# Lapses of sustained attention occur when goals compete: Evidences from the switch CPT

Matthieu Chidharom[1,2,3], Edward K. Vogel[1,2,3], Monica D. Rosenberg[1,2,3]

[1]Institute for Mind and Biology, University of Chicago, Chicago, USA;

[2]Department of Psychology, University of Chicago, Chicago, USA;

[3]Neuroscience Institute, University of Chicago, Chicago, USA

Correspondence:

Dr. Matthieu Chidharom

Institute for Mind and Biology - Department of Psychology

The University of Chicago

940 East 57th Street

Chicago, Illinois 60637

Email: matthieuchidharom@gmail.com

Word count: 5352

**ABSTRACT**

Sustained attention is the ability to maintain focus on a specific goal over time, but lapses in attention are frequent. Many theories have attributed these lapses to a transient failure of control in maintaining the goal in mind. However, these proposals have been challenged because recent findings have shown more engagement of cognitive control during states more prone to lapses. We hypothesized that lapses occur during periods of high competition between goals, requiring stronger cognitive control. To test this goal-competition hypothesis, we developed a Switch-Continuous Performance Task in which subjects alternated task goals between blocks—either switching or holding the same goal—in an effort to manipulate periods of higher and lower competition between goals. Participants viewed a bilateral display showing a scene (indoor/outdoor) and a face (male/female) on each trial. At the start of each 20-trial block, a cue instructed participants to perform either the scene task (e.g., press for frequent indoor scenes, not infrequent outdoor scenes) or the face task (e.g., press for frequent male faces, not infrequent female faces). Results showed more attention lapses during switch than repeat blocks, suggesting that lapses occur during periods of high competition between goals. In a second study, we monetarily rewarded performance on only one task (scene or face) to create unequal competition between goals. We found that switching to an unrewarded goal—but not a rewarded goal—produced more lapses. Together, these findings support the goal-competition hypothesis as an explanation for the occurrence of sustained attention lapses.

**Keywords**: Distraction, cognitive control, commission errors, goal-competition, task-switching

## PUBLIC SIGNIFICANCE STATEMENT

In this study, we show that sustained attention lapses occur when distracting goals interfere and compete with the current goal. This competition is even stronger when the distracting goal is associated with a greater benefit for its achievement.

## INTRODUCTION

In everyday life, we frequently shift our attention between tasks, making it difficult to sustain focus on a single goal for extended periods. Lapses in sustained attention can arise swiftly, leading to performance impairments in the ongoing task. To study these lapses in research, participants are generally engaged in go/no-go or continuous performance tasks (CPTs) in which they are instructed to press a response button when frequent go stimuli appear and inhibit or switch their response when rare no-go stimuli appear (Robertson et al., 1997). Lapses of sustained attention are operationalized as errors on these no-go trials, called commission errors. Although several theories and models have attempted to explain why our attention lapses, none can clearly understand their occurrence and explain the full set of empirical results in a single model. In this study, we test the possibility that attention lapses occur when distracting goals compete for control with the ongoing task.

Major theories posit a central role of cognitive control in sustaining attention over time and avoiding lapses. For example, the resource-control theory (Thomson et al., 2015) suggests that the reduction of cognitive control over the course of a task explains the decline in vigilance and the increased occurrence of lapses over time. This has been supported by behavioral results showing that individuals with stronger cognitive control were better able to keep their thoughts on the task (Kane et al., 2007) and had fewer sustained attention lapses (McVay & Kane, 2009a). This view is also supported by brain imaging data. In the meta-analysis of 67 fMRI studies by Langner and Eickoff (2013), the authors identified several frontal regions associated with cognitive control and activated during sustained attention tasks, such as the midcingulate cortex and the dorsolateral prefrontal cortex (Langner & Eickhoff, 2013). The key role of cognitive control in sustained attention is also corroborated by the oscillatory model of sustained attention (Clayton et al., 2015). In their model, Clayton and colleagues suggests that the activity of frontomedial theta oscillations (4 - 8 Hz), a frequency band strongly associated with cognitive control (Cavanagh et al., 2012), is essential for maintaining attention over time in order to monitor and evaluate ongoing cognitive processes according to the current task goal. For example, the occurrence of an error after a no-go trial is typically followed by an increased frontal midline theta power (Chidharom, Krieg, Pham, et al., 2021; van Driel et al., 2015). Such frontal power increase is an indicator of performance monitoring and predicts subsequent enhancements in post-error reaction-time slowing (Cavanagh et al., 2009), an adaptation mechanism to maintain performance on task and avoid future lapses (Cavanagh et al., 2009; Chidharom et al., 2025).

Although cognitive control models help explain overall performance and vigilance decrements, they do not help in understanding both the effect of reward and attentional fluctuations on sustained attention task performance. Monetary rewards were found to eliminate the vigilance decrement (Esterman et al., 2016) and decrease the rate of attention lapses (Esterman et al., 2014, 2016, 2017; Massar et al., 2016; Seli et al., 2015), which doesn't fit with the idea that the resources of cognitive control are limited. The results on attentional fluctuations also contradict these views. Esterman and colleagues (2013) have identified, with fine-grained temporal precision, periods of good and poor attention based on reaction time (RT) variability (Esterman et al., 2013). The authors found that periods of high RT variability, called 'out-of-the-zone' states, are characterized by a higher lapse rate compared to periods of 'in-the-zone' states of low RT variability. According to the control models of sustained attention, one might expect to see reduced activity in cognitive control networks during periods of poor attention, where lapses are frequent. However, fMRI results show the opposite pattern of results: the dorsal attention network (DAN), implicated in goal-directed attention, was found to be more active during 'out-of-the-zone' states (Esterman et al., 2013; Jones et al., 2024; Song et al., 2023). Using a reverse logic, Yamashita and colleagues (2021) isolated two attentional states based on brain activity and also demonstrated that higher DAN activity predicts greater

RT variability and a higher proportion of attentional lapses (Yamashita et al., 2021). Electrophysiological data also raise questions about the adequacy of the control models in understanding the empirical results. For example, if control monitoring is critical for maintaining attention over time, the oscillatory model by Clayton et al. (2015) would predict an impairment of monitoring mechanisms during out-of-the-zone periods. However, recent studies failed to find any modulations of the monitoring process by sustained attentional states. The frontal midline theta oscillations were not modulated by the attentional states, neither after a conflicting no-go stimuli (Chidharom, Krieg, & Bonnefond, 2021), nor after a no-go error (Chidharom, Krieg, Pham, et al., 2021).

Alternatively to control models, the mindlessness hypothesis assumes that attentional lapses occur because the goal is monotonous and under-stimulating. The rapid automation of performance in CPT results in an automatic, or “mindless,” approach to the task at hand, increasing boredom and the emergence of mind-wandering (Manly et al., 1999; Robertson et al., 1997). This hypothesis provides an explanation for the effect of reward on sustained attention: the absence of a decline in vigilance and a reduction in lapses can be attributed to decreased boredom. However, this hypothesis does not account for all findings. In fact, the assumption that CPTs are easy and boring to perform is contradicted by participants’ subjective reports, which describe CPTs as cognitively demanding and stressful (see Hart, 2006; Hart & Staveland, 1988). Similarly, if the CPT is made more difficult for the participant, the mindlessness hypothesis should predict a reduction in sustained attention lapses. However, studies have shown an increased decline in vigilance for more challenging tasks (Helton & Russell, 2011, 2013; Helton & Warm, 2008; Smit et al., 2004).

Since both control-based models and the mindlessness hypothesis are not fully satisfactory, new ideas have emerged in recent years, particularly the notion that lapses occur due to stronger competition between goals. In a philosophical article, Shepherd (2019) attempted to explain mind-wandering, a major cause of lapses in CPT tasks (Andrillon et al., 2021; Bastian & Sackur, 2013; Chidharom et al., 2025; Chidharom & Bonnefond, 2023; Kane & McVay, 2012; McVay & Kane, 2009b). He suggests that mind-wandering happens when our mind seeks to engage in more beneficial tasks than the current goal. This idea is particularly inspired by studies showing that the medial prefrontal cortex (mPFC) plays a critical role in detecting and implementing control for beneficial or rewarded goals (Shenhav et al., 2013). For example, the mPFC was more engaged during periods of higher rewards in humans (Kouneiher et al., 2009) and in macaques (Kennerley et al., 2011). Similarly, this structure is also activated during mind-wandering, through the DMN engagement, motivating the hypothesis the brain is seeking more beneficial tasks to perform. This leads to an interesting idea: during a sustained attention task, the relevant goal is not just maintained through cognitive control but remains active alongside other, irrelevant and potentially distracting goals. Oberauer (2024) further suggests that sustained attention tasks are similar to task-switching tasks. While a person focuses on one goal, they still have many other goals and interests that are only temporarily set aside. Switching to alternative goals can cause distractions and reduce performance. This connection between task-switching and sustained attention was recently discussed in a review by Lee & Schumacher (2024). The authors highlight that the cognitive flexibility needed to switch between tasks relies on neural dynamics similar to those that support maintaining attention over time. They argue, for example, that control networks (e.g., FPCN or DAN), which help adjust task representations and manage interference during task switching, also play a key role in sustained attention by enabling prolonged engagement in a task while resisting distractions. Although the idea that alternative goals can capture attention and induce lapses is gaining traction in the literature, it has not been experimentally tested in classic sustained attention tasks like the CPT.

In this study, we aim to define and experimentally test the goal-competition hypothesis. We propose that lapses in sustained attention occur when alternative goals compete with the targeted goal and distract the mind based on their perceived benefits. If this hypothesis is correct, it could explain both attention fluctuations and the effect of motivation on lapses. Increased cognitive control engagement during error-prone periods could be due to a greater need to manage interference caused by goal competition. Similarly, the reduction of lapses through motivation could be explained by a decrease in competition between the rewarded target goal and alternative goals, based on their perceived benefits.

To test the goal-competition hypothesis, we designed the Switch-CPT, a task that combines a task-switching paradigm with a classic sustained go/no-go CPT. In this task, participants viewed a bilateral display showing a scene (indoor/outdoor) and a face (male/female) on each trial. Every 20 trials, a cue instructed them to perform either the scene task (e.g., press for frequent indoor scenes, not for infrequent outdoor scenes) or the face task (e.g., press for frequent male faces, not for infrequent female faces). Participants alternated task goals between blocks—either switching or maintaining the same goal—to manipulate periods of high and low competition between goals, respectively. Indeed, the switch cost that is characterized by slower reaction times on switch trials compared to repeat trials (Monsell, 2003; Wylie & Allport, 2000), result from greater competition between goals due to task-set inertia or proactive interference (see Kiesel et al., (2010), for review). Switch blocks are therefore considered periods of high competition between the two goals, while repeat blocks are periods of low competition (**Figure 1**). If lapses in sustained attention occur due to increased goal competition, we therefore hypothesize a higher number of no-go errors on the next trials following a switch compared to a repeat period.

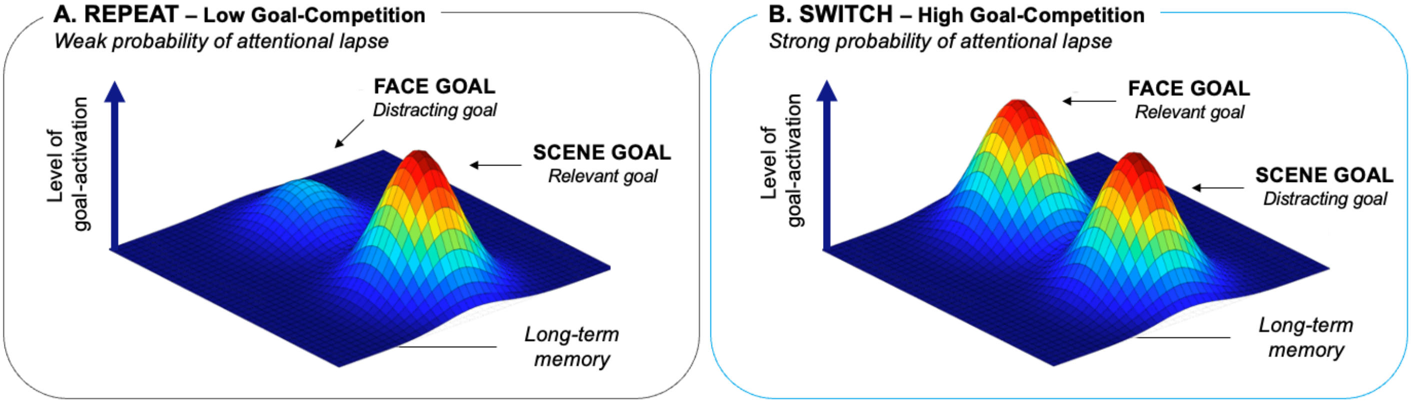


**Figure 1. The Goal-Competition Hypothesis - Sustained attention lapses occur when distracting goals compete with the relevant goal for access to working memory.** In the switch-CPT, participants must switch between a scene categorization goal and a face categorization goal. If the participant has to maintain the scene goal in mind and repeat it across blocks, goal competition is low (A). However, if the participant has to switch to the face goal, the scene goal becomes a distractor and temporarily competes with the face goal (B), increasing the risk of attentional lapses.

*EXPERIMENT 1*

## 2. METHODS

### 2.1 Participants

Thirty subjects participated in the study (mean age = 24.4, SD = 3.5, 16 females, 14 males). This sample size and exclusion criterion was predefined beforehand and registered on Open Science Framework (https://osf.io/c7etm/). All participants reported normal or corrected-to-normal vision and normal color perception. Exclusion criteria were a history of neurological disorder. All participants gave their informed consent, and the protocol was approved by the local ethics committee. Subjects were paid for their participation.

### 2.2 Stimuli

Stimuli were presented on a gray background (90.0 cd/m2). Trials began with the presentation of a red or a blue square (3 × 3 cm) that appeared at the center of the screen for 500 ms, instructing participants to categorize either scenes (indoor/outdoor) or faces (male/female). This cue was followed by a white central fixation point for 500 ms. Two square scene and face images (9 x 9 cm) were then presented simultaneously for 1000 ms, one to the left and one to the right of the fixation point. The distance from the fixation point to the center of each image was 6 cm. 995 indoor scenes and 1341 outdoor scenes from the SUN image database (Xiao et al., 2010) were used similarly to previous sustained attention studies (Corriveau, Chao et al., 2024; Corriveau, James et al., *2025*). For faces, all races and neutral expressions from the Chicago Face Database (Correll & Wittenbrink, 2015) were used and included 363 female faces and 351 male faces. All images were randomly presented to participants.

### 2.3 Procedure

During the switch-CPT, participants were instructed to categorize either scenes (indoor/outdoor) or faces (male/female) in a go/nogo paradigm. If the cue color directed the participant to focus on the face goal, they were required to press for male faces (go trials) and refrain from pressing for female faces (no-go trials). The same logic applied to the scene goal. The cue color and go/no-go subcategories (indoor/outdoor for scenes and male/female for faces) were counterbalanced across participants. For each category, the rate of no-go trials was about 15%. The cue was appearing every 20 trials and was either the same as the previous block (repeat condition) or a shift to the alternative goal (switch condition). Participants performed a short training before completing 1280 trials and took approximately 45 minutes **(Figure 2).**

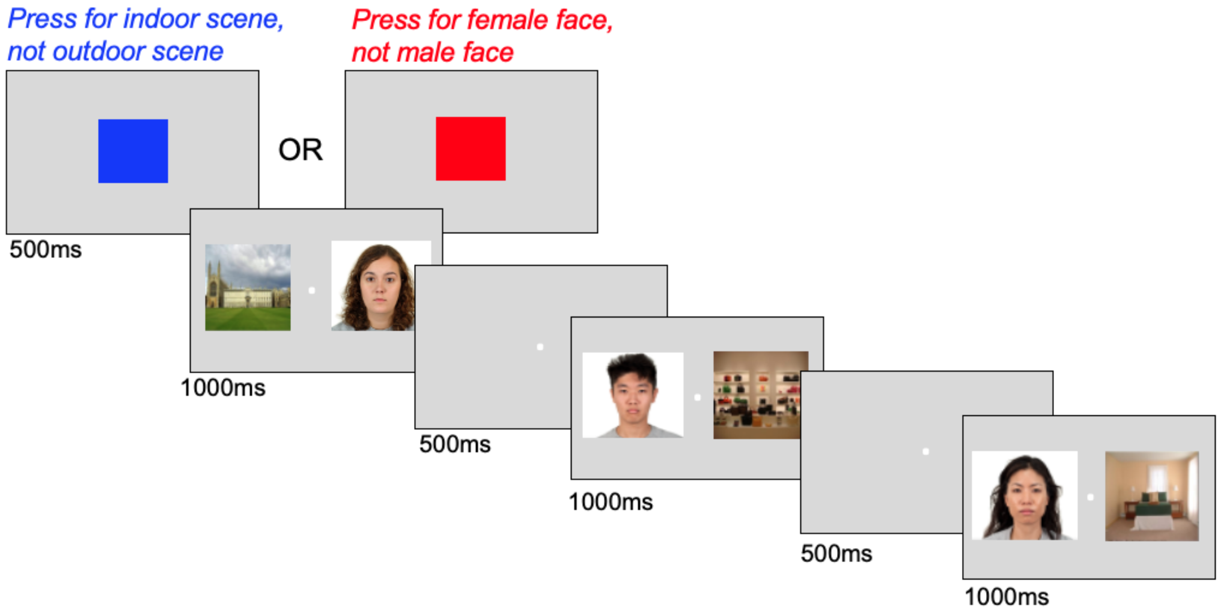


**Figure 2. The Switch-CPT**. In this task, participants had to pursue either the scene goal or the face goal, depending on the cue that appeared every 20 trials. In this example, go trials (85%) consisted of indoor scenes and female faces, while no-go trials (15%) consisted of outdoor scenes and male faces.

### 2.4 Data analysis.

*Overall performance.* In each block, the percentage of commission errors is the number of errors on no-go trials divided by the total number of no-go trials. The mean RT was calculated from the correct responses on the go trials.

*Within-block Performance.* According to the literature, increased competition between goals is expected to occur immediately after a switch. To examine this effect, we applied Gaussian smoothing to the percentage of errors on no-go trials and the mean RTs for each subject. The Gaussian kernel had a standard deviation of 3 trials, and the smoothing was conducted using a filter window encompassing 7 trials (consistent with the block procedure described in Chidharom et al., 2025).

### 2.5 Statistical analysis

To study the effect of condition (switch vs. repeat) on overall performance, paired t-tests were performed. However, the switch cost effect only occurs on the first trials following a switch (Barcelo et al., 2008; Yeung et al., 2006). Therefore, based on this a priori hypothesis and as indicated in the preregistration, t-tests were used to examine within-block performance and detect differences in performance between the switch and repeat conditions for each trial from 1 to 20. To complement these analyses with measures that are not influenced by multiple comparisons, Bayesian statistics are also reported. A 2-tailed significance level of .05 was used for all tests.

## 3. RESULTS

### 3.1 Overall Performance

#### *3.1.1 Errors on no-go trials*

The t-test revealed a nonsignificant effect of condition with more no-go trial errors during switch (mean ± SE; 19.1% ± 2.20) compared to repeated blocks (16.7% ± 1.73), $t(29) = -1.81$, $p = .080$, $d = -.33$, 95% CI [-0.70, 0.04].

#### *3.1.2 Reaction times on go trials*

The t-test did not reveal an effect of the condition on reaction times between switch (566 ms ± 12.8) and repeated blocks (565 ms ± 11.2), $t(29) = -0.38$, $p = .705$, $d = -.07$, 95% CI [-0.43, 0.29].

### 3.2 Within-block Performance

#### *3.2.1 Errors on no-go trials*

In order to study whether the percentage of no-go errors evolves within the block depending on the condition (switch vs. repeat), paired t-tests were performed from trial 1 to 20 after block onset. This revealed a significant effect of the condition from trial 1 to trial 7 after the cue onset, $t(29) = 2.07$, $p = .048$, $d = .38$, 95% CI [0.00, 0.75]; with higher rate of no-go errors during switch (20.6 % ± 2.60) compared to repeated blocks (15.6 % ± 1.99) **(Figure 3)**. See supplementary table S1 for detailed statistics.

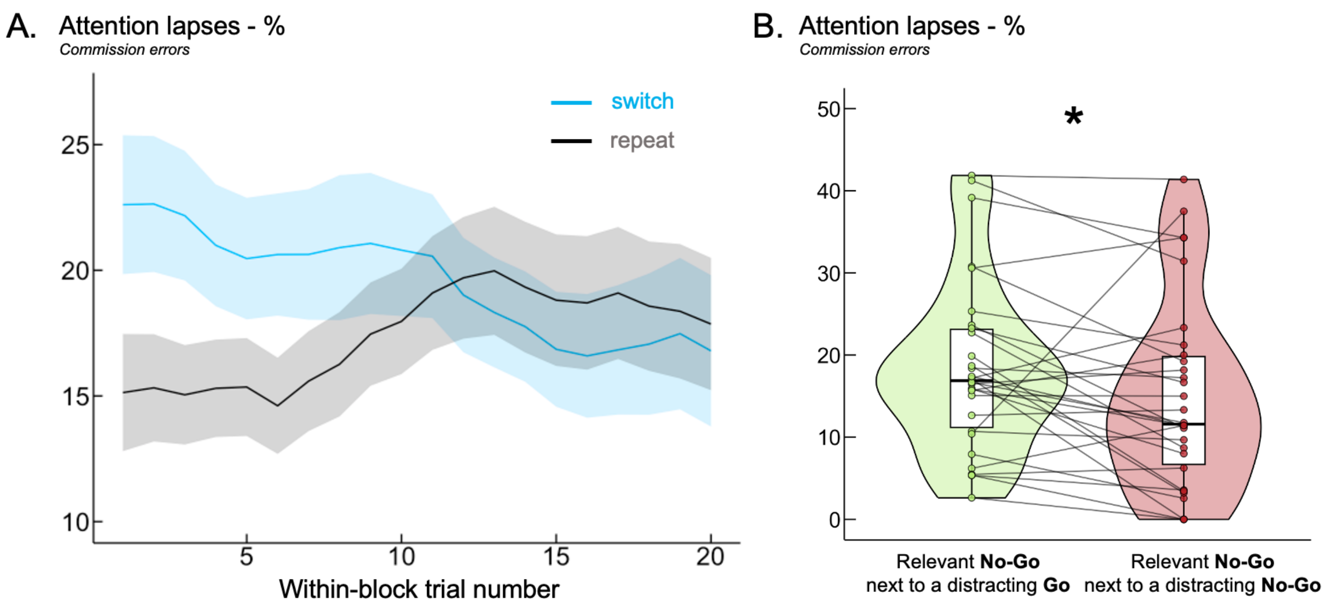


**Figure 3. Effect of the competition on lapse rate**. (A) Switching goal increases the rate of errors on no-go trials compared to repeat periods and remains significant up to 7 trials after the cue onset. (B) The competition also exists between the S-R mapping. When a relevant no-go is next to an irrelevant no-go (low competition), participants make fewer errors compared to when a relevant no-go is next to an irrelevant go trial (high competition). Shaded areas on 3A represent standard errors; * p < .05.

*3.2.2 Reaction times on go trials*

No effect of reaction time was found across trials (all p-values > .05) (**Figure 4**). See supplementary table S2 for detailed statistics.

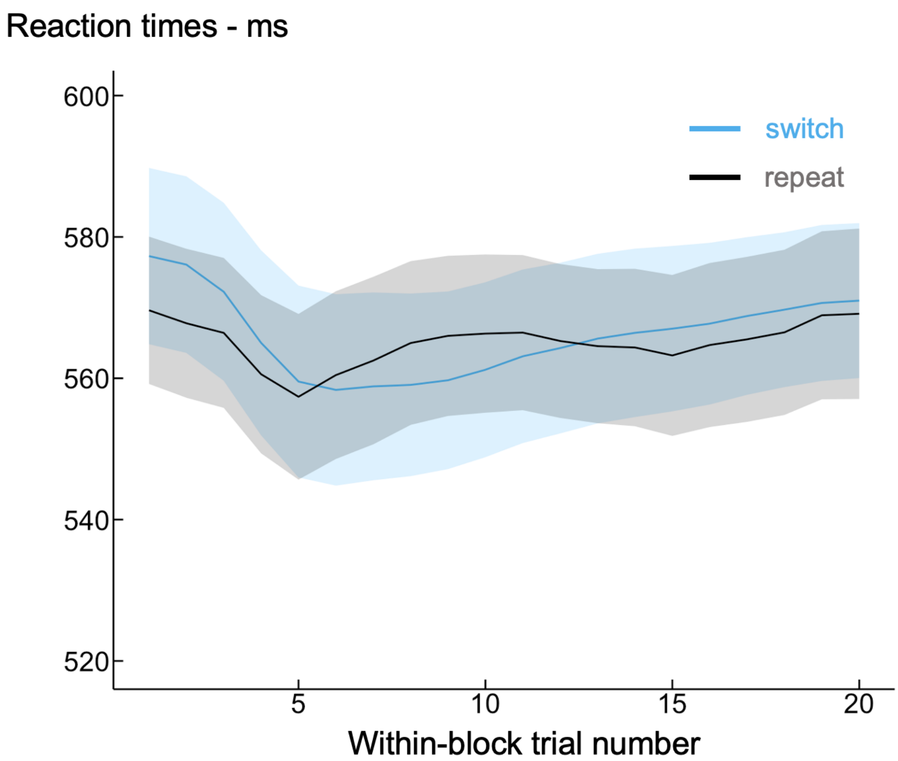


**Figure 4. Effect of the competition on reaction times**. No difference in reaction time between switch and repeat periods.

### 3.3. Exploratory analysis

Beyond competition between goals, we can also examine the competition between task-set instructions. A low-competition combination for the task-set would involve presenting a no-go trial next to an irrelevant no-go trial. In this case, the instructions from both task-sets (scene and face) align, as both stimuli require the participant not to respond. Conversely, a high-competition situation between task-sets would involve presenting a no-go trial next to an irrelevant go trial. Here, the two instructions are contradictory: one requires no response, while the other requires a response on the button press. Thus, we hypothesize fewer commission errors in the low-competition situation (no-go - no-go trials) compared to the high-competition situation (no-go - go trials). We performed a t-test, which revealed a significant effect of the combination, $t(29) = 2.201$, $p = .04$, $d = .40$, 95% CI [0.03, 0.77], with higher errors on no-go trials in the no-go-go combination (18.32% ± 1.90) than in the no-go-no-go combination (16.88% ± 2.11) **(Figure 3B)**.

## 4. INTERIM DISCUSSION

The goal of Experiment 1 was to test the hypothesis that goal-competition explains failures in sustained attention. Our results show an increase in errors on no-go during the first trials after a switch compared to repeat cues in a CPT design, suggesting that the error-prone periods can be driven by goal-competition. This aligns with Shepherd's (2019) philosophical perspective on mind-wandering, as well as theoretical reflections on task-switching and sustained attention proposed by Oberhauer (2024) and Lee and Schumacher (2024). This also opens the possibility that the greater engagement of control during out-of-the-zone periods—where errors are more likely—can be explained by the need to manage stronger interference between goals.

However, in Experiment 1, goals compete due to their activation dynamics through cognitive control during switch periods, rather than based on their expected benefits. Indeed, achieving the scene goal does not yield more benefits than achieving the face goal. Therefore, the idea that more beneficial distractor goals capture our attention and induce attentional failures, suggested by Shepherd (2019) and the related neural data (Shenhav et al., 2013), remains to be demonstrated.

### *EXPERIMENT 2*

In Experiment 2, we aimed to create an asymmetric competition between the two goals by manipulating their level of benefits **(Figure 5)**. To do so, we kept the same design as in Experiment 1 but introduced a monetary reward for one of the two goals based on performance. As a result, goal competition was no longer symmetrical as in Experiment 1; instead, the rewarded goal became more competitive for access to control compared to the unrewarded goal **(Figure 5B)**. This allows us to formulate two hypotheses. First, we expect to replicate the effect of motivation on sustained attention, with a reduction in no-go errors for the rewarded goal compared to the unrewarded goal. Additionally, if the rewarded goal competes for control more than the unrewarded goal, competition should be weaker when switching to this goal**.** Thus, we hypothesize an absence of switch costs on no-go errors for rewarded goal blocks **(Figure 5D)**, while switch costs should still be observed for unrewarded goal blocks **(Figure 5C)**. Such a result could explain how motivation, by reducing competition between goals, decreases sustained attention lapses—an effect that current cognitive control models and limited-resource theories fail to account for.

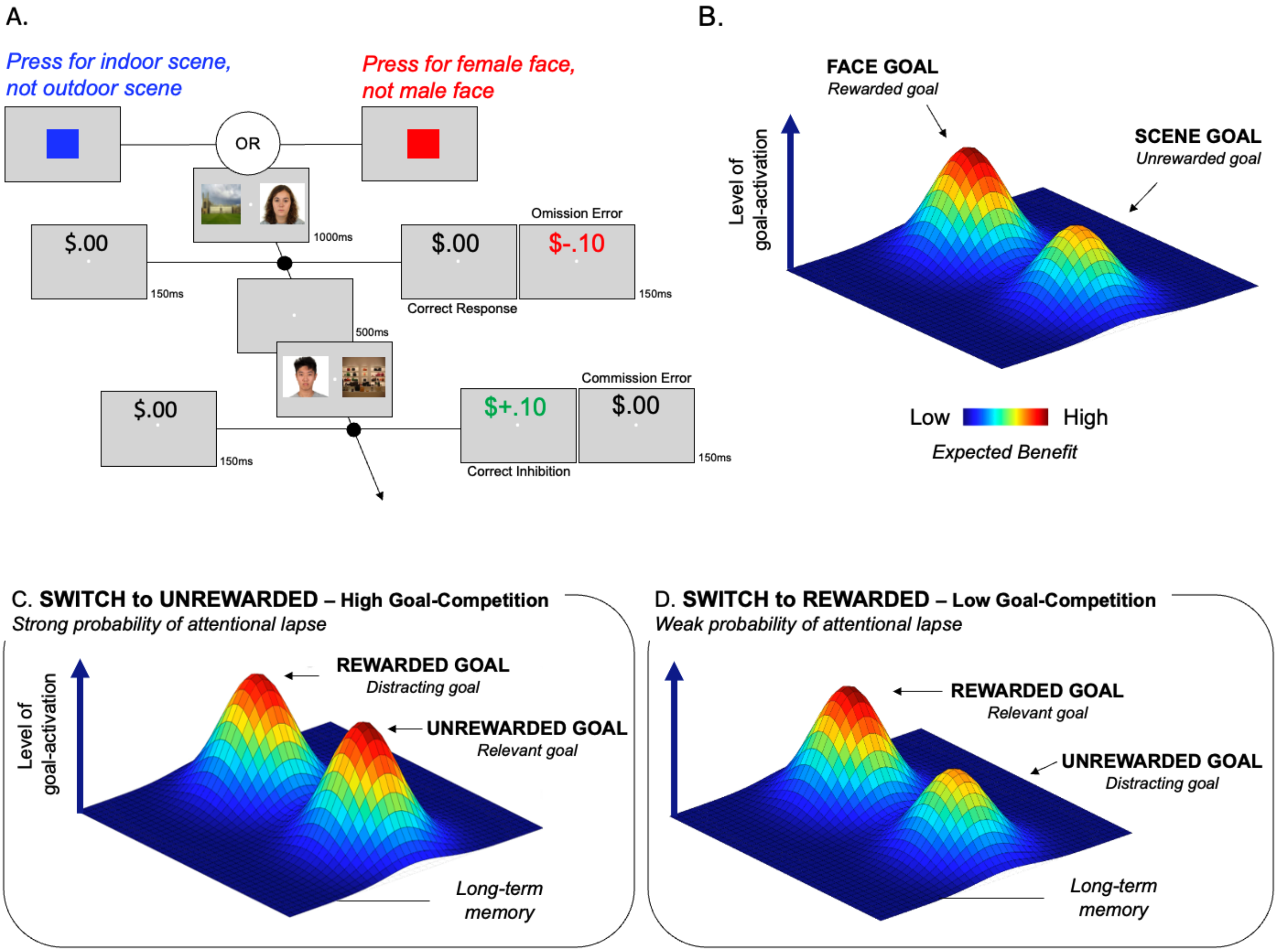


**Figure 5**. **The Switch-CPT with a rewarded goal**. (A) The task is similar to Experiment 1, except for the introduction of monetary rewards for one of the two goals and the appearance of a feedback window. In this example, the face goal is rewarded with a bonus of +$0.10 for correct inhibitions on no-go trials and a penalty of -$0.10 for omissions on go trials. Since the scene goal is not rewarded, the feedback always remains at $0.00. (B) According to the goal competition hypothesis, the introduction of a beneficial goal induces asymmetric competition, with greater weight assigned to the activation of the rewarded goal. In a context of task-switching, transitioning to an unrewarded goal leads to strong competition with the previously

rewarded but now distracting goal, increasing the likelihood of attentional lapses (C). Conversely, switching to a rewarded goal reduces competition, as the rewarded goal receives a stronger activation weight, making it dominant and minimizing interference (D) .

## 2. METHODS

### 2.1 Participants

Thirty five subjects participated in the study (mean age = 23.1, SD = 3.7, 20 females, 15 males). The sample size was determined using G*Power 3.1, based on the largest effect size observed for the condition (switch vs. repeat) on no-go errors in Experiment 1. Using an effect size of 0.57 (two-tailed), the calculation estimated that 35 participants were required to achieve a power of 0.90. No other parameters differed from those in Experiment 1.

### 2.2 Stimuli and procedure

The stimuli and procedures were the same as in Experiment 1, except for the introduction of monetary rewards. As before, participants were instructed to perform the face or scene task based on the color of the cue. However, they were informed that one of the two goals was associated with monetary rewards, allowing them to earn approximately $8 extra in addition to a base pay of $20. When completing the rewarded goal, a correct inhibition on no-go trials was rewarded with +$0.10, and was displayed in green on the screen after each trial. A missed response on a go trial incurred a penalty of -$0.10, displayed in red. All other trials displayed feedback of $0.00 in black. Feedback was presented on the screen for 150 ms (**Figure 5A**). The cue color, the go/no-go subcategories, and the rewarded goal were counterbalanced across participants. Additionally, because the presentation of monetary feedback extended the duration of trials, Experiment 2 was reduced to 1120 trials to ensure a similar task duration as in Experiment 1.

### 2.3 Data analysis and statistical analysis.

The data analysis was similar to that of Experiment 1. For the overall performance analysis, ANOVAs were conducted to account for the within-subject factor of Reward (rewarded vs. unrewarded goal). For the within-block performance analysis, given that Experiment 1 demonstrated that the effect of competition follows cue onset, we conducted t-tests comparing switch and repeat conditions separately for the rewarded and unrewarded goals.

## 3. RESULTS

### 3.1 Overall Performance

*3.1.1 Errors on nogo trials*

The ANOVA revealed a main effect of reward, $F(1,34) = 26.04$, $p < .001$, $\eta^2p = .43$; with lower errors on no-go trials during rewarded goal (15.3% ± 2.64) compared to unrewarded goal (26.6% ± 2.07) blocks (**Figure 6A**). No main effect of the condition on no-go errors during the switch (21.7% ± 2.28) compared to repeated blocks (20.2% ± 2.05), $F(1,34) = 1.84$, $p = .183$, $\eta^2p = .05$; and no interaction between the reward and condition was observed, $F(1,34) = 1.27$, $p = .268$, $\eta^2p = .04$.

*3.1.2 Reaction times on go trials*

The ANOVA performed on the mean reaction times revealed a main effect of condition, $F(1,34) = 6.44$, $p = .016$, $\eta^2p = .16$; with slower RTs during switch (529 ms ± 12.8) compared to repeated blocks (522 ms ± 12.6). No main effect of the reward was observed for rewarded goal (524 ms ± 12.3) compared to the unrewarded goal blocks (528 ms ± 14.0), $F(1,34) =$

0.263, $p$ = .611, $\eta^2p$ =.01. No reward and condition interaction was found, $F(1,34)$ = .203, $p$ = .655, $\eta^2p$ =.01.

### *3.1.3 Exploratory analysis*

Here we wanted to test, as in Experiment 1, if a low-competition combination for the task-set that involves presenting a no-go trial next to an irrelevant no-go trial, is modulated by the reward. We then performed an ANOVA with the within subject factor combination (no-go - no-go trials vs. no-go - go trials) and reward (rewarded vs. unrewarded). The ANOVA revealed a main effect of reward, $F(1,34)$ =33.31, $p < .001$, $\eta^2p$ =.50; with fewer no-go errors during the rewarded goal (14.9% ± 2.17) compared to the unrewarded goal (26.7% ± 2.61). Surprisingly, no main effect of combination was observed between the no-go-go (20.7% ± 2.12) and the no-go-no-go condition (20.9% ± 2.48) contrary to Experiment 1 , $F(1,34)$ = 0.01, $p$ = .931, $\eta^2p$ =.00; nor a combination and reward interaction, $F(1,34)$ = 1.15, $p$ = .291, $\eta^2p$ =.03.

## 3.2 Within-block Performance

### *3.2.1 Errors on no-go trials*

In order to see if we replicate the findings of Experiment 1 on the unrewarded goal, paired t-tests were performed and revealed higher no-go errors for switch (27.82% ± 3.52) compared to repeat blocks (21.9% ± 2.68) up to 4 trials after the cue onset, $t(34)$ = 2.18, $p$ = .036, $d$ = .37, 95% CI [0.03, 0.71]. As expected, no effect was observed for the rewarded goal between switch (11.3% ± 1.57) and repeated condition (13.5% ± 2.55) , $t(34)$ = -1.07, $p$ = .291, $d$ = - .18, 95% CI [-0.51, 0.15] (**Figure 6B**). See supplementary table S3 for detailed statistics.

### *3.2.2 Reaction times on go trials*

For the unrewarded goal, the paired t-tests revealed slower RTs for switch (542 ms ± 15.6) compared to repeat (508 ms ± 18.1) blocks, up to 3 trials after the cue onset, $t(34) = 2.09$, $p = .044$, $d = .35$, 95% CI [0.01, 0.69]. For the rewarded goals, the paired t-tests revealed a difference between the switch (526 ms ± 13.0) and repeat condition (517 ms ± 12.5), up to 9 trials after the cue onset, $t(34) = 2.09$, $p = .044$, $d = .35$, 95% CI [0.00, 0.69]. See supplementary table S4 for detailed statistics.

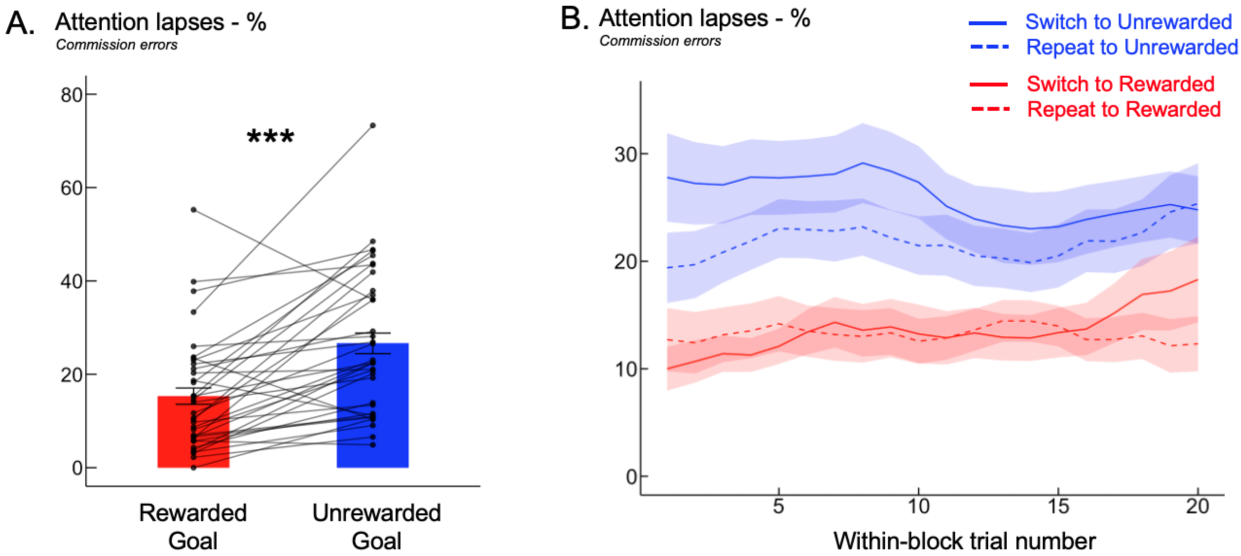


**Figure 6. Effect of reward on lapse rate.** (A) The error rate on no-go trials is lower for the rewarded goal compared to the unrewarded goal. (B) Replication of Experiment 1 for the unrewarded goal, showing higher error rates on no-go trials immediately after a switch compared to a repeat period. This effect was absent for the rewarded goal. Shaded areas represent standard errors; *** $p < .001$.

## 4. GENERAL DISCUSSION

The aim of this study was to test whether lapses in sustained attention occur when alternative goals compete with the targeted goal and whether this competition depends on the goals' relative perceived benefits. In Experiment 1, we showed that periods of high competition between goals induce more lapses in sustained attention, as evidenced by an increase in no-go errors after a period in which participants had to switch to another goal compared to staying on the same goal. In Experiment 2, we demonstrated that the level of competition between goals is linked to their perceived benefits. Specifically, switching to a beneficial goal does not lead to more lapses, unlike switching to a non-rewarded goal, suggesting a reduced level of competition for rewarded goals. Taken together, these results support the hypothesis of goal competition in the occurrence of attentional lapses and open new perspectives for understanding failures in sustained attention.

Periods of strong competition between goals induce more lapses in sustained attention. This is evidenced by the results of our Experiment 1, where participants made significantly more no-go errors during switch periods than during repeat periods. Experiment 2 replicates these results in the unrewarded goal condition, which is the most similar to Experiment 1. Such an increase in errors occurs immediately after the presentation of the cue, suggesting that competition arises transiently in the trials following the activation of the alternative goal.

These findings suggest an explanation for the increased engagement of control during out-of-the-zone periods. If error-prone periods can be explained by stronger competition between goals, we can also assume that out-of-the-zone states—characterized by high RT variability and increased errors—are also periods during which other goals compete in the mind with the targeted goal and could explain counterintuitive neuroimaging results. Indeed, Esterman et al. (2013) showed an increase in control network activity during out-of-the-zone states and could suggest the presence of stronger interference caused by goal competition, requiring greater engagement of cognitive control to keep the targeted goal in mind.

However, if periods of strong competition between goals are more error-prone and require greater control to resolve interference, then why are mind-wandering periods associated with a reduction in cognitive control? We might thus consider that different forms of goal competition exist. According to Shepherd (2019), mind-wandering occurs when alternative goals are perceived as more beneficial to pursue than the current goal. Thus, we can hypothesize that during mind-wandering periods, strong goal competition arises when alternative goals are perceived as more rewarding than the ongoing task. In other words, it is the alternative goals that shift in the competition. Conversely, out-of-the-zone periods might reflect times when alternative goals are not necessarily perceived as more beneficial, but rather when maintaining the targeted goal becomes increasingly costly over the course of the task, taxing more resources to maintain relevant goals in mind. In this case, it is not the alternative goals that shift in the competition, but the current goal itself. This aligns with the interpretation of a more effortful state described by Esterman and colleagues (2019). The difference in the origin of this goal competition could also explain why, in a recent study, we found that out-of-the-zone periods and mind-wandering fluctuate independently (Chidharom et al., 2025).

Beyond goal competition based on a cost-benefit evaluation, it is also possible that the origin of the competition differs between declarative and procedural working memory (Oberauer, 2009). Based on the presentation of probes during the CPT, mind-wandering may reflect greater competition between goals for access to declarative working memory. In contrast, out-of-the-zone periods, characterized by RT variability, may be more related to competition between task sets for access to procedural working memory. The existence of competition within procedural working memory is particularly supported by our complementary analyses of Experiment 1. We found that the presentation of a no-go target alongside a no-go distractor led to fewer lapses compared to when a no-go target was presented alongside a go distractor. This could be explained by the fact that both no-go stimuli activate the same response set—refraining from pressing the response button. In this combination, competition between task sets is low. However, if a no-go target is paired with a go distractor, the response sets are in opposition (not pressing for no-go vs. pressing for go), generating greater competition within the stimulus-response schema and leading to attentional lapses. This effect was not replicated in Experiment 2, possibly due to the introduction of reward. However, in another ongoing experiment, in which participants categorize numbers and letters instead of scenes and faces—without monetary rewards—we replicate the results of Experiment 1, showing fewer lapses for the no-go/no-go combination (22.5% ± 3.34) compared to no-go/go (27.5% ± 3.12); $t(19) = 4.43$, $p < .001$, $d = .99$ (Chidharom, Jones, Rosenberg and Vogel, in prep). If the results of this switch CPT reveal the role of goal competition in attention lapses, future studies should aim to test the possibility of competition occurring at multiple levels and stemming from different origins.

Beyond the question of where competition takes place, the question of how and based on what criteria goals compete with each other is also central. Our results suggest that goals compete based on their associated benefits. Indeed, the results of Experiment 2 show that switching to a rewarded goal does not induce more no-go errors compared to the repeat condition, while switching to an unrewarded goal does. This suggests that a goal is more competitive based on its benefits, thereby reducing interference from alternative goals. This also helps to explain why no-go errors are more frequent in the unrewarded goal condition compared to the rewarded goal condition. Indeed, maintaining an unrewarded goal in the presence of a more beneficial goal induces greater competition, increasing the risk of lapses. This can also be observed when comparing the repeat conditions of Experiments 1 and 2. In the Experiment 2, maintaining an unrewarded goal is more difficult because a more beneficial alternative goal exists, leading to approximately 25% lapses. In Experiment 1, maintaining attention on an unrewarded goal is easier since no directly manipulated alternative beneficial goal is present, leading to fewer lapses (around 17%). Taken together, these results propose a new theoretical framework to explain the effect of motivation on sustained attention. Indeed, the idea that cognitive control resources are limited does not explain why monetary rewards have been found to eliminate the vigilance decrement (Esterman et al., 2016) and reduce the rate of attention lapses (Esterman et al., 2014, 2016, 2017; Massar et al., 2016; Seli et al., 2015). The goal competition hypothesis provides an explanation for the effect of motivation on the reduction of lapses by predicting that a rewarded goal reduces competition with alternative goals.

In conclusion, our study provides initial evidence for the existence of competition between goals as an explanation for the occurrence of lapses in sustained attention. We also show that this competition is driven by the benefits associated with each goal and is reduced for the most beneficial goals. Future experimental studies should aim to manipulate costs in addition to benefits to explore the extent to which they impact competition, as well as investigate how this hypothesis can explain attentional deficits in disorders such as ADHD.

## AUTHORS CONTRIBUTION

MC contributed to conceptualization, data curation, formal analysis, methodology, investigation, project administration, software, validation, supervision, visualization, writing—original draft, and writing—review and editing. E.KV. and M.D.R were involved in conceptualization, resources, funding acquisition, supervision and writing—review and editing.


## FUNDING

This research was supported by Office of Naval Research Multidisciplinary University Research Initiatives (MURI) N00014-23-1-2768 to E.K.V. and M.D.R.


## TRANSPARENCY AND OPENNESS

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and the study. Experiment 1 was pre registered and all data, analysis code, and research materials are available at (https://osf.io/c7etm/). Data were analyzed using MATLAB R2023b and Rstudio, version 2023.12.1.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

**REFERENCES**

Andrillon, T., Burns, A., Mackay, T., Windt, J., & Tsuchiya, N. (2021). Predicting lapses of attention with sleep-like slow waves. *Nature Communications*, *12*(1), 3657. https://doi.org/10.1038/s41467-021-23890-7

Barcelo, F., Periáñez, J. A., & Nyhus, E. (2008). An information theoretical approach to task-switching: Evidence from cognitive brain potentials in humans. *Frontiers in Human Neuroscience*, *2*. https://doi.org/10.3389/neuro.09.013.2007

Bastian, M., & Sackur, J. (2013). Mind wandering at the fingertips: Automatic parsing of subjective states based on response time variability. *Frontiers in Psychology*, *4*, 573.

Cavanagh, J. F., Cohen, M. X., & Allen, J. J. B. (2009). Prelude to and resolution of an error: EEG phase synchrony reveals cognitive control dynamics during action monitoring. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *29*(1), Article 1. https://doi.org/10.1523/JNEUROSCI.4137-08.2009

Cavanagh, J. F., Zambrano-Vazquez, L., & Allen, J. J. B. (2012). Theta lingua franca: A common mid-frontal substrate for action monitoring processes. *Psychophysiology*, *49*(2), Article 2. https://doi.org/10.1111/j.1469-8986.2011.01293.x

Chidharom, M., & Bonnefond, A. (2023). Mind-wandering does not always rhyme with proactive functioning! Changes in the temporal dynamics of the mPFC-mediated theta oscillations during moments of mind-wandering. *Biological Psychology*, *181*, 108598. https://doi.org/10.1016/j.biopsycho.2023.108598

Chidharom, M., Bonnefond, A., Vogel, E. K., & Rosenberg, M. D. (2025). Objective markers of sustained attention fluctuate independently of mind-wandering reports. *Psychonomic Bulletin & Review*. https://doi.org/10.3758/s13423-025-02640-6

Chidharom, M., Krieg, J., & Bonnefond, A. (2021). Impaired Frontal Midline Theta During Periods of High Reaction Time Variability in Schizophrenia. *Biological Psychiatry:*

*Cognitive Neuroscience and Neuroimaging*, *6*(4), Article 4. https://doi.org/10.1016/j.bpsc.2020.10.005

Chidharom, M., Krieg, J., Pham, B.-T., & Bonnefond, A. (2021). Conjoint fluctuations of PFC-mediated processes and behavior: An investigation of error-related neural mechanisms in relation to sustained attention. *Cortex*. https://doi.org/10.1016/j.cortex.2021.07.009

Clayton, M. S., Yeung, N., & Kadosh, R. C. (2015). The roles of cortical oscillations in sustained attention. *Trends in Cognitive Sciences*, *19*(4), Article 4.

Esterman, M., Grosso, M., Liu, G., Mitko, A., Morris, R., & DeGutis, J. (2016). Anticipation of monetary reward can attenuate the vigilance decrement. *PloS One*, *11*(7), Article 7.

Esterman, M., Noonan, S. K., Rosenberg, M., & Degutis, J. (2013). In the zone or zoning out? Tracking behavioral and neural fluctuations during sustained attention. *Cerebral Cortex (New York, N.Y.: 1991)*, *23*(11), Article 11. https://doi.org/10.1093/cercor/bhs261

Esterman, M., Poole, V., Liu, G., & DeGutis, J. (2017). Modulating Reward Induces Differential Neurocognitive Approaches to Sustained Attention. *Cerebral Cortex (New York, N.Y.: 1991)*, *27*(8), Article 8. https://doi.org/10.1093/cercor/bhw214

Esterman, M., Reagan, A., Liu, G., Turner, C., & DeGutis, J. (2014). Reward reveals dissociable aspects of sustained attention. *Journal of Experimental Psychology: General*, *143*(6), 2287–2295. https://doi.org/10.1037/xge0000019

Hart, S. G. (2006). Nasa-Task Load Index (NASA-TLX); 20 Years Later. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *50*(9), 904–908. https://doi.org/10.1177/154193120605000909

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In P. A. Hancock & N. Meshkati

(Eds.), *Advances in Psychology* (Vol. 52, pp. 139–183). North-Holland. https://doi.org/10.1016/S0166-4115(08)62386-9

Helton, W. S., & Russell, P. N. (2011). Working memory load and the vigilance decrement. *Experimental Brain Research*, *212*(3), 429–437. https://doi.org/10.1007/s00221-011-2749-1

Helton, W. S., & Russell, P. N. (2013). Visuospatial and verbal working memory load: Effects on visuospatial vigilance. *Experimental Brain Research*, *224*(3), 429–436. https://doi.org/10.1007/s00221-012-3322-2

Helton, W. S., & Warm, J. S. (2008). Signal salience and the mindlessness theory of vigilance. *Acta Psychologica*, *129*(1), 18–25. https://doi.org/10.1016/j.actpsy.2008.04.002

Jones, H. M., Yoo, K., Chun, M. M., & Rosenberg, M. D. (2024). Edge-Based General Linear Models Capture Moment-to-Moment Fluctuations in Attention. *Journal of Neuroscience*, *44*(14). https://doi.org/10.1523/JNEUROSCI.1543-23.2024

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For Whom the Mind Wanders, and When: An Experience-Sampling Study of Working Memory and Executive Control in Daily Life. *Psychological Science*, *18*(7), 614–621. https://doi.org/10.1111/j.1467-9280.2007.01948.x

Kane, M. J., & McVay, J. C. (2012). What mind wandering reveals about executive-control abilities and failures. *Current Directions in Psychological Science*, *21*(5), Article 5.

Kennerley, S. W., Behrens, T. E. J., & Wallis, J. D. (2011). Double dissociation of value computations in orbitofrontal and anterior cingulate neurons. *Nature Neuroscience*, *14*(12), 1581–1589. https://doi.org/10.1038/nn.2961

Kiesel, A., Steinhauser, M., Wendt, M., Falkenstein, M., Jost, K., Philipp, A. M., & Koch, I. (2010). Control and interference in task switching—A review. *Psychological Bulletin*, *136*(5), 849–874. https://doi.org/10.1037/a0019842

Kouneiher, F., Charron, S., & Koechlin, E. (2009). Motivation and cognitive control in the human prefrontal cortex. *Nature Neuroscience*, *12*(7), 939–945. https://doi.org/10.1038/nn.2321

Langner, R., & Eickhoff, S. B. (2013). Sustaining attention to simple tasks: A meta-analytic review of the neural mechanisms of vigilant attention. *Psychological Bulletin*, *139*(4), Article 4.

Lee, Y., & Schumacher, E. H. (2024). Cognitive flexibility in and out of the laboratory: Task switching, sustained attention, and mind wandering. *Current Opinion in Behavioral Sciences*, *59*, 101434. https://doi.org/10.1016/j.cobeha.2024.101434

Manly, T., Robertson, I. H., Galloway, M., & Hawkins, K. (1999). The absent mind: Further investigations of sustained attention to response. *Neuropsychologia*, *37*(6), 661–670. https://doi.org/10.1016/S0028-3932(98)00127-4

Massar, S. A., Lim, J., Sasmita, K., & Chee, M. W. (2016). Rewards boost sustained attention through higher effort: A value-based decision making approach. *Biological Psychology*, *120*, 21–27.

McVay, J. C., & Kane, M. J. (2009a). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(1), 196–204. https://doi.org/10.1037/a0014104

McVay, J. C., & Kane, M. J. (2009b). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(1), Article 1.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*(3), 134–140. https://doi.org/10.1016/S1364-6613(03)00028-7

Oberauer, K. (2024). The meaning of attention control. *Psychological Review*, *131*(6), 1509–1526. https://doi.org/10.1037/rev0000514

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*(6), Article 6.

Seli, P., Cheyne, J. A., Xu, M., Purdon, C., & Smilek, D. (2015). Motivation, intentionality, and mind wandering: Implications for assessments of task-unrelated thought. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(5), 1417–1425. https://doi.org/10.1037/xlm0000116

Shenhav, A., Botvinick, M. M., & Cohen, J. D. (2013). The Expected Value of Control: An Integrative Theory of Anterior Cingulate Cortex Function. *Neuron*, *79*(2), 217–240. https://doi.org/10.1016/j.neuron.2013.07.007

Shepherd, J. (2019). Why does the mind wander? *Neuroscience of Consciousness*, *2019*(1), niz014. https://doi.org/10.1093/nc/niz014

Smit, A. S., Eling, P. A. T. M., & Coenen, A. M. L. (2004). Mental effort causes vigilance decrease due to resource depletion. *Acta Psychologica*, *115*(1), 35–42. https://doi.org/10.1016/j.actpsy.2003.11.001

Song, H., Shim, W. M., & Rosenberg, M. D. (2023). Large-scale neural dynamics in a shared low-dimensional state space reflect cognitive and attentional dynamics. *eLife*, *12*, e85487. https://doi.org/10.7554/eLife.85487

Thomson, D. R., Besner, D., & Smilek, D. (2015). A resource-control account of sustained attention: Evidence from mind-wandering and vigilance paradigms. *Perspectives on Psychological Science*, *10*(1), Article 1.

van Driel, J., Swart, J. C., Egner, T., Ridderinkhof, K. R., & Cohen, M. X. (2015). (No) time for control: Frontal theta dynamics reveal the cost of temporally guided conflict anticipation. *Cognitive, Affective, & Behavioral Neuroscience*, *15*(4), Article 4. https://doi.org/10.3758/s13415-015-0367-2

Wylie, G., & Allport, A. (2000). Task switching and the measurement of “switch costs.” *Psychological Research*, *63*(3), 212–233. https://doi.org/10.1007/s004269900003

Yamashita, A., Rothlein, D., Kucyi, A., Valera, E. M., & Esterman, M. (2021). Brain state-based detection of attentional fluctuations and their modulation. *NeuroImage*, *236*, 118072. https://doi.org/10.1016/j.neuroimage.2021.118072

Yeung, N., Nystrom, L. E., Aronson, J. A., & Cohen, J. D. (2006). Between-Task Competition and Cognitive Control in Task Switching. *Journal of Neuroscience*, *26*(5), 1429–1438. https://doi.org/10.1523/JNEUROSCI.3109-05.2006