Attention, Perception, & Psychophysics
https://doi.org/10.3758/s13414-023-02803-4

Effects of goal-setting on sustained attention and attention lapses

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Accepted: 28 September 2023

Abstract

In three experiments, we examined the effects of goal-setting on sustained attention and attention lapses. We measured both behavioral task performance and subjective attentional states during a four -choice reaction time task (Experiments 1 and 2 administered online; Experiment 3 conducted in-person). Experiment 1 compared a vague goal versus a specific goal. The specific goal reduced lapses in the form of long response times (RTs) but did not impact task-unrelated thoughts. Experiment 2 expanded on E1 by making the specific goal progressively harder. Behavioral lapses (i.e., long RTs) were reduced in the harder-over-time goal condition compared to the control condition. Additionally, while RTs increased with time-on-task in the control condition, RTs in the harder-over-time goal condition remained stable with time-on-task. Experiment 3 aimed to replicate the results of E2 in-person and adjusted the difficulty of the harder-over-time goals to be slightly harder. The results largely replicated E2. Overall, setting specific and difficult task goals led to a reduction in lapses of attention and increased sustained attention performance.

Keywords Attention

Introduction

Sustained attention involves maintaining attention on a task for a period of time that can range from seconds to hours. The ability to sustain attention is a key component of our attentional system that is vital to everyday life. It is heavily influenced by factors such as motivation, arousal, and alertness (Jennings & van der Molen, 2005; Sadaghiani & D'Esposito, 2015; Steinborn et al., 2017; Unsworth & Miller, 2021). Additionally, there are factors that can help facilitate the restoration of attentional capacity, like rest breaks (see Schumann et al., 2022). Sometimes tasks requiring sustained attention are relatively boring and unchallenging (also referred to as vigilant attention; Robertson et al., 1997; Robertson & O'Connell, 2010). Multiple studies have found evidence that it is typically harder to maintain attention on tasks that are boring/easy and repetitive versus ones that require some sort of cognitive challenge (Langner & Eickhoff, 2013; Robertson & O'Connell, 2010). Although we generally perform fine in sustained attention situations, occasionally we experience lapses in attention. These could be, for example, daydreaming about a new crush, being distracted by honking cars driving by, or even just having your mind go blank. Essentially, attention lapses reflect momentary shifts of attention away from the task at hand that can lead to failures in completing intended actions (Casner & Schooler, 2014; Lindquist & McLean, 2011; Unsworth et al., 2021; Unsworth & McMillan, 2017), the consequences of which range from forgetting to forward an email to your colleague to missing a red light and causing a car accident. Given how common attention lapses are, it is vital to understand the nature of these lapses and to investigate ways in which we can reduce their occurrence and severity. The main goal of the current study was to examine whether increasing

Public Significance Statement Our ability to sustain attention is critical in a number of everyday tasks. In the current study we demonstrate that setting specific and difficult goals leads to a reduction in behavioral lapses of sustained attention and a reduction of time-on-task effects. Theoretically, specific and difficult goals result in participants allocating more attentional effort to the task that helps sustain attention and mitigate lapses. These results further our understanding of lapses of attention and potential ways to curb lapses.

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Published online: 23 October 2023

attentional effort (intensity of attention) via goal-setting can lead to a reduction in lapses of attention.

Attention lapses

Sustaining attention can be easier said than done, as attention fluctuates across short and long intervals. At times attention is concentrated on a particular task, promoting favorable levels of task-engagement and performance. Alternatively, attention can be captured by other sources leading to varying levels of task disengagement and subsequent drops in performance. These fluctuations away from a task can be considered lapses in attention and can impede or completely derail intentions to perform a task-relevant action (Unsworth & McMillan, 2017).

One of the most common approaches to examining lapses of attention has been to examine response time (RT) and variability in RT as indices of fluctuations and lapses of attention (for review, see Unsworth et al., 2021). For example, using five different homogenous mental tasks, Bills (1931) found that unusually long RTs would pop up and their occurrence typically increased over time. Bills (1931) considered an unusually long RT as a response greater than twice the average RT for a participant and referred to these as "blocks." His explanation was that participants experienced these blocks to take mini-rests mid-task. In other words, their mind was blocking/preventing them from being fully present on every trial as a way to combat fatigue (Bills, 1931, 1935). In subsequent work, Bertelson and Joffe (1963) found that “block” trials were preceded by increasing RTs and errors, and followed by better performance. They connected this return of task performance to Bills’ theory that blocks help dispel fatigue. In mild opposition to Bills’ theory that blocks are a type of short rest, Broadbent (1958) proposed blocks were shifts in attention towards task-irrelevant stimuli. More recently, these long RTs have been utilized/conceptualized as a measure of attention lapses (Dinges & Powell, 1985; Esterman et al., 2013; Steinborn et al., 2016; Unsworth & Robison, 2016; Unsworth & Robison, 2020). In particular, examining the full RT distribution can provide a means of examining lapses of attention by assuming that on some trials participants are focused on the current task resulting in a fast RT, whereas in other trials they are experiencing a block or lapse resulting in a longer RT. Thus, RT distributions reflect a mixture of focused and lapsed trials (van Breukelen et al., 1995). Indeed, a number of studies have suggested that particularly slow RTs provide an imperfect marker of lapses of attention (e.g., Dinges & Powell, 1985; Steinborn et al., 2016; Unsworth & Robison, 2016; Van Breukelen et al., 1995; Weissman et al., 2006; Williams et al., 1959). We say imperfect because although lapses of attention likely contribute to RT variability and long RTs, RT variability and long RTs could also be due to shifts in the overall RT distribution, inter-trial interval timing of a task, speed–accuracy trade-offs, and even blinks and eye movements (e.g., Johns et al., 2009; Steinborn & Langner, 2012). Likewise, overly fast RTs (impulsive responses to the stimuli) may be conceptualized as lapses, also affecting the distribution (Bedi et al., 2023).

Another way to examine attention lapses is with subjective measures. Many researchers have utilized thought probes to discern what participants are thinking about throughout a task and whether those thoughts are task-related or unrelated (Giambra, 1995; Hull, 1981; for reviews, see Smallwood & Schooler, 2006; Smallwood & Schooler, 2015). Task-unrelated thoughts (TUTs) are typically found to be negatively correlated with task performance (McVay & Kane, 2010; Smallwood & Schooler, 2006; Unsworth & McMillan, 2014; for review, see Mooneyham & Schooler, 2013). TUTs can also be split into internal distraction (i.e., mind-wandering), external modes of distraction, or even just mind-blanking (Stawarczyk et al., 2011; Unsworth & Robison, 2016; for review, see Smallwood & Schooler, 2006). Thus, the thought probes mentioned above can be used to differentiate between task-related and task-unrelated thoughts or delve even deeper and examine different types of TUTs. Importantly, recent research by Unsworth et al. (2021, 2022) suggested that behavioral lapse measures and TUT measures are moderately related but distinct measures (see also Kucyi et al., 2016). This means they aren’t necessarily interchangeable, and the use of both can provide a better look into what is occurring during a lapse.

Examining both RT variability and TUTs, prior research has found that various motivational manipulations can lead to a reduction in lapses of attention (Esterman et al., 2014; Massar et al., 2016; Unsworth et al., 2022; Seli et al., 2015). For example, Massar et al. (2016) found that lapses were reduced in blocks of trials where participants received a reward versus blocks with no reward. Additionally, Steinborn et al. (2017) found a reduction in lapses of attention when investigating effort mobilization wherein participants were given “Try Hard” instructions versus when participants received no particular instructions. Steinborn et al. (2017) conclude that this result is due to the effort mobilization instructions affecting performance stability (persistence) with regard to RT. Furthermore, Unsworth et al. (2022) noted a reduction in lapses utilizing that “Try Hard” method, and suggested that participants increased their attentional effort (intensity) to the task under “Try Hard” instructions, resulting in better task performance and fewer lapses. This aligns with other prior research that suggests motivation tends to lead to a reduction in attention lapses seemingly via an increase in attentional effort (Botvinick & Braver, 2015; Massar et al., 2016; Westbrook & Braver, 2015). In other words, when properly motivated, individuals can mobilize effort to increase their intensity of attention, leading to better performance and a reduction in attention lapses during a task.

Goal-setting theory and sustained attention

It has been long suggested in industrial-organizational psychology research that one way to increase task performance is to set specific, difficult goals (Locke & Latham, 1990, 2002; Robison et al., 2021). In particular, there are two primary components of goal setting: content and intensity (Locke & Latham, 1990). Under the umbrella of content is goal-specificity, which can range from vague ("do your best") to specific ("aim to keep all your responses under .400 s for the duration of the 25-min task"). Also under content is goal-difficulty, which can range from easy to impossible, and is dependent on the abilities/motivation of the person performing the task. Setting specific and difficult, but achievable, goals often leads to higher performance outcomes over vague goals (Locke & Latham, 1990). Locke and Latham (1990, 2002) argue that goals affect performance in four ways: (1) they direct attention and effort toward a task (i.e., away from off-task thoughts), (2) they increase the level of effort and intensity of attention toward that task, (3) they prolong effort and persistence, and (4) they motivate the self-development of strategies to increase performance. Thus, with specific and difficult goals, participants direct attention to on-task behaviors (rather than off-task), increase the intensity of effort to accomplish the task goal, and maintain effort and persistence as the task progresses (Locke & Latham, 1990).

Based on the above-mentioned goal-setting theory, Robison et al. (2021) explored whether they could affect sustained task engagement by employing goal-setting techniques. Robison et al. (2021) had participants perform the psychomotor vigilance task after receiving differing goal instructions. The psychomotor vigilance task is a simple RT task in which the participant's only goal is to press the spacebar once they see a row of zeros on the screen begin to count up on each trial (Dinges & Powell, 1985; Robison et al., 2021). It is uncomplicated but requires that the participant remain engaged. The relevant behavioral measures of interest were particularly slow RTs (i.e., the slow tail of the RT distribution) and subjective measures of task engagement collected via thought probes that assessed momentary attentional states (i.e., mind-wandering/task-unrelated thoughts). Robison et al. (2021) hypothesized that setting a specific goal would improve sustained attention and reduce attention lapses in the form of fewer slower RTs and fewer reported task-unrelated thoughts. They found evidence in two experiments that setting specific goals primarily affected the slow tail of the RT distribution. However, this effect was not replicated in their Experiment 4, which used a range of goal levels. Additionally, TUTs were only reduced when feedback was incorporated into the task. They also found little evidence that pairing goals with an incentive (both time-based and cash) led to a reduction in attention lapses. Robison et al. also examined whether goal-setting would influence time-on-task effects in which performance on sustained attention tends to get worse over time (i.e., vigilance decrement; Parasuraman, 1986; Parasuraman & Davies, 1977; Mackworth, 1950; Robison et al., 2021; see also, See et al., 1995). In two experiments, Robison et al. found evidence that time-on-task effects were reduced (but not eliminated) in the goal condition, suggesting that goal-setting can enhance overall sustained attention. Overall, Robison et al. (2021) provided mixed evidence for their goal-setting manipulations and leave room for further questions in this area. Thus, the primary aim of our study was to further examine whether goal-setting can reduce lapses of attention and enhance sustained attention.

Current study

In the present study, we utilized a four-choice RT task to test our hypotheses that setting a specific goal would lead to a reduction in attention lapses and improve performance on a sustained attention task and further explore the effects of specificity of goal-setting in Experiments 2 and 3. This task was selected due to its long-standing use in lapses of attention research (e.g., Bertelson & Joffe, 1963; Steinborn et al., 2017; Unsworth et al., 2021) and ability to generalize goal-setting effects in sustained attention beyond the psychomotor vigilance task used in all experiments of Robison et al. (2021).

Consistent with more recent research, we assessed lapses in attention behaviorally in terms of examining the slow tail of the RT distribution (e.g., Robison et al., 2021; Tse et al., 2010; Unsworth et al., 2010; Unsworth & Robison, 2016). This is because sometimes important experimental effects can be found in different parts of the overall distribution that would otherwise be obscured in a summary score (Balota & Yap, 2011). Although the slow RTs of the RT distribution are our primary behavioral measure of attention lapses, we also examined the overall number of lapses/blocks (RTs more than 2× the subjects mean) to be consistent with prior research and enable backwards comparison (e.g., Bertelson & Joffe, 1963; Bills, 1931, 1935; Broadbent, 1958; Unsworth et al., 2021; Williams et al., 1959). In addition to the behavioral measures, we included thought probes that measure subjective attentional states. These thought probes have been used to examine task-related/unrelated thoughts and how they are affected by experimental manipulations (e.g., Smallwood & Schooler, 2015; Robison et al., 2021).

In Experiment 1, we investigated the effect of goal-specificity (i.e., setting a specific goal vs. a vague goal) on sustained attention and whether attention lapses would be reduced. We hypothesized that setting a specific goal would reduce lapses in attention. In Experiment 2, we explored whether setting specific goals that get progressively harder over time heightens the effect of goal specificity. We hypothesized that setting goals that increase in difficulty over the course of the task would reduce attention lapses. In Experiment 3, we sought to replicate the effects of Experiment 2 in-person, while also making the goals slightly more difficult. Collectively, in the current study we examined whether goal-setting instructions would improve sustained attention and reduce lapses of attention.

Experiment 1

The aim of Experiment 1 was to examine whether setting a specific, difficult (yet attainable) goal would enhance sustained attention. Based on goal-setting theory, we hypothesized that setting a specific and difficult goal would decrease the occurrence of behavioral markers of attention lapses and reduce task-unrelated thoughts. Participants performed the four-choice RT task with either specific goal (i.e., keep your RT below .400 s while responding accurately) or a vague goal (i.e., respond as quickly and accurately as possible) instructions.

Methods

Participants

A sample of 113 subjects was recruited from the University of Oregon human subjects pool and earned partial course credit for their online participation. One participant was excluded for having less than 80% overall task accuracy (58%), and three participants for having less than 50% accuracy within any block. Based on the distributions of # of lapses, two participants with more than ten lapses (more than 3 standard deviations above the mean) were excluded as well. One participant was excluded for performing the task on a tablet. This left a final sample of 108 for the analyses (54 in the control condition and 54 in the goal condition; 73 women, 34 men, one preferred not to say). The task lasted approximately 26 min. Prior to beginning, the participants provided informed consent and completed a quick demographic survey.

Task

Participants completed a four-choice RT task containing 200 trials that was programmed with Psychopy (as seen in Fig. 1; Peirce & MacAskill, 2018). Each trial starts with a 1-s fixation (+). Then, four white boxes appear in a row at the center of the screen. After a random time interval (1–3 s in .250-s intervals), a black target (**X**) appears inside one of the white boxes. The participant's objective was to press the key on the keyboard that corresponds to the location of the target ('C', 'V', 'B', 'N'). After the participant's response, they saw a 1-s feedback screen showing whether their answer was correct or incorrect, with correct answers also displaying their RT. At pseudo-random points in the task, the participant answered a thought probe and received a goal-reminder before continuing.

Thought-probes

At ten pseudo-random (after 15, 20, or 25 trials in a set order) points during the task, the participants were provided with a thought-probe that assessed their attentional state just prior to the onset of the probe. The display read, "Press the key that best describes what you were thinking about *just prior* to this screen appearing." Participants responded with

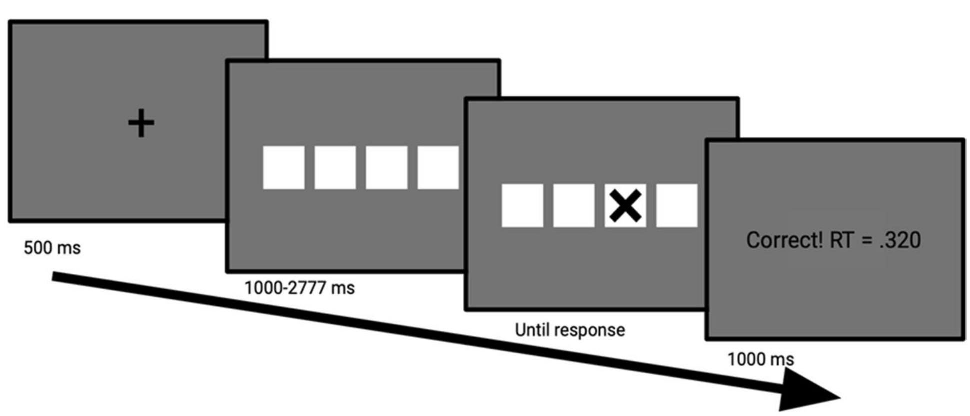

Fig. 1 Task paradigm visual for a single trial on the four-choice reaction time task

a numeric key press (1–5) corresponding to their answer: (1) I was totally focused on the current task, (2) I was thinking about my performance on the task, (3) I was distracted by sights/sounds in my environment, (4) I was thinking about things unrelated to the task, and (5) My mind was blank. Response 1 is coded as on-task, response 2 as task-related, and responses 3–5 as task-unrelated thoughts (TUTs).

Goal-setting instructions

Experiment 1 had two conditions: control (no-goal) and goal. In the control condition, participants received the following instructions: "Your goal on this task is to respond as quickly and accurately as possible. Your reaction time and accuracy will be recorded." In the goal condition the participants are told: "Your goal on this task is to keep your reaction times under .400 s while staying as accurate as possible. Your reaction time and accuracy will be recorded."

After completion of the task, participants were asked to rate their goal commitment. Those in the control condition were asked: "How committed were you to the goal of responding as quickly and accurately as possible?" The goal group saw: "How committed were you to the goal of keeping your response times under .400 s while staying as accurate as possible?" Subjects provided their response with a keypress between 1 and 7 indicating their goal commitment (anchors: 1 = "Not committed at all", 4 = "Somewhat committed", 7 = "Totally committed").

Data analysis

We trimmed any RTs outside 150 mms to 10 s so the results would not be skewed by anticipatory responses or abnormally long RTs.

We analyzed the RT distributions by rank-ordering RTs from smallest to largest within-participant and splitting them into five equal bins. We used these bins as our primary measure for behavioral attention lapses. This provided us with a more detailed look at the experimental effects on the entire distribution of RTs, as opposed to the more simplistic number of lapses measure (discussed below). This is important because experimental manipulations can have effects on particular aspects of a distribution (i.e., among the slowest RTs; Balota & Yap, 2011). To analyze the distributions, we performed a 2 (condition: goal vs. control) × 5 (bin) mixed ANOVA. We analyzed the number of lapses for the sake of completeness, as that method is used in other work (e.g., Bertelson & Joffe, 1963; Bills, 1931, 1935; Broadbent, 1958; Unsworth et al., 2021; Williams et al., 1959). Any trial in which the RT was over twice a participant's mean RT was considered a lapse. A t-test was used to compare the number of lapses by condition.

Finally, we assessed subjective measures of task-engagement via thought probes. We analyzed differences in proportion of task-unrelated thoughts (TUTs) between groups by dividing the number of thought-probes in which participants reported TUTs by the total number of probes (10). A t-test was used to compare the proportion of TUTs by condition.

Results

Comparing RT distributions revealed a large main effect of bin, $F(4, 424) = 662.431$, $p < .001$, $\eta p^2 = .862$, which is to be expected since the bins are rank-ordered from smallest to largest. There was no main effect of condition, $F(1, 106) = 2.558$, $p = .113$, $\eta p^2 = .024$. But importantly, there was a condition × bin interaction, $F(4, 424) = 3.394$, $p = .009$, $\eta p^2 = .031$. This interaction indicates that, as hypothesized, the largest effect on RTs is exhibited among the slowest RTs (bin 5; see Fig. 2 below), suggesting that participants who were given a specific goal experienced fewer and/or less-severe lapses in attention.

Subjects in the control condition (M = 1.22, SD = 1.449) and those in the goal condition (M = .8, SD = 1.139) did not differ significantly in total number of lapses during the task, $t(106) = 1.698$, $p = .092$, $\eta p^2 = .026$ (see Table 1).

Additionally, we did not find evidence for an effect on TUTs. Participants in the control condition (M = .439, SD = .325) and those in the goal condition (M = .515, SD = .299) did not differ significantly in proportion of TUTs experienced during the task, $t(106) = -1.262$, $p = .210$, $\eta p^2 = .015$ (see Table 1).

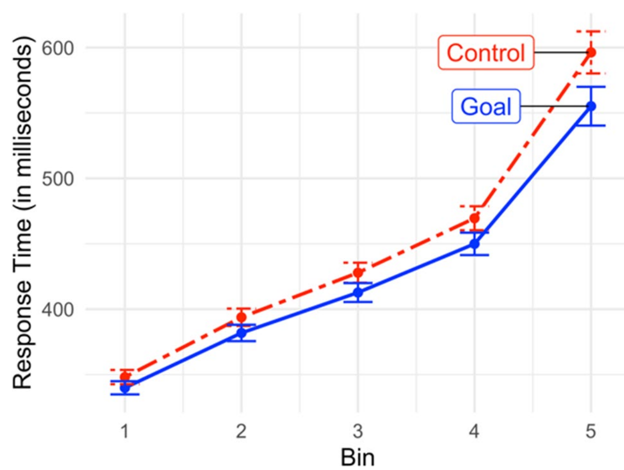

Fig. 2 Response times (RTs) by bin and condition for Experiment 1. *Note.* Bin = response times rank-ordered fastest to slowest (1 = fastest, 5 = slowest). Results show those in the control (no goal) condition had significantly longer slow RTs

Table 1 P-values and effect sizes for all experiments

Experiment/analysis	
Exp. 1	
RT Distribution (Condition × Bin interaction)	p = .009, ηp^2 =.031*
# of Lapses × Condition	p = .092, ηp^2 = .026
Prop. of TUTs × Condition	p = .210, ηp^2 = .015
Exp. 2	
RT Distribution (Condition × Bin interaction)	p < .001, ηp^2 = .059*
# of Lapses × Condition	p = .033, ηp^2 = .046*
Prop. of TUTs × Condition	p = .249, ηp^2 = .014
RT Block (Block × Condition interaction)	p = < .001, ηp^2 = .112*
# of Lapses Block (Block × Condition interaction)	p = .061, ηp^2 = .028
Prop. TUTs Block (Block × Condition interaction)	p = .188, ηp^2 =. 017
Exp. 3	
RT Distribution (Condition × Bin interaction)	p < .001, ηp^2 = .068*
# of Lapses × Condition	p = .071, ηp^2 = .041
Proportion of TUTs × Condition	p = .748, ηp^2 = .001
RT Block (Block × Condition interaction)	p < .001, ηp^2 = .099*
# of Lapses Block (Block × Condition interaction)	p = .026, ηp^2 = .045*
Prop. TUTs Block (Block × Condition interaction)	p = .986, ηp^2 = .000

Note. * = p-value less than .05

RT response time, *Prop.* proportion, *TUTs* task-unrelated thoughts

Discussion

Overall, Experiment 1 demonstrated partial evidence for our hypotheses. Setting a specific and difficult goal reduced attention lapses in terms of the slow tail of the RT distribution. In line with goal-setting theory (Locke & Latham, 1990), it is likely that participants in the goal condition increased their attentional effort (intensity of attention) to the task, resulting in better overall sustained attention and fewer lapses of attention. However, we did not find evidence for an effect on number of lapses (i.e., blocks) or subjective reports of TUTs. The lack of effect on number of lapses could mean that it is a less sensitive behavioral measurement of attention lapses than looking at the RT distribution. It could be the case that the particular goal given did not create a large enough difference to be detected, perhaps by being too easy. Additionally, the absence of evidence for the hypothesis that goal specificity leads to fewer TUTs is consistent with prior research suggesting that TUTs are meaningfully related to other measures (Robison & Unsworth, 2018; Unsworth et al., 2021) but may be capturing different aspects of attention lapses than observed behavioral outcomes (e.g., Kucyi et al., 2016; Unsworth et al., 2022) that is not impacted to the same degree by goal-setting. Overall, results from Experiment 1 suggest some evidence that goal-setting can enhance sustained attention.

Experiment 2

Experiment 2 aimed to replicate and extend the results from Experiment 1. Specifically, we wanted to replicate the general finding that goal-setting reduced lapses overall, and investigate whether an alternative goal-setting method would similarly reduce lapses. We did this by making the specific goal progressively harder over time (HOT). This HOT condition was used to determine if goal manipulations can cause participants to perform better on the sustained attention task over time, since typically we see that performance suffers as the task goes on (Parasuraman, 1986; Parasuraman & Davies, 1977; Mackworth, 1950; Robison et al., 2021; see also, See et al., 1995) and lapses tend to increase with time-on-task (e.g., Unsworth & Robison, 2016). That is, Locke and Latham (2002) argue that setting goals should stabilize effort and the intensity of attention across a prolonged period, as effort and task performance typically decline as a function of time-on-task. To do this we set a goal of responding within 450 ms for the first third of the task, 400 ms for the next third, and 350 ms for the last third. We hypothesized that setting a specific, progressively harder goal would decrease the occurrence of behavioral attention lapses and reduce task-unrelated thoughts. We further hypothesized that an increase in goal difficulty would lead participants to either increase or maintain their effort/intensity of attention in order to persist and protect against time-on-task effects.

Methods

Participants

A sample of 112 subjects was recruited from the University of Oregon human subjects pool and earned partial course credit for their online participation. Five participants were excluded for having less than 80% overall task accuracy, and five participants for having less than 50% accuracy within any block. Based on the distributions of number of lapses, one participant with 14 lapses (more than 3 standard deviations above the mean) was excluded as well. One participant was excluded for performing the task on a tablet. This left a final sample of 100 for the analyses (51 in control condition and 49 in HOT condition; 68 women, 27 men, five preferred not to say). The task lasted approximately 25 min. Prior to beginning, the participants provided informed consent and completed a quick demographics survey.

The methods for Experiment 2 were the same as Experiment 1 with the following exceptions.

Task

The four-choice RT task contained 180 trials. The goal-setting instructions broke the task up into three blocks of 60 trials each.

Thought-probes

Nine pseudo-randomly dispersed thought-probes were included.

Goal-setting instructions

Experiment 2 had two conditions: control (no-goal) and harder-over-time (HOT). In the control condition, participants received the initial instruction: “Your goal on this task is to respond as quickly and accurately as possible. Your reaction time and accuracy will be recorded.” In the second and third blocks, control saw: “Remember, your goal on this task is to respond as quickly and accurately as possible.” In the HOT condition, the participants received the initial instruction: "Your goal on this task is to keep your reaction times under .450 s while staying as accurate as possible. Your reaction time and accuracy will be recorded." This applied to the first block. For block 2, the participants were told: "Your new goal on this task is to keep your reaction times under .400 s while staying as accurate as possible. Your reaction time and accuracy will be recorded." Finally, block 3 had the instruction: "Your new goal on this task is to keep your reaction times under .350 s while staying as accurate as possible. Your reaction time and accuracy will be recorded."

After completion of the task, participants were asked to rate their goal commitment. Those in the control condition were asked: “How committed were you to the goal of responding as quickly and accurately as possible?” The HOT condition saw: “How committed were you to the goals of keeping your response time under .450 s, .400 s, and .350 s while staying as accurate as possible?” Subjects provided their response with a keypress between 1 and 7 indicating their goal commitment (anchors: 1 = ”Not committed at all”, 4 = “Somewhat committed”, 7 = “Totally committed”).

Data analysis

The same analyses as Experiment 1 were performed. Additionally, since the goal-setting instruction changed over time for the goal condition, we looked at both of the behavioral measures and the TUT measure over time using mixed 2 (condition) × 3 (time-on-task block) ANOVAs

Results

As in Experiment 1, we examined RT distribution between conditions. The results showed a main effect of bin, $F(4, 392) = 258.71$, $p < .001$, $\eta p^2 = .725$. There was a significant main effect of condition, $F(1, 98) = 6.623$, $p = .012$, $\eta p^2 = .063$, suggesting that the control condition was slower overall (see Fig. 3a). Importantly, there was also see a bin × condition interaction, $F(4, 392) = 6.147$, $p < .001$, $\eta p^2 = .059$, again indicating the largest effect on RTs is exhibited among the slowest RTs (bin 5, see Fig. 3a below). These results largely replicate Experiment 1.

Since the goal changed over time, we also looked at RT, number of lapses, and proportion of task-unrelated thoughts by time block. First, looking at RT using a 2 × 3 mixed ANOVA, we found a significant main effect of block, $F(2, 196) = 4.178$, $p = .017$, $\eta p^2 = .041$, a significant main effect of condition, $F(1, 98) = 6.625$, $p = .012$, $\eta p^2 = .063$, and a significant block × condition interaction, $F(2, 196) = 12.356$, $p = <.001$, $\eta p^2 = .112$. As shown in Fig. 3b, RTs for those in the HOT condition remain relatively stable over time, while in the control condition RTs tend to increase over the course of the task. That is, participants in the control condition demonstrated a time-on-task effect, $F(2, 100) = 11.67$, $p < .001$, $\eta p^2 = .19$. But participants in the HOT condition did not, $F(2, 96) = 1.78$, $p = .175$, $\eta p^2 = .036$. The largest difference between conditions is seen in the last block where the hardest goal is given to the HOT participants (see Fig. 3b).

The results of a 2 × 3 mixed ANOVA for number of lapses by block indicated significant main effects of block, $F(2, 196) = 7.13$, $p = .001$, $\eta p^2 = .068$, and

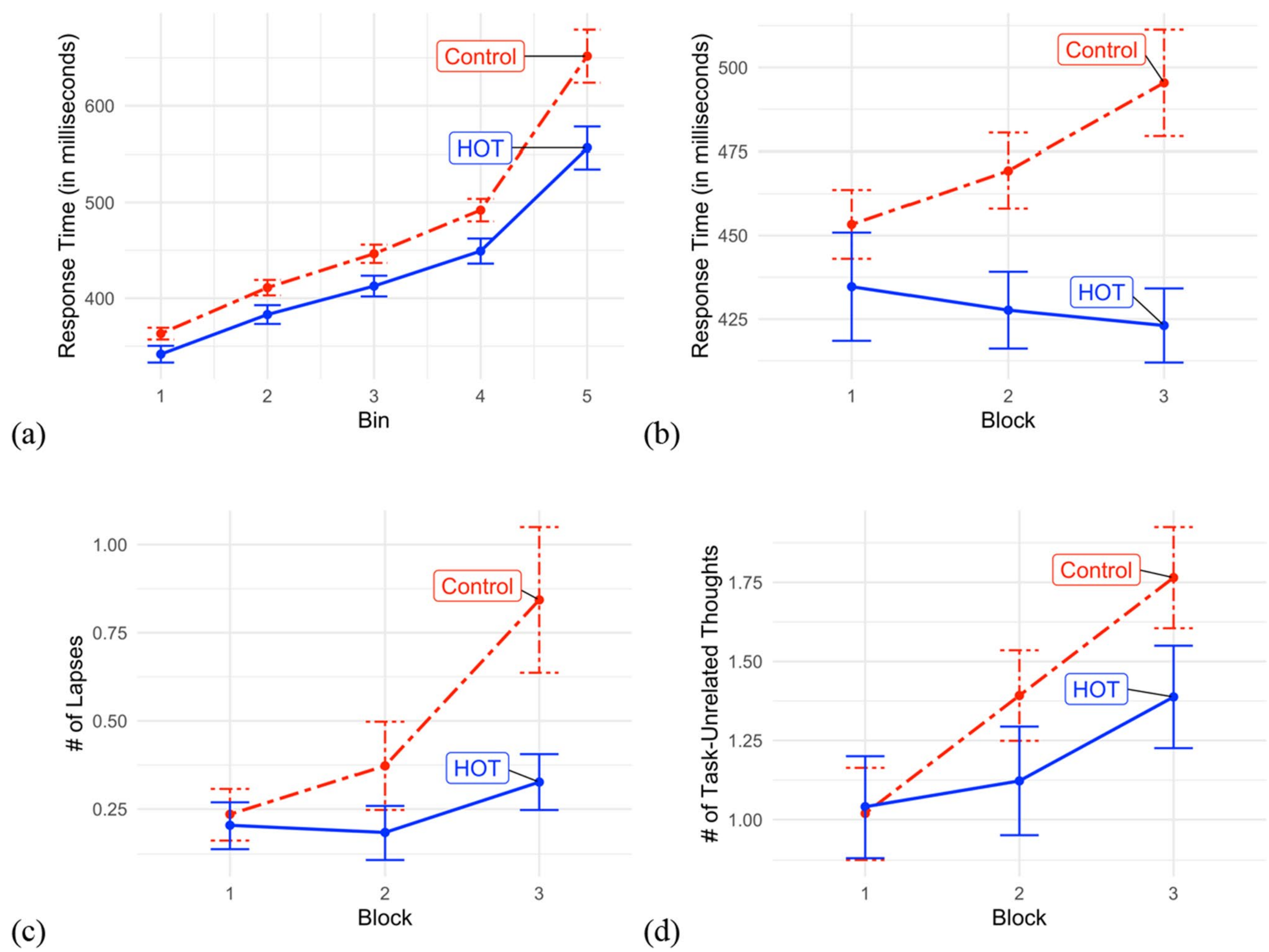

Fig. 3 Results for Experiment 2. (**a**) Response times (RTs) by bin and condition. Bin = response times rank-ordered fastest to slowest (1 = fastest, 5 = slowest). Results show those in the control condition had significantly longer slow RTs and were slower overall. (**b**) RTs by block and condition. There were three blocks in total (1 = first, 3 = last). Results show those in the control condition responding slower over time, while the HOT subjects maintain speed. (**c**) Number of lapses by block and condition. Results indicate a main effect for block (both conditions experienced more lapses over time). (**d**) Number of task-unrelated thoughts by block and condition. Results indicate a main effect for block (both conditions experienced more task unrelated thoughts over time)

condition, $F(1, 98) = 4.703$, $p = .033$, $\eta p^2 = .046$. The block × condition interaction did not reach conventional levels of significance, $F(2, 196) = 2.841$, $p = .061$, but the results are generally similar to those when examining the full RT distribution (Fig. 3c).

The ANOVA on TUTs revealed a significant main effect of block, $F(2, 196) = 11.956$, $p < .001$, $\eta p^2 = .109$. However, there was no effect of condition, $F(1, 98) = 1.343$, $p = .249$, $\eta p^2 = .014$, nor a block × condition interaction, $F(2, 196) = 1.686$, $p = .188$, $\eta p^2 = .017$ (see Table 1). These results indicate that, like Robison et al. (2021), both conditions experienced more TUTs as time went on, but the experimental manipulation did not appear to affect their occurrence (see Fig. 3d).

Discussion

Experiment 2 replicated and extended the results from Experiment 1. Specifically, setting a goal that progressed in difficulty reduced behavioral attention lapses consistent with Experiment 1. Additionally, the HOT goal benefitted overall sustained attention as seen by the fact that the typical time-on-task effect was eliminated in the HOT condition but was still present in the control condition. Interestingly, while the HOT condition performed better and were able to maintain their RTs over time, they did not become faster over time which might be expected due to the goal getting harder. This could be because the goals were not difficult enough and didn't push them towards optimal performance. The maintenance is potentially due to subjects being motivated to maintain attentional effort over the course of the task. Finally, consistent with Experiment 1 (and Robison et al., 2021) there was still no evidence that the HOT goal reduced the number of TUTs experienced during the task.

Experiment 3

Experiment 3 sought to replicate the results of Experiment 2 in an in-person environment with minor changes to the format of the task. Additionally, the goals given in the HOT condition were slightly harder to further test whether we could push the participants to become faster over time or whether they would maintain their RTs similar to Experiment 2. Overall, our hypotheses match those of Experiment 2.

Methods

Participants

A sample of 81 subjects was recruited from the University of Oregon human subjects pool and earned partial course credit for their participation. No participants were excluded from the analyses (40 in control condition and 41 in HOT condition; 58 women, 23 men). The participants provided informed consent, completed a demographic survey, and completed three other cognitive tasks prior to beginning. They were also given brief verbal instructions before starting.

The methods for Experiment 3 were the same as Experiment 2 with a few exceptions.

Task

The four-choice RT task contained 180 trials (three blocks with 60 randomized trials each) and was programmed using E-Prime 2.0.

Thought-probes

Each of the three blocks contained five random thought-probes (15 total).

Goal-setting instructions

Experiment 3 had two conditions: control (no-goal) and harder-over-time (HOT). In the control condition, participants received the initial instruction: "Your goal on this task is to respond as quickly and accurately as possible. Your reaction time and accuracy will be recorded." In blocks 2 and 3, control saw: "Remember, your goal on this task is to respond as quickly and accurately as possible." In the HOT condition, the participants received the initial instruction: "Your goal on this task is to keep your reaction times under .425 s while staying as accurate as possible. Your reaction time and accuracy will be recorded." This applied to the first block. For block 2, the participants were told: "Your new goal on this task is to keep your reaction times under .375 s while staying as accurate as possible. Your reaction time and accuracy will be recorded." Finally, block 3 had the instruction: "Your new goal on this task is to keep your reaction times under .325 s while staying as accurate as possible. Your reaction time and accuracy will be recorded."

After completion of the task, participants were asked to rate their goal commitment. Those in the control condition were asked: "How committed were you to the goal of responding as quickly and accurately as possible?" The HOT condition saw: "How committed were you to the goals of keeping your response time under .425 s, .375 s, and .325 s while staying as accurate as possible?" Subjects provided their response with a keypress between 1 and 7 indicating their goal commitment (anchors: 1 = "Not committed at all", 4 = "Somewhat committed", 7 = "Totally committed").

Results

Consistent with the prior experiments, there was a main effect of bin on RTs, $F(4, 316) = 256.375$, $p < .001$, $\eta p^2 = .764$, a main effect of condition, $F(1, 79) = 7.762$, $p = .007$, $\eta p^2 = .089$, and a bin × condition interaction, $F(4, 316) = 5.768$, $p < .001$, $\eta p^2 = .068$, and, when examining the full RT distributions (Fig. 4a). Like the prior experiments, participants in the goal condition were faster overall and there was a clear reduction in the slow tail of the RT condition compared to participants in the control condition.

Like Experiment 2, we looked at RT, number of lapses, and TUTs by time block. First, looking at RT we found a significant main effect of block, $F(2, 158) = 7.081$, $p = .001$, $\eta p^2 = .082$, a significant main effect of condition, $F(1, 79) = 7.79$, $p = .007$, $\eta p^2 = .09$,and a significant block × condition interaction, $F(2, 158) = 8.715$, $p < .001$, $\eta p^2 = .099$. As in Experiment 2, RTs for those in the HOT condition remain relatively stable over time, while RTs in the control condition increased over time (see Fig. 4b). That is, participants in the control condition demonstrated a time-on-task effect, $F(2, 78) = 8.80$, $p < .001$, $\eta p^2 = .18$, but, participants in the HOT condition did not, $F(2, 80) = .24$, $p = .629$, $\eta p^2 = .006$.

The ANOVA for number of lapses indicated a significant main effect of block, $F(2, 158) = 4.254$, $p = .016$, $\eta p^2 = .051$. Unlike Experiment 2, there was no main effect of condition, $F(1, 79) = 3.361$, $p = .071$, $\eta p^2 = .041$. However, there was a block × condition interaction, $F(2, 158) = 3.749$, $p = .026$, $\eta p^2 = .045$ (see Table 1). Figure 4c illustrates that the control condition appears to experience more lapses as time goes

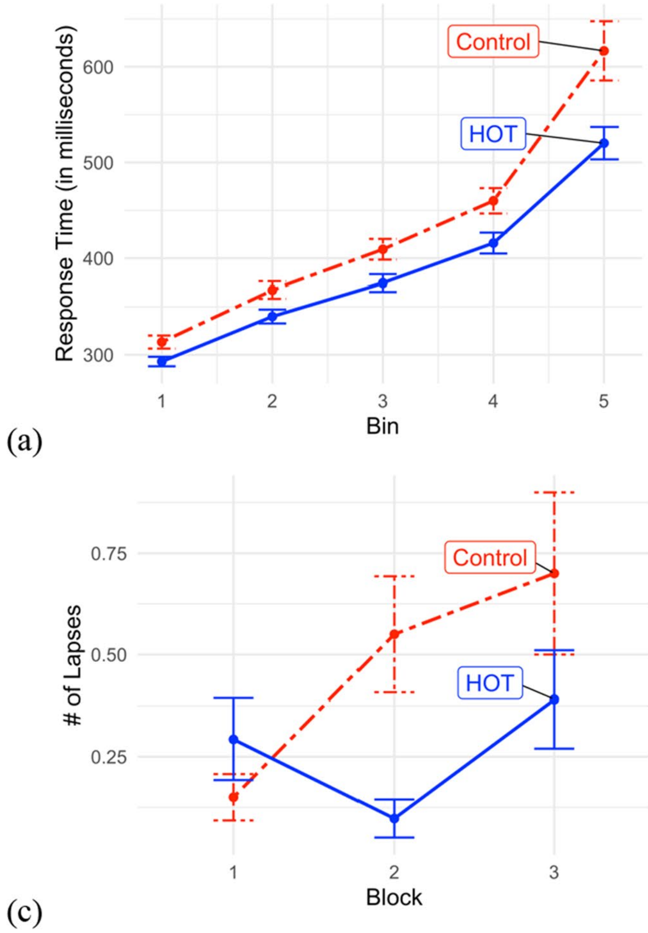

Fig. 4 Results for Experiment 3. (**a**) Response times (RTs) by bin and condition. Bin = response times rank-ordered fastest to slowest (1 = fastest, 5 = slowest). Results show those in the control condition had significantly longer slow RTs and were slower overall. (**b**) RTs by block and condition. There were 3 blocks total (1 = first, 3 = last). Results show those in the control condition responding slower over time, while the HOT subjects maintain speed. (**c**) Number of lapses by block and condition. Results indicate a main effect for block (both conditions experienced more lapses over time). (**d**) Number of task-unrelated thoughts by block and condition. Results indicate a main effect for block (both conditions experienced more task unrelated thoughts over time)

on, but the HOT condition has a drop in lapses in the second block before increasing in block three.

The ANOVA on TUTs revealed a significant main effect of block, $F(2, 158) = 30.172$, $p < .001$, $\eta p^2 = .276$. However, there was no effect of condition, $F(1, 79) = .104$, $p = .748$, $\eta p^2 = .001$, or block × condition interaction, $F(2, 156) = .015$, $p = .986$, $\eta p^2 = .000$ (see Table 1). This is consistent with Experiment 2 wherein both conditions experienced more TUTs over the course of the task (see Fig. 4d).

Discussion

The results of Experiment 3 replicated Experiment 2. In both experiments, the HOT goal condition displayed fewer attention lapses and faster overall RTs. Consistent with Experiment 2, the HOT goal enhanced overall sustained attention and eliminated the time-on-task effect, which was still seen in the control condition. Interestingly, with the HOT goal we were unable to make participants faster over time. This could be because the goals were all uniformly shifted down 25 ms from the goals set in Experiment 2. In order to manipulate task performance in the manner intended, the goal timings may need to be spread further apart from each other. However, even though they did not speed up, participants given the HOT goal maintained their RTs during the task, suggesting that the goals motivated participants to maintain (or even increase) their effort/intensity of attention throughout the task. Consistent with the prior experiments, there was no difference in TUTs between conditions, suggesting that self-reports of lapses were not influenced by the goal-setting manipulations. Overall, Experiment 3 helped reinforce the results of Experiment 2 and strengthened the idea that progressively harder goals can work to reduce attention lapses and maintain task performance.

General discussion

We investigated the effects of goal-setting on attention lapses in the context of sustained attention in three experiments. Participants performed a four-choice RT task modeled after prior research (e.g., Bertelson & Joffe, 1963; Steinborn et al., 2017; Unsworth et al., 2021) and were either given specific and difficult goals or vague (be fast and accurate) goals. In each experiment participants in the goal condition demonstrated a reduction in the slow tail of the RT distribution compared to the control group, suggesting that there was an overall reduction in the number of particularly slow RTs. We additionally examined the overall number of lapses/blocks in each experiment and found that the number of lapses were generally reduced in the goal-setting condition, but this effect only reached conventional levels of significance in Experiment 2 (see below). Thus, setting specific and difficult goals served to reduce behavioral lapses of attention compared to the more general (and vague) be fast and accurate goals consistent with Robison et al. (2021). Theoretically, with specific and difficult goals participants increased attentional effort (intensity of attention; Locke & Latham, 2002; Kahneman, 1973; Unsworth & Miller, 2021) to the task, which resulted in more concentration and task engagement, and fewer lapses of attention. Thus, goal-setting, like other motivational manipulations, can lead individuals to increase their attentional effort (Botvinick & Braver, 2015; Massar et al., 2016; Unsworth et al., 2022; Westbrook & Braver, 2015), resulting in better task performance.

While there was evidence that goal-setting tended to reduce lapses of attention (particularly when examining the full RT distribution), there was no evidence in any of the experiments that goal-setting had an impact on TUTs. Thus, goal-setting did not have an impact on self-reports of off-task attentional states. These results are generally consistent with Robison et al. (2021), who found that goal-setting had mixed effects on reducing behavioral lapses, but little to no effect on reducing TUTs. Additional research has also found differential effects for behavioral lapse measures and self-reports of TUTs (e.g., Kucyi et al., 2016; Unsworth et al., 2022). For example, Steinborn et al. (2017) found that "Try Hard" instructions reduced behavioral lapses. Later, Unsworth et al. (2022), noted in their results that while "Try Hard" instructions reduced behavioral lapses, they had no effect on TUTs. The current results, along with prior research, reinforces the idea that although behavioral lapses and TUTs are correlated, and likely index many similar processes, they are also distinct and don't always align. Future research is needed to better examine similarities and differences between behavioral markers of lapses and self-reports.

Experiments 2 and 3 further demonstrated that goal-setting can enhance overall sustained attention via time-on-task effects. As noted previously, performance tends to deteriorate with time-on-task (vigilance decrement; Parasuraman, 1986; Parasuraman & Davies, 1977; Mackworth, 1950; Robison et al., 2021; see also, See et al., 1995) and this was generally the case for the control condition in Experiments 2 and 3. However, when participants were given progressively harder goals across blocks, overall RTs remained stable. Thus, the time-on-task effect was eliminated. As noted previously, this could be due to participants in the HOT goal condition maintaining the same level of attentional effort and intensity throughout the task (persistence), while participants in the control condition do not, resulting in stable RTs. Or it could be that with progressively more difficult goals, participants in the HOT goal condition ramp up their effort and intensity to try and attain the new goals, which offsets the typical time-on-task effect. Thus, there are multiple ways in which the HOT goals could have impacted performance with changes in attentional effort (e.g., Hockey, 1997). Future research is needed to better examine potential mechanisms that are operating with the HOT goals that allow for a stabilization of task performance and an elimination of the time-on-task effect.

Collectively, the current results suggest that goal-setting manipulations enhanced sustained attention and reduce lapses of attention. However, we note that there is an important potential factor that could influence the results. Namely goal commitment. Studies examining goal-setting in variety of situations have suggested that goals only work to the extent that participants are committed to them (Locke & Latham, 1990). Thus, if participants are not committed to the assigned goals, or if there is considerable variability across participants in goal commitment, then this could influence the overall results. As noted in the *Methods*, we measured goal commitment at the end of each task. To see if goal commitment influenced the results, we redid all the analyses after covarying out individual differences in goal commitment (with an analysis of covariance). As seen in Table 2 (see the Appendix), after covarying out goal commitment, almost all effect sizes increased and some results that were not significant in the original analyses became significant. The only results that were not meaningfully affected were the TUT analyses, consistent with the previous discussion on the differences between behavioral lapses and TUT measures. This could mean that participants high on goal commitment expend more effort on the task, and those who are low on goal commitment may have enough attentional resources, but they do not direct them towards the task. Essentially, goal setting only works if the subject is committed to the goal.

Tedious and repetitive tasks are all around us and affect outcomes from getting housework done to high-impact jobs. Investigating ways to reduce attention lapses can have real-world safety/efficiency outcomes, including reducing the number of railroad accidents, improving work performance, and enhancing classroom experiences. The current research suggests that setting goals can help individuals better sustain their attention and reduce attention lapses. Thus, goal-setting techniques are a promising avenue to explore in the pursuit of reducing attention lapses.

Limitations and future directions

As noted above, one limitation of the current study is that we did not directly measure attentional effort to examine whether goal setting and enhanced sustained attention were in fact due to changes in attentional effort. One potential way of examining changes in attentional effort is to use pupillary responses. A great deal of prior research has suggested that phasic pupil dilation changes as a function of the cognitive demands of a task (for review, see Beatty & Lucero-Wagoner, 2000). Kahneman (1973) and Beatty (1982) suggested that these phasic pupillary responses are reliable and valid psychophysiological markers of attentional effort (intensity of attention). Indeed, a number of studies have demonstrated that various motivational manipulations are associated with larger phasic pupillary responses as well as enhanced task performance (e.g., Chiew & Braver, 2013, Massar et al., 2016; Unsworth et al., 2022). Thus, future research is needed to examine if goal-setting is associated with a greater allocation of attentional effort as indexed with larger phasic pupillary responses in the goal condition vs. the control condition. Likewise, changes in pupillary responses with progressively more difficult goals in the HOT condition can shed light on potential changes in effort allocation in terms of whether participants are maintaining effort across blocks (similar responses) or whether they are ramping up effort with harder goals (larger phasic pupillary responses). Furthermore, changes in arousal could be examined via changes in baseline pupil diameter (a metric of arousal) in order to determine if goals have an effect on overall arousal during sustained attention tasks. Thus, future pupillometry research could help elucidate potential changes in attentional effort and arousal as a function of goal-setting.

Another limitation of Experiments 1 and 2 is that participants accessed them online from their personal devices and not a controlled environment. As such, we have no way of knowing exactly what was occurring during data collection or if there were significant environmental differences between Experiments 1 and 2. For example, participants could have been engaging in activities like watching television, listening to music, or even performing the task with one hand while playing with their phone in the other. Experiment 3, which was conducted in the lab, largely replicated the results from the prior experiments suggesting that performing the task online did not unduly influence the results. Nonetheless we note that not knowing what participants were doing or whether there were possible distractors in the environment is a limitation for the online experiments.

Conclusion

The current experiments found evidence that setting a specific and difficult goal improves sustained attention and reduces behavioral attention lapses, but has no discernable effect on TUTs. Further, we found that taking a specific goal and increasing its difficulty over the course of a task further reduced the occurrence of attention lapses and eliminated the time-on-task effect. Collectively, the current results suggest that goal-setting techniques can help individuals better sustain their attention and reduce attention lapses.

Appendix

Table 2 Comparison of p-values and effect sizes before/after using an analysis of covariance to covary out goal commitment

Experiment/analysis	No goal commitment covariable	With goal commitment covariable
Exp. 1		
RT Distribution (Condition × Bin interaction)	p = .009, ηp^2 =.031	p < .001, ηp^2 = .057*
# of Lapses × Condition	p = .092, ηp^2 = .026	p = .034, ηp^2 = .042*
Prop. of TUTs × Condition	p = .210, ηp^2 = .015	p = .610, ηp^2 = .002
Exp. 2		
RT Distribution (Condition × Bin interaction)	p < .001, ηp^2 = .059	p < .001, ηp^2 = .151*
# of Lapses × Condition	p = .033, ηp^2 = .046	p = .001, ηp^2 = .116*
Prop. of TUTs × Condition	p = .249, ηp^2 = .014	p = .017, ηp^2 = .057*
RT Block (Block × Condition interaction)	p = < .001, ηp^2 = .112	p < .001, ηp^2 = .142*
# of Lapses Block (Block × Condition interaction)	p = .061, ηp^2 = .028	p = .016, ηp^2 = .042*
Prop. TUTs Block (Block × Condition interaction)	p = .188, ηp^2 =. 017	p = .268, ηp^2 = .031
Exp. 3		
RT Distribution (Condition × Bin interaction)	p < .001, ηp^2 = .068	p < .001, ηp^2 = .122*
# of Lapses × Condition	p = .071, ηp^2 = .041	p = .006, ηp^2 = .092*
Proportion of TUTs × Condition	p = .748, ηp^2 = .001	p = .219, ηp^2 = .019
RT Block (Block × Condition interaction)	p < .001, ηp^2 = .099	p < .001, ηp^2 = .143*
# of Lapses Block (Block × Condition interaction)	p = .026, ηp^2 = .045	p = .014, ηp^2 = .053*
Prop. TUTs Block (Block × Condition interaction)	p = .986, ηp^2 = .000	p = .955, ηp^2 = .001

Note. * = Analyses where either the effect size for an already statistically significant analysis increased, or the result became statistically significant when it was previously not significant

RT response time, *Prop.* proportion, *TUTs* task-unrelated thoughts

Open Practices Statement This study was not preregistered and the data will be made available on the Open Science Framework.

Author Notes This research was supported by Office of NavalResearch grant N00014-22-1-2083.

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