily available to listen to both my hardships and prosperity throughout my program.

-Z

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Chapter 1: Introduction

Imagine Sarah, a college student, sitting at her desk trying to complete an important research paper. As she delves into her work, she finds herself constantly distracted by the TV playing in the background. Her attention drifts away from the task at hand, and she struggles to maintain productive focus, ending up engaged in the task-irrelevant media. Fortunately, her task-irrelevant engagement is interrupted by a reminder to continue to focus on writing her research paper, which she set on her laptop before her study session began. Using the reminder, she shifts her attention back on her main task of writing, once again successfully ignoring background distractions. Sarah's strategy to stay on task may be familiar to at least some students who deploy various strategies to stay on task while studying, writing papers, and reading. As a step towards addressing situations such as the one experienced by Sarah, the overall goals of this thesis are to explore 1) to what extent individuals will deploy reminders to pay attention to a primary task, 2) whether the use of such attentional reminders varies as a function of the presence of media-based distractions, and 3) whether attentional reminders influence primary task performance.

1.1 Nudging and Self-Nudging

Individuals often find themselves in complex environments where their limited capacity hinders their ability to act in their best interest (Unsworth & Robinson, 2015). Distractions, competing stimuli, and cognitive overload can make it challenging to prioritize and make decisions aligned with their goals (Noonan et al., 2018; Pasqualotto et al., 2022). In such situations, interventions that subtly guide behaviour toward more desirable outcomes can be helpful (Oullier et al., 2010; Thaler & Sunstein, 2008). Such interventions have been referred to as 'nudges' (de Ridder et al., 2022; Hansen & Jespersen, 2013; Thaler & Sunstein, 2008). By strategically shaping a person's environment through modifications of available options or embedding cues that influence a person's attention, nudges can help individuals overcome cognitive biases, reduce decision fatigue, and navigate complex environments more effectively (Battaglio et al., 2019; Halpern, 2016; Rao et al., 2018; Thaler & Sunstein, 2008).

For example, Johnson and Goldstein (2003) investigated the impact of nudging in the form of default options on the likelihood people agreed to participate in an organ donation program. Online respondents were asked whether they would be donors based on one of three questions with varying default conditions. In the 'opt-in' condition, participants were told to assume that they had just moved to a new state where the default was *not to be* an organ donor, and they were given a choice to confirm or change that status. In the 'opt-out' condition participants were given the identical scenario with the exception that the default was *to be* a donor. Finally, in the third, 'neutral' condition participants were required to choose without being presented with a prior default response. Respondents could change their choice with a simple mouse click. The form of the question had a dramatic impact. It was shown that donation rates were about twice as high when opting-out (82%) than when opting-in (42%). The opt-out condition did not differ significantly from the neutral condition. Thus, varying default settings, which is an aspect of the available choices (i.e., "choice architecture"; Leal & Oliveira, 2021; Sunstein, 2015), appears to be an effective way to influence behavior.

In addition to default settings, various kinds of visual cues can serve as effective nudges to bias people's decisions and responses. For example, Hollands and Marteau (2016) explored how food choices are influenced by showing people images of foods paired with images of positive and negative health consequences of their consumption. Participants were randomly allocated to one of six conditioning procedures that paired images of either energy-dense snack foods or fruit, with (a) images of negative health outcomes, (b) images of positive health outcomes, or (c) no image (a control). The primary outcome measure was the person's food choice assessed post-intervention with a behavioral choice task. The researchers found that presenting images of negative health outcomes led to more healthy food choices relative to no image and positive image conditions, irrespective of whether they were paired with images of energy-dense snack foods or fruit. Images of positive health outcomes did not alter food choices. This study replicated and extended previous research showing that presenting images of negative health consequences increases healthy food choices.

While nudge interventions typically involve a person (sometimes referred to as a 'choice architect'; Mele et al., 2021; Mills & Sætra, 2022) modifying another person's choice environment, people can also become their own choice architects. Becoming one's own choice architect, whereby one intentionally designs or modifies one's own environment, cues, or prompts to influence and guide one's behaviour in desired directions, is referred to as 'self-nudging' (Reijula & Hertwig, 2020). Sarah's intervention in the opening scenario involved a type of self-nudge because she was the architect of her own behavioral modification. Compared to other-initiated nudges, self-nudges have received much less empirical study.

Although self-nudging techniques can take various forms depending on the context and a person's goals, everyday experience suggests that one relatively common form involves the implementation of personal reminders. People use personal reminders such as alerts, notifications, sticky notes, or digital calendars to prompt themselves to perform certain tasks or follow a specific schedule (Harkin et al., 2016; Milkman et al., 2011; Fishbach & Dhar, 2005; Duckworth et al., 2018; Mcdonald et al., 2011; Brewer et al., 2017). By setting reminders, individuals create an external mechanism and transfer cognitive processes or information storage from their minds to external tools or systems, a process known as 'cognitive offloading' (Burnett

& Richmond, 2020; Dawson, 2020; Risko & Dunn, 2015; Risko & Gilbert, 2016). Reminders, self-initiated or set by a 'choice architect' (i.e., set externally by experimenter) have been found to enhance prospective memory, which involves remembering to perform intended actions at a future time (Gibert, 2015; Henry et al., 2012; Henry et al., 2019; Scarampi & Gilbert, 2020; Scarampi & Gilbert, 2021).

Henry and colleagues (2012) investigated the role of reminders on prospective memory, assessing whether the effect of receiving reminders on prospective remembering is dependent on the initiation source (self vs. experimenter set). Participants were tested on their performance on Virtual Week (Rendell & Craik, 2000), a computerized board game, in which participants move around the board with the roll of a die, with each circuit of the board representing a waking day. Participants must also remember to carry out other tasks at set times as shown on a virtual clock, calibrated to their position on the board. Prospective memory performance was measured based on ability to carry out other tasks while doing a modified version of this task, in which participants were given varying levels of access to reminders. Participants encountered three counterbalanced reminder conditions: no reminders, self-initiated reminders, and experimenter-initiated reminders. Researchers were interested in whether participants will receive the greatest prospective memory benefit when they are provided with reminder cues at fixed, arbitrary times (experimenter-initiated), or when they are instead given the resources to access reminder cues as often as they need, and at times of their own choosing (self-initiated). The results indicated that while the provision of reminders enhanced prospective memory performance, no difference was seen between self-initiated and experimenter-initiated reminder conditions. These data support the role of both self- and externally generated external reminders as an aid to prospective remembering.

To examine cognitive processes involved in setting reminders, Gilbert (2015) investigated a web-based "intention offloading" task, in which participants fulfilled an intention on each trial, after a brief filled delay. On each trial, participants sequentially removed a set of numbered circles from a box, by dragging each circle in turn to the bottom edge. They were instructed to remove target circles by dragging them to an alternative edge (e.g., "please drag 7 to the top instead"). Participants were given the option of setting an external reminder, by placing the target circles next to the intended edge at the start of the trial. When they did this, the intention was offloaded in the sense that it was now directly cued by the location of the target circle. Consequently, there was no need to mentally rehearse the intended behavior. An everyday analogy might be leaving an object in a noticeable position so that it cues an intended behavior (e.g., leaving something by the front door so that one remembers to bring it with them when leaving the house). This task significantly predicted participants' fulfilment of a naturalistic intentionions embedded within their everyday activities up to one week later (with greater predictive ability than more traditional prospective memory tasks, albeit with weak effect size). Investigating performance of the intention–offloading task revealed three main findings. First, intention offloading promoted intention fulfillment: permitting this strategy boosted performance, and participants who set more reminders fulfilled more intentions. Next, participants were more likely to offload intentions when they had three targets to remember rather than one. Thus, the decision to offload intentions was influenced by memory load. Finally, participants were more likely to offload intentions when they encountered an interruption in the ongoing task. Thus, the decision to offload intentions was also influenced by the ongoing task in which the memory load was embedded. The latter two findings show that participants offload intentions adaptively based on the difficulty of the task, seeing as a higher memory load and the presence of interruption both reduced intention fulfillment in a matched version of the task that disallowed intention offloading. These results suggest the importance of metacognitive processes in triggering intention offloading, which can increase the probability that intentions are eventually fulfilled.

1.2 Maintaining Attention

The problem that Sarah was trying to solve with a self-nudge in the opening scenario was that her attention disengaged from the primary task of working on her paper and engaged with a distraction in the environment. Task disengagement and its causes have been studied in various forms, with researchers examining distraction (Lavie, 2005; Hsu et al., 2014; Tremblay et al., 2005), absent-mindedness (Cheyne et al., 2006; Reason & Lucas, 1984), mind-wandering (Kane et al., 2007; Smallwood & Schooler, 2006; Wegner, 1997), stimulus-independent thought (Antrobus, 1968; Teasdale et al., 1995), task-unrelated/related thought (Cheyne et al., 2009, 1995; Smallwood et al., 2004; Smallwood et al., 2003), tune outs and zone outs (Schooler, 2002; Schooler et al., 2005; Smallwood et al., 2007), and mind pops (Kvavilashvili & Mandler, 2004). Task disengagement is problematic in many situations because it leads to reduced attentional resources being allocated to demanding aspects of the primary task (Manly et al., 1999; Robertson et al., 1997; Smallwood and Schooler, 2006; Smallwood et al., 2007), which can ultimately lead to performance errors. For example, consequential errors have been documented when attentional disengagement occurs from various tasks such as driving (He et al., 2011), classroom learning (Risko et al, 2013; Wammes et al., 2019), reading (Cheyne et al., 2009; Forrin et al., 2021), and piloting airplanes (Reason, 1979).

Task disengagement and the associated performance decrements often tend to increase when people are required to maintain attention on a task for a prolonged period, an issue that has been extensively studied in the vigilance literature (Mackworth, 1948; Mackworth, 1950; Thomson et al., 2014). Vigilance refers to the sustained attention required to detect rare and infrequent target events in an environment characterized by frequent non-target events or distractors (Thomson et al., 2015). It has long been known that attention, and consequently performance, wanes over time (both empirically and anecdotally) in situations in which there is typically little for the observer to do, as in the monitoring of automated systems (Molloy & Parasuraman, 1996). For example, Parasuraman and Davies (1984) examined attentional lapses and vigilance decrement in the context of monitoring a simulated nuclear power plant -- a task that demands sustained attention. In a simulated nuclear power plant monitoring task, participants were trained to detect and respond to specific critical events (i.e., potential hazards and anomalies). They were then required to sustain their attention over an extended period of time while monitoring for critical events. The results showed evidence of a vigilance decrement whereby participants' performance declined over time during the monitoring task, indicating that their attention was more likely to disengage as time progressed during the task.

With modern technological advances, we often find ourselves dividing our attention between multiple tasks. While this may seem like a productive way to live, our attentional capacity is limited, and generally this yields a decline in performance in one or more of the many tasks that we try to simultaneously complete (Horrey et al., 2009; Pashler, 1994; McDowell et al., 1997; Hermer-Vazquez et al., 1999). Some people believe that they are immune to the costs of multitasking and commonly engage in potentially dangerous behavior, such as driving while talking on the phone (Donohue et al., 2012). To examine the degree to which some people may be more resilient to the effects of multitasking, Donohue and colleagues (2012) investigated whether avid action videogame players, who have been shown to have heightened attentional capacities, are particularly adept multitaskers. Participants completed three visually demanding experimental paradigms (a driving videogame, a multiple-object-tracking task, and a visual search), with and without answering unrelated questions via a speakerphone (i.e., with and without a dual-task component). All the participants, videogame players and nonvideo game players alike, performed worse while engaging in the additional dual-task for all three paradigms, and there were no differences in how videogame players and nonvideo game players were affected. This suggests that having heightened attentional capacities may not offer immunity from dual-task costs.

Ralph et al., (2020) demonstrated that even the presentation of a task-irrelevant video that participants were not required to watch served as a distraction that led to poorer performance and that people were aware of the performance costs associated with completing a task in the presence of a non-required video (i.e., media multitasking). The researchers had participants complete an attentionally demanding 2-back task, which involves presenting participants with a stream of stimuli (e.g., letters) and requiring them to indicate when a presented stimulus matches the one presented two trials earlier. Participants completed the high-demand task both independently and while a non-required video was simultaneously played above the 2-back stimuli on the computer screen. To determine whether people were subjectively sensitive to the impact that the concurrent video had on primary-task performance, subjective estimates of performance were collected following both trial types (No-Video vs. Video trials), as were explicit beliefs about the influence of the video on performance. Their results indicated that the addition of the non-required, task-irrelevant video reduced performance on the 2-back task and that people reported that they were aware of this impact.

In some situations (e.g., monitoring during vigilance tasks), sustaining attention on a primary task requires the exertion of effort. The idea that attentional effort is important for task performance has a long history in psychology and is a key component of various cognitive-energetic models of performance (Botvinick & Braver, 2015; Hockey, 2013; Kahneman, 1973; Kanfer & Ackerman, 1989; Kurzban et al., 2013; Sarter et al., 2006; Shenhav et al., 2017; Westbrook & Braver, 2015; Wickens, 2020). Attentional effort reflects temporal changes in goal-directed arousal and determines the number of attentional resources that are allocated to a particular task in a given moment (Kahneman, 1973). The exertion of effort is influenced by several factors including a person's motivation, presence or absence of incentives, current arousal levels, task difficulty, personality factors, self-efficacy, task goals, as well as the costs and benefits of allocating effort (Kurzban et al., 2013; Locke & Latham, 2015). In general, attentional effort regulates the extent to which control is engaged in performing the primary task (Shenhav et al., 2017). The engagement of effort is also required when attention wanes from the current task in order to bring attention back to the task (Cheyne et al., 2018). The term "focus-back effort" has been introduced to refer to the conscious and deliberate exertion of mental energy required to redirect one's attention and regain focus on a task or activity after experiencing a distraction or attentional drift (i.e., mind wandering) (He et al., 2023; He et al., 2021).

Given the problematic influence of attention lapses on task performance, prior research has examined the degree to which various interventions can reduce such lapses. Studies have examined the benefits of attention training (Peng & Miller, 2016; Tang & Posner, 2009), attention state training or mindfulness training (Tang & Posner, 2009; Zeidan et al., 2010; Davidson & Kaszniak, 2015; Xu et al., 2017) and increasing motivation (Unsworth et al., 2022;

Seli et al., 2015; Seli et al., 2016). For example, prior studies have examined 'effort mobilization' (Unsworth et al., 2022) as a motivational approach to enhance sustained attention and reduce lapses of attention. A key aspect of this approach is the notion that individuals rarely allocate all of their attentional resources to a given task, and that they can mobilize additional effort to draw more attention to the task when necessary or when requested. Unsworth et al. (2022) examined the extent to which effort mobilization would enhance sustained attention performance and reduce the occurrence of lapses of attention. Participants performed a variant of the psychomotor vigilance task (PVT; Lim & Dinges, 2008) in which participants see a row of zeros and are told that when the numbers begin counting up (like a stopwatch) they must press a key as fast as possible. They were randomly assigned to either a control condition or an effort mobilization condition. In the control condition, participants performed a standard version of the PVT. In the effort mobilization condition, participants performed the same PVT task, but on 20% of trials they were instructed to "Try Hard" before the onset of the trial. The results showed that participants who received the Try Hard instructions demonstrated faster overall performance with a reduction in very long reaction times and reported fewer off-task thoughts compared to participants in the control condition.

In addition to the aforementioned techniques, attentional engagement could also conceivably be improved by using specific self-nudges, as suggested by the opening scenario involving Sarah. Self-nudges could be particularly useful in helping individuals reengage their attention during moments in which they are prone to be inattentive (Hansen & Jespersen, 2013; Sunstein et al., 2019; Hollands et al., 2016). Reminders to pay attention to the primary task can be employed to provide timely and explicit nudges to engage focus-back effort and redirect our attention back to the primary task and discourage us from getting too absorbed in secondary media activities (Wilmer et al., 2017). Attentional reminders may even reduce the cognitive load associated with continuously monitoring and redirecting our attention, freeing up mental resources for higher engagement with, and better performance, on the primary task (Minear et al., 2016; Rosen et al., 2013). Such reminders may be particularly effective when one is distracted by task-irrelevant media (e.g., a TV or video playing in the background), a situation that increases the likelihood of attentional disengagement from a primary task (Ralph et al., 2020). Considering the preceding discussion, it seems reasonable to suspect that people might choose to deploy reminders to pay attention to a primary task, particularly when distractions are present and staying on task is more difficult.

1.3 The Present Studies

In the present studies, we first sought to determine whether people would opt to set reminders to pay attention when faced with a cognitively demanding task. To this end, in Experiments 1 and 2 participants were asked to complete an attentionally demanding 2-back task, and after being given a preview of the task, they were asked to set how many (if any) reminders they wanted to receive during the task to return their attention back to the primary task. Second, we explored whether people would modulate the number of attentional reminders they selected depending on the presence or absence of a continuous distraction. To achieve this, in Experiments 1 and 2, participants completed the 2-back task on its own (no distraction condition) or while a distracting video was played on the computer screen above the 2-back task stimuli (distraction condition). Critically, participants were given a preview of the 2-back task and the video (if present) before setting their reminders. We expected that people may set more reminders when a distracting video is present than when it is absent, and performance will be positively correlated with number of reminders. Third we examined the impact of attentional reminders on performance. In Experiments 1 and 2 this was done by examining the relation between the number of reminders people chose to set and their performance. Our expectation was that performance would improve as the number of reminders people chose to receive increased. We further addressed this issue in Experiment 3, in which participants completed the 2-back task in the presence of a distracting video; in this study half of the participants receiving regular attentional reminders (i.e., they were not able to choose the number of reminders they were to receive) while the other half did not receive any reminders. We hypothesised that participants who received reminders would perform better on the 2-back task than participants who did not receive a reminder.

Chapter 2: The Self-deployment and Effectiveness of Attentional Reminders

2.1 Experiment 1

2.1.1 Methods

Participants

Participants were recruited through the University of Waterloo's participant management software (SONA) which includes mostly students taking undergraduate courses in psychology. Participants received 0.5 participant credits to be applied to their course grades. In total, data were collected from 185 participants (46 males, 135 females, 4 unknown) with an age range of 17–40 years old (M = 19.89, SD = 2.52). We determined, a priori, that we would aim to collect data from approximately 80 participants per counterbalance condition, for a total anticipated sample of 160 participants. This sample size was sufficient to detect similar small effect sizes in prior studies conducted in our laboratory.

Materials

The 2 -Back Task

Performance on the 2-back task reflects both working memory and sustained attention. On each trial of the task, participants were presented with one of nine numbers (between 0 and 9) for 500 ms, followed by a fixation cross for 2000 ms. Participants were instructed to indicate by pressing the 'Enter' key whether the current number matched the number presented two numbers earlier. Across the 479 trials, there were 48 numbers that matched the letter presented two numbers back (i.e., target prevalence of 10%) and 431 numbers that did not. Each number appeared equally often as a target and a non-target. Targets appeared in the center of the screen on a white background. Participants did not receive any feedback about their responses. Altogether, the experimental task took 20 minutes to complete.

Distracting Video

The distracting video was a TED Talk titled Brain Magic presented by Keith Barry. The 19:50 long video included both audio commentary and visual elements that conveyed various magic tricks presented by Keith Barry. The video has been used in previous studies (Ralph et al., 2020) and was chosen because an understanding of the talk involved engagement with both its video and audio components. The video was presented in full colour in the upper portion of the participant's display.

Procedure

Participants were provided with a link to an online version of the study. After providing informed consent participants were randomly assigned to one of two experimental conditions. In one condition of the experiment the "Brain Magic" TED talk was embedded in the upper portion of the screen and was played constantly throughout the experimental block (Video condition). In the other condition of the experiment, no such video was played (No Video condition; see Figure 1). Prior to completing the Video Present condition, participants were explicitly told that they did not have to engage with the video while completing the 2-back (i.e., to clarify that video viewing was non-required). The specific instructions were as follows:

> "There will be a video playing above **the task**. Remember that your **primary task is the number task**. Therefore, please ensure that you pay full attention to the number task and that the video does not impair your performance. Ensure that your volume is at a comfortable level and that your volume is not turned off."

Figure 1. Visualization of our two experimental conditions.

Prior to the initiation of the 2-back task participants were informed that they will undergo a one-minute practice block prior to the main task. After they completed the practice block, participants were informed that they would be allowed to set reminders that will appear throughout the task; they were told that the reminders would encourage them to pay attention to the 2-back task. Specifically, they were instructed as follows:

> "Importantly, the study includes a visual reminder, designed to prompt you to pay attention to the primary number task. They will be referred to as 'attentional reminders.' An example of an attentional reminder is shown below:

Within the range of 0-20 minutes, participants were allowed to select how frequently they would like the attentional reminders to appear throughout the task. Each attentional reminder was presented for 5 seconds. Participants were allowed to set as few as 0 attentional reminders to as many as 20 reminders throughout the task. Specifically, they were instructed as follows:

> “You have the option to set how frequently (minutes) you would like to receive these attentional reminders throughout the 20-minute task. Please use the slider below to set how frequently you would lie the attentional reminders to appear (in minutes).”

To clarify that participants did not have to engage with the video while completing the 2-back task before the video condition, as it was non-required, the set of instructions was provided prior to the experimental block:

"You will have the opportunity to watch a video, embedded on one side of the window, while you complete the task. There will be no test on the content of this video, and you are not required to watch it. However, you may watch the video while you do the task if you wish."

To emphasize that the primary task was a "required" task, the instructions ended with:

"Please do your best to respond to each letter and to perform the task (the n-back) to the best of your ability."

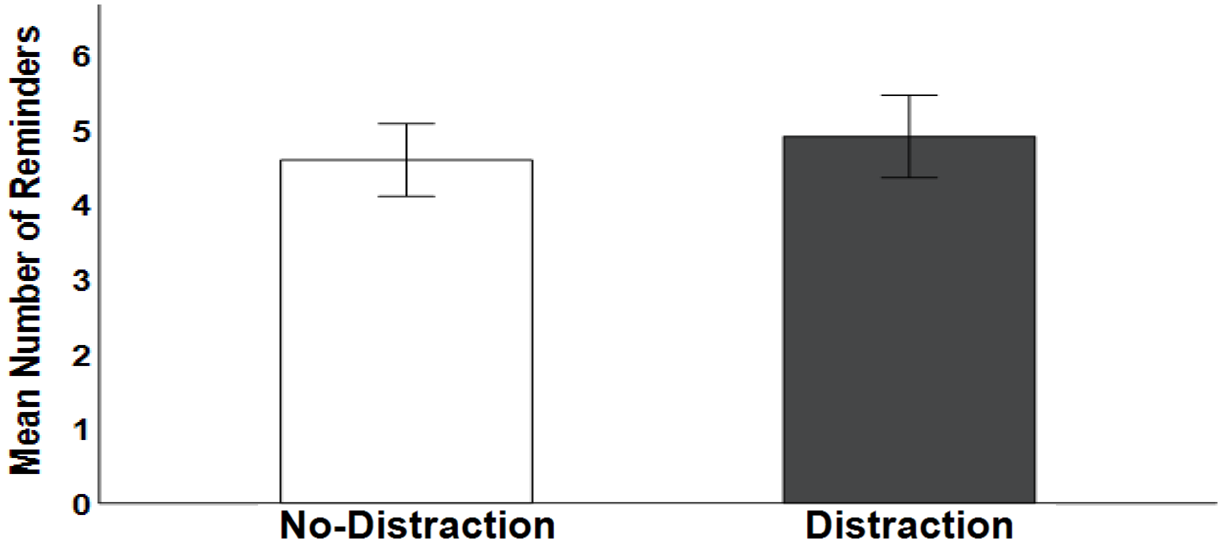
At the end of the study sessions, participants were also given responsible research resources on self-nudging and provided a feedback letter debriefing them of the studies purposes.

2.1.2 Results

We began by analysing the number of reminders that participants selected. We calculated how many reminders participants received based on the reminder intervals they selected (= Total Time of Experimental Task / Reminder Interval; rounded down). The majority of the participants (82%) chose to receive at least on reminder. The mean number of reminders for the Distraction and No Distraction conditions is shown in Figure 2. The influence of Distractor Condition (Distraction vs. No Distraction) on the number of reminders was assessed with a one-way between-participant ANOVA. The analysis revealed that there was no significant difference in the number of reminders participants chose to receive across the two groups $F(1,183) = .184$, $p = .67$, $\eta^2 p = .001$. Thus, anticipating the presence of a distracting video did not seem to influence the number of attentional reminders participants' chose to deploy for themselves.

Figure 2.

Mean Number of Reminders by Condition.



Note: Error bars: +/- 1 SE

Performance on the 2-back was assessed in terms of proportion of hits (proportion of 2-back targets correctly identified) and proportion of false alarms (proportion of non-targets incorrectly identified as targets). The mean proportion hits and false alarms for the Distraction and No Distraction conditions are shown in Figure 3. Each of these two performance measures was submitted to a one-way ANOVA with Distraction Condition (Distraction vs. No Distraction) as the independent variable. There was a main effect of Distraction Condition on proportion of hits, $F(1,172) = 8.42$, $p = .004$, $\eta^2 p = .047$, such that participants correctly detected more 2-back targets when the distracting video was absent than when it was present. There was no main effect of Distraction Condition on proportion of false alarms, $F(1,171) = .30$, $p = .586$, $\eta^2 p = .002$. Thus, participants performed better (in terms of hits) on the 2-back task in the absence of a distracting video, compared to when the distracting video was present.

Finally, we collapsed across experimental conditions, computed Spearman's rank correlations between each of our performance metrics (proportion of hits and proportion of false alarms) and number of reminders to assess the relation between performance and the number of reminders. The correlations are shown in the bottom two panels of Figure 3. The correlation between the number of reminders and proportion of hits was near zero, $r(173) = .01$ $p = .92$. However, there was a positive, albeit small, correlation between the number of reminders and proportion of false alarms, $r(174) = .16$, $p = .03$.

2.1.3 Discussion

Experiment 1 yielded several interesting findings. In addition to finding that the presence of a non-required video impaired performance on the attention-demanding primary task (2-back), we found that: (a) 82% of participants set at least one attentional reminder, (b) the number of reminders participants set was independent of whether the primary task was completed in isolation, or when a distracting video was present, and (c) changes in false alarms were positively correlated with changes in number of reminders. This last finding was somewhat unexpected as it suggests that performance decreases (i.e., false alarm errors increase) as the number of reminders increase. Although this finding could mean that attentional reminders are detrimental to task performance, there are several other possible explanations. For instance, there is also the possibility that people who perform more poorly (i.e., have higher false alarms) also recognize that they need to set more attentional reminders for themselves. Finally, another possibility is that the small relation between the number of attentional reminders and false alarms was spurious.

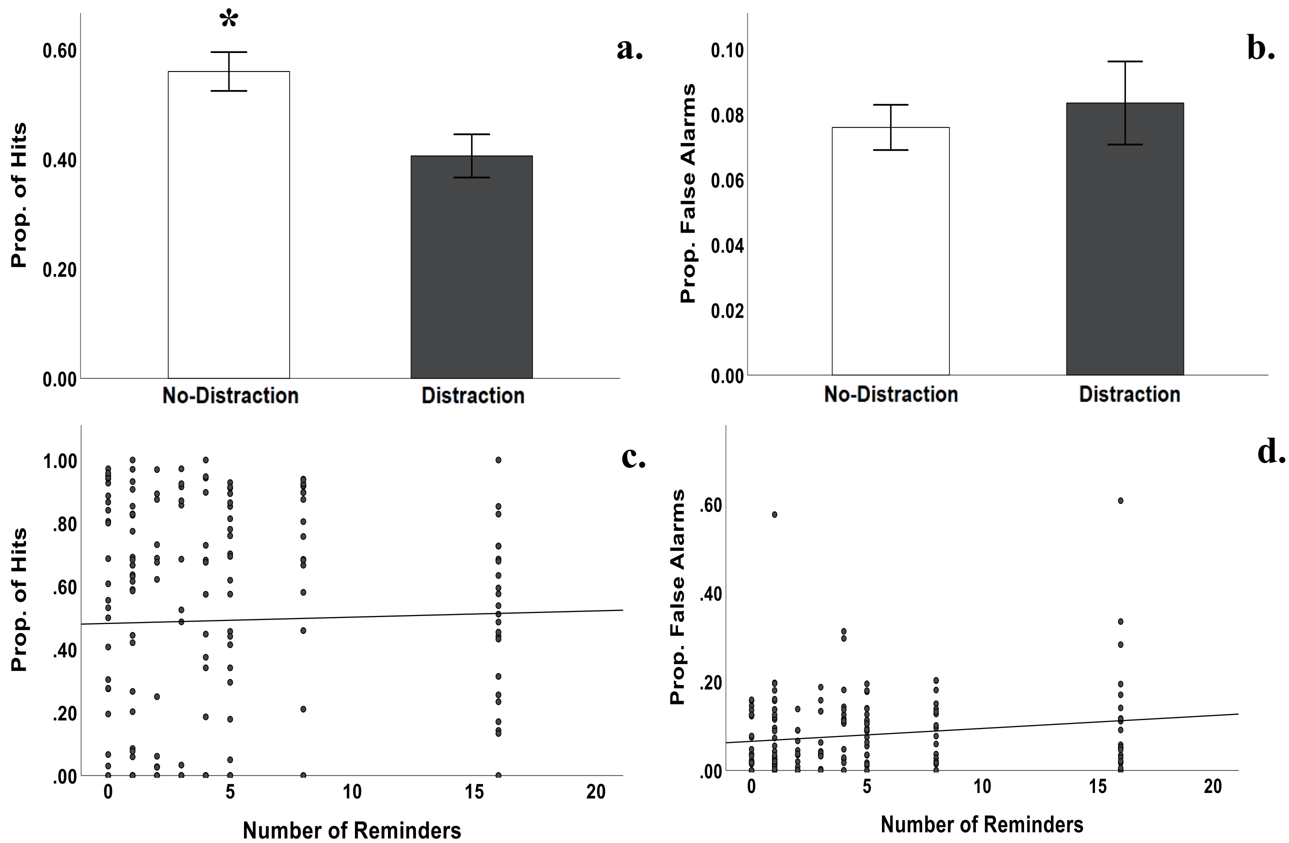


Figure 3. *Performance metrics on 2-back task for condition and number of reminders*. (**a**) Proportion of hits by condition, (**b**) proportion of false alarms by condition, (**c**) proportion of hits by number of reminders, (**d**) proportion of false alarms by number of reminders. (**a** & **b**) are means, and error bars +/- 1 SE. (**a** & **b**) Statistical analysis by a one-way ANOVA and (**c** & **d**) spearman correlations. (**a** & **d**)* $p< 0.01$.

2.2 Experiment 2

Experiment 2 had two goals. First, we sought to evaluate whether the frequency of attentional reminders would have a more pronounced effect on task performance if we made the attentional reminder more salient. In Experiment 2 we used a similar paradigm to that of Experiment 1, with the exception that we added an audible whistle that played along with the visual attentional reminder. Nakashima and Crébolder (2010) found that when participants have an audiovisual alert, response times in a divided attention task were not significantly different from the visual alert, indicating that the auditory component was not distracting; the researchers made the claim that the audiovisual alert is more likely to be detected over the visual alert when operators are looking away from the displays.

Second, because we failed to find an influence of distraction on reminder setting in Experiment 1, in Experiment 2 we explored whether reminder setting might be affected by the presence of a distracting video if we give participants a longer preview of (i.e., practice with) the task context, including the presence or absence of the distracting video. Since in Experiment 1 participants chose the number of reminders they were to receive after the practice trials and before the beginning of the experiment proper, the practice trials served as the only basis on which the presence or absence of the video might influence their choices about the number of reminders they wish to receive. However, in Experiment 1 the practice session was relatively short, lasting only 1 minute. Thus, in Experiment 2 we increased the practice session to 5 minutes so that participants might gain more experience concerning the potential influence of the distracting video on their performance before selecting the reminder intervals (i.e., frequency). Our general prediction was that with this longer practice (i.e., preview), people may set more audiovisual reminders when a distracting video is present than when it is absent.

2.2.1 Method

Participants

Data was collected from 108 participants (22 males, 79 females, 7 unknown) with an age range of 17–37 years old ($M = 19.5$, $SD = 3.04$), who were recruited through the University of Waterloo's participant pool. Participants received 0.5 participant credits to applied to their course grades for 30 minutes of participation. The original intention regarding sample size was to match the sample size of Experiment 1. However, we were not able to collect the same number of participants due to issues with data collection related to COVID-19.

Materials and Procedure

The materials and procedure were the same as those in Experiment 1 with a few modifications. First, we increased the amount of time that participants practiced the task (i.e., the practice block) from 1 minutes (in Experiment 1) to 5 minutes. Second, we added an audio cue to accompany the visual reminder such that every time the reminder appeared an audible whistle played.

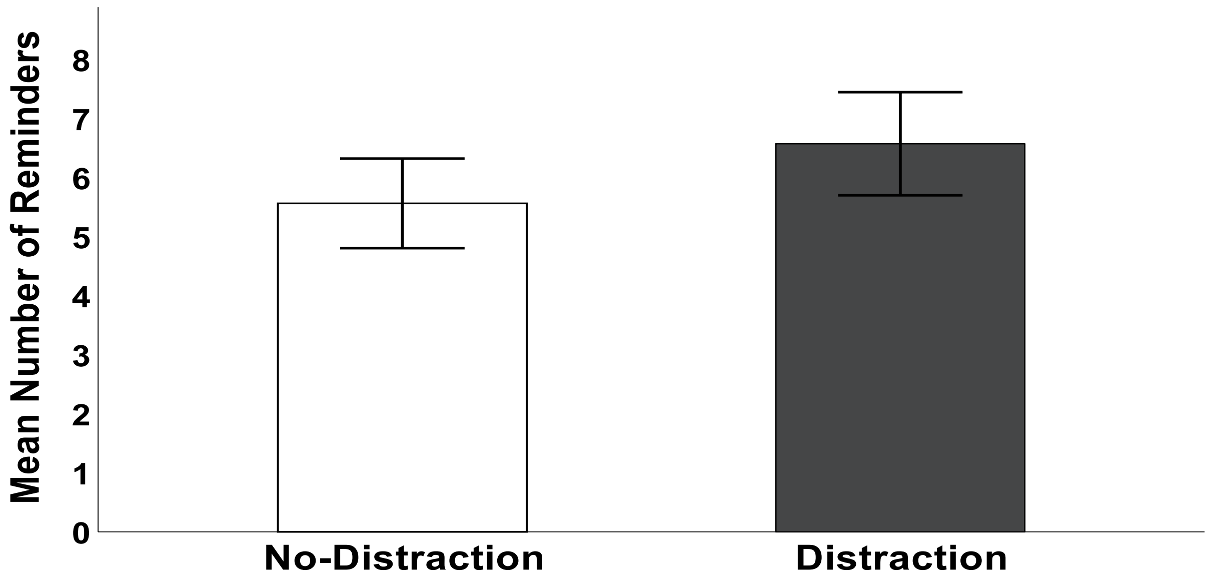
2.2.2 Results

We conducted the same analyses as in Experiment 1. As before, first we calculated how many reminders participants received based on the reminder intervals they selected. Most of the participants (88%) chose to receive at least on reminder. Figure 4 shows the mean number of reminders selected by participants in the Distraction and No Distraction conditions. The number of reminders data were assessed with a one-way ANOVA with distraction (Distraction vs. No Distraction) as a between-participant factor. The analysis revealed that there was no significant difference in the number of reminders participants chose to receive across the two groups

$F(1,107) = .765$, $p = .38$, $\eta^2p = .007$. Thus, anticipating the presence of a distracting video did not seem to influence the number of attentional reminders participants chose to deploy.

Figure 4.

Mean Number of Reminders by Condition.



Note: Error bars: +/- 1 SE

Figure 5 shows the mean proportion hits and false alarms for the Distraction and No Distraction conditions. Each of these two performance measures was submitted to a one-way ANOVA with Distraction Condition (Distraction vs. No Distraction) as the between-participant factor. The analyses failed to reveal a significant main effect of Distraction Condition either on proportion of hits, $F(1,107) = .018$, $p = .89$, $\eta^2p < .01$, or on proportion of false alarms, $F(1,107) = .19$, $p = .66$, $\eta^2p = .002$.

Finally, as in Experiment 1 we combined the data in the two experimental conditions and computed a Spearman's correlation coefficient between each of our performance metrics (proportion of hits and proportion of false alarms) and number of reminders. The correlations are shown in the bottom two panels of Figure 5. Neither the correlation between the number of reminders and the proportion of hits, $r(106) = .09$, $p = .360$, nor the correlation between the number of reminders and the proportion of false alarms, $r(106) = -.02$, $p = .88$ reached significance.

2.2.3 Discussion

As in Experiment 1, the majority of participants set at least one attentional reminder, suggesting again that participants will opt to use attentional reminders when faced with a cognitively demanding task. Replicating the findings of Experiment 1, Experiment 2 also showed that the number of reminders participants set was independent of whether the primary task was completed when a distracting video was present or absent. This occurred even though we gave participants a 5-minute preview of the task together with the distracting video in the Distraction condition and without the video in the No Distraction condition. However, contrary to the results of Experiment 1, we found no relation between the number of reminders set and performance, nor was performance influenced by the presence of the distracting video. These results suggest that the correlation between the number of attentional reminders and false alarms shown in Experiment 1 was likely a spurious type-I error. Thus, while participants chose to set reminders to pay attention, those choices were not influenced by task context, nor did they influence performance.

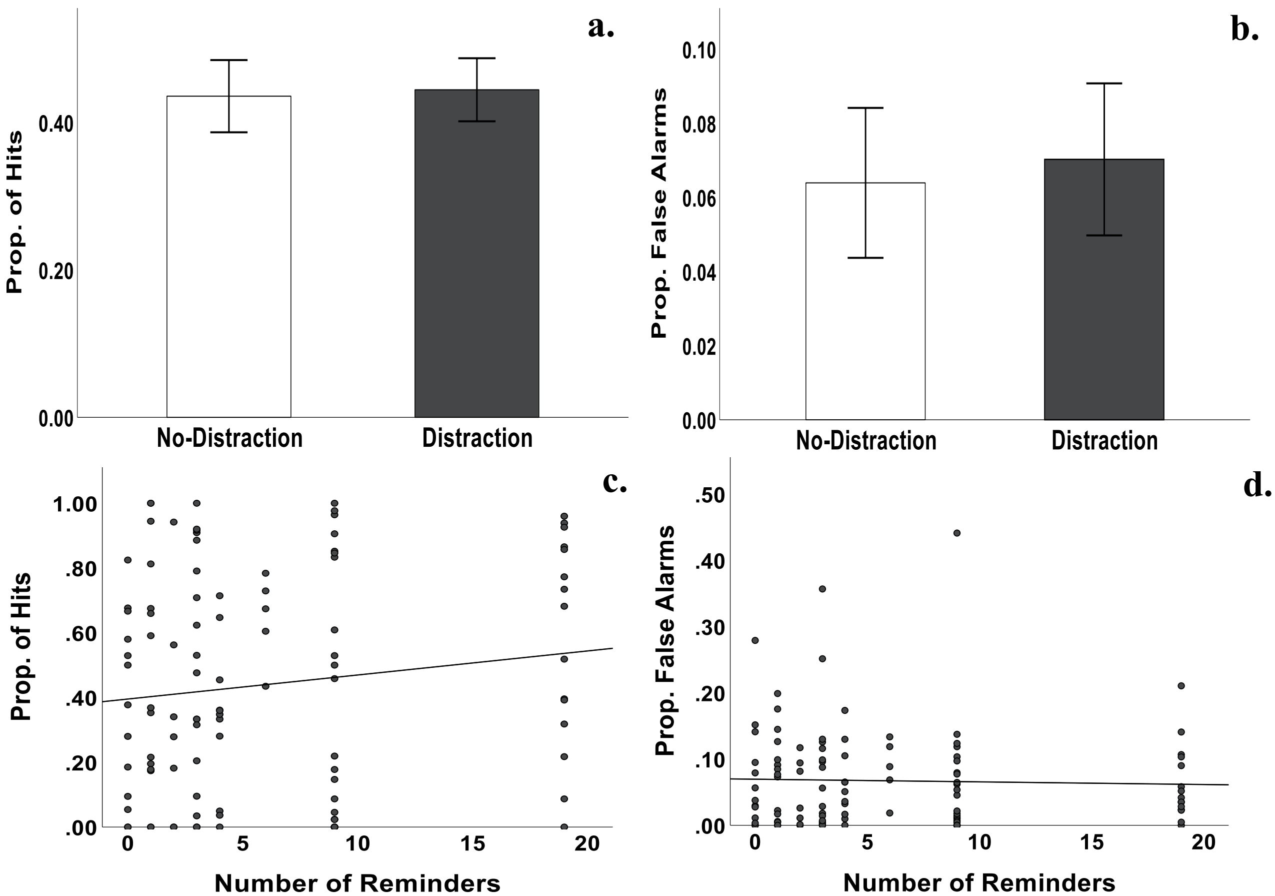


Figure 5. *Performance metrics on 2-back task for condition and number of reminders*. (**a**) Proportion of hits by condition, (**b**) proportion of false alarms by condition, (**c**) proportion of hits by number of reminders, (**d**) proportion of false alarms by number of reminders. (**a** & **b**) are means, and error bars +/- 1 SE. (**a** & **b**) Statistical analysis by a one-way ANOVA and (**c** & **d**) spearman correlations. (**a** & **d**)* $p < 0.01$.

2.3 Experiment 3

In Experiment 3, we extended our prior findings by further exploring the effects of receiving a reminder to pay attention on primary task performance. In Experiment 1 and 2 we gave control over the number of attentional reminders to the participants, which meant that the influence of the number of reminders on performance could only be assessed using a correlational design. Under these conditions, we failed to find a reliable relation between the number of attentional reminders chosen and task performance. In Experiment 3, we used a similar paradigm to that of Experiment 1 and 2, except that we removed participants capacity to self-select their reminders, instead randomly assigning participants to a 'Reminder' condition or 'No Reminder' condition. Participants completed the 2-back task in the presence of a task irrelevant distracting video to make it difficult to pay attention. We hypothesised that participants who receive reminders would perform better on the 2-back task than participants who did not receive reminders.

2.3.1 Methods

Participants

As in the previous two studies, participants were recruited through SONA, The University of Waterloo's participant management software. Participants received 0.5 credits to be applied to their course grades. In total, data were collected from 102 participants (33 males, 64 females, 5 unknown) with an age range of 18–51 years old (M = 21.41, SD = 1.11). The original intention was to match the sample size of Experiments 1 and 2. However, we were not able to collect the targeted number of participants due to issues with data collection related to COVID-19.

Materials & Procedure

Experiment 3 followed a similar methodology to Experiment 2 with a few exceptions. First, in Experiment 3 all participants were presented with a distracting video (Keith Barry's TED Talk, entitled "Brain Magic") embedded in the upper portion of the screen and the video played constantly throughout task. Second, participants were randomly assigned to either a Reminder condition or a No Reminder condition. Participants in the Reminder condition were presented with the visual/audio reminder to pay attention to the primary task (as in Experiment 2) every 2 minutes. Prior to the initiation of the experimental block, participants were informed that they will undergo a practice block with the 2-back task (20 trials, 2 targets; 10% target prevalence). The experimental block of the task took participants 20 minutes to complete, with 479 trials.

2.3.2 Results

The mean proportions of hits and false alarms during the 2-back task for the Reminder and No Reminder conditions are shown in Figure 6. An independent sample t-test with Reminder condition (Reminder vs. No Reminder) as the between-participant variable revealed that participants who received reminders ($M = .43$, $SD = .33$) did not have more hits on the 2-back task than participants who did not receive a reminder ($M = .38$, $SD = .26$), $t(100) = .91$, $p = .18$, d =.18. The difference in false alarms between participants who received reminders ($M = .10$, SD = .15) and those who did not receive a reminder ($M = .09$, $SD = .11$) also did not reach significance, $t(100) = .48$, $p = .32$, $d = .10$.

2.3.3 Discussion

Experiment 3 revealed that the attentional reminders did not significantly influence performance on the 2-back task in the presence of a distracting video. Therefore, we did not find any evidence suggesting that frequently deployed attentional reminders improve performance on an attention demanding task.

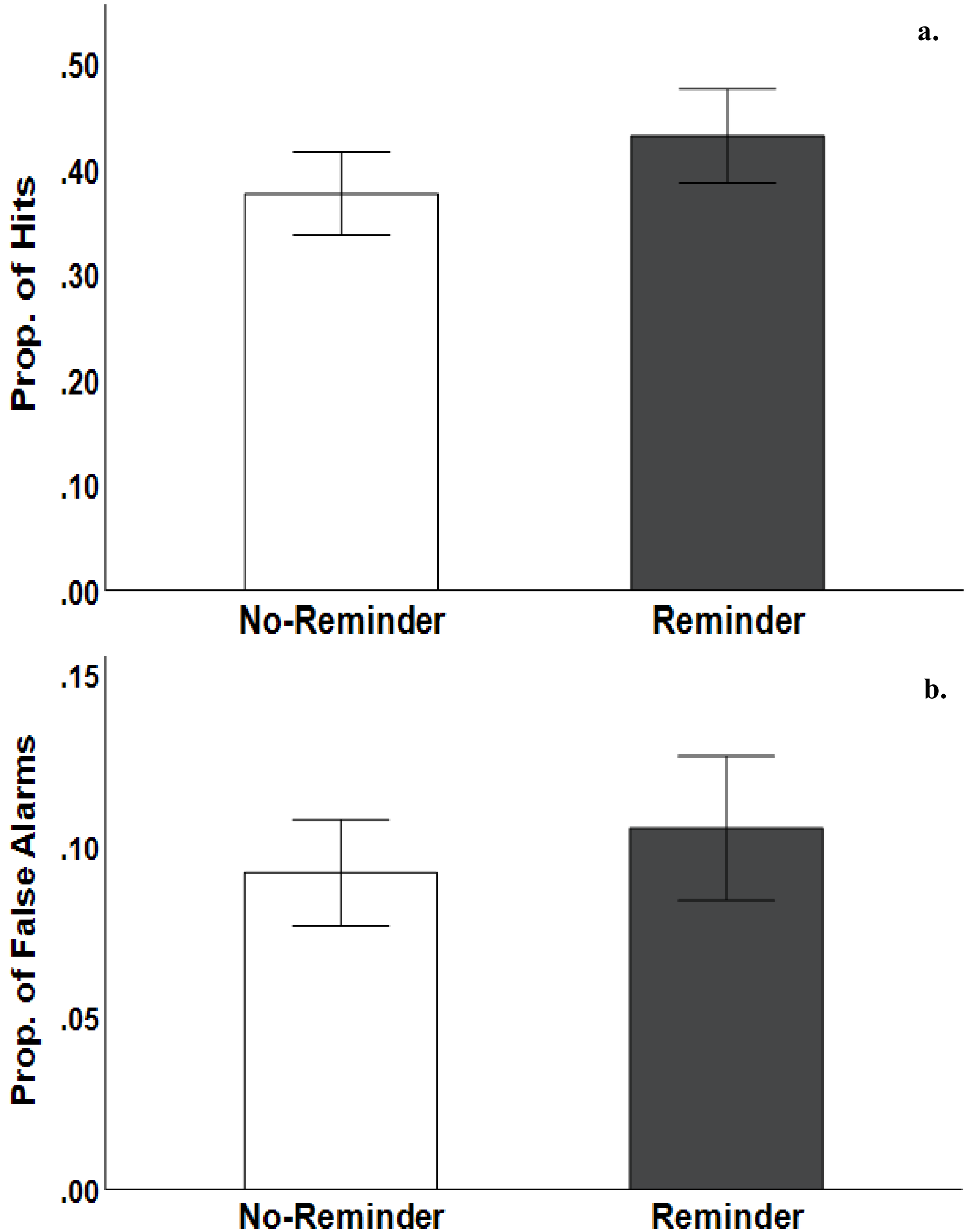


Figure 6. *Performance metrics on 2-back task by condition* (**a**) Proportion of hits, (**b**) proportion of false alarms. All are means, and error bars +/- 1 SE. Statistical analysis by an independent t-test, and * $p< 0.05$.

Chapter 3: General Discussion

In the present studies we aimed to investigate 1) whether people self-deploy attentional reminders when asked to complete an attentionally demanding task (Experiments 1 & 2), 2) whether people modulate the number of attentional reminders they selected depending on the presence or absence of a continuous distraction (Experiments 1 & 2), and 3) whether reminders to pay attention improve performance on the attentionally demanding task (Experiment 1, 2, & 3). To address these issues, in the first two experiments we explored participants' voluntary use of reminders to pay attention to a primary task while they were or were not simultaneously presented with a distracting video. The rationale underlying the manipulation of the presence of a distracting video was that attentional reminders might be deployed more often and have a greater effect on performance in the presence of distraction than in its absence. In a final experiment, participants either did or did not receive experimenter-set reminders to pay attention to a primary task; in this experiment, all participants were presented with a distracting video.

Before discussing the findings relevant to our primary aims, it is worth noting the inconsistent influence of the task-irrelevant, non-required distracting video on task performance across Experiments 1 and 2. Based on prior studies, we expected that performance on a primary task might be impaired by the presence of a distracting video relative to its absence (Phillips et al., 2016; Ralph et al., 2020). However, this effect emerged only in Experiment 1 and not in Experiment 2, even though the experiments were quite similar, with an audio cue being added to the reminder in Experiment 2. These results could suggest that the impacts of task-irrelevant distractions on performance are unreliable, or that they vary systematically as a function of subtle variations in experimental context.

Turning to our main aims, first, the present experiments revealed that a significant proportion of participants (82% in Experiment 1 and 88% in Experiment 2) chose to set attentional reminders, suggesting a natural inclination to use reminders to sustain focus on demanding tasks. Second, we found that the anticipation of the presence of a distracting video during the task did not influence people's choices about the number of attention reminders they deployed. A third important finding, one which might be disappointing to those who might be inclined to use attentional reminders, was that there was no systematic and strong relation between the number of reminders deployed and task performance in Experiments 1 and 2, nor was there an effect of attentional reminders on performance when the presence of reminders was manipulated experimentally in Experiment 3. Although we did find a relation between the number of reminders deployed and false alarms in the 2-back in Experiment 1, this relation indicated an increase in false alarms with more reminders contrary to expectations, and this pattern was not replicated in Experiment 2. Importantly, the lack of meaningful effects of visual attentional reminders on task performance suggests that self-selected reminders may not serve as useful technique to enhance performance in attention demanding tasks.

One possible reason we failed to find a robust effect of attentional reminders on performance is that people may not know what specific strategies to implement in order to pay more attention. In our studies we prompted participants to "Stay on Task", which may have been somewhat ambiguous. Perhaps it would have been more effective if we reminded people to "Pay attention to the primary number task always keep the last three numbers in your mind to detect any possible matches". Giving direct and explicit reminders to engage in a particular behaviour in a cognitive task has been explored by Manly et al., (2004), who investigated how alerting participants when they speeded their responses would impact their response accuracy in the

Sustained Attention to Response Test (SART; Robertson et al., 1997). In the SART, participants are presented with a sequence of stimuli on a computer screen and asked to respond quickly to every stimulus except for a rare predetermined target stimulus. In this paradigm, erroneous responses to the rare target are typically preceded by faster responses to non-targets. Using this paradigm Manly et al. showed that presenting participants with an auditory tone reminding them to specifically *slow down* reduced erroneous responses to targets. The strength of Manley and colleague's (2004) intervention was that it clearly specified the sort of behavior the participants were to enact in order to improve their behavior.

Another possible reason that we failed to find strong influences of attentional reminders on performance is that the attentional reminders we implemented were not deployed precisely when participants' attention lapsed. In all our experiments, the nudges were presented at various time points that were determined independent of each participant's momentary attentional states. As such, some of the reminders may have come at a time that participants were already paying full attention to the primary task. This may have rendered many of the reminders less effective than if they were presented precisely at the time when a participant's attention lapsed. To accurately send attentional reminders when participants are most likely to benefit from them, it is important to understand when participants attention starts to wane from the primary task. One way to identify moments of inattention is to make use of thought probes (Thomson et al., 2013; McVay et al., 2009; Seli et al., 2013; Seli et al., 2015; Seli et al., 2016) that ask participants about their current attention focus. Thought-probe techniques can be used to examine fluctuations in attentional state and be used to classify various attentional states (i.e., focused; Smallwood & Schooler, 2006; Schooler et al., 2004, inattentive; Unsworth et al., 2010; McVay & Kane, 2012, mind-wandering; Seli et al., 2015; Seli et al., 2016, and/or distracted; Unsworth & McMillan, 2014; Unsworth & Robinson, 2016). Attentional reminders could be made contingent on moments when participants report being inattentive. Thought probes indexing attentional engagement (asking participants about their attentional engagement throughout the primary task) could be combined with reminders to assist their 'focus back effort' (He et al., 2023; He et al., 2021) in reengaging their attention with the primary task precisely when attention has waned. Interestingly, thought probes could also be thought of as subtle interventions (i.e., nudges) aimed at understanding an individual's cognitive and emotional state (McVay & Kane, 2012; Wiemers & Redick, 2019) even though they do not impose specific actions or decisions on individuals. Instead, they gently prompt individuals to reflect on their thoughts or experiences, providing insights without enforcing a particular behaviour (McVay & Kane, 2012). By accurately timing the moments that participants are in need of assistance in redirecting their attention, we might see a greater effect of reminders on performance on the 2-back.

The notion of nudging, wherein external cues or prompts are strategically used to influence behavior, has gained considerable attention as a potential tool to improve task performance, particularly in attention-demanding contexts (Kozyreva et al., 2020). However, the "nudge approach" has been criticized for having a "limited evidence base" (Lin et al., 2017). The meta-analysis conducted by Maier et al., (2022) sheds light on the potential limitations and nuances of nudging interventions. Researchers found no evidence for the effect of nudges on behaviour after adjusting for publication bias (the publication of positive findings, and the non-reporting of null findings), which raises several important points that contribute to our understanding of the discrepancies observed in the present study. One key consideration is the potential for publication bias to influence the perception of nudging's effectiveness. It is possible that studies reporting positive effects of nudging are more likely to be published, leading to an overestimation of its impact in the literature. The current study's results and those of Maier et al., (2022) together emphasize the importance of accounting for such biases when interpreting the literature on behavioral interventions. Moreover, the lack of any replicable significant effects in our study might be attributed to various factors. The efficacy of nudging interventions can be influenced by the context, modality of reminders, and individual differences (Thaler & Sunstein, 2008). The absence of a clear effect could indicate that attentional reminders, even when self-selected, might not consistently translate into improved task performance, particularly in the complex interplay of attentional control, distractions, and cognitive demands. It is possible that while individuals proactively adopt nudging strategies, the intricate mechanisms underlying cognitive processes, as well as the task context, can contribute to varying outcomes.

In light of these insights, future research should explore the nuances of nudging interventions to identify under what circumstances they are most effective. While individuals consistently choose to use reminders, their impact varies based on task demands and the modality of reminders. Incorporating approaches to account for publication bias and examining the interplay between individual choice, task characteristics, and cognitive processes can offer a more comprehensive understanding of the potential benefits and limitations of nudging as a behavioral intervention. As we continue to unravel the complexities of human behavior and decision-making, it is essential to critically evaluate and refine interventions like attentional reminders to optimize their real-world applicability and assistance with cognitive performance.

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Appendix A

Multimedia Appendix

This appendix is an audio file of the audio component of the attentional reminder used in Experiments 1 and 2.

The file name of this audio file is “Whistle.mp3”.

If you accessed this thesis from a source other than the University of Waterloo, you may not have access to this file. You may access it by searching for this thesis at http://uwspace.uwaterloo.ca.

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