REGULATING MIND-WANDERING AND SUSTAINED ATTENTION WITH GOAL-SETTING, FEEDBACK, AND INCENTIVES

by

MATTHEW K. ROBISON

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DISSERTATION APPROVAL PAGE

Student: Matthew K. Robison

Title: Regulating Mind-Wandering and Sustained Attention with Goal-Setting, Feedback, and Incentives

This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Psychology by:

Nash Unsworth	Chair
Dasa Zeithamova-Demircan	Core Member
Elliot Berkman	Core Member
David Wagner	Institutional Representative

and

Sara D. Hodges	Interim Vice Provost and Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

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DISSERTATION ABSTRACT

Matthew K. Robison

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Title: Regulating Mind-Wandering and Sustained Attention with Goal-Setting, Feedback, and Incentives

The present set of experiments investigated three potential means of regulating mind-wandering and sustained attention: goals, feedback, and incentives. The experiments drew up goal-setting theory from industrial/organizational psychology, theories of vigilance and sustained attention, and recent experimental work examining mind-wandering and sustained attention. Experiment 1 investigated the role of goal-difficulty and goal-specificity. Providing a difficult goal for participants only improved sustained attention compared to a condition with no specific goal. Experiment 2 investigated the role of feedback in isolation and in combination with goals. Feedback improved sustained attention and reduced mind-wandering, but it did so regardless of whether or not the feedback was tied to a specific goal. Experiment 3 investigated how two different incentives – money and early release from the experiment – affected sustained attention and mind-wandering. The incentives had no effect on task performance, but participants in the early release condition reported being more motivated, more alert, and mind-wandered less throughout the task. I discuss the results of the experiments in light of predictions made by goal-setting theory as well as theories of vigilance and sustained attention.

CURRICULUM VITAE

NAME OF AUTHOR: Matthew K. Robison

GRADUATE AND UNDERGRADUTE SCHOOLS ATTENDED:

University of Oregon, Eugene, Oregon
University of Notre Dame, Notre Dame, Indiana

DEGREES AWARDED:

Doctor of Philosophy, 2018, University of Oregon
Master of Science, 2014, University of Oregon
Bachelor of Business Administration, 2013, University of Notre Dame

AREAS OF SPECIAL INTEREST:

Individual differences in working memory capacity and attention control
Sustained attention
Mind-wandering

GRANTS, AWARDS, AND HONORS:

Clarence and Lucille Dunbar Scholarship, University of Oregon, 2014, 2016
Graduate Travel Award, Psychonomic Society, 2015
General University Scholarship, 2017

PUBLICATIONS:

Unsworth, N., & Robison, M. K. (In press). Tracking mind-wandering and arousal state with pupillometry. *Cognitive, Affective, & Behavioral Neuroscience*.

Unsworth, N., Robison, M. K., & Miller, A. L. (In press). Pupillary correlates of fluctuations in sustained attention. *Journal of Cognitive Neuroscience*.

Adam, K. C. S., Robison, M. K., & Vogel, E. K. (In press). Contralateral delay activity tracks fluctuations in working memory performance. *Journal of Cognitive Neuroscience*.

Robison, M. K., Miller, A. L., & Unsworth, N. (In press). Individual differences in working memory capacity and filtering. *Journal of Experimental Psychology: Human Perception and Performance*.

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CHAPTER I

INTRODUCTION

A burgeoning body of research has demonstrated that mind-wandering is a common mental state that is often associated with deficits in task performance (Callard, Smallwood, Golchert, & Margulis, 2013; Smallwood & Schooler, 2006; Smallwood & Schooler, 2015). Mind-wandering can defined as any task-unrelated thought that is relatively independent of any immediate external stimulus. Prior research has demonstrated that mind-wandering is harmful for task performance on simple stimulus-detection tasks (e.g., Antrobus, Greenberg, & Singer, 1966) as well as higher-level tasks like reading (Schooler, Reichle, & Halpern, 2004), academic performance (Wammes, Seli, Cheyne, Boucher, & Smilek, 2016), and driving (Yanko & Spalek, 2014). Sometimes, mind-wandering can have serious consequences, such as driving accidents (Galéra et al., 2012) and catastrophic operator errors (Reason, 1990). Strategies for reducing mind-wandering could thus potentially improve academic outcomes, workplace productivity, and public safety. Therefore, recent research has attempted to reduce the frequency with which mind-wandering occurs (Sanders, Wang, Smallwood, & Schooler, 2017; Seli, Schacter, Risko, & Smilek, in press; Xu, Purdon, Seli, & Smilek, 2017).

The proposed set of experiments will focus on mind-wandering in the context of sustained attention, which is the ability to maintain focus on a single task (or set of tasks) for a period of time. Performance on tasks requiring sustained attention typically deteriorates as a function of time. With time-on-task, behavioral performance decreases, self-reported alertness decreases, self-reported task engagement decreases, mind-wandering increases, and physiological arousal decreases (Hopstaken, van der Linden, Bakker, & Kompier, 2015a, 2015b; Hopstaken, van der Linden, Bakker, Kompier, & Leung, 2016; Mackworth, 1948; Parasuraman, 1977; Parasuraman & Davies, 1977; Unsworth & Robison, 2016, in press). This effect is commonly referred to as the vigilance decrement. Various hypotheses have been proposed for why this is the case (for recent reviews, see Fortenbaugh, DeGutis, & Esterman, 2017; Langner & Eickhoff, 2013; Thomson, Benser, & Smilek, 2015). Later, I will describe four theories of vigilance and sustained attention, and what specific predictions they would make for the present study.

In my own work, I have been trying to understand what factors – both cognitive and conative – predict mind-wandering at the level of individual differences. Consistently, intrinsic self-reported motivation is one of the strongest predictors of both mind-wandering and task performance (Robison & Unsworth, 2015, 2018a, 2018b; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Unsworth & McMillan, 2013). People who report higher levels of motivation report fewer instances of mind-wandering and demonstrate better task performance. And importantly, motivation is consistently uncorrelated with some cognitive abilities (e.g., working memory capacity), which also predict fewer instances of mind-wandering and better task performance (Robison & Unsworth, 2015, 2018b; Unsworth & McMillan, 2013). Further, several experiments have provided participants with motivational incentives to counteract time-on-task effects in sustained attention (Berghum & Lehr, 1964; Bevan & Turner, 1965; Brewer, Lau, Wingert, Ball, & Blais, 2017; Esterman, Reagan, Liu, Turner, & DeGutis, 2014; Esterman et al., 2016; Hopstaken et al., 2015a, 2015b, 2016; Massar, Lim, Sasmita, & Chee, 2016; Seli et al., in press). These experiments have shown that providing a motivational incentive can restore task engagement, alertness, motivation, and performance, even after participants have been completing the task for a long period of time. Thus, both intrinsic and extrinsic motivation seem to be important factors that affect task engagement and mind-wandering. Therefore, motivational manipulations provide a potentially fruitful avenue for improving task engagement and reducing mind-wandering.

The present study uses an extended version of the psychomotor vigilance task (PVT; Dinges & Powell, 1985) to measure sustained attention. In this task, participants are given a series of trials for a period of time (about 30 min in the present study). On each trial, the task shows participants a row of blue zeros centered on the screen that look like a paused stopwatch (00.000). After a random interval between 2 and 10 s later, the stopwatchs "turns on" and the numbers start scrolling. The participant's task is simple: press a key (the spacebar in the present study), as quickly as possible. After the participant presses the key, the reaction time for that trial remains on-screen for 1 s (e.g., 00.378). The next trial then begins. The PVT is a useful task for several reasons. It is a simple reaction time task, so measures of behavioral performance are rather straightforward (i.e., mean reaction times, variability in reaction times, etc.) Because the dependent variable is so simple, participants can easily decipher how well (or poorly) they performed on a given trial, as they are given their reaction time for each trial. Despite its rather straightforward nature, it is difficult and rather monotonous, and performance typically wanes as a function of time, consistent with vigilance decrements in classic signal detection paradigms (e.g., Mackworth, 1948). Because we have used this extended version in previous research (Unsworth & Robison, 2016, in press), it is well-characterized as far as behavioral performance, self-reports of mind-wandering, and pupillometry.

A separate yet related line of research in industrial/organizational psychology has focused on how motivational factors affect task performance in both laboratory and applied settings. One relevant theoretical approach is goal-setting theory. Locke and colleagues have argued that goal-setting is an important element of task performance (Locke, Cartledge, & Knerr, 1970; Locke, Shaw, Saari, & Latham, 1981; Locke & Latham, 2002). Commonly, people who are more intrinsically motivated report setting specific goals for themselves. Further, when people are given specific, difficult goals, they tend to perform better compared to when they are given no goals, vague goals (e.g., "do your best"), or easy goals (Locke & Latham, 2002). So, the incentivizing experiments mentioned earlier may be motivating participants not because they provide a reward, but because they give participants a specific goal toward which they can strive.

Goal-setting theory posits four mechanisms by which goals can affect task performance (Locke & Latham, 2002). The first is that goals direct attention toward a specific task and away from any goal-irrelevant activities. From a sustained attention perspective, a goal would thus keep an individual focused on a task to avoid attending to either internal (e.g., mind-wandering about the upcoming weekend) or external (e.g., checking one's watch or phone) sources of distraction. The second mechanism is an energizing function – they have more of an impact when the goal is difficult, as difficult goals require more effort. In sustained attention, the performance goal is usually rather straightforward (e.g., respond as quickly as possible on each trial, detect and respond to targets as accurately as possible). But there is rarely any specific standard the individual must meet. So providing such a standard might encourage people to put forth more effort toward performing well on the task. The third mechanism is persistence – goals encourage people to maintain their effort on a task. Sustained attention notoriously worsens with time. Thus, goals might work to keep people more engaged with a sustained attention task for a longer period of time, perhaps mitigating the classic vigilance decrement. The fourth mechanism is strategic – goals encourage people to discover or develop strategies for more effective or efficient performance. In the current study, this might lead participants to pursue a specific strategy (e.g., stare as intently as possible at the zeros), or to try different strategies (e.g., use the thumb to press the spacebar, then try the index finger). Whatever these strategies may be, they all lead to more engagement with the task, which should improve performance. Goal-setting theory was originally developed to address performance in an applied/industrial setting. However, it may offer insights into specifically cognitive issues, especially sustained attention. Thus, the proposed set of experiments will combine work from industrial/organizational psychology, cognitive psychology, and cognitive neuroscience to examine how goal setting can reduce mind-wandering and improve sustained attention.

In addition to goal-setting, the present set of experiments also investigated how feedback, with and without a goal paired with it, affects sustained attention. A wealth of research has examined how feedback (sometimes called "knowledge-of-results" or "knowledge-of-score") affects performance on a variety of tasks. Most relevant to the current study are experiments showing improvements to vigilance with feedback (Church & Camp, 1965; Johanson, 1922; Pollack & Knapf, 1958; Sipowicz, Ware, & Baker, 1962; Warm, Epps, & Ferguson, 1974). With regard to goal-setting theory, some have argued that feedback is actually a necessary component of the effectiveness of goals (Erez, 1977; Locke, 1967, 1968; Locke & Bryan, 1968, 1969; Locke, Cartledge, &

Koppel, 1968). As an example, in an experiment examining performance on a simple clerical task, Erez (1977) manipulated the presence of performance feedback across conditions. In one condition, participants were given no information about their performance. In the experimental conditions, participants were given feedback that their performance was among the highest 10%, 25%, 50%, 75%, or 90% of people. Goal-setting was manipulated by instructing people to try and be one of the five above-mentioned performance thresholds, or by giving no specific goal. Results demonstrated that feedback alone did not improve performance, nor did goal-setting. But when they were combined, participants outperformed those in control conditions. Thus feedback was a necessary, but not sufficient, means of improving performance on a fairly simple task. However, when examining vigilance specifically, Warm et al. (1974) found an effect of feedback on reaction times and reaction time variability, even when the feedback was false. Warm et al. argue that the effect of feedback is primarily motivational in nature. Therefore, in the context of sustained attention, feedback may be effective even when it is not tied to a specific standard. In the present investigation, I combined goal-setting and feedback to see how these aspects of sustained attention tasks might regulate task engagement in a way that improves performance and mitigates the effects of time.

Finally, the present set of experiments investigated how incentives, in combination with goals, might affect sustained attention. Prior research on vigilance (Bergum & Lehr, 1964; Bevan & Turner, 1965), as well as more recent research leveraging techniques like EEG and pupillometry (Esterman et al., 2014, 2016; Hopstaken et al., 2015a, 2015b, 2016; Massar et al., 2016; Seli et al., in press), have shown that incentives can improve sustained attention, reduce mind-wandering, and potentially counteract the effects of mental fatigue. In regards to the present study, incentives should magnify the effects of goals by encouraging people to actually meet those goals. In the absence of any incentive or reward, goals set forth by someone else (e.g., an experimenter) may be rather useless. But by providing a reason to meet the goal laid forth for them, an incentive may make a goal more worthy of an individual's attention. Therefore, the present study also investigates how two different types of incentives – cash and early release from an experiment – might enhance the effectiveness of a goal on sustained attention.

In Figure 1, I have outlined an overarching framework for how goals would theoretically affect sustained attention. This framework is derived from Locke's goal-setting theory, prior experimental work examining the effects of incentives on task engagement, motivation, and alertness, as well as my own work examining mind-wandering, sustained attention, and arousal (Esterman et al., 2014, 2016; Hopstaken et al., 2015a, 2015b, 2016; Unsworth & Robison, 2016). In this framework, goals affect task engagement, which in turn produces changes in arousal, effort, mind-wandering, motivation, and subjective alertness. All of these have downstream effects on task performance. Under the labels for arousal and effort, mind-wandering, motivation, and alertness, I have listed how I measured each of these variables. I used pre-trial pupil diameter and task-evoked pupillary responses to measure arousal and allocations of attentional effort. Previous research has demonstrated that task-evoked pupil responses are valid indicators of effort on a number of tasks, including memory and attention tasks (Alnaes et al., 2014; Beatty, 1982a, 1982b; Beatty & Lucero-Wagoner, 2000; Hess &

Polt, 1964; Hopstaken et al., 2015a, 2015b, 2016; Kahneman, 1973; Kahneman & Beatty, 1966; Massar et al., 2016; Unsworth & Robison, 2015, 2016, in press). Further, research has demonstrated that baseline pupil diameter can index arousal levels. Presumably, baseline pupil diameter measures tonic activity in the locus coeruleus-norepinephrine system, which regulates arousal (Morad, Lemberg, Yofe, & Dagan, 2000; Murphy, O'Connell, O'Sullivan, Robertson, & Balsters, 2014; Murphy, Robertson, Balsters, & O'Connell, 2011; Unsworth & Robison, 2016, in press). Thought probes measured mind-wandering and other subjective attentional states, and self-reports at various points throughout the task assessed subjective levels of motivation and alertness. Finally, the dependent variable in regards to task performance was response time (RT: mean RTs, RT variability, RT distributions, and lapses: RTs > 500 ms; Lim & Dinges, 2008). In succession, Experiments 1, 2, and 3 examined how goal-difficulty and goal-specificity, feedback, and incentives moderate the effects of goals on sustained attention via these various theoretical mechanisms.

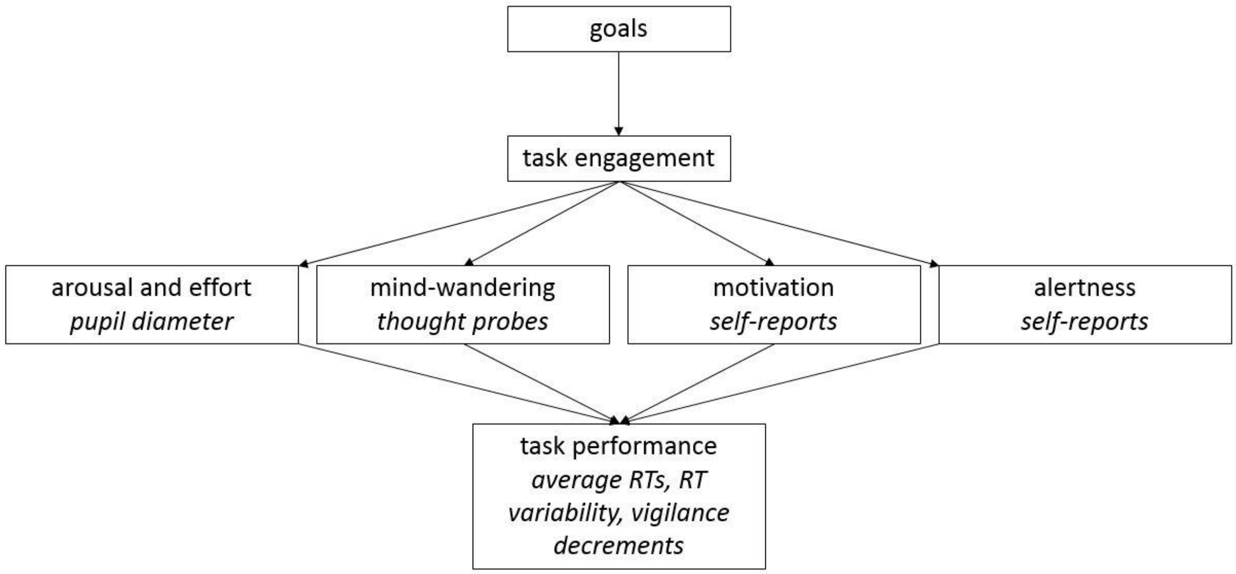


Figure 1. Framework for how goals affect task engagement and task performance via various psychological mechanisms.

In the present study, I also address several oft-cited explanations for decrements of sustained attention across time: resource theory, mindlessness theory, motivational control theory, and resource-control theory. Resource theory argues that vigilance and sustained attention require cognitive resources. Over time these resources become depleted, and this is what accounts for decrements in task performance and task engagement (Grier et al., 2003; Warm, Parasuraman, & Matthews, 2008). As people try to exert attention to detect targets or respond quickly, the pool of resources they must draw upon to do so becomes smaller, and thus people cannot exert their attention as effectively. In the present study, resource theory would predict that alertness and effort would decrease across time, but any failure to exert attention fully to the task would be because participants physiologically cannot do so. As evidence for this account, resource theorists cite evidence from individual differences in cerebral flood flow and changes in cerebral flood flow across time during vigilance tasks (Matthews et al., 2010; Warm, Parasuraman, & Matthews, 2009). Thus, resource theory would predict decreases in physiological indicators of arousal, decreases in subjective alertness, increases in unintentional mind-wandering, but no changes in motivation, commitment to a task goal, or intentional mind-wandering. Resource theory would also predict that providing more difficult goals would have no effect on performance, or even a negative effect, as more difficult tasks theoretically deplete resources more quickly than easier tasks (Caggiano & Parasuraman, 2004; Helton & Russell, 2011). And vice versa, an easy goal should produce mitigated effects of time on arousal, alertness, and performance.

Mindlessness theory argues that vigilance and sustained attention tasks are inherently monotonous and boring. Thus performance decrements occur not because sustained attention tasks are difficult, but because they are not engaging (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Thus, as time progresses, people voluntarily disengage from the task because of understimulation. In the present study, mindlessness theory would predict that changes in task performance should be accompanied by decreases in motivation and increases in *intentional* mind-wandering, but no changes in *unintentional* mind-wandering, which represent instances in which people are trying to maintain focus on the task, but cannot.

The motivational control theory takes into account the goals of the individual, the individual's affective state, and their interaction (Hockey, 2011). Within this theory, individuals select a goal (e.g., pay attention to this task) amongst a set of competing goals (e.g., plan my weekend) and exert control to keep the selected goal active. During task completion, the cognitive system must continually keep the goal active to perform the task well. If the individual is meeting the goal without sensing strain, they continue to maintain that level of effort and maintain the goal. If the individual is not meeting the goal – provided some implicit or explicit feedback – they can do one of two things: they can adjust their goal, or they can adjust their effort level. An increase in effort may produce strain and lead to mental fatigue, whereas maintaining or adjusting effort downward sacrifices task performance. The cost of the strain (i.e., fatigue) must be weighed against the outcome obtained by the exertion of such strain (i.e., some implicit or explicit reward). The individual can also adjust their goal. A downward adjustment in the goal can allow the individual to maintain or adjust effort downward while pursuing a new level of satisfactory task performance. Thus, during the completion of some sustained task, there is a consistent interaction between goal-selection, task performance, and effortful control. In the present study, the motivational control theory would predict that any conditions that increase motivation will change the pattern of performance across time. That is, conditions that promote motivation should lead to more sustained activation of the task goal and thus smaller changes to task performance. However, participants who have easier goals can more easily adapt their goal to changes in performance or task engagement (e.g., when it is quite vague), should show smaller changes in alertness across time, as they can more effectively shield themselves from mental fatigue.

Finally, the resource-control account of mind-wandering and sustained attention (Thomson et al., 2015) posits that resources do not become depleted across time, but rather the allocation of resources between task-focus and mind-wandering changes. In a sustained attention situation, people must exert executive control to prevent the occurrence of mind-wandering and maintain task focus. Mind-wandering often constitutes thoughts about personal concerns or unresolved goals (Klinger, 1999, 2009). If the valence of these goals supersedes the valence of the task-goal, personal concerns (and thus mind-wandering) can capture attention (McVay & Kane, 2010). Executive control wanes across time because people either learn to allocate fewer resources to the task, or because they feel the "cost" of exerting such control is not worth any subjective "gains," and thus more resources are allocated to mind-wandering. Therefore the resource-control account predicts an increase in mind-wandering across time, a decrease in motivation, and a decrease in effort. Thomson et al. (2015) make a specific prediction that early in the task, mind-wandering is unintentional, but that later in the task, as motivation decreases, mind-wandering becomes more intentional as people deliberately disengage from the task. Thus, the resource-control account predicts that intentional mind-wandering will increase at a faster rate than unintentional mind-wandering across time. Similar accounts propose that cognitive control and effort are allocated based on a tradeoff between task-based effort and other uses of mental energy (e.g., Boksem & Tops, 2008; Kurzban, Duckworth, Kable, & Myers, 2013). But because Thomson et al. (2015) specifically address the relationship between sustained attention and mind-wandering, it is particularly relevant here. The four theories described above account for changes in performance across time (e.g., vigilance decrements) differently. This is an active debate, and in addition to testing potential means of reducing mind-wandering in the context of sustained attention, the results of the present study can test predictions made by these four respective theories.

Present study

The proposed experiments will use an extended version of the psychomotor vigilance task (PVT; Dinges & Powell, 1985) as a measure of sustained attention. The PVT is a simple reaction time task that requires participants to respond as quickly as possible to a visual stimulus. With time, PVT reaction times tend to increase and become more variable, and extremely long reaction times (i.e., lapses) become more likely. Further, mind-wandering is quite common on this task, and it also tends to increase with time (Unsworth & Robison, 2016). Finally, arousal (measured by pupil diameter) tends to decrease with time-on-task, and differences in momentary arousal are predictive of both behavioral performance and self-reported off-task subjective states (i.e., mind-wandering, mind-blanking; Massar et al., 2016; Unsworth & Robison, 2016, in press). The proposed experiments will apply goal-setting theory to the investigation of sustained attention and mind-wandering. If by providing participants with specific difficult goals, feedback, and/or incentives we can reduce mind-wandering and improve sustained attention, this will open doors for future research into applied settings such as the workplace, classrooms, and public safety.

CHAPTER II

EXPERIMENT 1: GOAL-SETTING

The first experiment leveraged findings from industrial/organizational psychology (Locke & Latham, 2002) and cognitive psychology (Esterman et al., 2014; 2016; Hopstaken et al., 2015a; 2015b; 2016; Massar et al., 2016; Seli et al., in press) to investigate how arousal, subjective motivation and alertness, mind-wandering, and task performance change based on goal-setting. Goal-setting was manipulated across conditions with three different sets of instructions. In all conditions, participants completed a 30-min sustained attention task. In the control condition, participants were given rather standard instructions to respond as quickly as possible on each trial. In the hard-goal condition, participants were given a goal of keeping their average reaction time below 300 ms. Only about 10% of people met this performance threshold in our previous work, so that is why I chose this specific threshold (Unsworth & Robison, 2016). In the easy-goal condition, participants were given a goal of keeping their average reaction time below 800 ms. In our previous work (Unsworth & Robison, 2016, in press), average reaction times were around 350 ms, and the slowest participant had an average reaction time of 458 ms. So the difficult goal will be rather hard to achieve, and the easy goal will be trivial.

In reference to the framework laid out in Figure 1, goal specificity and difficulty should moderate the overarching goal of responding quickly to the stimulus on every trial (Figure 2). The no-goal condition was the default situation in which participants are given a rather vague instruction to respond quickly. The difficult-goal condition provided a specific and rather challenging standard to which participants can compare their performance. Finally, the easy-goal condition provided a specific goal, but the standard was a trivially easy one to meet. The easy-goal condition also provided a crucial comparison with which I could test whether providing *any* specific goal, regardless of difficulty, affected performance.

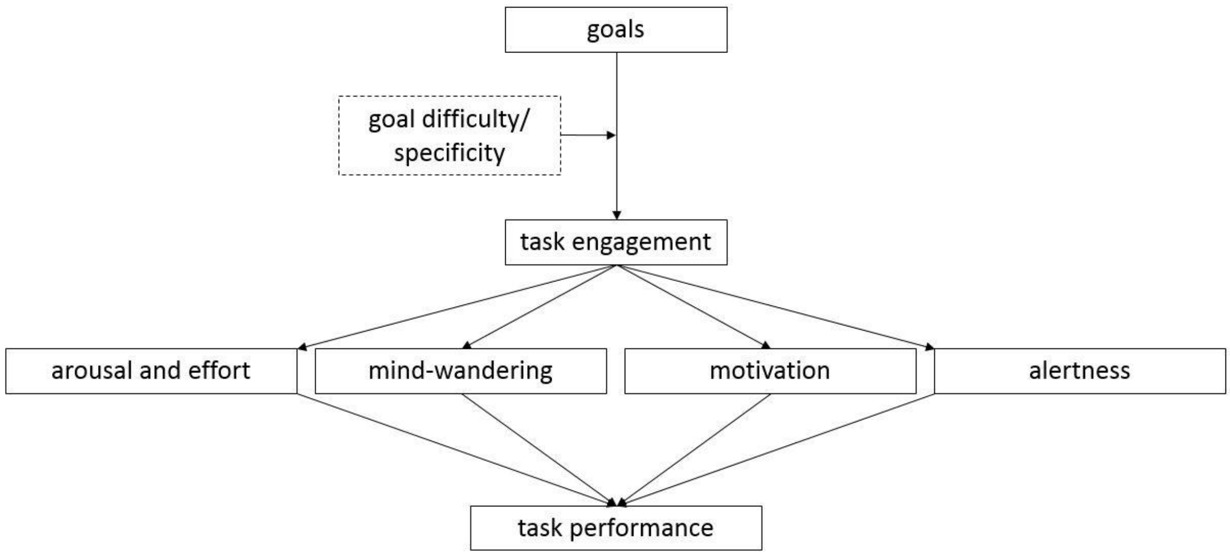


Figure 2. Theoretical framework for how goal-specificity and goal-difficulty might moderate the effect of goals.

Based on goal-setting theory and the framework proposed above, I hypothesized that, compared to the control condition, the difficult goal would do the following: 1) increase/stabilize arousal 2) increase task engagement such that average task-evoked pupillary responses would be larger and/or less variable, 3) increase task performance such that the RT distribution would shift and/or narrow, 4) increase subjective motivation and alertness, and 5) reduce self-reported instances of task disengagement (i.e., more on-task reports and fewer mind-wandering) reports.) Also, I hypothesized that the easy-goal condition would not have these effects, and may even have had the opposite effect on each of the dependent variables.

Method

Participants and procedure

A sample of 105 participants (*N* = 35 in each condition, *M* age = 19.14, 75 females, 30 males) from the human subjects pool at the University of Oregon completed the study in exchange for partial course credit. Participants first completed informed consent and demographics forms. They were randomly assigned to a goal-setting condition and completed a 30-min version of the PVT.

Task

PVT. The PVT is a measure of sustained attention (Dinges & Powell, 1985). Each trial began with a row of blue zeros centered on the screen with spaces for second and milliseconds (<u>0.000</u>). After a random interval ranging from 2 to 10 s in 500-ms intervals, the zeros began counting up in 17-ms intervals like a stopwatch. The participant's task was to press the spacebar as quickly as possible when they noticed the numbers start counting. After the participant pressed the spacebar, their reaction time remained on-screen in red font for 1 s (e.g., <u>00.378</u>). A 500-ms blank screen separated each trial. Trials began with a 2-s fixation screen on which five fixation crosses were centered. This fixation screen served two purposes. First, it allowed the pupil to return to a baseline level before the subsequent trial. Second, it allowed me to measure trial-to-trial changes in arousal. Participants first completed 5 practice trials. Then, they received their condition's specific goal instructions and completed 5 consecutive blocks of 28 trials.

Goal instructions. In the vague/no-goal condition, participants were told, "Previous research has shown that good performance on this task is a fast reaction time. So your goal should be to keep your average reaction time as low as possible." In the hard-goal condition, participants were told, “Previous research has shown that good performance on this task is a reaction time below 300 milliseconds. So your goal should be to keep your average reaction time below 300 milliseconds.” In the easy-goal condition, participants were told, “Previous research has shown that good performance on this task is a reaction time below 800 milliseconds. So your goal should be to keep your average reaction time below 800 milliseconds.”

Pupil data. A Tobii T300 eye-tracker continuously recorded pupil diameter from both eyes throughout the entire task at a sampling rate of 120 Hz, and I used the left pupil diameter for all analyses. Missing data due to blinks and off-screen fixations were excluded from the analyses. The primary dependent variables were pre-trial pupil diameter and task-evoked pupillary responses. Pre-trial pupil diameter was measured as the average pupil diameter during the 2-s inter-trial fixation screen. The task-evoked response was measured as a change from baseline (the last 200 ms of the pre-stimulus interval). The peak dilation on each trial was measured during the window from 500 to 800 ms post-stimulus onset. Participants sat about 60 cm from the screen with their heads fixed in a chinrest. Each participant’s eyes were calibrated to the eye-tracker at the beginning of the experimental session. If calibration was poor, I re-calibrated until the eye-tracker properly tracked the participant’s eyes.

Self-reports. After each of the 5 blocks, participants rated their subjective alertness and motivation on a scale of 1 to 7. For the alertness reports, a statement appeared on the screen that said, “Please rate how alert you feel right now.” Below the statement were the numbers 1 to 7, equally spaced. Under the numbers 1 and 7, the anchors read, “not at all” and “very alert” respectively. For the motivation reports, a statement appeared on the screen that said, “Please rate how motivated you feel right now to perform well on the task.” Below the statement were the numbers 1 to 7, equally spaced. Under the numbers 1 and 7, the anchors read “not at all” and “very motivated,” respectively.

Thought probes. Participants received 4 thought probes during each block of the task. (20 probes total). The probes asked participants, “What were you thinking about just before this screen appeared?” Response options included 1) I was totally focused on the task, 2) I was thinking about my performance on the task or how long it is taking, 3) I was distracted by sights/sounds in the room or by physical sensations (hungry/thirsty), 4) I was intentionally thinking about things unrelated to the task 5) I was unintentionally thinking about things unrelated to the task, and 6) My mind was blank. Response 1 was scored as on-task, response 2 as task-related interference, response 3 as external distraction, response 4 as intentional mind-wandering, response 5 as unintentional mind-wandering, and response 6 as mind-blanking. During the introduction to the task, participants received specific instructions about these thought probes and how to categorize their thoughts.

Post-experiment questionnaire. At the end of the task, participants were given a sheet of paper with the question, “What was your goal on this task?” Participants wrote their response under the question. Participants were also asked, “Before you came to the lab for this study, had you heard anything (from classmates, friends, etc.) about this specific study?” Participants checked Yes or No, and if they had heard anything, they were asked to report what they knew coming into the lab.

Results

Task performance

Unless otherwise noted, for this and all subsequent analyses, I analyzed the effects of time and condition on the dependent variables with 5 x 3 mixed ANOVAs with block (1 to 5) as a within-subjects factor and condition (no goal, hard goal, easy goal) as a between-subjects factor. Table 1 shows mean RTs by block for each goal-setting condition. First, I trimmed the RTs to avoid skew from extremely short and extremely long responses by eliminating any RT shorter than 200 ms or longer than 3000 ms. This procedure eliminated 41 total RTs across all participants. The analysis on mean RTs indicated a main effect of block ($F(4, 408) = 29.15$, $p < .001$, partial $\eta^2 = .22$), such that RTs increased across time (linear effect: $F(1, 102) = 36.13$, $p < .001$, partial $\eta^2 = .22$). However, there was no significant main effect of goal-setting condition ($F(2, 102) = 1.83$, $p = .17$, partial $\eta^2 = .04$), nor was there a block x condition interaction ($F(8, 408) = .58$, $p = .80$, partial $\eta^2 = .01$). Inspection of Table 1, however, does show that participants in the hard-goal condition had the lowest RTs, at least numerically. Because I had hypothesized that the hard-goal and no-goal conditions would differ, I specifically compared these conditions. This comparison did indeed indicate a small but significant difference in overall RTs between these conditions ($t(68) = 2.23$, $p = .03$). Examining the differences as a function of block did not reveal a block x condition interaction ($F(4, 272) = 1.74$, $p = .14$, partial $\eta^2 = .03$). So there is some evidence that providing a difficult goal did improve task performance by reducing RTs overall, but not significantly more than providing *any* specific goal.

Table 1

Mean reaction times by block and goal-setting condition in Experiment 1

		Condition		
Block	No goal	Hard goal	Easy goal	Overall
1	368 (42)	353 (38)	363 (33)	362 (38)
2	384 (55)	363 (44)	381 (49)	376 (50)
3	401 (51)	374 (50)	396 (70)	390 (62)
4	430 (88)	395 (64)	417 (133)	414 (100)
5	441 (94)	396 (68)	425 (151)	421 (111)
Overall	405 (59)	376 (47)	397 (82)	393 (65)

Note. Standard deviations are in parentheses.

Table 2 shows RT variability[1] by block for each condition. There was a main effect of block on RT variability ($F(4, 408) = 9.28$, $p < .001$, partial $\eta^2 = .08$), such that RTs became more variable across time (linear effect: $F(1, 102) = 22.62$, $p < .001$, partial $\eta^2 = .18$). However there was no main effect of condition ($F(2, 102) = .29$, $p = .75$, partial $\eta^2 = .01$), nor a block x condition interaction ($F(8, 408) = 1.04$, $p = .40$, partial $\eta^2 = .02$). So although participants in all three conditions showed an increase in RT variability as a function of time, the goal-setting manipulations did not moderate these effects.

[1] Variability was measured as the coefficient of variation within each block (standard deviation/mean).

Table 2

Reaction time variability by block and condition in Experiment 1

		Condition		
Block	No goal	Hard goal	Easy goal	Overall
1	.16 (.06)	.18 (.10)	.15 (.04)	.16 (.07)
2	.17 (.07)	.19 (.14)	.18 (.06)	.18 (.10)
3	.19 (.13)	.17 (.08)	.18 (.09)	.18 (.10)
4	.22 (.13)	.22 (.13)	.18 (.09)	.21 (.14)
5	.26 (.17)	.22 (.14)	.22 (.12)	.23 (.15)
Overall	.20 (.10)	.19 (.09)	.19 (.06)	.19 (.08)

Note. Standard deviations are in parentheses.

As a final step, I analyzed RTs in two additional ways. In the first, I examined the distribution of RTs across conditions. To do so, I rank-ordered each individual's RTs and averaged them into quintiles. Thus, each participant had an average value of their fastest 20% of responses to their slowest 20% of responses. It is possible that although the goal-setting instructions did not improve reaction times overall, the goal may have reduced the skew of the RT distributions. If this was the case, I should observe a significant difference in the slowest 20% of RTs across conditions. However, a 5 x 3 mixed ANOVA with bin as a within-subjects factor and condition as a between-subjects factor did not reveal a main effect of condition ($F(2, 102) = 1.91$, $p = .15$, partial $\eta^2 = .04$) or a bin x condition interaction ($F(2, 102) = .36$, $p = .70$, partial $\eta^2 = .01$). Table 3 shows these data. Specifically comparing the hard-goal and no-goal conditions revealed significant differences in all bins (ps < .03) *except* bin 5 ($p = .14$), likely due to the fact that bin 5 had the most between- and within-subject variability.

Table 3

Reaction time distributions by condition in Experiment 1

	Condition		
Bin	No goal	Hard goal	Easy goal
1	318 (31)	301 (21)	313 (27)
2	353 (40)	331 (29)	346 (36)
3	383 (50)	356 (36)	373 (44)
4	420 (62)	389 (49)	414 (79)
5	551 (151)	504 (114)	533 (226)

Note. Standard deviations are in parentheses.

Finally, I examined the frequency of "lapse" trials (RTs > 500 ms) across time and conditions. I summed how often participants encountered such trials within each block and examined such trials across conditions. Table 4 shows these data. The analysis indicated a significant main effect of block ($F(4, 408) = 29.21$, $p < .001$, partial $\eta^2 = .22$), such that lapse trials became more common across time (linear effect: $F(1, 102) = 50.67$, $p < .001$, partial $\eta^2 = .33$), but there was no main effect of condition ($F(2, 102) = 2.00$, $p = .14$, partial $\eta^2 = .04$), nor a block x condition interaction ($F(8, 408) = 1.66$, $p = .11$, partial $\eta^2 = .03$). So although lapse trials became more common across time, this effect did not differ significantly differ across conditions. However, comparing the hard-goal and no-goal conditions did reveal a marginal difference in the total number of lapses. Overall, participants in the hard-goal condition ($M = 10.74$, $SD = 10.79$) experienced slightly fewer lapses than participants in the no-goal condition ($M = 18.17$, $SD = 19.42$, $t(68) = 1.98$, $p = .05$).

Table 4

Lapses by block and condition in Experiment 1

	Condition		
Block	No goal	Hard goal	Easy goal
1	1.46 (1.93)	1.26 (1.91)	1.57 (1.85)
2	2.49 (3.51)	1.23 (1.94)	2.29 (3.04)
3	3.42 (3.98)	2.03 (2.31)	2.83 (3.58)
4	5.00 (6.01)	3.00 (3.48)	3.43 (4.25)
5	5.60 (6.11)	3.23 (3.33)	3.86 (4.43)

Note. Standard deviations are in parentheses.

Motivation and alertness ratings

My next set of analyses focused on subjective reports of motivation and alertness as a function of time and condition. The analysis on motivation indicated a significant main effect of block ($F(4, 408) = 50.76$, $p < .001$, partial $\eta^2 = .33$), such that motivation ratings decreased across time (linear effect: $F(1, 102) = 93.16$, $p < .001$, partial $\eta^2 = .48$). However there was no main effect of condition ($F(2, 102) = .04$), nor a block x condition interaction ($F(8, 408) = .48$, $p = .97$, partial $\eta^2 = .01$). So although participants in all three conditions reported decreases in motivation as they spent more time on the task, this pattern did not differ across conditions, and no condition reported higher motivation ratings overall. Figure 3 shows these data.

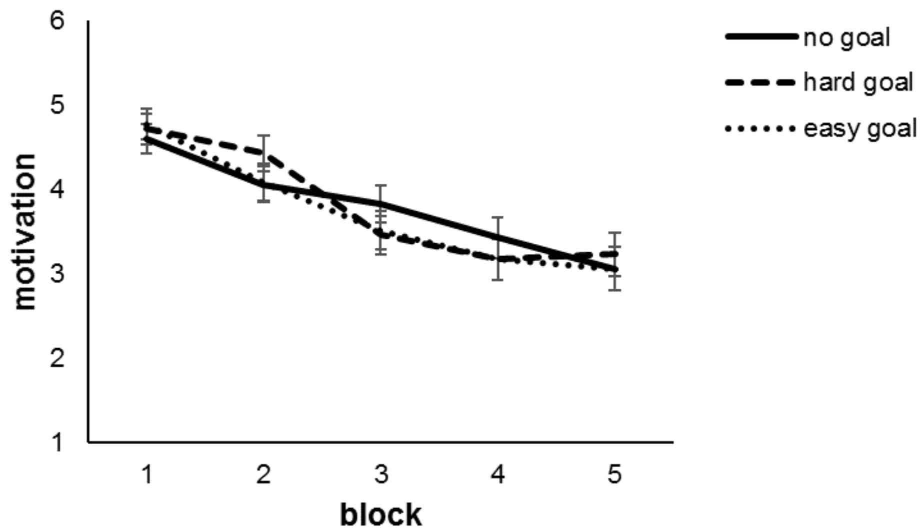


Figure 3. Motivation ratings by block and condition in Experiment 1. Error bars represent +/- one standard error of the mean.

The analysis on alertness ratings indicated a significant main effect of block (F(4, 408) = 65.55, $p < .001$, partial $\eta^2 = .39$), such that subjective alertness decreased across time (linear effect: F(1, 102) = 152.84, $p < .001$, partial $\eta^2 = .60$). However there was no main effect of condition (F(2, 102) = .06, $p = .94$, partial $\eta^2 = .001$), nor a block x condition interaction (F(8, 408) = 1.40, $p = .20$, partial $\eta^2 = .03$). So although alertness ratings dropped over time, this effect did not differ across conditions, and no group reported higher alertness ratings overall. Figure 4 shows these data.

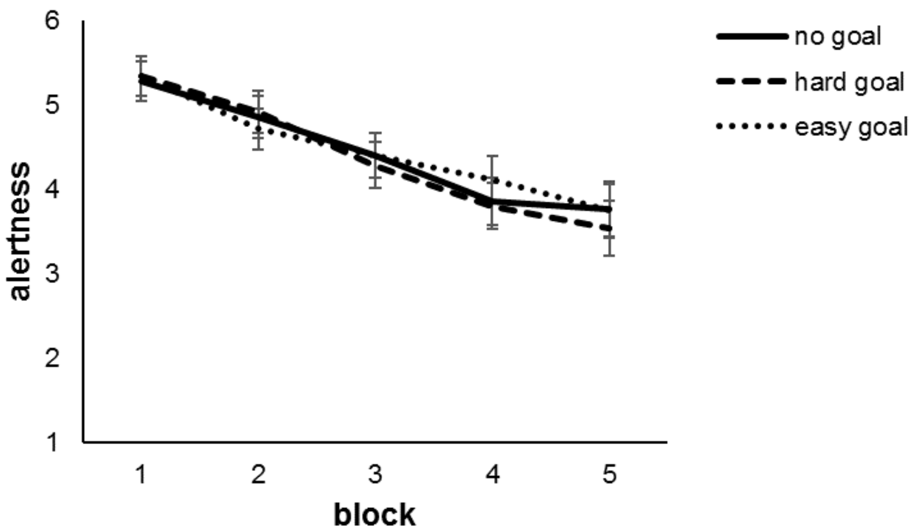


Figure 4. Alertness ratings by block and condition in Experiment 1. Error bars represent +/- one standard error of the mean.

Thought probes

My next set of analyses examined responses to the thought probes. First I computed proportions of each thought probe response for each block for each participant. As a reminder, I hypothesized that participants in the hard goal condition would show less mind-wandering than participants in the other two conditions. To test this hypothesis, I entered mind-wandering responses into a 2 x 5 x 3 mixed ANOVA with within-subject factors of intention (intentional, unintentional) and block and a between-subjects factor of condition. The ANOVA indicated a main effect of intention ($F(1, 102) = 72.72$, $p < .001$, partial $\eta^2 = .42$), such that unintentional mind-wandering was more common than intentional mind-wandering, a main effect of block ($F(4, 408) = 25.52$, $p < .001$, partial $\eta^2 = .10$), such that mind-wandering became more common across time, and a block x intention interaction ($F(4, 408) = 4.68$, $p < .001$, partial $\eta^2 = .04$), such that unintentional mind-wandering increased at a greater rate than intentional mind-wandering. Simple-effects analysis indicated that both intentional mind-wandering (linear effect: $F(1, 104) =$

9.32, $p = .003$, partial $\eta^2 = .08$) and unintentional mind-wandering (linear effect: $F(1, 104) = 39.39$, $p < .001$, partial $\eta^2 = .28$) increased across time. However, there was no main effect of goal-setting condition on mind-wandering reports ($F(2, 102) = .40$, $p = .67$, partial $\eta^2 = .01$), no block x condition interaction ($F(8, 408) = 1.34$, $p = .22$, partial $\eta^2 = .03$), no intention x condition interaction ($F(2, 102) = 1.83$, $p = .17$, partial $\eta^2 = .04$), and no block x intention x condition interaction ($F(8, 408) = 1.49$, $p = .17$, $\eta^2 = .03$). There was also a main effect on on-task reports ($F(4, 408) = 10.03$, $p < .001$, partial $\eta^2 = .09$), which decreased across time (linear effect: $F(1, 102) = 28.75$, $p < .001$, partial $\eta^2 = .09$). However there was no main effect of condition on on-task reports ($F(2, 102) = .002$, $p = .99$, partial $\eta^2 < .001$). Thus, the goal-setting manipulation did not have any appreciable effect on mind-wandering nor its pattern of occurrence across time. The block x intention interaction is plotted in Figure 5. Table 5 shows proportions for all thought-probe response options by condition, collapsed across blocks.

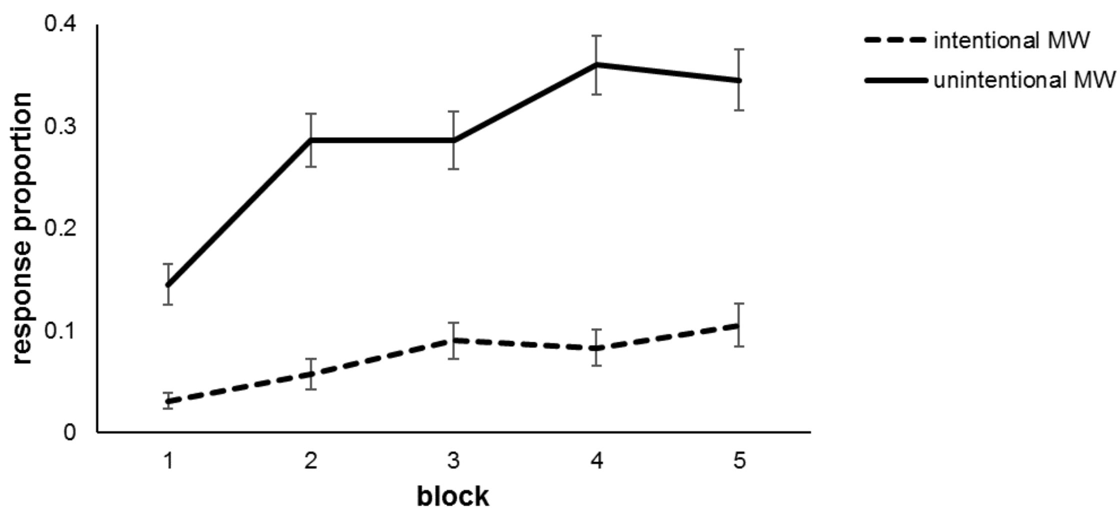


Figure 5. Intentional and unintentional mind-wandering (MW) by block in Experiment 1. Error bars represent +/- one standard error of the mean.

Table 5

Thought probe response proportions by condition in Experiment 1

	Condition		
Response	No goal	Hard goal	Easy goal
On-task	.18 (.19)	.17 (.16)	.18 (.16)
Task-related interference	.28 (.17)	.29 (.16)	.27 (.16)
External distraction	.08 (.10)	.11 (.14)	.08 (.10)
Intentional mind-wandering	.06 (.07)	.10 (.14)	.06 (.09)
Unintentional mind-wandering	.30 (.21)	.24 (.20)	.31 (.18)
Mind-blanking	.11 (.12)	.09 (.16)	.09 (.10)

Note. Standard deviations are in parentheses.

Pupillometry

In addition to measuring task performance (i.e., reaction times), self-reports of motivation and alertness, and self-reports of attentional states throughout the task, I also continuously measured pupil diameter to index 1) changes in arousal across time, and 2) effortful allocation of attention to the task. I measured arousal on a trial-by-trial basis by averaging pupil diameter across the 2-s pre-trial fixation screen. I then averaged these measurements within each block for each individual. I also computed variability in arousal by measuring the coefficient of variation of pre-trial pupil diameter within each block. Variability in pre-trial pupil diameter would be indicative of fluctuations in arousal.

Presumably, pre-trial pupil diameter measures moment-to-moment global arousal levels (Morad et al., 2000; Murphy et al., 2011, 2014; Unsworth & Robison, 2016, in press). The analysis on mean pre-trial pupil diameter indicated a significant main effect of block ($F(4, 408) = 28.99$, $p < .001$, partial $\eta^2 = .22$), but no effect of condition ($F(2, 102) = .84$, $p = .43$, partial $\eta^2 = .02$) nor a block x condition interaction ($F(8, 408) = 1.36$, $p = .21$, partial $\eta^2 = .03$). So although arousal decreased across time (linear effect: $F(1, 102) = 39.68$, $p < .001$, partial $\eta^2 = .28$), this effect did not differ across conditions, nor did the goal-setting instructions have a global effect on arousal. Figure 6 shows this pattern.

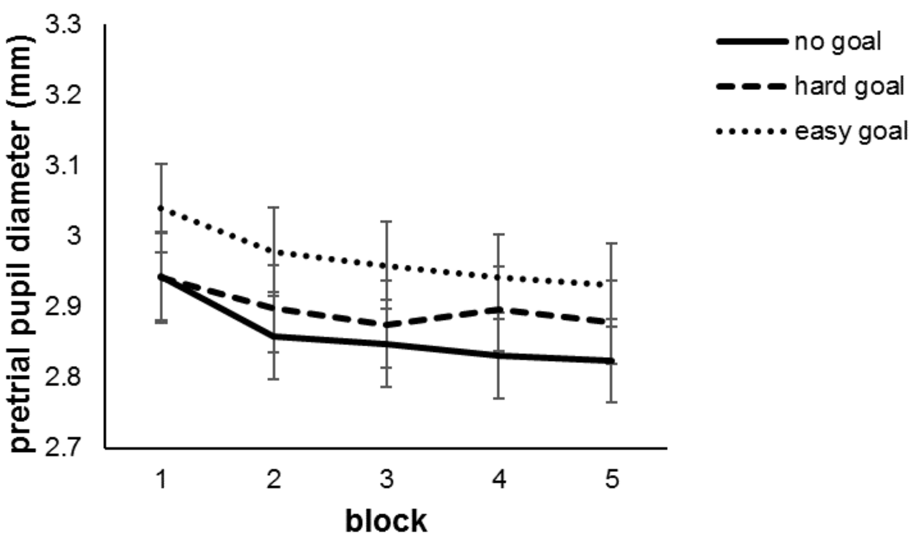


Figure 6. Pre-trial pupil diameter by block and condition in Experiment 1. Error bars represent +/- one standard error of the mean.

Next I submitted variability in pre-trial pupil diameter to the same analysis. There was a significant main effect of block ($F(4, 404) = 10.58$, $p < .001$, partial $\eta^2 = .10$), such that pre-trial pupil diameter became more variable across time (linear effect: $F(1, 101) = 35.83$, $p < .001$, partial $\eta^2 = .26$), but no main effect of condition ($F(2, 101) = .03$, $p = .97$, partial $\eta^2 = .001$), nor a block x condition interaction ($F(8, 404) = 1.24$, $p = .27$, partial $\eta^2 = .02$).[2] So although pre-trial pupil diameter became more variable on a trial-to-

[2] The degrees of freedom for this test were slightly different than previous analyses, as one participant did not have enough valid pupil data in block 5 to compute variability within that block.

trial basis as a function of time, indicating more fluctuations in arousal, this effect did not differ across conditions, and no group showed significantly more variability overall. Figure 7 shows these data.

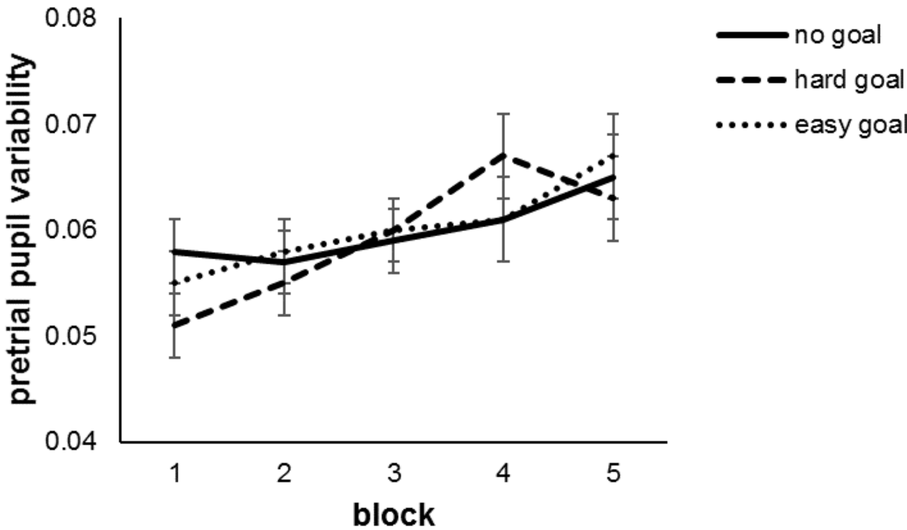


Figure 7. Variability in pre-trial pupil diameter by block and condition in Experiment 1. Error bars represent +/- one standard error of the mean.

The next set of analyses focused on task-evoked pupillary responses. These responses were baseline-corrected on a trial-by-trial basis. For each trial, I averaged pupil diameter over the final 200 ms of the pre-stimulus interval. I then averaged post-stimulus pupil diameter into a series of 20-ms bins over the post-stimulus interval and subtracted the baseline measurement from each of these values. The resulting waveforms are plotted as a function of block in Figure 8. Consistent with prior work (Unsworth & Robison, 2016), task-evoked responses decreased across time ($F(4, 412) = 10.31$, $p < .001$, partial $\eta^2 = .09$).

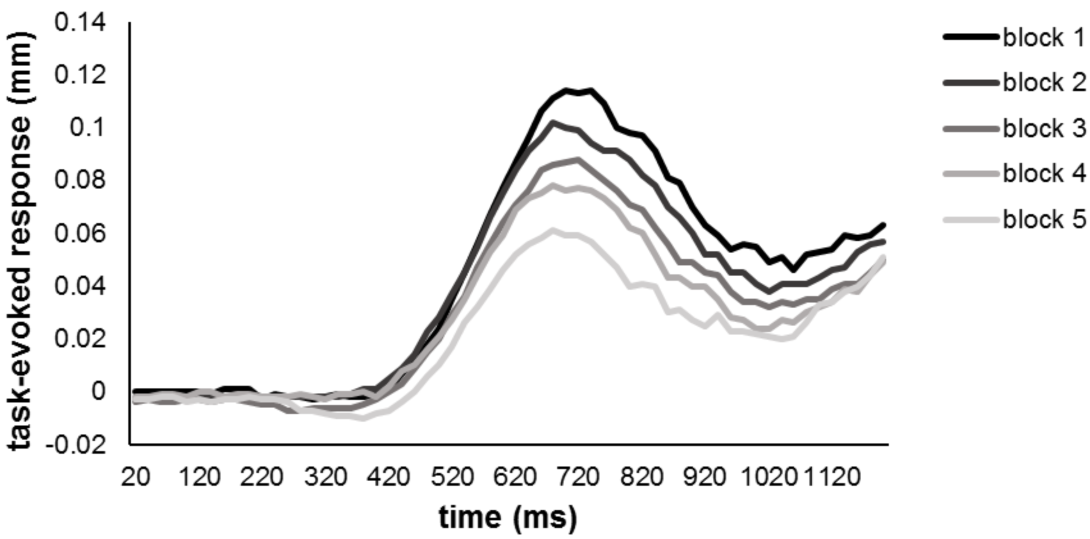


Figure 8. Task-evoked pupillary responses by block in Experiment 1.

Presumably, the task-evoked response measures the deployment of attentional effort on each trial (Alnaes, 2014; Beatty, 1982a, 1982b; Beatty & Lucero-Wagoner, 2000; Hess & Polt, 1964; Hopstaken et al., 2015a, 2015b, 2016; Kahneman, 1973; Kahneman & Beatty, 1966; Massar et al., 2016; Unsworth & Robison, 2015, 2016, in press). To statistically compare task-evoked responses across block and condition, I computed the peak response over the interval from 500 – 800 ms post stimulus onset for each trial for each individual. I then averaged these peak responses within each block for each participant. The analysis indicated a significant main effect of block ($F(4, 408) = 31.35$, $p < .001$, partial $\eta^2 = .24$), such that the average maximum task-evoked response decreased across time (linear effect: $F(1, 102) = 81.30$, $p < .001$, partial $\eta^2 = .44$), but no effect of condition ($F(2, 102) = .13$, $p = .88$, partial $\eta^2 = .003$), nor a block x condition interaction ($F(8, 408) = 1.03$, $p = .41$, partial $\eta^2 = .02$). So although task-evoked responses decreased across time, this effect did not differ across conditions, and no condition showed greater task-evoked responses overall. Figure 9 shows this pattern.

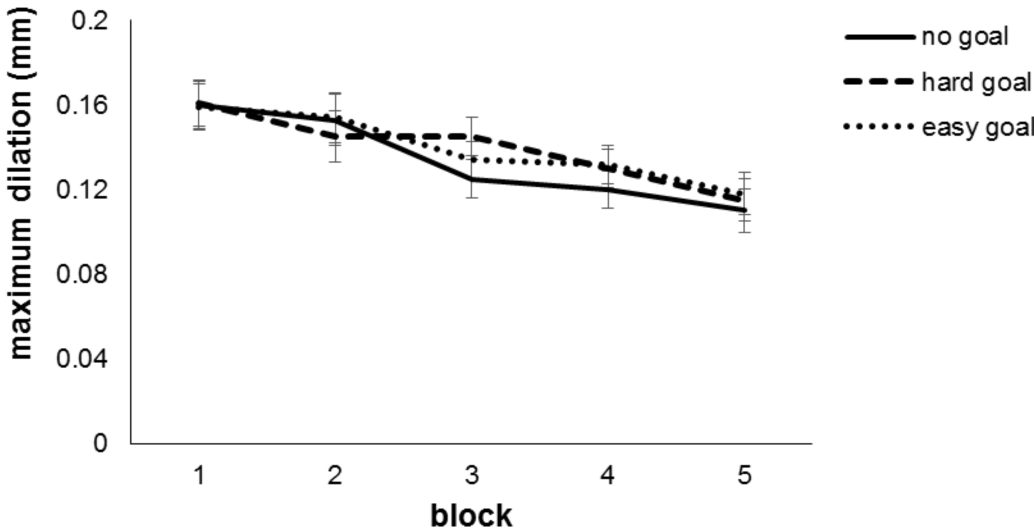


Figure 9. Maximum task-evoked pupillary responses by block and condition in Experiment 1. Error bars represent +/- one standard error of the mean.

Post-experiment questionnaire

After completing the task, participants responded to the question, "What was your goal on this task?" by writing their response on a sheet of paper. I recorded these responses verbatim and counted how often participants mentioned a specific goal (e.g., keeping their average reaction time below 300 ms) and how often this goal matched their experimental condition assignment. Only 9 of 35 participants (26%) in the hard goal condition mentioned the goal of keeping their reaction time below 300 ms, and only 1 out of 35 participants in the easy goal condition (3%) mentioned the goal of keeping their reaction time below 800 ms. No participants in the no-goal condition mentioned a specific goal other than trying to respond quickly. Therefore, these goals may not have been internalized by the majority of participants. This is something that will be addressed in Experiments 2 and 3.

Discussion

In Experiment 1, I investigated the effects of goal-setting and goal difficulty on sustained attention. In one condition, participants received standard instructions to be as fast as possible on each trial (no goal). In a second condition, participants received instructions to try to keep their average reaction time below 300 ms (hard goal). In a third condition, participants received instructions to try to keep their average reaction time below 800 ms (easy goal). I had hypothesized that participants in the hard goal condition would show better task performance (faster and less variable RTs), less mind-wandering, higher motivation and alertness, and that these findings would be corroborated by pupillometric indicators of arousal and effort. However, these hypotheses were not supported by the data. Consistent with prior research on this task, participants demonstrated a gradual decline in task performance (RTs became longer and more variable), an increase in mind-wandering, decreases in motivation and alertness, and decreases in pupillary measures of arousal and effort. Many of the group comparisons found no differences. Participants in all three conditions showed roughly equal motivation, alertness, arousal, effort, and mind-wandering across time. Consistent with my hypothesis, participants in the hard-goal condition did show better task performance (i.e., faster RTs) than participants in the no-goal condition. However, the difference between these groups was quite small.

There are several possible reasons for why few group differences arose as a result of varying task instructions. The first is that participants received no feedback as to how they were or were not meeting the goal set forth for them. Although they received their reaction time on each individual trial, and thus had some general idea of their average performance, they did not know specifically whether they were at or below the target. Therefore, it may have been difficult for participants, especially in the hard goal condition, to adjust their effort to meet the task goal. Experiment 2 directly addresses the role of feedback in combination with goal-setting. A second possibility is that there was no incentive to meet the goal laid out for them by the experimenter. Therefore, participants may not have felt the additional effort required to meet the goal was worth it. Experiment 3 directly addresses the role of incentives in combination with goals. A third possibility is that the hard goal was actually too hard to meet. So participants down-adjusted their effort to pursue some more general goal (e.g., be as fast as possible) or another specific goal (e.g., try to stay under 500 ms on each trial). The post-experimental questionnaires indicated that the majority of participants, even in the hard and easy goal conditions, reported that their goal was simply to be as fast as possible. A final possibility is that resource depletion does not allow people, regardless of their goals, to overcome the costs of repeated deployment of attention. Although people might try to maintain a certain level of performance, the depletion of some cognitive resource prevents them from sustaining their attention. But if this is the case, I should have seen an effect of a goal very early on (e.g., during block 1) before resource depletion occurred.

Although group differences did not arise for most dependent variables, participants in all three conditions showed remarkably consistent effects of time on nearly all the dependent variables. As time progressed, RTs became slower and more variable, lapses (RTs longer than 500 ms) became more common, participants reported more mind-wandering (especially unintentional mind-wandering), self-reported motivation and alertness decreased, pre-trial pupil diameter decreased and became more variable (indicating reductions in arousal and more fluctuations in arousal), and task-evoked pupil responses decreased (indicating reductions in task-based effort on each trial). These results are consistent with prior work using the PVT and other sustained attention tasks (Hopstaken et al., 2015a, 2015b, 2016; Massar et al., 2016; Unsworth & Robison, 2016).

Whether the effects of time on the dependent variables were due to a reduction in some cognitive resource that becomes depleted across time, mindlessness, or dynamic adjustments in effort, is still not entirely clear. On one hand, it appears as if the participants were losing mental energy across time: they report decreases in alertness, and these reports are corroborated by reductions in arousal across time. Further, participants also reported increases in unintentional mind-wandering. Together these findings support the idea that participants are trying to sustain their attention to the task, but can't, which would be predicted by a resource account (Grier et al., 2003; Warm et al., 2008). However, a resource-account would make the prediction that participants in the hard-goal condition would show even greater effects of time on task performance and motivation. Even though the external stimulation was identical across conditions, presumably pursuing a more difficult goal is more mentally taxing than pursuing a vague or easy goal. From the opposite direction, the easy-goal condition should have showed less of a change in arousal and alertness across time. But clearly neither were the case.

Participants also reported decreases in motivation and increases in intentional mind-wandering. These results support the idea that participants are choosing to reduce their effort as time progresses, which is more consistent with the mindlessness, motivational control, and resource-control theories (Hockey, 2011; Robertson et al., 1997; Thomson et al., 2015). However, these theories would predict that intentional mind-wandering would increase at a much faster rate than unintentional mind-wandering, as any adjustment in effort or resource-allocation would be under the control of the participant. The opposite was true. Although both types of mind-wandering increased across time, unintentional mind-wandering increased at a significantly faster rate than intentional mind-wandering. So Experiment 1 cannot unequivocally distinguish between vigilance decrements being due to resource depletion, volitional shifts in effort/resource-allocation, or a combination of both. Clearly some sort of mental fatigue is occurring, and performance is dropping as a result. However, the changes in performance across time were neither entirely due to a voluntary disengagement from the task nor a depletion of resources that prevented effective allocation of attention.

CHAPTER III

EXPERIMENT 2: GOAL-SETTING AND FEEDBACK

One element of goal-setting interventions is that there is typically either implicit or explicit feedback about one's performance on their task. Depending on the availability and salience of feedback, this information can moderate the effect of a goal (Locke & Latham, 2002). In the typical PVT, the participant's reaction time remains on-screen for 1 s. So on every trial, participants know how quickly they responded. However, a naïve participant is likely unaware of what constitutes a fast or slow reaction time. Further, they probably cannot sense that their reaction times are getting slower. Vigilance decrements in the PVT are on the magnitude of 40 – 50 ms. So other than extremely slow reaction times, participants are probably unaware of how their performance is changing over time, or of how it compares to typical performance. Therefore, in this context, feedback alone might have an effect on motivation, arousal, and task engagement (McCormack, 1959; Church & Camp, 1970). However Locke and colleagues have argued that feedback is only useful insofar as it provides some information as to how a person is meeting (or failing to meet) a performance standard (Locke et al., 1981; Locke & Latham, 2002). Thus, feedback might only affect performance when it is paired with a goal. Further, the feedback might provide a crucial means of adjusting behavior in pursuit of a goal (Erez, 1977; Sipowicz et al., 1962). If a person has a specific goal but does not know how well they are keeping pace with such a goal, the goal standard may be virtually useless. But if the participant is given specific feedback on how their performance is meeting (or falling short of) the goal, the participant may be better able to regulate their attention and task engagement in pursuit of that goal (Bandura & Cervone, 1983).

Experiment 2 examined the effect of feedback on its own, as well as its potential interactive effect with goal-setting. Goals and feedback were manipulated across conditions in a 2 x 2 design. In the no-feedback conditions, feedback was nearly eliminated. The 1-s feedback screen following each trial was replaced with a mask, and between blocks participants were told that the current block had ended and the next block was about to begin. In the feedback conditions, participants received the standard 1-s feedback screen on every trial. Plus, at the end of each block of trials, they saw their average reaction time for that block, as well as their average reaction time for the entire experiment. This feedback provided participants information on how their performance is changing over time, which theoretically would allow them to adjust their behavior. In the goal conditions, participants will be given a specific, difficult goal (keep their average reaction time below 300 ms). Thus, participants in the goal + feedback condition were able to compare their current level of performance to a standard and adjust their behavior accordingly. Similar to Experiment 1, participants in all conditions were asked about their current level of motivation and alertness following each block of trials (before they received feedback about their performance on that block).

In regards to the framework, feedback would theoretically moderate the effect of a goals on task engagement and task performance (Figure 3). On one hand, if people have a goal to meet, but have no information as to how they are progressing toward or meeting the goal, the goal may have limited effectiveness. On the other hand, feedback may provide people with the necessary information they need to regulate their behavior in pursuit of the goal (Erez, 1977; Payne & Hauty, 1955; Strang et al. 1974). If they know their current level of performance is below the standard, they may be able to adjust their task engagement or effort level in order to reduce the gap between their current performance and their desired performance. However, we must also recognize that feedback in and of itself may have a moderating effect on task engagement (Church & Camp, 1965; Pollack & Knapf, 1958; Warm et al., 1974). In a typical sustained attention task, people may not be aware that their performance has started to slip. But once given information that shows their performance is worsening, people may adjust their task engagement to counteract such effects. So in Experiment 2, we provided conditions that have no feedback and no goal, feedback with no goal, and feedback plus a difficult goal.

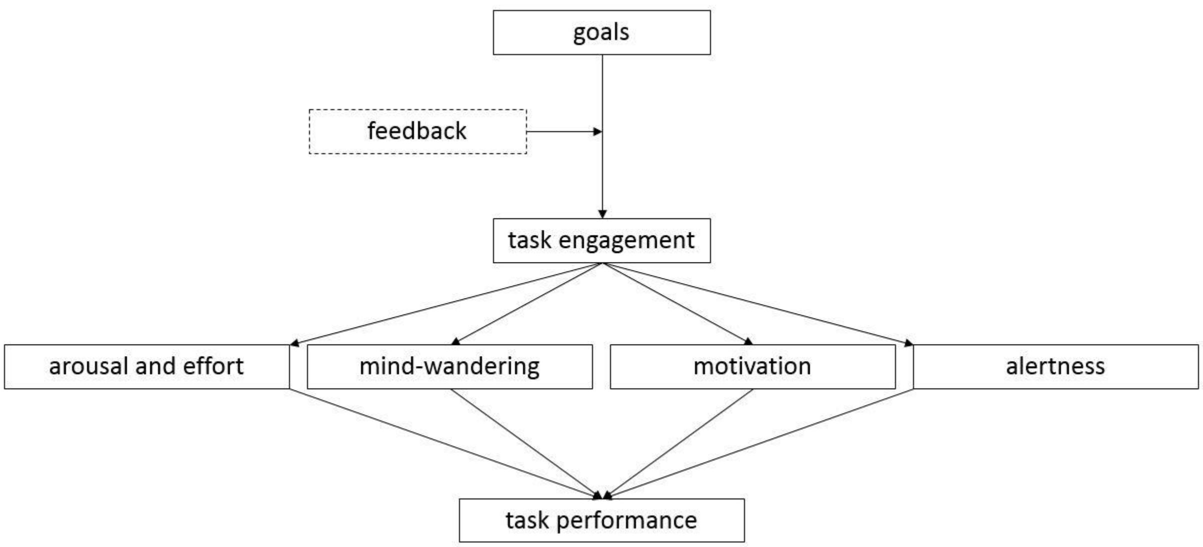


Figure 10. Theoretical framework for how feedback might moderate the effect of goals.

I hypothesized that feedback would exert a regulating role task engagement and interact with goal-setting. Specifically, I hypothesized that reaction times would be faster and/or less variable, mind-wandering would decrease, and arousal would stabilize when participants were given feedback. Further, I expected the effect of feedback to be greater when participants were given a specific, difficult goal. I also expected the complete absence of feedback to have the opposite effect. That is, I expected task performance to be worse in the complete absence of explicit feedback on a trial-to-trial basis.

Method

Participants and procedure

A sample of 144 participants from the human subjects pool at the University of Oregon completed the study in exchange for partial course credit. Three participants misunderstood the task instructions – they thought the goal was to keep their average RT below 30 s as opposed to 300 ms, 1 participant fell asleep during the task, and 1 participant had heard about the study before coming to the lab. These participants were excluded from the final analyses, leaving a final sample of 139 participants (goal + feedback condition: $N = 35$; goal + no feedback: $N = 35$; no goal + feedback: $N = 35$, no goal + no feedback: $N = 34$; M age = 19.61, 86 females, 49 males, 1 non-binary gender). Participants completed informed consent and demographics forms. They were then randomly assigned to a feedback condition and completed the PVT. A Tobii T300 eye-tracker continuously recorded eye data at a sampling rate of 120 Hz.

PVT. The task was nearly identical to that used in Experiment 1 with the exception that feedback screens were added between blocks, and trial-by-trial feedback was altered in the no-feedback conditions. In lieu of a feedback screen, the no-feedback conditions showed a screen telling participants that the current block of trials had ended, and that the next block would begin shortly. In all conditions, the block-by-block feedback screens appeared and remained on-screen for 8 s. Participants completed 5 consecutive blocks of 28 trials.

Goal instructions and feedback. Goals and feedback were fully crossed between conditions in a 2 x 2 design. In the goal + feedback condition, participants were told, "Previous research suggests that good performance on this task is a reaction time below 300 milliseconds. Therefore, your goal on this task will be to keep your average reaction time below 300 milliseconds. After each block of trials, you will see a screen with your average reaction time for that block and your average reaction time overall." The feedback screens between each block told participants, "Your average reaction time for that block was ___ milliseconds. Your average reaction time for the task is ___ milliseconds." If a participant's average reaction time was below 300 ms, the feedback screen also said, "You are currently on pace to meet the goal, keep it up!" If their average reaction time was above 300 ms, the feedback screen said, "You are not currently on pace to meet the goal, try to respond faster!" In the no-goal + feedback condition, participants were told to respond as quickly as possible on each trial. Between each block, these participants received their average reaction time for the preceding block and for the task overall. In the goal + no-feedback condition, participants were given the goal of keeping their average reaction time below 300 ms, but the feedback screens told them, "That is the end of this block of trials. The next block is about to begin," and the 1-s post-trial feedback screen was be replaced with a mask ("XX.XXX" in red font). In the no-goal + no-feedback condition, participants were told to respond as quickly as possible. The feedback screens said, "That is the end of this block of trials. The next block is about to begin," and the 1-s post-trial feedback screen was replaced by the mask.

Self-reports. See Experiment 1.

Thought probes. See Experiment 1.

Post-experiment questionnaire. See Experiment 1.

Results

Task performance

Trimming and averaging procedures for RTs were identical to Experiment 1. Table 6 shows mean RTs by block for each condition. For this and all subsequent analyses, unless otherwise noted, I submitted the data to 5 x 2 x 2 mixed ANOVAs with a within-subject factor of block and between-subjects factors of goal (goal, no goal) and feedback (feedback, no feedback). The analysis on RTs indicated a main effect of block ($F(4, 540) = 41.40$, $p < .001$, partial $\eta^2 = .24$), such that RTs increased across time (linear effect: $F(1, 135) = 70.03$, $p < .001$, partial $\eta^2 = .34$). The analysis also indicated a main effect of feedback ($F(1, 135) = 5.15$, $p = .03$, partial $\eta^2 = .04$), such that participants who received feedback performed better overall. However there was no main effect of goal-setting ($F(1, 135) = .94$, $p = .33$, partial $\eta^2 = .01$), nor a goal-setting x feedback interaction ($F(1, 135) = 0.11$, $p = .74$, partial $\eta^2 = .001$). Further the effect of block did not interact with goal-setting ($F(4, 540) = .86$, $p = .49$, partial $\eta^2 = .01$) or feedback ($F(4, 540) = .89$, $p = .47$, partial $\eta^2 = .01$), and there was no block x goal x feedback interaction ($F(4, 540) = 1.79$, $p = .13$, partial $\eta^2 = .01$).

Although the three-way interaction was not significant, I examined the effect of feedback separately in the goal and no-goal conditions. In the goal conditions, a 2 (feedback, no feedback) x 5 (block) ANOVA, the main effect of feedback is not significant ($F(1, 68) = 3.51$, $p = .065$, partial $\eta^2 = .05$), but there is a block x feedback interaction ($F(4, 272) = 2.69$, $p < .03$, $\eta^2 = .04$). Further breakdown of conditions shows that RTs showed a steeper effect of time in the no-goal + feedback condition (linear effect: $F(1, 34) = 18.01$, $p < .001$, partial $\eta^2 = .35$) than in the goal + feedback condition (linear effect: $F(1, 34) = 10.24$, $p = .003$, partial $\eta^2 = .23$). In the no-goal conditions, the main effect of feedback was not significant ($F(1, 67) = 1.81$, $p = .18$, partial $\eta^2 = .03$), and there was no block x feedback interaction ($F(4, 268) = .31$, $p = .87$, partial $\eta^2 = .01$). Breaking down the conditions further showed that participants in the no-goal + feedback condition (linear effect: $F(1, 34) = 21.11$, $p < .001$, partial $\eta^2 = .38$) and participants in the no-goal + no-feedback condition (linear effect: $F(1, 34) = 21.32$, $p < .001$, partial $\eta^2 = .39$) showed about the same effects of time on RTs. In all conditions, participants' RTs showed significant slowing as time progressed. However this effect was shallowest when participants were given a goal and feedback, which is consistent with my hypothesis about the moderating effect of feedback on goal-setting. However the evidence for this interaction is quite weak, and the hypothesized three-way interaction among goal-setting, feedback, and block was not significant.

Table 7 shows data for RT variability as a function of block and condition. The analysis on RT variability indicated a linear main effect of block ($F(4, 540) = 5.99$, $p < .001$, partial $\eta^2 = .04$), such that RT variability increased across time (linear effect: $F(1, 135) = 14.54$, $p < .001$, partial $\eta^2 = .10$). There were no main effects of goal-setting ($F(1, 135) = .67$, $p = .41$, partial $\eta^2 = .01$) or feedback ($F(1, 135) = 2.32$, $p = .13$, partial $\eta^2 = .02$), no goal-setting x feedback interaction ($F(1, 135) = .51$, $p = .48$, partial $\eta^2 = .004$), and no three-way interaction among block, goal-setting, and feedback ($F(4, 540) = 1.87$, $p = .11$, partial $\eta^2 = .01$). So although feedback reduced RTs, it did not make RTs more stable across time.

Table 6

Mean reaction times by block and condition in Experiment 2

	Condition				
Block	G + F	G + NF	NG + F	NG + NF	Overall
1	362 (38)	369 (52)	356 (47)	380 (52)	367 (48)
2	364 (52)	388 (64)	377 (67)	393 (57)	380 (61)
3	369 (49)	403 (74)	389 (84)	408 (62)	392 (70)
4	367 (57)	410 (82)	391 (72)	417 (73)	399 (72)
5	386 (78)	424 (100)	414 (90)	430 (74)	413 (62)
Overall	372 (50)	399 (69)	385 (62)	405 (57)	390 (62)

Note. G + F = goal + feedback, G + NF = goal + no feedback, NG + F = no goal + feedback, NG + NF = no goal + no feedback. Standard deviations are in parentheses.

Table 7

Reaction time variability by block and condition in Experiment 2

	Condition				
Block	G + F	G + NF	NG + F	NG + NF	Overall
1	.17 (.07)	.17 (.05)	.16 (.06)	.20 (.13)	.17 (.08)
2	.15 (.05)	.18 (.07)	.17 (.10)	.18 (.09)	.17 (.08)
3	.16 (.12)	.19 (.09)	.18 (.10)	.21 (.13)	.18 (.11)
4	.17 (.09)	.21 (.11)	.20 (.12)	.21 (.11)	.19 (.11)
5	.19 (.11)	.23 (.16)	.23 (.17)	.20 (.14)	.21 (.14)
Overall	.17 (.06)	.20 (.07)	.19 (.09)	.20 (.08)	.19 (.07)

Note. G + F = goal + feedback, G + NF = goal + no feedback, NG + F = no goal + feedback, NG + NF = no goal + no feedback. Standard deviations are in parentheses.

I also analyzed the distribution of RTs as a function of condition. As expected, there was a main effect of bin ($F(4, 540) = 359.16$, $p < .001$, partial $\eta^2 = .73$). Although goal-setting did not interact with bin (F(4, 540) = .86, p = .49, partial η^2 = .01), feedback did (F(4, 540) = 2.56, p = .04, partial η^2 = .02). There was no significant three-way interaction among bin, goal-setting, and feedback (F(4, 540) = .92, p = .45, partial η^2 = .01). So the better performance for participants in the feedback conditions can be partially explained by a change in the RT distributions. Participants who received feedback reduced the skew of their RT distributions, as group differences became larger in the slower bins. Table 8 shows these data.

Table 8

Reaction time distributions in Experiment 2

	Condition			
Bin	G + F	G + NF	NG + F	NG + NF
1	306 (26)	315 (33)	309 (31)	320 (26)
2	334 (36)	350 (45)	340 (41)	356 (34)
3	358 (46)	378 (57)	365 (48)	386 (46)
4	387 (58)	416 (75)	398 (62)	425 (61)
5	474 (94)	536 (149)	512 (165)	542 (136)

Note. G + F = goal + feedback, G + NF = goal + no feedback, NG + F = no goal + feedback, NG + NF = no goal + no feedback. Standard deviations are in parentheses.

A final analysis of RTs examined lapses (RTs > 500 ms). The analysis indicated a main effect of block (F(4, 540) = 27.79, p < .001, partial η^2 = .17), such that lapses became more frequent across time (linear effect: F(1, 135) = 48.79, p < .001, partial η^2 = .27), and an effect of feedback that was nearly significant (F(1, 135) = 3.76, p = .06, partial η^2 = .03). So feedback also slightly reduced lapses in those conditions. Table 9 shows these data. In summary, the between-subject manipulations had a few effects on task performance: participants in the feedback conditions reduced the skew of their RT distributions and encountered fewer lapses, which led to faster RTs overall. However there was no evidence for an effect of goal-setting on task performance, nor an interaction between goal-setting and feedback.

Table 9

Lapses by block and condition in Experiment 2

	Condition			
Block	G + F	G + NF	NG + F	NG + NF
1	1.23 (1.68)	2.11 (3.44)	1.34 (2.21)	2.08 (3.41)
2	1.69 (3.12)	3.11 (4.91)	2.06 (4.33)	2.71 (3.71)
3	1.51 (2.64)	3.51 (5.12)	2.37 (3.90)	3.24 (3.53)
4	2.37 (3.78)	3.86 (4.93)	2.80 (3.44)	4.00 (5.38)
5	2.94 (3.85)	4.49 (6.20)	3.74 (4.69)	5.23 (5.73)

Note. G + F = goal + feedback, G + NF = goal + no feedback, NG + F = no goal + feedback, NG + NF = no goal + no feedback. Standard deviations are in parentheses.

Motivation and alertness ratings

The analysis on alertness ratings indicated a effect of block on alertness ratings (F(4, 540) = 49.77, p < .001, partial η^2 = .27) such that alertness ratings dropped across time (linear effect: F(1, 135) = 132.33, p < .001, partial η^2 = .50). There were no main effects of goal-setting (F(1, 135) = .04, p = .85, partial η^2 = .00) or feedback (F(1, 135) = 1.17, p = .28, partial η^2 = .01), and no goal-setting x feedback interaction (F(1, 135) = 2.10, p = .15, partial η^2 = .02). However, the effect of block did significantly interact with goal-setting (F(4, 540) = 2.52, p = .04, partial η^2 = .02). There was no feedback x block interaction (F(4, 540) = .15, p = .96, partial η^2 = .001), and no goal-setting x feedback x block interaction ($F(4, 540) = .15$, $p = .96$, partial $\eta^2 = .001$). Participants who were given the goal reported a slightly shallower drop in alertness ratings across time. Figure 11 shows this pattern.

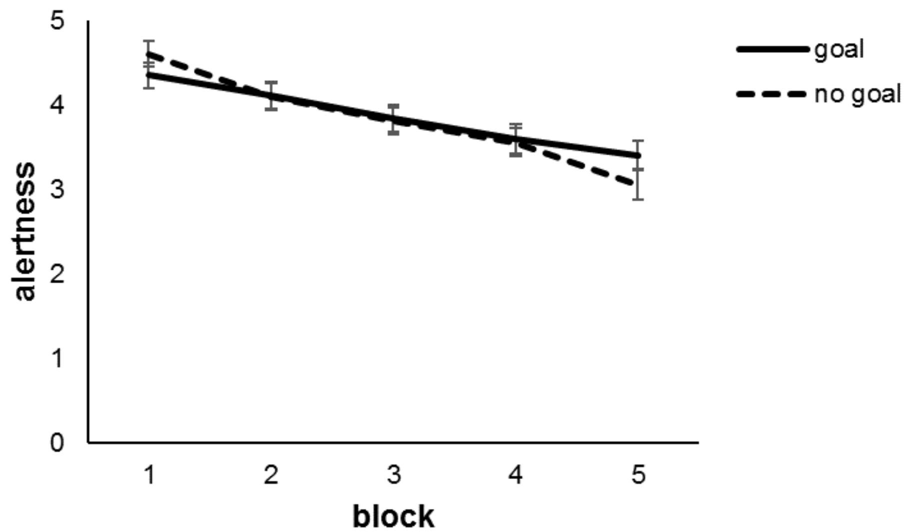


Figure 11. Alertness ratings by block and goal-setting condition, collapsed across feedback conditions, in Experiment 2. Error bars represent +/- one standard error of the mean.

The analysis on motivation ratings indicated a main effect of block ($F(4, 540) = 53.54$, $p < .001$, partial $\eta^2 = .28$), such that motivation decreased across time (linear effect: $F(1, 135) = 120.30$, $p < .001$, partial $\eta^2 = .47$). Although there were no main effects of goal-setting (F(1, 135) = 1.35, $p = .25$) or feedback ($F(1, 135) = 1.75$, $p = .19$), there was a small but significant goal-setting x feedback interaction ($F(1, 135) = 4.06$, $p = .04$, partial $\eta^2 = .03$). Participants in the goal + feedback reported the highest levels of motivation, overall. There was no block x goal-setting interaction ($F(4, 540) = 1.97$, $p = .10$, partial $\eta^2 = .01$), no block x feedback interaction ($F(4, 540) = 1.56$, $p = .18$, partial $\eta^2 = .01$), and no block x goal-setting x feedback interaction ($F(4, 540) = .92$, $p = .45$, partial

$\eta^2 = .01$). Figure 12 shows the goal-setting x feedback interaction on average motivation ratings.

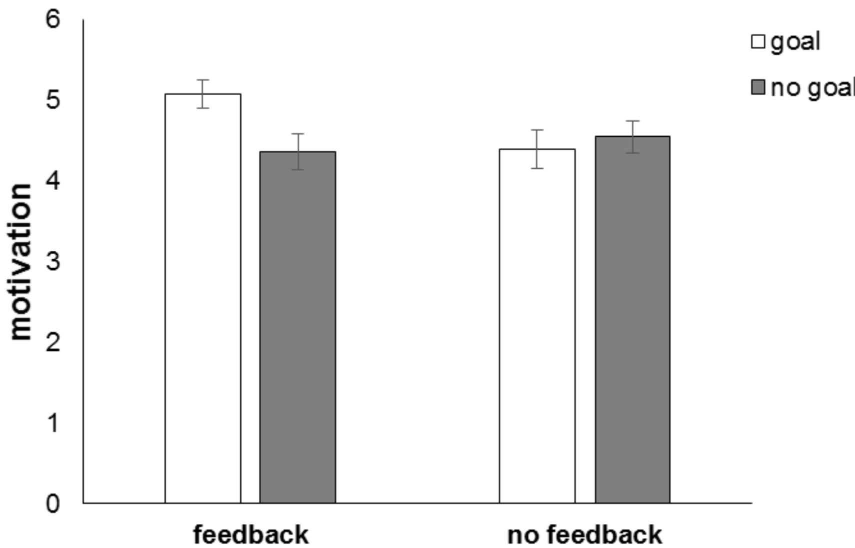


Figure 12. Average motivation ratings by goal-setting and feedback conditions in Experiment 2. Error bars represent +/- one standard error of the mean.

Thought probe responses

I had hypothesized that participants in the goal-setting and feedback conditions would show reduced mind-wandering, and that goal-setting and feedback would interact, such that participants in the goal + feedback condition would report the least amount of mind-wandering. To specifically test these hypotheses, I submitted mind-wandering reports to a 2 x 2 x 2 x 5 mixed ANOVA with within-subjects factors of intentionality (intentional mind-wandering vs. unintentional mind-wandering) and block and between-subjects factors of goal-setting and feedback. The analysis indicated a main effect of block ($F(4, 540) = 17.30$, $p < .001$, partial $\eta^2 = .11$), such that mind-wandering increased across time (linear effect: $F(1, 135) = 45.02$, $p < .001$, partial $\eta^2 = .25$), a main effect of intentionality ($F(1, 135) = 206.06$, $p < .001$, partial $\eta^2 = .60$), such that participants reported more unintentional mind-wandering than intentional mind-wandering, and a block x intentionality interaction ($F(4, 540) = 6.55$, $p < .001$, partial $\eta^2 = .05$), such that unintentional mind-wandering increased at a faster rate than intentional mind-wandering. Simple effects analyses indicated that both unintentional mind-wandering (linear effect: $F(1, 135) = 35.44$, $p < .001$, partial $\eta^2 = .21$) and intentional mind-wandering (linear effect: $F(1, 135) = 4.00$, $p = .05$, partial $\eta^2 = .03$) increased across time, which replicates Experiment 1. The analysis also indicated a main effect of feedback ($F(1, 135) = 5.92$, $p = .02$, partial $\eta^2 = .04$), such that participants in the feedback conditions reported less mind-wandering overall. However there was no main effect of goal-setting ($F(1, 135) = 2.79$, $p = .10$, partial $\eta^2 = .02$) nor a feedback x goal-setting interaction ($F(1, 135) = 2.29$, $p = .13$, partial $\eta^2 = .02$). There was also no block x goal-setting ($F(4, 540) = .74$, $p = .57$, partial $\eta^2 = .01$), block x feedback ($F(4, 540) = .67$, $p = .61$, partial $\eta^2 = .01$), or block x goal-setting x feedback interaction ($F(4, 540) = 1.59$, $p = .18$, partial $\eta^2 = .01$). Finally, there was no block x intentionality x goal-setting ($F(4, 540) = .94$, $p = .44$, partial $\eta^2 = .01$) or block x intentionality x feedback interaction ($F(4, 540) = .70$, $p = .60$, partial $\eta^2 = .01$). There was a small but significant block x intentionality x goal-setting x feedback interaction ($F(4, 540) = 3.04$, $p = .02$, partial $\eta^2 = .02$, indicating the effects of time on the two types mind-wandering differed slightly across conditions. But overall, I found only partial evidence for my hypotheses. While people in the feedback conditions showed reduced mind-wandering overall, mind-wandering was unaffected by goal-setting. Figure 13 shows these data. Data for all thought probe responses collapsed across blocks are listed in Table 10.

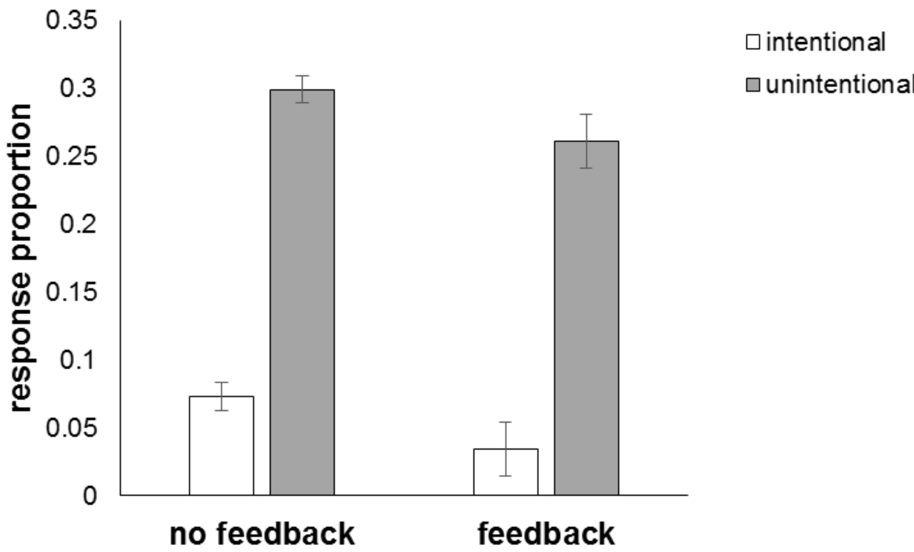


Figure 13. Mind-wandering reports as a function of intentionality and feedback condition in Experiment 2. Error bars represent +/- one standard error of the mean.

Table 10

Thought probe response proportions in Experiment 2

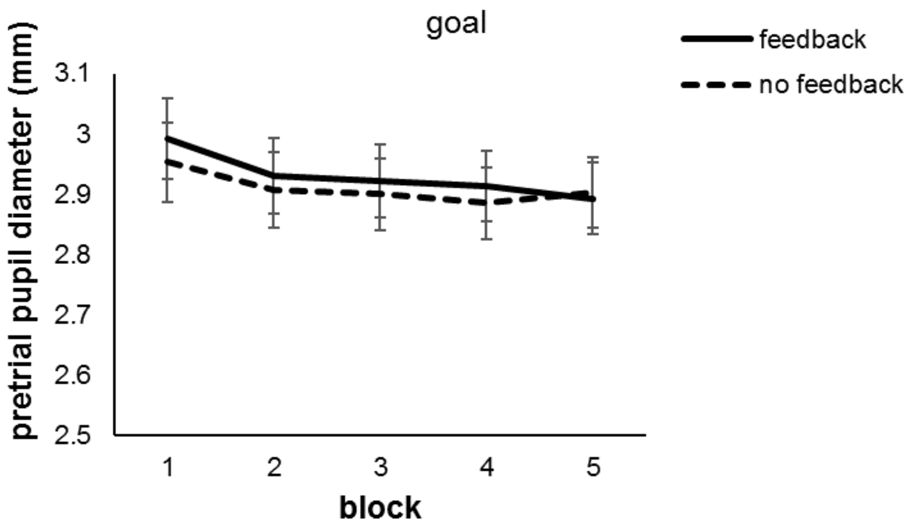
	Condition			
Response	G + F	G + NF	NG + F	NG + NF
On-task	.23 (.20)	.25 (.20)	.22 (.21)	.21 (.19)
Task-related interference	.39 (.18)	.20 (.14)	.27 (.20)	.25 (.17)
External distraction	.07 (.09)	.07 (.08)	.07 (.11)	.08 (.09)
Intentional MW	.02 (.05)	.08 (.09)	.05 (.07)	.07 (.10)
Unintentional MW	.22 (.18)	.29 (.17)	.30 (.19)	.31 (.13)
Mind-blanking	.06 (.10)	.11 (.17)	.11 (.12)	.09 (.11)

Note. G + F = goal + feedback, G + NF = goal + no feedback, NG + F = no goal + feedback, NG + NF = no goal + no feedback. MW = mind-wandering. Standard deviations are in parentheses.

Pupillometry

Similar to Experiment 1, I first analyzed pre-trial pupil diameter as a function of time and condition. The analysis on mean pre-trial pupil indicated a main effect of block ($F(4, 536) = 22.26$, $p < .001$, partial $\eta^2 = .14$), such that pre-trial pupil diameter decreased across time (linear effect: $F(1, 134) = 29.94$, $p < .001$, partial $\eta^2 = .17$). There was no main effect of goal-setting ($F(1, 134) = .91$, $p = .34$, partial $\eta^2 = .01$) or feedback ($F(1, 134) = 1.20$, $p = .28$, partial $\eta^2 = .01$) and no goal-setting x feedback interaction ($F(1, 134) = .55$, $p = .46$, partial $\eta^2 = .004$). The effect of block did not interact with goal-setting ($F(4, 536) = .04$, $p = .99$, partial $\eta^2 < .001$) or feedback ($F(4, 536) = .45$, $p = .76$, partial $\eta^2 = .003$), and there was no three-way interaction between block, goal-setting, and feedback ($F(4, 536) = 1.46$, $p = .21$, partial $\eta^2 = .01$). So although arousal decreased across time, this effect did not differ across conditions. Figure 14 shows these results.

a)



b)

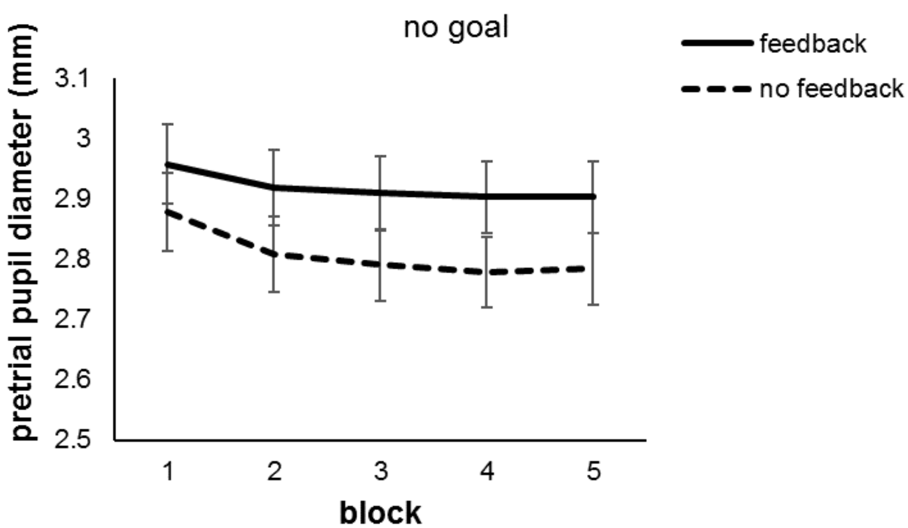
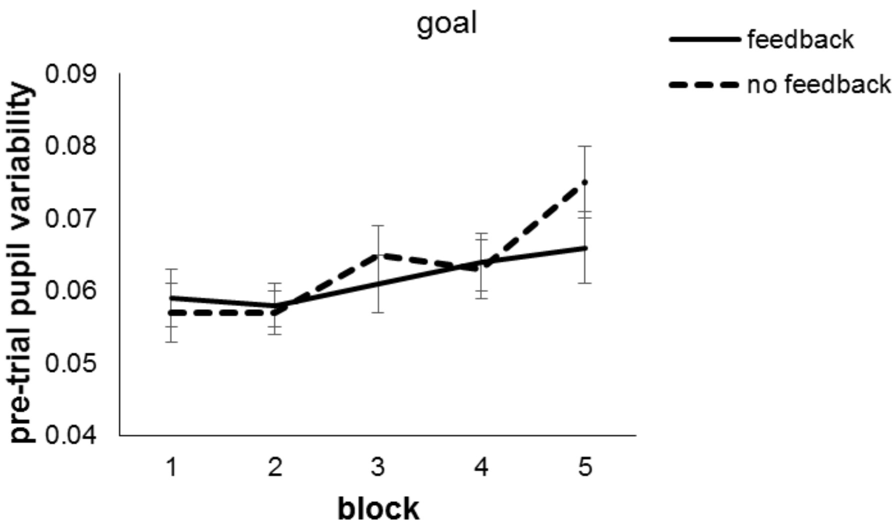


Figure 14. Pretrial pupil diameter as a function of block and feedback in the a) goal and b) no-goal conditions. Error bars represent +/- one standard error of the mean.

The analysis on pre-trial pupil variability indicated a main effect of block (F(4, 536) = 22.34, $p < .001$, partial $\eta^2 = .14$), such that pre-trial pupil variability increased across time (linear effect: F(1, 134) = 52.10, $p < .001$, partial $\eta^2 = .28$). But similar to mean pre-trial pupil diameter, there were no main effects of goal-setting ($F(1, 134) = .11$, $p = .74$, partial $\eta^2 = .001$) or feedback ($F(1, 134) = .82$, $p = .37$, partial $\eta^2 = .01$), and no goal-setting x feedback interaction ($F(1, 134) = .14$, $p = .71$, partial $\eta^2 = .001$). Further, the effect of block did not interact with goal-setting ($F(4, 536) = .38$, $p = .83$, partial $\eta^2 = .003$) or feedback ($F(4, 536) = 1.30$, $p = .29$, partial $\eta^2 = .01$), and there was no three-way interaction among block, goal-setting, and feedback ($F(4, 536) = 1.60$, $p = .17$, partial $\eta^2 = .01$). So although arousal fluctuated more as time progressed, this effect did not differ across conditions. Figure 15 shows these data.

a)



b)

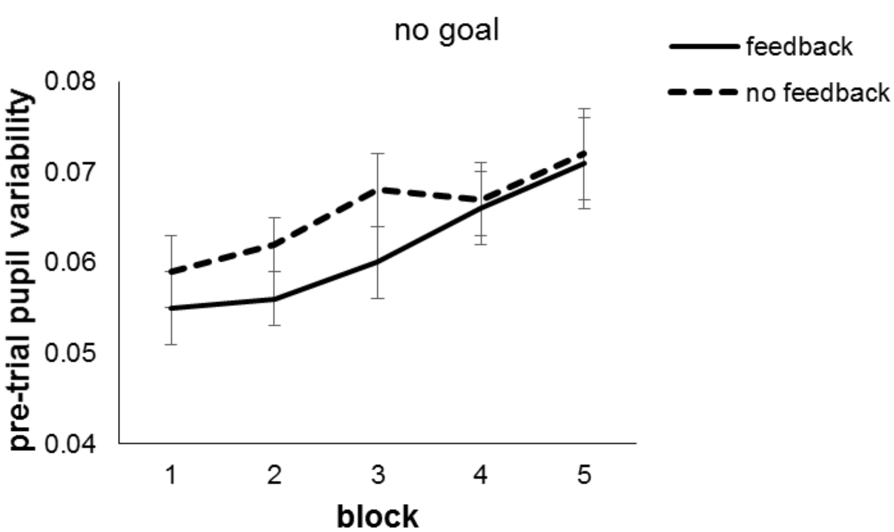


Figure 15. Pre-trial pupil variability for the feedback and no feedback conditions in the a) goal and b) no goal conditions. Error bars represent +/- one standard error of the mean.

The next set of analyses focused on task-evoked pupil responses. Binning and baselining procedures were identical to Experiment 1. The task-evoked waveforms by block, collapsed across conditions, are depicted in Figure 16. Similar to Experiment 1, task-evoked responses decreased across blocks ($F(4, 520) = 18.70$, $p < .001$, partial $\eta^2 = .13$).

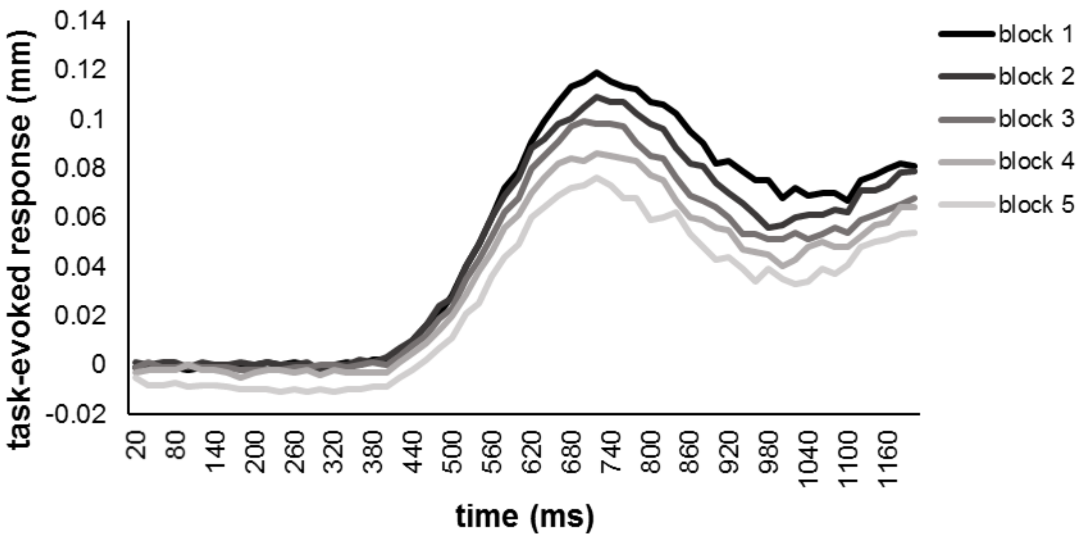
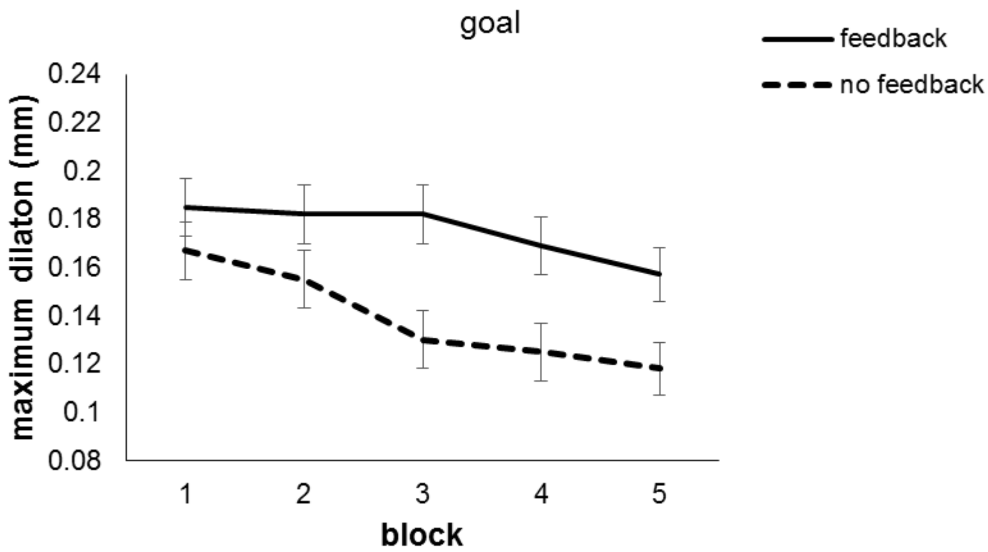


Figure 16. Task-evoked pupillary responses by block in Experiment 2.

To compare task-evoked responses across goal-setting and feedback conditions, I computed a peak dilation for each trial using the same method in Experiment 1 and averaged these values within blocks for each participant. The analysis on maximum dilations indicated a main effect of block ($F(4, 536) = 28.16$, $p < .001$, partial $\eta^2 = .17$), such that maximum dilations decreased across time (linear effect: $F(1, 134) = 83.13$, $p < .001$, partial $\eta^2 = .38$). There was no main effect goal-setting ($F(1, 134) = .08$, $p = .78$, partial $\eta^2 < .01$), but there was a significant main effect of feedback ($F(1, 134) = 11.62$, $p = .001$, partial $\eta^2 = .08$), such that participants in the feedback conditions showed greater task-evoked responses overall. Goal-setting and feedback did not significantly interact

($F(1, 134) = .001$, $p = .98$, partial $\eta^2 < .001$). There was no block x goal-setting interaction ($F(4, 536) = .13$, $p = .97$, partial $\eta^2 = .001$), no block x feedback interaction ($F(4, 536) = .91$, $p = .46$, partial $\eta^2 = .01$), and no three-way interaction among block, goal-setting, and feedback ($F(4, 536) = 1.82$, $p = .12$, partial $\eta^2 = .01$). Figure 17 shows this pattern. Largely, the task-evoked responses corroborated the effects on task performance and mind-wandering. Participants in the feedback conditions showed faster RTs, less mind-wandering, and greater task-evoked pupillary responses, overall.

a)



b)

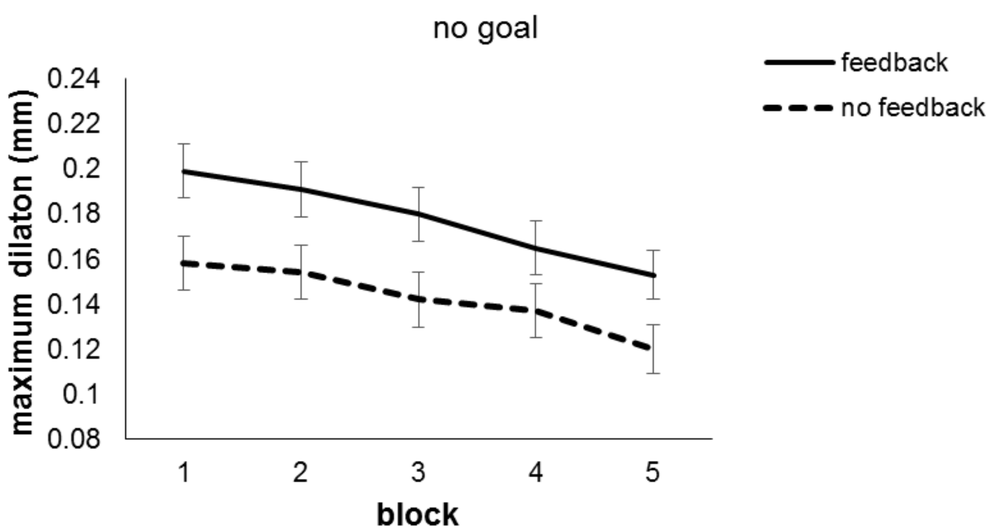


Figure 17. Average maximum task-evoked pupillary response by feedback condition for the a) goal and b) no-goal conditions. Error bars represent +/- one standard error of the mean.

Post-experiment questionnaire

To see if the goal-setting manipulation "sunk in" with participants, I examined how often participants in each condition mentioned the specific goal of keeping their average RT below 300 ms. I first transcribed their hand-written responses verbatim, then coded whether or not the specific goal was mentioned. Whereas only 6% of participants in the goal + no feedback condition mentioned the goal in their post-experiment questionnaire, 47% of participants in the goal + feedback condition mentioned the goal. So at least subjectively, participants in the goal + feedback condition seemed to internalize the goal more than the participants in the goal + no feedback condition. However, this did not lead to significantly better behavioral performance for these participants. If anything, it increased their motivation, as evidenced by the goal-setting x feedback interaction on motivation ratings. But it produced no other significant differences.

Discussion

Experiment 2 examined the effects of goal-setting, feedback, and their combination. In a 2 x 2 design, participants were given either a difficult goal or no goal, and trial-by-trial and block-by-block feedback or no feedback at all. I had hypothesized that feedback would benefit sustained attention, that goal-setting would benefit sustained attention, and together they would have an interactive effect. However, the only factor that had a significant effect on task performance, mind-wandering, and pupillary measures of effort was feedback. Participants who received trial-by-trial and block-by-block feedback about their performance, regardless of whether or not they received the difficult goal instructions, showed faster RTs, fewer lapses, reductions in mind-wandering, and greater task-evoked pupillary responses. I did not find any strong evidence for an effect of goal-setting, similar to Experiment 1, nor did I observe evidence for interactive effects of goal-setting and feedback. In other words, the effect of feedback was not stronger for participants who received feedback about a specific goal. Interestingly, although participants in the feedback conditions showed the above-mentioned effects, they did not report higher levels of motivation or alertness, and they did not show greater overall arousal, as measured by pre-trial pupil diameter. But collectively, the bulk of the evidence in Experiment 2 points to the idea that feedback has a facilitative effect on sustained attention.

All of the time-on-task effects from Experiment 1 replicated in Experiment 2. As time progressed, participants' RTs increased and became more variable, they reported lower levels of motivation and alertness, they reported more mind-wandering, and the pupillary measures indicated decreases in arousal and effort. Interestingly, even participants in the feedback conditions, who showed improvements in sustained attention across a number of different metrics, still demonstrated these trends. So despite having a facilitative effect on sustained attention, feedback was not sufficient to eliminate the effects of time.

Although it is clear that feedback had a significant impact on performance in a number of ways, it is not clear whether this was due to the trial-by-trial or the block-by-block feedback. As a reminder, the standard version of the PVT gives the participant their RT for 1 s following each trial. In the no-feedback conditions, this feedback screen was replaced by a visual mask (XX.XXX). Additionally, participants did not receive feedback as to how close they were to the goal, or how they were doing in general, and thus had no idea how they could adjust their effort accordingly (but see Cross-Experimental Analyses).

The lack of an effect of goal-setting may be due to some of the same factors as Experiment 1. First, there was no incentive to reach the goal. So similar to Experiment 1, participants may have decided that the effort required to reach the goal was not worth it. Second, the goal may have been too difficult. Indeed, only one participant in Experiment 2 actually kept their average RT below 300 ms. So again, participants may have adjusted their personal goals downward in the face of the difficulty of reaching the goal.

In regards to the goal-setting framework, in this case feedback was a necessary and sufficient means of improving sustained attention. Without feedback, the difficult goal did not have any significant effects on the dependent variables. But without a goal, feedback still had a significant effect on several dependent variables including task performance, mind-wandering, and pupillary indicators of effort. These results are inconsistent with Erez's (1977) argument that feedback is a necessary, but not sufficient, aspect of goal-setting. But they are also inconsistent with goal-setting theory's argument (Locke & Latham, 2002) that feedback is simply a moderator of the effect of goals. In this case, feedback did not need to be paired with a goal to be effective. These results are most consistent with those of Warm et al. (1974), who found that feedback reduced vigilance decrements in reaction times and reaction time variability, even when the feedback was false. However, Warm et al. argued that the primary mechanism by which feedback effected performance was via motivation. And in Experiment 2, there was no main effect of feedback on motivation. Rather, there was a feedback x goal-setting interaction. Feedback only produced a significant change in motivation when it was paired with a specific goal.

In regards to the resource, mindlessness, and motivational control theories of vigilance and sustained attention, the results again did not unequivocally support one theory. Some results, like the decreases in alertness, arousal, and unintentional mind-wandering across time, are consistent with predictions made by resource theories of vigilance and sustained attention. However, participants also reported decreases in motivation and intentional mind-wandering across time. These results are inconsistent with resource theories, but are rather consistent with mindlessness theories. The majority of the evidence is consistent with the motivational control and resource-control theories. Clearly, participants were making downward adjustments in effort across time, as reflected by both self-reports of motivation and task-evoked pupillary responses. Also, some participants in both the goal and no-goal conditions explicitly reported changes in their goals across time. For example, one participant in the no-goal + feedback condition said, “At first I wanted to see how fast I could react to the changing numbers. I wanted to be as fast as I could. That desire waned as the task progressed and I got tired/sore.” One participant in the goal + no feedback condition said, “[My goal was] to do as instructed to the best of my ability, pressing the button as soon as possible. My resolve to accomplish this goal gradually ebbed.” However other participants in the goal conditions reported their goal was to get their average below 300 ms throughout the task. These different types of reactions – continual goal activation in the face of and downward adjustments of goal standards – are both predicted by the motivational control theory.

However, some results are inconsistent with this account. Specifically, the motivation control theory argues that the adaptive response to a downward adjustment in goals prevents mental fatigue, as people prevent themselves from the consistent strain toward a demanding task goal. This would predict that people who abandoned the difficult goal in favor of some easier or more general goal would not show as much of an effect of time on alertness and arousal. In other words, participants who did not report trying to maintain the goal of keeping their average reaction time below 300 ms should report greater alertness than participants who strained to pursue that goal throughout the task. But this was not the case, as they showed roughly equal overall alertness ($t(67) = 1.15$, $p = .26$), and they did not show different patterns of alertness across time ($F(4, 268) = .36$, $p = .84$, partial $\eta^2 = .01$).

With regard to the resource-control theory, many of the predictions made by the theory are supported: changes in task performance were accompanied by decreases in motivation and increases in mind-wandering across time. Further, feedback increased task engagement via reduced mind-wandering. However, the increase in task engagement did not eliminate or even mitigate the vigilance decrement. Although participants showed an overall improvement in task performance when given feedback, the feedback conditions showed roughly the same downward trend in performance as the no-feedback conditions, as there was no block x feedback interaction. Further, similar to Experiment 1, the pattern of intentional and unintentional mind-wandering across time is the opposite of what would be predicted by the resource-control theory. Unintentional mind-wandering increased at a significantly faster rate than intentional mind-wandering across time.

CHAPTER IV

EXPERIMENT 3: GOAL-SETTING AND INCENTIVES

Although prior research has shown that the simple act of setting a specific, difficult goal is sufficient to improve performance, incentives have been shown to magnify or enhance the effect of goals (Locke & Bryan, 1966; Locke & Latham, 2002). Specifically, the incentives produce greater goal commitment among individuals. So Experiment 3 examined how incentives moderate the effect of goals. The task parameters, set-up, and design were nearly identical to those in Experiments 1 and 2. But in Experiment 3, there were three conditions with incentive manipulated between conditions. In each condition, participants were told that their goal would be to keep their average reaction time below 300 ms. The incentive for meeting this goal differed across conditions. In the cash-incentive condition, participants were told that they would receive $10 if they met the goal. In the time-incentive condition, participants were told that the experimental session would last 1 hr. But if they met the performance goal after 30 min, they would be released from the experiment early. In the no-incentive condition, participants were given no incentive to meet the goal. I hypothesized that the incentives would enhance the effect of the difficult goal. The conditions also offered the opportunity to compare the efficacy of a time-based incentive versus a monetary incentive. Although several studies have successfully mitigated sustained attention deficits using monetary incentives (Berghum & Lehr, 1964; Bevan & Turner, 1965; Esterman et al., 2016; Massar et al., 2016; Smith, Lucaccini, & Epstein, 1967), and several have used time-based incentives (Esterman et al., 2014; Hopstaken et al., 2015a, 2015b; Seli et al., in press). Only one study, to my knowledge, has directly compared these two incentives

(Esterman et al., 2014), and they did not find any differences in performance across monetary and time incentive conditions.

In regards to the proposed framework, incentives should theoretically moderate the effect of goals on task engagement via goal commitment (see Figure 18). In a goal-setting situation, such as those in Experiment 1, the goal is set by the experimenter, and there is no particular reason for the participant to meet that goal, other than being instructed to do so and some social desirability norm (e.g., wanting to seem competent), the participant has no external incentive. Therefore, an incentive might increase goal commitment, which in turn would affect task engagement and task performance (Mowen, Middlemist, & Luther, 1981). To measure this directly, I will also ask participants to report their current level of goal commitment throughout the task, in addition to their motivation and alertness.

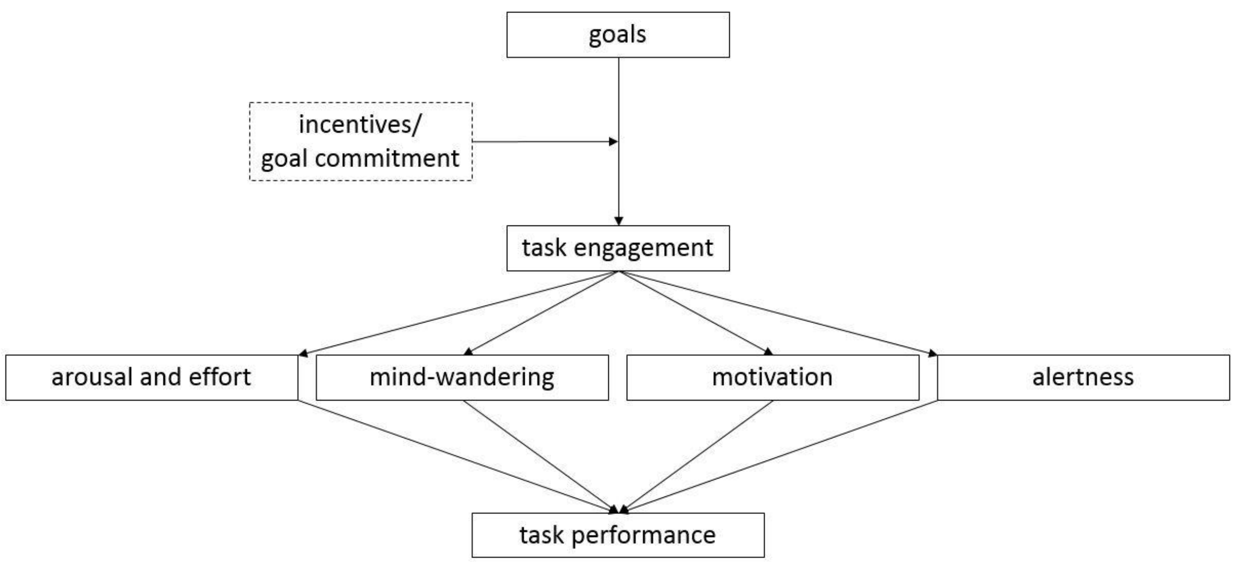


Figure 18. Theoretical framework for how incentives might moderate the effect of goals.

Method

Participants and procedure

A sample of 118 participants from the human subjects pool at the University of Oregon completed the study in exchange for partial course credit. Participants first completed informed consent and demographics forms. Participants were randomly assigned to an incentive condition. Six participants indicated on the post-experimental questionnaire that they had heard about the study, one participant felt sick and had to take a break in the middle of the experiment, so these participants were replaced. The final sample included 111 participants (no-incentive condition: $N = 37$; time incentive condition: $N = 36$; cash incentive condition: $N = 38$; M age = 19.39, 68 females, 42 males, 1 non-binary gender).

PVT. The task was identical to that used in Experiments 1 and 2, and the feedback screens between blocks were identical to those used in the goal + feedback condition of Experiment 2. Participants in all conditions completed 5 blocks of 28 trials.

Goal instructions and incentives. All participants were recruited to the lab under the impression that the experimental session would last 1 hour, and that they would receive 1 course credit for their participation. In all three conditions, participants were told, “Previous research suggests that good performance on this task is a reaction time below 300 milliseconds. Therefore, your goal on this task will be to keep your average reaction time below 300 milliseconds. After each block of trials, you will see a screen with your average reaction time for that block, your average reaction time overall, and how your performance compares to your goal.” The no-incentive condition was identical to the goal + feedback condition in Experiment 1, with the exception that questions about goal commitment were included. In the time-incentive condition, participants were told, "This task will take 1 hour. At the midway point of the task, if you have met the goal (i.e., kept your average reaction time below 300 ms), you will be allowed to stop the experiment early and leave the session. You will still receive 1 credit for participating today. If you have not met the goal, you will continue the task for another 30 minutes." In the monetary incentive condition, participants were told, "At the end of the task, if you have met the goal (i.e., kept your average reaction time below 300 ms), you will receive a $10 cash bonus in addition to 1 credit for your participation. If you have not met the goal, you will only receive course credit." All participants who kept their average reaction time below 300 ms were given the $10 bonus, regardless of condition, and all participants were released from the experiment after 30 min, regardless of performance, and given course credit for 1 hour of participation.

Self-reports. In addition to the motivation and alertness questions, participants were asked to report their current level of goal commitment on a 7-point scale (1 = not committed at all, 7 = totally committed) at the end of each block.

Thought probes. See Experiment 1.

Post-experiment questionnaire. See Experiment 1.

Results

RTs

Trimming and averaging procedures were identical to Experiments 1 and 2. Table 11 shows average RTs by block and condition. Unless otherwise noted, for all subsequent analyses I analyzed the data with 5 x 3 mixed ANOVAs with a within-subjects factor of block and a between-subjects factor of condition. The analysis on mean RTs indicated a main effect of block ($F(4, 432) = 21.19$, $p < .001$, partial $\eta^2 = .16$), such that RTs increased across time (linear effect: $F(1, 108) = 29.39$, $p < .001$, partial $\eta^2 = .21$). However there was no main effect of condition ($F(2, 108) = .22$, $p = .80$, partial $\eta^2 = .004$), and there was no block x condition interaction ($F(8, 432) = .59$, $p = .78$, partial $\eta^2 = .01$). So providing participants with an incentive to meet a difficult goal did not improve performance beyond providing that goal alone, and it did not eliminate the effect of time on RTs.

Table 11

Mean reaction times by block and condition in Experiment 3

	Condition			
Block	No incentive	Time incentive	Cash incentive	Overall
1	345 (45)	348 (42)	346 (39)	346 (38)
2	346 (43)	346 (44)	359 (44)	351 (44)
3	360 (55)	364 (65)	367 (51)	364 (57)
4	375 (76)	366 (56)	376 (58)	372 (63)
5	378 (90)	374 (88)	388 (63)	380 (80)
Overall	360 (54)	360 (54)	367 (46)	362 (51)

Note. Standard deviations are in parentheses.

Table 12 shows RT variability data by block and condition. The analysis on RT variability indicated a main effect of block $F(4, 432) = 4.34$, $p = .002$, partial $\eta^2 = .04$), such that RTs became more variable across time (linear effect: $F(1, 108) = 12.81$, $p = .001$, partial $\eta^2 = .11$). However there was no main effect of condition ($F(2, 108) = .15$, $p = .86$, partial $\eta^2 = .003$), and no block x condition interaction ($F(8, 432) = .64$, $p = .74$, partial η^2 = .01). So overall, participants' RTs became more variable across time. But this effect did not differ based on the incentive provided to meet a difficult goal.

Table 12

Reaction time variability in each block and condition in Experiment 3

	Condition			
Block	No incentive	Time incentive	Cash incentive	Overall
1	.16 (.08)	.17 (.08)	.15 (.06)	.16 (.07)
2	.15 (.09)	.16 (.09)	.19 (.13)	.17 (.11)
3	.19 (.13)	.17 (.10)	.18 (.13)	.18 (.12)
4	.20 (.11)	.19 (.11)	.20 (.11)	.20 (.11)
5	.19 (.12)	.19 (.16)	.21 (.14)	.20 (.14)
Overall	.18 (.08)	.18 (.08)	.19 (.09)	.18 (.08)

Note. Standard deviations are in parentheses.

As two final steps, I also analyzed RTs by their distribution and the occurrence of lapses. Table 13 shows reaction times by bin and condition, and Table 14 shows the number of lapses per block by condition. A 5 x 3 mixed ANOVA with a within-subjects factor of bin and a between-subjects factor of condition indicated a main effect of bin (F(4, 432) = 220.87, p < .001, partial η^2 = .67). But there was no bin x condition interaction (F(4, 432) = .04, p = .99, partial η^2 = .001). So there was no evidence for a difference in the distribution of RTs across conditions. Finally, the analysis on lapses indicated a maid effect of block (F(4, 432) = 13.61, p < .001, partial η^2 = .11), such that lapses became more common across time (linear effect: F(1, 108) = 24.77, p < .001, partial η^2 = .19). But there was no main effect of condition on lapses (F(2, 108) = .19, p = .82, partial η^2 = .004), and the effect of block did not interact with condition (F(4, 432) =

1.18, p = .31, partial η^2 = .02). Collectively, the analyses on RTs all come to the same conclusion: providing an incentive to meet a difficult goal did not significantly alter performance on the task over and above simply providing the goal. Providing the goal without an incentive produced similar task performance to giving this goal and offering a reward for meeting it.

Table 13

Reaction time distributions in each condition in Experiment 3

	Condition			
Bin	No incentive	Time incentive	Cash incentive	Overall
1	295 (22)	293 (20)	299 (22)	296 (21)
2	320 (30)	320 (29)	325 (29)	322 (29)
3	342 (38)	342 (39)	348 (37)	348 (37)
4	373 (57)	372 (55)	380 (49)	380 (49)
5	473 (145)	471 (138)	484 (108)	476 (130)

Note. Standard deviations are in parentheses.

Table 14

Lapses in each block and condition in Experiment 3

	Condition			
Block	No incentive	Time incentive	Cash incentive	Overall
1	.84 (1.24)	1.36 (2.49)	1.08 (2.13)	1.09 (2.01)
2	1.05 (2.05)	1.19 (1.97)	1.26 (1.81)	1.17 (1.93)
3	1.59 (2.68)	1.75 (3.12)	1.61 (2.22)	1.65 (2.67)
4	2.30 (3.55)	1.75 (2.45)	2.50 (3.53)	2.18 (3.22)
5	2.22 (3.42)	2.03 (3.07)	2.97 (3.26)	2.41 (3.25)
Overall	1.60 (2.23)	1.62 (2.27)	1.88 (2.18)	1.70 (2.21)

Note. Standard deviations are in parentheses.

Motivation and alertness ratings

Figures 19 and 20 show mean alertness and motivation ratings, respectively, by block and condition. The analysis on alertness ratings indicated a main effect of block ($F(4, 432) = 27.13$, $p < .001$, partial $\eta^2 = .20$), such that alertness decreased across time (linear effect: $F(1, 108) = 62.01$, $p < .001$, partial $\eta^2 = .37$). There was also a significant main effect of condition ($F(2, 108) = 4.87$, $p = .009$, partial $\eta^2 = .08$). However there was no significant interaction between condition and block ($F(2, 108) = 1.32$, $p = .27$, partial $\eta^2 = .02$). Participants in the time incentive condition reported significantly higher alertness ratings overall compared to the no-incentive condition ($t(71) = 2.05$, $p = .04$) and compared to the cash incentive condition ($t(72) = 3.06$, $p = .003$). However, there was no significant difference in overall alertness ratings between the no-incentive and the cash incentive conditions ($t(73) = .89$, $p = .37$). Only the difference between the cash incentive and time incentive conditions is significant after correcting for multiple comparisons. So although there was no difference in the pattern of changes in alertness across time between conditions, participants in the time incentive condition reported higher alertness, overall.

The analysis on motivation ratings corroborated the alertness reports. There was a main effect of block on motivation ratings ($F(4, 432) = 31.66$, $p < .001$, partial $\eta^2 = .23$), such that motivation decreased across time (linear effect: $F(1, 108) = 65.78$, $p < .001$, partial $\eta^2 = .38$), and a significant main effect of condition ($F(2, 108) = 4.41$, $p = .01$, partial $\eta^2 = .08$), but no interaction between block and condition ($F(2, 108) = .52$, $p = .60$, partial $\eta^2 = .01$). Similar to the alertness ratings, participants in the time-incentive condition reported higher motivation ratings overall compared to the cash-incentive condition ($t(72) = 2.93$, $p = .005$) and the no-incentive condition ($t(71) = 2.09$, $p = .04$), with no difference between the cash incentive and no-incentive conditions ($t(73) = .86$, $p = .39$). Again, only the difference between the time incentive and cash incentive conditions was significant after correcting for multiple comparisons. Figure 14 shows this pattern. Interestingly, although they did not show superior task performance, participants in the time-incentive condition reported higher overall alertness and motivation than participants in the cash-incentive condition, and participants in the cash-incentive condition reported the lowest levels of motivation.

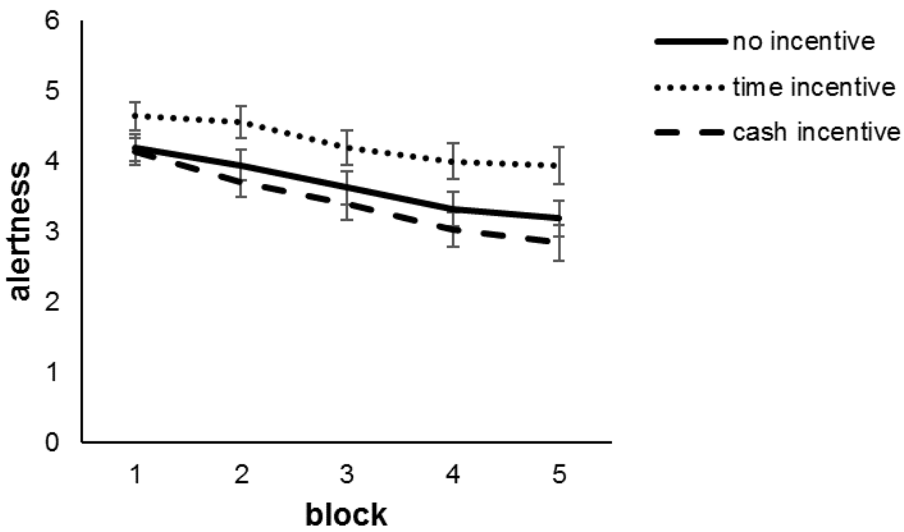


Figure 19. Alertness ratings by block for each condition in Experiment 3. Error bars represent +/- one standard error of the mean.

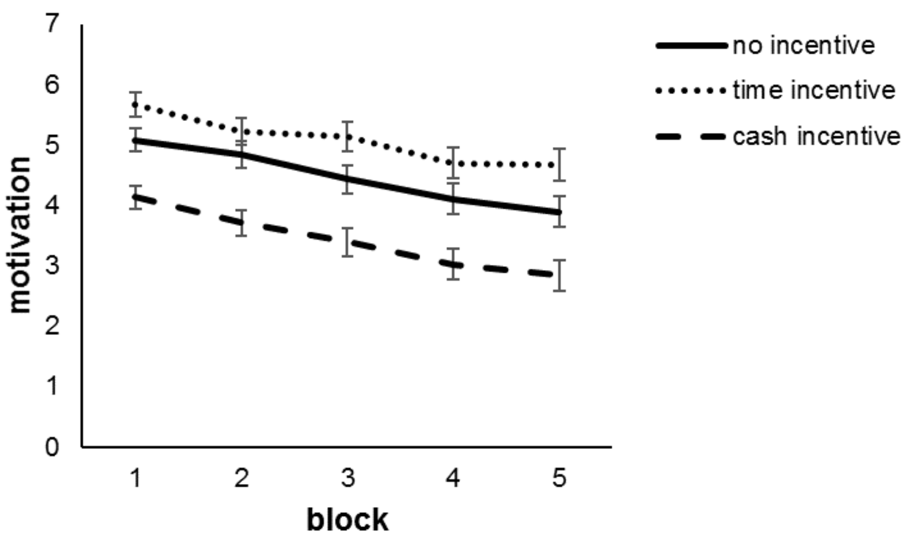


Figure 20. Motivation ratings by block for each condition in Experiment 3. Error bars represent +/- one standard error of the mean.

Goal commitment

Due to a programming error, the goal commitment responses were not recorded for participants in the no-incentive condition. So unfortunately, I was unable to examine the effect of incentives on goal commitment compared to a no-incentive condition. However, these responses were successfully recorded for the cash incentive and time incentive conditions. I submitted these responses to a 2 x 5 mixed ANOVA with a between-subjects factor of condition and a within-subjects factor of block. The ANOVA indicated a main effect of block ($F(4, 288) = 33.48$, $p < .001$, partial $\eta^2 = .32$), such that goal commitment decreased across time (linear effect: $F(1, 72) = 81.74$, $p < .001$, partial $\eta^2 = .53$), and a significant effect of condition ($F(1, 72) = 8.42$, $p = .005$, partial $\eta^2 = .11$), but no block x condition interaction ($F(4, 288) = 1.34$, $p = .26$, partial $\eta^2 = .02$). Figure 21 shows this pattern. Similar to the findings with motivation and alertness ratings, participants in the time incentive condition reported significantly greater commitment toward the goal than participants in the cash incentive condition.

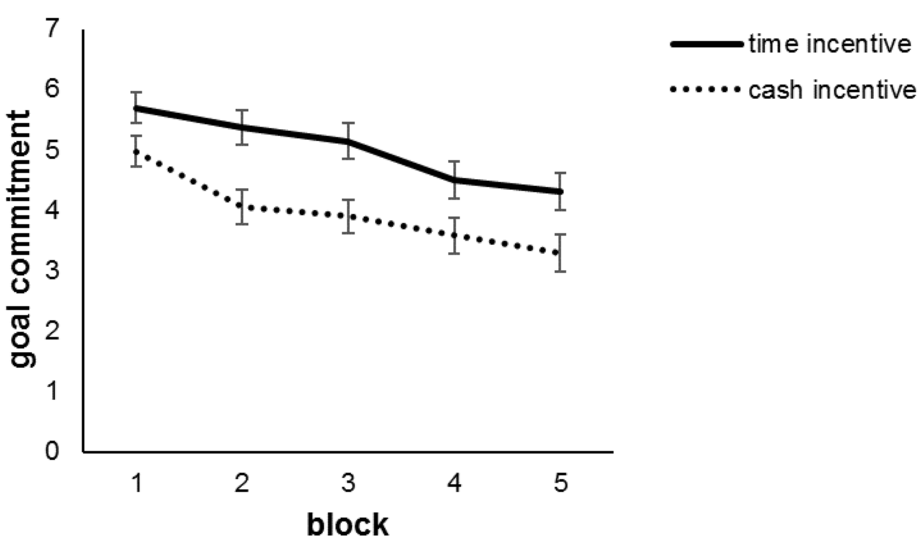


Figure 21. Goal commitment by block in the time-incentive and cash-incentive conditions in Experiment 3. Error bars represent +/- one standard error of the mean.

Thought probe responses

I had hypothesized that another result incentives would be a reduction in mind-wandering by participants in the incentive conditions. To test this hypothesis, I examined mind-wandering reports across time for each condition. I submitted responses to a 2 x 5 x 3 mixed ANOVA with within-subjects factors of intentionality (intentional, unintentional) and block and a between-subjects factor of condition. The analysis indicated a main effect of block ($F(4, 432) = 12.22$, $p < .001$, partial $\eta^2 = .10$), such that mind-wandering increased across time (linear effect: $F(1, 108) = 37.54$, $p < .001$, partial $\eta^2 = .26$), and a main effect of intentionality ($F(1, 108) = 80.15$, $p < .001$, partial $\eta^2 = .43$), such that participants reported more unintentional mind-wandering than intentional mind-wandering. Unlike Experiments 1 and 2, there was no block x intentionality interaction ($F(4, 432) = 1.75$, $p = .14$, partial $\eta^2 = .02$). But simple effects analysis indicated that both intentional mind-wandering ($F(1, 110) = 10.44$, $p = .002$, partial $\eta^2 = .09$) and unintentional mind-wandering ($F(1, 110) = 19.70$, $p < .001$, partial $\eta^2 = .15$) increased linearly across time. Finally, there was no significant main effect of condition ($F(2, 108) = .63$, $p = .53$, partial $\eta^2 = .01$), no block x condition interaction ($F(8, 432) = .82$, $p = .59$, partial $\eta^2 = .02$), and no block x condition x intentionality ($F(8, 432) = .42$, $p = .91$, partial $\eta^2 = .01$). The effects of block and intentionality depicted in Figure 22. Proportions for all thought probe responses, collapsed across block, are listed in Table 15.

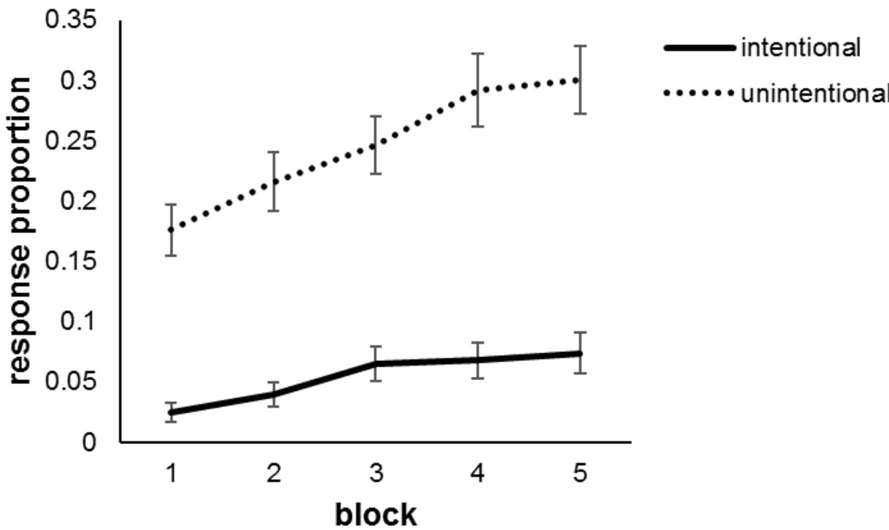


Figure 22. Intentional and unintentional mind-wandering across blocks, collapsed across conditions, in Experiment 3. Error bars represent +/- one standard error of the mean.

Table 15

Thought probe response proportions in Experiment 2

	Condition		
Response	No incentive	Time incentive	Cash incentive
On-task	.21 (.17)	.21 (.22)	.18 (.16)
Task-related interference	.31 (.18)	.38 (.21)	.38 (.19)
External distraction	.08 (.12)	.05 (.08)	.09 (.15)
Intentional MW	.06 (.11)	.05 (.07)	.05 (.08)
Unintentional MW	.27 (.25)	.24 (.16)	.23 (.17)
Mind-blanking	.08 (.14)	.08 (.16)	.06 (.10)

Note. MW = mind-wandering. Standard deviations are in parentheses.

Pupillometry

The analysis on mean pre-trial pupil diameter indicated a significant main effect of block ($F(4, 424) = 19.19$, $p < .001$, partial $\eta^2 = .15$), such that pre-trial pupil diameter decreased across time (linear effect: $F(1, 106) = 25.00$, $p < .001$, partial $\eta^2 = .19$). But there was no significant effect of condition ($F(2, 106) = .66$, $p = .52$, partial $\eta^2 = .01$), and the block x condition interaction was not quite significant ($F(8, 424) = 1.91$, $p = .06$, partial $\eta^2 = .04$). Figure 23 depicts these data.

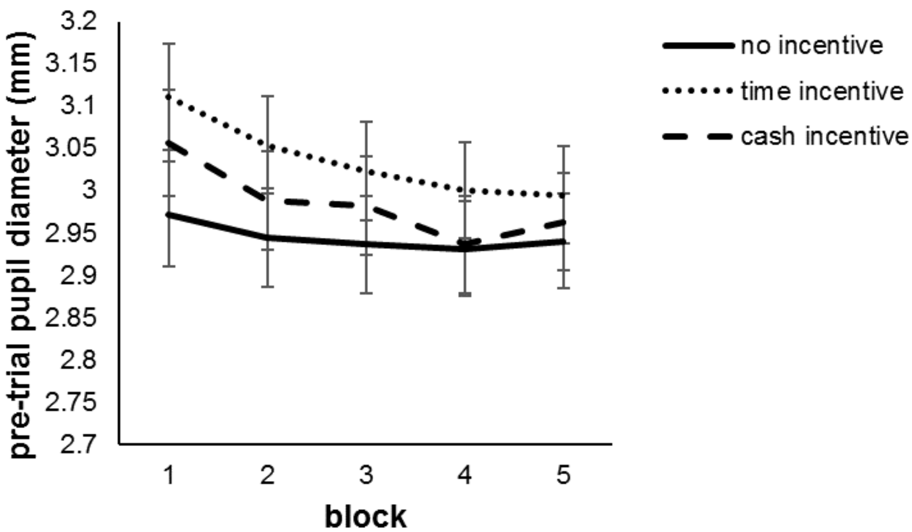


Figure 23. Pre-trial pupil diameter across blocks for each condition in Experiment 3. Error bars represent +/- one standard error of the mean.

The analysis on pre-trial pupil variability indicated a significant main effect of block ($F(4, 424) = 6.35$, $p < .001$, partial $\eta^2 = .06$), such that pre-trial pupil showed more variability across time (linear effect: $F(1, 106) = 16.12$, $p < .001$, partial $\eta^2 = .13$). However the effect of condition was not quite significant ($F(2, 106) = 2.83$, $p = .06$, partial $\eta^2 = .05$), and there was no block by condition interaction ($F(8, 424) = .55$, $p = .82$, partial $\eta^2 = .01$). Figure 24 shows these data.

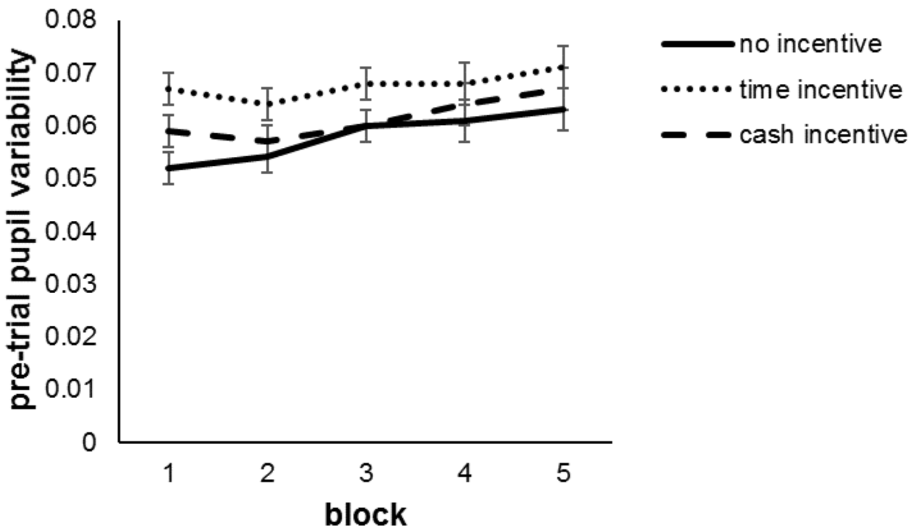


Figure 24. Pre-trial pupil variability across blocks for each condition in Experiment 3. Error bars represent +/- one standard error of the mean.

The next set of analyses focused on task-evoked pupillary responses. Binning and baseline-correction procedures are identical to Experiments 1 and 2. Similar to Experiments 1 and 2, task-evoked pupillary responses decreased across time ($F(4, 412) = 5.85$, $p < .001$, partial $\eta^2 = .05$). The waveforms are shown in Figure 25. The waveforms and the effect of block on these waveforms are largely consistent with Experiments 1 and 2.

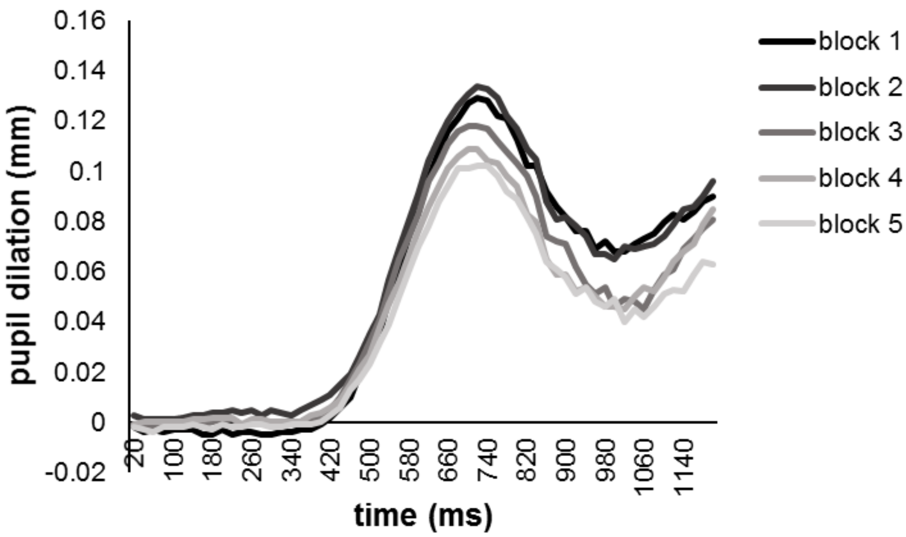


Figure 25. Task-evoked pupillary responses by block in Experiment 3. Error bars represent +/- one standard error of the mean.

To examine the effects of incentives on task-evoked responses, I computed an average peak dilation by taking the peak dilation on each trial within the window from 500 to 800 ms post stimulus onset. Although there was a significant main effect of block on maximum dilations ($F(4, 424) = 10.38$, $p < .001$, partial $\eta^2 = .09$), such that maximum dilations decreased across time (linear effect: $F(1, 206) = 24.96$, $p < .001$, partial $\eta^2 = .19$), there was no main effect of condition ($F(2, 106) = 1.09$, $p = .34$, partial $\eta^2 = .02$), and no block x condition interaction ($F(8, 424) = 1.33$, $p = .23$, partial $\eta^2 = .02$). Figure 26 shows this pattern.

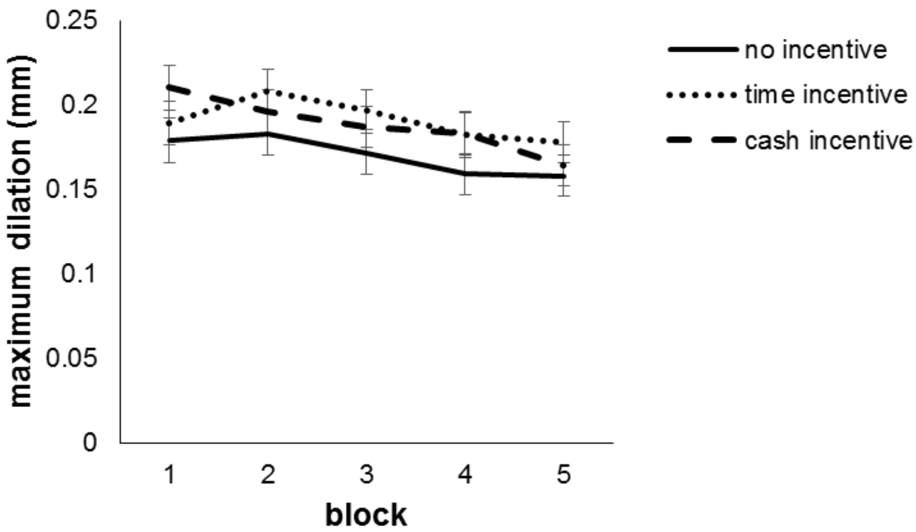


Figure 26. Maximum task-evoked pupillary responses by block and condition in Experiment 3. Error bars represent +/- one standard error of the mean.

Post-experiment questionnaires

Just as in Experiments 1 and 2, I recorded participants' responses to the post-experiment questionnaire to see how often people directly mentioned the goal of keeping their average RT below 300 ms. A total of 59% of people in the no-incentive condition, 75% in the time incentive condition, and 68% in the cash incentive condition specifically reported the experimental goal. So the majority of participants in every condition appeared to adhere to the goal set forth at the beginning of the task. However, some individuals reported an adjustment in their goal during the task, and this is something I will address in the General Discussion.

Discussion

Experiment 3 examined the combination of goal-setting, feedback, and incentives. The no-incentive condition in Experiment 3 was identical to the goal + feedback condition in Experiment 2. In the time-incentive condition, participants received the incentive of early release from the experiment for meeting the goal. In the cash-incentive condition, participants received the incentive of a monetary bonus. Interestingly, the groups performed about equally on the task, they reported similar amounts of mind-wandering, and the pupillometric indicators of arousal and task-based effort did not differ across the three conditions. The only significant effects of condition were on alertness and motivation ratings. Participants in the time-incentive condition reported higher overall alertness and greater overall motivation than participants in the other conditions. Somewhat surprisingly, participants in the cash-incentive condition reported the lowest overall motivation and alertness ratings. And even very early in the task, participants in the cash-incentive condition showed the lowest motivation (see Figure 14). Finally, participants in the time-incentive condition reported greater goal commitment than participants in the cash-incentive condition. However, participants in both conditions reported decreases in goal commitment across time.

There are several reasons why the incentives did not impact sustained attention and mind-wandering in the hypothesized ways. First, similar to Experiments 1 and 2, the goal may have been too difficult. Participants in the cash-incentive and time-incentive condition both reported decreases in goal commitment across time, similar to the consistently observed effects of time on motivation and alertness. So even when given a considerable incentive to meet a difficult goal, participants still reported waning motivation, alertness, and commitment to the goal across time. However, it is possible that some participants did indeed maintain motivation and commitment to the goal across the duration of the task, whereas others "quit" on the goal at some point during the task when they realized it was unlikely they would actually reach it. Then, when averaging across such people across within a condition, we observe a linear decrease in motivation and commitment across time. A second possible reason is that the motivation incentive was not sufficient to convince participants to maintain their motivation and commitment to the goal for the entire task duration. Perhaps $10, or a potential early release from the experiment, is not enough to convince people to fully commit to a task goal. However, it is still unclear why the cash incentive would produce lower motivation among participants than no incentive at all. This is a surprising finding that begs replication before it can be adequately interpreted. Future research can address how the magnitude of such incentives interacts with goal-setting manipulations. A third possible reason is the incentive structure. In the present experiment, the incentive was awarded in an all-or-nothing manner. So again, if participants made a metacognitive judgment that the goal (and thus the incentive) was out of reach, they could have adjusted their effort level downward. In future research, I can address whether different incentive structures interact with goal-setting. For example, if participants were rewarded based on how close they got to the goal, rather than in a binary all-or-nothing manner, this may encourage participants to pursue the goal with more consistency. A final possibility, which would be predicted by a resource theory of sustained attention, is that people truly cannot sustain their attention because of resource depletion. No matter how you incentivize them, set goals for them, or provide them with feedback, you cannot offset the inevitable decrements in performance across time.

Just as in Experiments 1 and 2, none of the theories of sustained attention and vigilance can account for all of the results. Again, the consistent downward trends in arousal and alertness would be predicted by resource theories, as would the increase in unintentional mind-wandering. However, the decreases in motivation and goal commitment across time are inconsistent with resource theories, which argue that people continually exert attention across the length of a task, but resource depletion prevents them from doing so effectively. The increase in intentional mind-wandering and decrease in motivation would indeed be predicted by mindlessness theories, which argue that simple tasks induce boredom and voluntary disengagement. But mindlessness theory predicts that changes would be entirely volitional, and this is clearly not the case. Finally, the motivational control theory can account for many of the results, as some participants are clearly adjusting their goals and effort in response to the demands of the task, as reflected by decreases in goal commitment across time. However, a motivational incentive should increase the desire of participants to actively maintain a goal. The fact that participants in the cash-incentive condition expressed even lower motivation than participants in the no-incentive condition is problematic for this view. Finally, with regard to the resource-control theory, the lack of an effect of an incentive goes against at least one of the predictions made by the theory. Providing an incentive should reduce mind-wandering – especially intentional mind-wandering – as participants have more to gain from active maintenance of the task goal as opposed to allocating resources to mind-wandering. Again, although unintentional mind-wandering did not increase at a significantly greater rate than intentional mind-wandering in Experiment 3, it was not the case that intentional mind-wandering increased at a faster rate than unintentional mind-wandering, as resource-control theory would predict. It is still possible that even very early on participants recognized the difficulty of meeting the goal and thus the incentive had little to no bearing on their decision to pursue the goal. Again, this is an area for future research.

CHAPTER V

CROSS-EXPERIMENTAL ANALYSES

Comparing certain conditions across experiments, I can test several outstanding questions. First, the no-feedback conditions in Experiment 2 removed both trial-by-trial and block-by-block feedback. However, in that particular experiment, it was impossible to specifically examine whether the trial-by-trial or block-by-block feedback facilitated participants. Essentially, the no-goal condition in Experiment 1 and the no-goal + feedback condition in Experiment 2 differed only in one respect: the presence or absence of trial-by-trial feedback. Participants in Experiment 1 received trial-by-trial feedback, whereas participants in Experiment 2 received no feedback at all. Their goal was the same. By directly comparing these conditions, we can assess whether the presence of the trial-by-trial feedback has an effect on the dependent variables. If there is a difference between these conditions in any respect, then the trial-by-trial feedback may be driving some of the effects of feedback in Experiment 2. If there are no differences between these conditions, then the block-by-block feedback is driving the effect. Specifically comparing these conditions did not indicate any significant differences in task performance, subjective reports of alertness and motivation, mind-wandering, or pupillary data. This suggests the beneficial effect of feedback was likely not due to the presence of trial-by-trial feedback but due to the block-by-block feedback.

Another comparison that allows us to directly test the effect of block-by-block feedback is by comparing the hard goal condition in Experiment 1 to the goal + feedback condition in Experiment 2. The sole difference between these conditions is that participants in Experiment 2 received both trial-by-trial and block-by-block feedback, whereas participants in Experiment 1 only received trial-by-trial feedback. Their goal was the same. Compared to Experiment 1, participants in Experiment 2 reported higher motivation ($t(68) = 2.41$, $p = .02$), less intentional mind-wandering ($t(68) = 2.71$, $p = .01$), and greater task-evoked pupillary responses overall ($t(68) = 2.20$, $p = .03$). So both comparisons across experiments come to the same conclusion: the presence of block-by-block feedback, rather than trial-by-trial feedback, led to greater effort, motivation, and task engagement.

Another open question which can be addressed via cross-experimental analyses is whether or not the lack of an effect of the time or cash incentives over the no-incentive group in Experiment 3 is due to abnormally good performance by the no-incentive group. The no-incentive condition in Experiment 3 and the goal + feedback condition in Experiment 2 are virtually identical. They received the same goal and feedback structure. If these two conditions show roughly the same patterns of task performance, self-reports, and pupillometry, then I can rule out the possibility that the no-incentive participants in Experiment 3 were an abnormally high-performing group, thus masking the effects of incentives. Participants in Experiment 2 reported greater motivation overall ($t(70) = 2.16$, $p = .04$), and slightly but not significantly less intentional mind-wandering ($t(70) = -1.92$, $p = .06$). But no other differences were significant, and in fact all of the differences just mentioned were in the opposite direction than would be worrisome for Experiment 3. Therefore, it does not appear to be the case that the no-incentive participants in Experiment 3 were not simply an abnormally engaged and high-performing group of participants.

CHAPTER VI

GENERAL DISCUSSION

The goal of the present set of experiments was to evaluate how goals, feedback, and incentives might regulate sustained attention via several theoretical mechanisms. In Figure 1, I outlined a framework for how goal-setting might moderate sustained attention via four potential mechanisms: arousal/effort, mind-wandering, motivation, and alertness. This framework is informed by goal-setting theory (Locke & Latham, 2002), motivational control theory (Hockey, 2011), depletion theories of sustained attention (Warm, Parasuraman, & Matthews, 2008), mindlessness accounts of sustained attention (Robertson et al., 1997; Manly et al., 1999), and resource-control accounts of sustained attention (Thomson et al., 2015). The experiments were designed not only to examine potential ways to improve sustained attention, but to test predictions made by competing accounts of sustained attention.

In Experiment 1, I manipulated goal-setting, and more specifically goal-specificity and goal-difficulty, across conditions. In one condition, participants were given standard instructions to try to respond as quickly as possible on each trial of a simple reaction time task (PVT). In the hard-goal condition, participants were instructed to try to keep their average reaction time below 300 ms. In an easy-goal condition, participants were instructed to try to keep their average reaction time below 800 ms. In prior research with this exact task, average reaction times were around 350 ms, and only about 10% of participants had an average reaction time below 300 ms. Therefore, we chose 300 ms as our performance standard for the hard-goal condition to be difficult but not impossible to reach. The easy goal was a rather trivially low standard to reach, but would allow us to rule out the possibility that any specific goal, regardless of difficulty, might affect sustained attention. Based on goal-setting theory, I had hypothesized that giving participants a specific, difficult goal would improve task performance, either by shortening reaction times or making them less variable, increase subjective motivation and alertness, reduce the frequency of mind-wandering, and increase physiological indicators of arousal and effort (i.e., pre-trial and task-evoked pupil diameter), relative to giving participants a vague goal or an easy goal. However, the goal-setting manipulation did not produce the hypothesized effects. Participants in all three conditions showed typical effects of time on sustained attention (i.e., vigilance decrements). With time, reaction times became longer and more variable, participants reported decreases in motivation and alertness, participants reported mind-wandering – intentionally and unintentionally – more often, and pupillary indicators of arousal and effort decreased. But I found very little evidence that the goal-setting manipulation affected sustained attention in the hypothesized ways. Participants who were given a specific, difficult goal had better task performance (i.e., faster overall RTs) than participants in the no-goal condition and slightly fewer lapses (i.e., RTs > 500 ms), but roughly the same patterns of mind-wandering, subjective states of motivation and alertness, and pupillary measurements of effort and arousal as participants who were given a specific, easy goal and participants who were given a non-specific goal of just responding as quickly as possible.

In Experiment 2, I manipulated the presence of feedback in combination with goal-setting in a 2 x 2 design with goal-setting and feedback fully-crossed across conditions. In the 2 goal-setting conditions, participants received the difficult goal from Experiment 1 – try to keep average reaction time below 300 ms. In the no-goal conditions, participants were given the standard instructions to try to respond as quickly as possible on each trial. In the feedback conditions, participants were given their average reaction time for the previous block, as well as their average reaction time for the task overall. In the no-feedback conditions, participants were not given such information between blocks. I also removed the trial-by-trial performance feedback, which in the standard version of the task gives the participant their reaction time for 1 s on each trial. This screen was replaced with a visual mask. Based on goal-setting theory and previous research utilizing feedback, I hypothesized that feedback would improve performance, increase motivation and alertness, reduce mind-wandering, and increase physiological indicators of arousal and effort. I also hypothesized that feedback and goal-setting would interact. That is, I expected the effect of feedback to be greater when this feedback was tethered to a specific goal, rather than simply provided to the participants in the absence of any specific goal. However, the results only provided strong evidence in favor of a global effect of feedback. Regardless of goal-setting condition, participants who received performance feedback showed faster reaction times – especially due to a reduction in extremely slow reaction times, reported fewer instances of both intentional and unintentional mind-wandering, and greater task-evoked pupillary responses, which presumably indicate greater effort. Other than for subjective motivation ratings, I did not observe any evidence for an interaction between goal-setting and feedback.

An open question regarding feedback was whether the effect was due to the trial-by-trial or block-by-block feedback. By comparing conditions across Experiments 1 and 2, it became clear that the block-by-block rather than trial-by-trial feedback was responsible for the effects observed in Experiment 2. By giving participants periodic information about their performance, and thus an idea of how their performance was changing across time, the feedback kept participants more effortfully engaged in the task. But this effect was evident for participants whose performance was being compared against a specific standard and for participants whose performance was not specifically tied to a standard.

Experiment 3 examined one additional potential moderator of goal-setting on sustained attention: motivational incentives. Perhaps, in Experiments 1 and 2 participants in the goal conditions felt relatively uncommitted to the performance standard set for them by the experimenter because there was no reward offered for meeting such a goal, or penalty for not meeting the goal. So in Experiment 3, I compared performance in a condition with a goal, but no reward for reaching that goal (no-incentive condition), to two incentive conditions in which participants were told they would receive either a $10 cash bonus (cash-incentive condition), or early release from the experiment (time-incentive condition). I had hypothesized, based on prior experiments offering rewards for good performance on sustained attention tasks (Massar et al., 2016; Seli et al., 2015), that participants in the incentive conditions would outperform participants in the no-incentive condition. Although participants in the time-incentive condition reported greater alertness, motivation, and goal-commitment than participants in the other conditions, there were no differences across conditions in task performance, mind-wandering, or pupillary indicators of arousal and effort. So I did not replicate prior studies using incentives (Hopstaken et al., 2015a, 2015b, 2016; Massar et al., 2016; Seli et al., in press).

Limitations

The present study had several limitations worth noting. First, with the exception of the effects of time within a session, some of the observed effects (e.g., the main effect of feedback on reaction times) were quite small. And further, some effects that were in the hypothesized directions (e.g., the interaction between goal-setting and feedback on reaction times), were small but non-significant. Tt is possible that some of the hypothesized effects exist, but require quite large sample sizes to detect. So one of the limitations of the current set of experiments could have been the sample size, given the between-subjects design. Ways to increase power could be to increase the sample sizes of the between-subjects design or to use a within-subjects design with a sample size similar to the present study. However, as with any within-subjects design, the experimental manipulations would be subject to ordering effects. Finally, if the effects are indeed very small, one has to begin to wonder how theoretically meaningful they truly are. This is an area for future research.

A second limitation of the current study is that the hard-goal conditions set a quite stringent threshold. I had based the standard (average reaction time < 300 ms) on the idea that 10% of people might hit the difficult goal without specifying it from prior research (Unsworth & Robison, 2016). A possible limitation is that the goal was too stringent a standard for many participants. Indeed, few participants met this goal. In Experiment 1, only 1 of the 35 participants who were given the difficult goal actually achieved it. In Experiment 2, only 1 of the 70 participants who were given the difficult goal achieved it. And only 7 of the 111 participants in Experiment 3 achieved the goal. So clearly it was not an impossible goal to reach, but its difficulty may have discouraged some participants. Indeed, some participants specifically noted that they adjusted their goal based on the fact that they did not think they would be able to keep their average reaction time below 300 ms. For example, one participant said, “300 [ms] was not gonna (sic) happen, so somewhere closer to 400 [ms] was the goal I was thinking about at some point.” Another participant said, “[My goal was] to get at least 350 [ms] for my average reaction time. 300 [ms] was too hard to achieve for me it seemed like.” This downward adjustment in goals is specifically predicted by the motivational control theory of mental fatigue (Hockey, 2011). Because the goal was so difficult, many participants found themselves not meeting the goal, and many adapted by adjusting their goal, adjusting their effort, or both. Certainly, participants were experiencing mental fatigue. Self-reported alertness dropped, unintentional mind-wandering increased, and arousal decreased. But the data also suggested that some decrements in performance across time were due to voluntary adjustments of effort. Intentional mind-wandering increased, self-reported motivation decreased, and pupillary measures of effort decreased across time. Whereas many people appear to be continually activating and pursuing the experimental goal, a substantial number of participants also seem to be, and indeed directly report, making adjustments to this goal to reduce mental strain.

A third limitation, which is most relevant to Experiment 3, is the combination of the goal, the feedback, and the incentive structure. Prior incentivizing studies on sustained attention used a rather vague performance goal to motivate participants (e.g., Seli et al., in press), only after the participants had already been completing the task for a period of time (Hopstaken et al., 2015a, 2015b, 2016), or used different incentive structures than the present study (Brewer et al., 2017; Massar et al., 2016). In Seli et al.’s (in press) study, participants expecting a 1-hr study were told they could leave the experiment early if after 30 min they had “achieved a certain level of performance” on the task (Seli et al., in press, P.3). All participants were released after 30 min. So in this particular study, the performance goal was quite vague. In the Hopstaken et al. (2015a, 2015b, 2016) studies, participants completed several blocks of a 2-back task for about 90 min. Before the last block of the task, participants were told that the remaining time in the experiment depended on their performance on the upcoming block, relative to their previous performance. They were told the remaining time would vary from 5 to 40 min. In reality, all participants were released after the next block (5 min later). Again, this goal was quite vague. In the Esterman et al. (2014, 2016) studies, participants were told that the reward (time or money) would be given based on their accuracy on the task. However, no specific accuracy threshold was set, and incentive structure was given. So in none of these cases did participants have any idea was the *specific* standard was that they needed to meet. And in the Hopstaken et al. studies, the goal wasn’t introduced until relatively late in the experimental session. In the Massar et al. (2016) study, participants were rewarded for every reaction time below their median reaction time, which was measured during an introductory block of trials. So in this study, the performance goal was specific, but it was much less difficult to meet, and the reward was not granted in an all-or-nothing manner. Finally, in Brewer et al. (2017), participants were paired into dyads and told whomever had the fewest reaction times below 500 milliseconds would receive a $10 gift card, which was placed on the desk between them. This manipulation introduced a competitive component, as well as some ambiguity as to how exactly they were performing compared to their competitor. These subtle differences in task parameters may be important, and future research can address which factors might moderate the effect of incentives. Interestingly, participants in the cash-incentive condition reported the lowest motivation and alertness, overall. It is not entirely clear why offering a monetary incentive would lead participants to report being even less motivated than participants who were offered no incentive at all.

Another possible reason for the lack of an effect of an incentive in Experiment 3 was the reward structure. As mentioned in the Discussion for Experiment 3, the incentive was offered in an all-or-nothing manner. Thus, perhaps even very early on, participants may have developed an impression of how likely it would be that they would actually earn the incentive. The interaction between goal-difficulty and incentive structure has been directly investigated in previous research. For example, Mowen et al. (1981) had participants complete math problems for 40 minutes. Three goal levels were manipulated across conditions: an easy goal (solve 30 problems), a moderate goal (solve 55 problems), and a difficult goal (solve 95 problems). They also manipulated incentive structure across conditions. In the piece-rate condition, participants were paid based on how many problems they answered correctly during the 40 min, regardless of their goal. In the bonus system, participants were paid a monetary bonus only if they reached their specific goal, with additional payments made for every problem solved correctly beyond the goal. Goal-difficulty and incentive significantly interacted such that participants answered the most math problems with an easy or moderate goal in the bonus incentive conditions, whereas participants answered the most problems with a difficult goal in the piece-rate incentive conditions. Thus, the incentive actually appeared to de-motivate participants if it was given in an all-or-nothing manner. This effect may have occurred in the present study. When participants realized they probably would not meet the goal, the incentive may have discouraged them to a point where they actually became de-motivated. In fact, this may account for why participants in the cash-incentive condition expressed lower motivation than participants in the no-incentive condition. In future research, I plan to manipulate incentive structures across goal conditions to examine whether the interaction that Mowen et al. (1981) observed replicates in sustained attention tasks.

Future Directions

In the future, I plan to follow up on the present set of experiments by addressing several remaining questions. To address the question of whether the difficult goal used in the present study was in fact too difficult to be a motivational force, I plan on completing a follow-up experiment in which goal-difficulty is parametrically manipulated between conditions. In one condition, participants will receive the difficult goal used in the present study (average reaction time < 300 ms). In another condition, participants will receive a moderately difficult goal (average reaction time below 375 ms). In both the hard-goal condition of Experiment 1 and the goal + feedback condition of Experiment 2, more than half of participants kept their average reaction time below this threshold. In a third condition, participants will have an easily attainable goal of keeping their average reaction time below 600 ms. All participants in the no-goal condition of Experiment 1, all but 1 participant in Experiment 2, and all participants in Experiment 3 kept their average reaction time below this threshold. If the moderate-goal condition produces better task performance, engagement, and motivation than the hard-goal condition, this would suggest that the hard goal does indeed induce some “quitting” among participants, which leads to downward adjustments in effort, motivation, and task-engagement.

A second future step will be to examine the interactions between goals and incentive structure. My first step will be to re-run Experiment 3, but with a different incentive structure. Rather than being told that they would be compensated monetarily if and only if they meet the goal, participants will be told they will be compensated based on how close they get to the set goal. For example, they will get $10 if they keep their average reaction time below 500 ms. Then, for every additional ms below 500, they will get a $0.10 bonus. A second step would be to see how all-or-nothing incentive structures interact with goal-difficulty. As mentioned earlier, Mowen et al. (1981) showed that goal-difficulty and incentive structures interact such that a piece-rate incentive structure is best when paired with a difficult goal, whereas an all-or-nothing incentive structure is best when paired with an easy goal. So by combining incentive structures and goals within sustained attention, we may be able to identify optimal conditions for task engagement. Another step would be to try to more directly replicate other experiments that have used incentives in combination with the PVT (Brewer et al., 2017; Massar et al., 2016). These experiments will give further insight into how people adjust their effort and engagement in a task given the tradeoffs they perceive between continual effort and partial disengagement.

A third future step will be to further investigate the subjective nature of sustained attention deficits. The present set of experiments attempted to quantify and objectify adjustments in motivation, affect, arousal, and effort. However there are still some unanswered questions. For example, do people realize that sustained attention and vigilance decrements are occurring, especially in the absence of feedback? Are the shifts toward intentional mind-wandering because people are bored with the task and are looking for some escape? Or, do they feel overwhelmed by the demands of the task and disengage as a coping mechanism? What individual differences (e.g., conscientiousness, cognitive ability) might moderate subjective responses to difficult sustained attention situations? One pathway for answering these questions could be structured interviews with participants following the task. Some of the best insights into how participants perceived the goal, their likelihood of meeting the goal, and their reactions to these conditions came from the post-experimental questionnaires. Further questioning of participants might reveal insights into the nature of sustained attention that are masked by our inability to quantify and codify certain affective and subjective responses.

Conclusion

Across 3 experiments, I did not find any conclusive evidence that setting difficult goals for people, even combined with incentives to meet these goals, reduces mind-wandering and improves sustained attention. However, I did find rather consistent evidence that providing feedback about performance throughout a sustained attention task kept people more engaged and motivated, improved their performance, and reduced mind-wandering. I attributed the lack of an effect of a difficult goal on sustained attention to the goal being too difficult, thus creating a situation where the demands of the task exceeded the ability of most participants to meet such a goal. This created a situation in which many participants adjusted their goals and effort level downward to some lower or more general performance standard. This interpretation is driven by consistent downward trends in motivation, increases in intentional mind-wandering, decreases in task-evoked pupillary responses, and decreases in goal-commitment. The extension of feedback effects on mind-wandering, the investigation of various levels of goal-difficulty, and the investigation of various incentive structures in combination with goals are necessary areas of future research into sustained attention.

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