The Subjective Experience of Being Out-of-the-Zone: Investigating Objective and Subjective Attention Fluctuations

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ABSTRACT

Sustained attention fluctuates continuously between periods of low and high attentional engagement. Two major approaches have been used in the literature to capture these fluctuations. An objective approach, based on reaction time (RT) variability, identifies periods known as in-the-zone (stable and accurate) and out-of-the-zone (variable and error-prone). A subjective approach relies on participants' self-reports regarding task-related and task-unrelated thoughts (TUTs). While both methods have proven effective in tracking attentional fluctuations, it remains unclear whether they capture the same type of fluctuations. In this study, we aimed to better characterize the subjective experience associated with objectively defined out-of-the-zone periods. Thirty participants completed a classic sustained attention task—the Continuous Performance Task (CPT)—in a go/no-go format. At several points during the task, participants were interrupted with subjective probes assessing their current mental state (task-focused, performance-focused, external distraction, daydreaming, and mind-blanking), as well as their perceived effort, opportunity cost, and arousal. Our results offer a nuanced view of the relationship between subjective and objective approaches. We found evidence for consistency: out-of-the-zone periods were more frequently associated with daydreaming than in-the-zone periods. However, inconsistencies also emerged. In-the-zone periods were marked by faster RTs, whereas subjective on-task periods were associated with slower responses. Arousal was reduced during TUT periods but did not differ between in- and out-of-the-zone periods. Together, these findings suggest that while RT variability reflects some aspects of subjective experience, subjective and objective approaches may diverge in how they capture performance dynamics and internal states such as arousal.

INTRODUCTION

You are a student, sitting in class, trying to sustain your attention during a lecture. A few minutes after the lecture begins, your mind starts to fluctuate between periods of focus and distraction. This situation—one we can all relate to—illustrates the fluctuations of sustained attention between high and low attentional states. Two main methods exist to detect these fluctuations. The first is the objective approach. Returning to the previous example, we might imagine that during the lecture, the teacher asks the class a question about what was just said. A period of diminished attention could be detected objectively by the student's inability to answer the question. In research, objective behavioral markers, primarily reaction time (RT) variability, are also used as an indicator of attentional states. The second method to detect this period of diminished attention is the subjective approach. In this context, the teacher might ask the student whether they were focused on the lecture or thinking about something else. This closely reflects the subjective measures used in research, in which participants typically report their internal experience during a sustained attention task—such as whether they felt focused or distracted. Although both methods have been effective in isolating fluctuations in attention, it is still unclear in the current literature whether the subjective approach captures the same type of attentional fluctuations as the objective approach. In this paper, we attempted to determine whether a participant's subjective experience can be tracked through objective measures of attention.

Sustained attention is commonly investigated using go/no-go tasks, also called continuous performance tasks (CPTs) that require participants to respond to all frequent-category stimuli (~90%) and withhold responses to the infrequent target stimuli (~10%; Robertson et al., 1997; Rosenberg et al., 2013). The inability to inhibit a prepotent response on no-go trials is called a commission error and is the classical index of attentional lapses in CPTs, correlating with individuals' tendency to being distracted in everyday life (Manly et al., 1999; Robertson et al., 1997). In such tasks, the objective approach identifies attentional states using a trial-to-trial measure of RT variability, also referred to as the variance time course (VTC). It calculates the absolute difference between a given trial's RT and the average correct-trial RT across the task. Then, using a median split of the VTC, trials are categorized to be either "in-the-zone," which is characterized by low RT variance, and "out-of-the-zone," which is characterized by high RT variance (Esterman et al., 2013). This approach has been shown to be effective in isolating attentional fluctuations, as it revealed that attention lapses (errors on no-go trials) are more frequent during out-of-the-zone periods than during in-the-zone periods (Esterman et al., 2013); an effect that has been replicated multiple times in the literature (Corriveau et al., 2025; Esterman et al., 2013; Rosenberg et al., 2013; Chidharom et al., 2021a, 2021b; 2025).

The second method is the subjective approach. It consists of presenting thought probes several times during the CPTs (McVay & Kane, 2009). These probes generally ask participants to report whether they are "on-task," meaning their attention was currently focused on the task, or whether they are "off-task," meaning they were thinking of things unrelated to the task at hand (Smallwood & Schooler, 2006; Unsworth & Robison, 2016). Several studies have also demonstrated that lapses are more frequent during periods of self-reported task-unrelated thoughts (TUTs) compared to periods of on-task attention (Andrillon et al., 2021; Chidharom et al., 2023; Chidharom et al., 2025; Kane & McVay, 2012), suggesting that subjective experience also offers valid insights into capturing the dynamics of attentional fluctuations.

Although both approaches have proven highly effective at capturing lapses, it remains unclear whether objective attentional states and subjective task-unrelated thoughts reflect the same or distinct types of attentional fluctuations. Two major hypotheses have been discussed in the literature (Chidharom et al., 2025). First, a number of findings support the *consistency hypothesis*—the idea that both methods capture the same type of fluctuations of sustained attention, and that periods of high RT variability are consistently associated with periods of TUTs. For instance, Bastian and Sackur (2013) demonstrated that the temporal proximity of a thought probe to a local peak in reaction time variability can predict the occurrence of TUTs. Similarly, studies using the metronome response task—where a participant is required to press a response button in rhythm with a metronome that emits beeps or visual signals at fixed intervals—show similar effects. Specifically, several studies have shown that behavioral variability in this task serves as a marker of off-task thought (Godwin et al., 2023; Seli et al., 2013). Moreover, research by Welhaf and Kane (2024a) also supports the *consistency hypothesis*, showing that although objective and subjective measures are not perfectly correlated, they share common variance indicative of general attentional disengagement. Their findings suggest that the moderate correlation between reaction time variability and self-reported TUTs reflects a shared underlying construct of attentional consistency. Follow-up analyses by Welhaf and Kane (2024b) emphasize this shared variance as the most valid representation of sustained attention, reinforcing the view that both objective and subjective indicators may, in fact, be tracking the same attentional fluctuations.

However, these robust findings contrast with another set of results that support the idea that the two approaches don't capture the same types of attentional fluctuations—this is known as *the inconsistency hypothesis* (Chidharom et al., 2025). This hypothesis suggests that periods of high TR variability do not consistently imply that participants experience TUTs. In a recent study, Chidharom and colleagues (2025) engaged participants in a SART (Sustained Attention to Response Task) with variable inter-trial intervals, combined with regularly presented thought-probes. While both objective and subjective approaches were effective in isolating periods of reduced attention—characterized by increased rates of no-go errors—objectively measured time spent “out of the zone” did not significantly overlap with periods of reported task-unrelated thoughts. Furthermore, behavioral markers such as post-error slowing showed distinct patterns depending on whether periods of low attention were captured through objective performance-based measures or subjective self-reports.

These findings are in line with inconsistencies observed in neuroscience research. For example, fMRI studies have shown a paradoxical role of the Default Mode Network (DMN) in attentional states. If the consistency hypothesis were correct, one would expect DMN activity—typically observed during subjectively reported task-unrelated thoughts—to also be higher during objectively defined out-of-the-zone periods. However, this is not what fMRI studies have reported. Specifically, both “in-the-zone” periods of high performance and off-task periods are associated with increased activity in the default mode network (DMN), compared to “out-of-the-zone” and on-task periods, respectively (Christoff et al., 2009; Esterman et al., 2013, 2014; Hasenkamp et al., 2012; Kucyi et al., 2016, 2023; Mittner et al., 2014). Kucyi and colleagues (2016) attempted to disentangle the variability in DMN activity and found that it is linked to both off-task thoughts (reflecting a low-efficiency state) and behavioral stability in reaction times (reflecting a high-efficiency state). These findings suggest that attentional fluctuations are multidimensional and cannot be fully captured by a single metric.

Moreover, there is also a clear contradiction in how cognitive control is thought to relate to attentional fluctuations. Subjective reports of being on-task are usually linked to stronger activation in brain networks involved in attentional control, such as the dorsal attention network (DAN) and the frontoparietal control network (FPCN) (Christoff et al., 2009; Hasenkamp et al., 2012; Kucyi et al., 2016; Mason et al., 2007; Mittner et al., 2014). EEG studies support this as well—for example, Chidharom et al. (2023) found increased frontal theta activity, a marker of cognitive control, before no-go trials, but only when participants report subjectively being on-task. This suggests that when people report being on-task, their brains show more signs of control engagement, and this helps them prepare for upcoming demands. However, objective measures tell a different story. For instance, during "in-the-zone" moments, participants perform better, even though these periods are associated with *less* evidence of control engagement. Indeed, during in-the-zone periods, DAN activity is actually lower than during out-of-the-zone periods (Esterman et al., 2013).

In light of these contradictions, the aim of the current study is to better characterize the subjective experience of objectively defined out-of-the-zone periods. To do so, we used a task that shares key features with those that have previously supported the consistency hypothesis (e.g., the metronome response task)—most notably by maintaining a fixed rhythmic presentation of stimuli. Under these conditions, which are more favorable to the consistency hypothesis, we aim to test whether TUTs are more prevalent during objectively defined out-of-the-zone periods, and more specifically, which type of TUT is most strongly associated with increased RT variability. Indeed, TUTs are not a uniform subjective experience, but rather consist of at least three distinct forms: external distraction, daydreaming (or mind-wandering), and mind-blanking (Robison & Unsworth, 2018; Stawarczyk et al., 2011; Unsworth & Robison, 2016a; Ward & Wegner, 2013; Unsworth et al., 2021).

In addition, we sought to further characterize the subjective nature of out-of-the-zone periods by asking participants about their perceived levels of effort, opportunity cost, and arousal—factors that have recently been identified as potential contributors to attentional fluctuations. Indeed, sustaining attention over time is effortful, and participants subjectively report that CPT tasks are demanding (Bambrah et al., 2019). FMRI data showing increased activation in control-related brain regions during objectively defined out-of-the-zone periods have also been interpreted as reflecting a more effortful and costly state for participants (Esterman et al., 2013; Esterman et al., 2019). Based on this, one could hypothesize that perceived effort of the current task would be higher during out-of-the-zone periods compared to in-the-zone periods. Opportunity-cost has also been proposed as a factor underlying out-of-the-zone periods (Esterman et al., 2019). For example, if individuals would rather engage in alternative tasks than the one at hand, their subjective perception of effort may increase (Kurzban et al., 2013). This idea has recently been described in the goal competition hypothesis, which posits that sustaining attention on a goal that competes with another is more cognitively demanding (Chidharom et al., *PsyArXiv*). Accordingly, we hypothesize that the motivation to pursue alternative goals is greater during out-of-the-zone periods than during in-the-zone periods. Finally, arousal is another factor that may influence reaction time variability. For instance, increasing arousal through the threat of shock has been shown to enhance sustained attention and reduce attention fluctuations (Grillon et al., 2016). Conversely, reduced arousal levels have been associated with increased RT variability (James et al., 2016; Canales-Johnson et al., 2020), aligning with recent findings linking sleep-like activity to attentional lapses (Andrillon et al., 2021). Based on this, we hypothesize that out-of-the-zone periods may be associated with changes in arousal levels.

Beyond allowing us to better characterize the subjective experience of objectively defined out-of-the-zone periods, self-reported measures of effort, opportunity cost, and arousal also provide a means to test the consistency between subjective and objective approaches. Indeed, the *consistency hypothesis* suggests that periods of reaction time variability correspond to moments of task-unrelated thoughts. If this hypothesis holds then the modulation of these subjective reports by attentional state should be similar whether assessed through subjective probes or objective markers. For example, the reduced level of arousal reported during TUT periods should also be present during objectively defined out-of-the-zone periods. Conversely, *the inconsistency hypothesis* suggests that periods of reaction time variability are different from TUTs. This hypothesis predicts that the effects of subjective and objective attentional states on probe reports will be different.

METHODS

Participants

Thirty participants (14 male, 16 female) completed the experiment. The average age was 24.00 years (*SD* = 4.16). Based on the smallest effect size observed for attentional states on lapses (f = .70) in prior work (Chidharom et al., 2025), a power analysis using G*Power 3.1 indicated that a sample of 9 participants would be sufficient (α = .05, power = 95%, two-tailed test). We defined a stop rule at 30 participants to have enough participants to perform parametric tests. The study was not preregistered. All participants reported normal or corrected-to-normal vision, no history of neurological disorders, and being in generally good health. Three participants were excluded following data collection for failing to complete the standard number of trials. All participants gave informed consent, and protocol was approved by the University of Chicago Institutional Review Board. Subjects were compensated for their participation at a rate of $20 per hour.

Stimuli

Stimuli were presented using MATLAB (Version 2024a, The MathWorks, Natick, MA, USA) and Psychtoolbox (Version 3.0.18; Kleiner et al., 2007). Trials began with the presentation of a central white fixation cross. Two square, trial-unique images (9 x 9 cm) were then presented simultaneously on either side of the fixation cross. The distance from the fixation point to the center of each image was 6cm. Images consisted of 1347 outdoor scenes and 1001 indoor scenes from the SUN image database (Xiao et al., 2016). Both the outdoor and indoor scenes were displayed in color. Additionally, 400 greyscale fractals, representing no specific scene, were displayed alongside the scene images (Ovalle-Fresa et al., 2022). Which side of the fixation cross the scene images were displayed on was random but balanced such that 50% of scene images were displayed on the left. All images were randomly presented to the participants.

Procedure

Participants completed a bilateral go/no-go task (**Fig. 1**) with periodic thought probes relating to their TUTs, effort, opportunity-cost and arousals. This continuous performance task included a real-time triggering protocol, which allowed us to control when probes were presented to the participants based on fluctuations in their objective attentional state throughout the experiment.

Continuous Performance Task

For each trial, a fixation cross appeared for 1000 milliseconds. Then, scene images were displayed on either side of the fixation cross for 500 milliseconds. Participants were instructed to categorize scenes as either outdoor or indoor. For instance, subjects were instructed to press the spacebar whenever an outdoor scene was displayed on the screen (go trials) and to withhold pressing the spacebar whenever an indoor scene was displayed on the screen (no-go trials). Go/no-go categories were counterbalanced among subjects. Go trials were displayed for 90% of trials and no-go trials were displayed for 10% of trials. Whether a go or no-go image was random with the exception that no-go trials were always followed by a go trial. All participants completed a short 30 trial practice session of the main task once before completing the task itself, which was 1200 trials. Response times (RT) were calculated as the time between when the image first appeared, and when the participant pressed the spacebar, were recorded at the conclusion of each trial.

Participants were also familiarized with and given a short explanation of each of the probes, though no probes were presented during the 30-trial practice session. Participants were instructed that the probes would appear every so often throughout the experiment but not told what triggered the probe appearance, so as not to influence their performance. When the probes were explained, we emphasized the fact that the questions referred to their current attentional state in the very instance of receiving the probe, rather than their general mood.

Real-time probe triggering based on attentional state

The reaction times calculated for each trial were used to track the participant's attentional state fluctuations in real time, which allowed us to control the frequency and timing of the probe appearances. As explained in the introduction, previous work has demonstrated that the variability of RT can be used to differentiate between high and low attentional states. Specifically, attention is split into in-the-zone periods of attention, reflected by relatively steady RTs, and out-of-the-zone periods of attention, reflected by highly variable RTs. The real-time designation of attentional states was calculated using an adapted version of the variance time course (VTC) state classification from Esterman et al. (2013). The VTC was calculated by taking the absolute deviance of the trial (absolute value of the z-scores) using the mean and standard deviation of RT from the previous trials. Trials with missing or unusable RT data, either due to a correct inhibition to a no-go trial or an erroneous press to a no-go trial, were excluded from RT calculation. Then, the VTC was smoothed by taking the mean of the previous 10 trials. The median of this smoothed VTC value was used to classify each trial. Trials were classified as either in-the-zone or out-of-the-zone depending on whether the absolute deviance of that trial fell above or below the median VTC, respectively. When a participant recorded 20 consecutive trials of either in-the-zone attention or out-of-the-zone attention, a series of probes were triggered. Once the probes were triggered, the number of consecutive attentional states ("counter") was reset. Additionally, the counter did not begin recording an attentional state until after the first 20 trials in the experiment were completed.

Once triggered, the following four self-report questions were displayed to participants in white text, each on consecutive screens with a grey background **(Figure 1)**:

1. **Task-related and task-unrelated thoughts.** Just before the interruption I was: 1) task focused (i.e., focusing on the task), 2) performance focused (i.e., focused on my performance on this task), 3) distracted by sights/sounds/physical sensations, 4) daydreaming; thinking about things unrelated to the task, 5) my mind is blank (Welhaf & Bugg, 2024).
2. **Effort.** On a scale from 0 (not at all) to 100 (extremely), please rate how effortful completing this task is to you at this very moment.
3. **Opportunity-cost**. On a scale from 0 (not at all) to 100 (extremely), please rate how much you would prefer to be completing other tasks (personal/professional) at this very moment.
4. **Arousal**. On a scale from 0 (sleepy) to 100 (alert), please rate how awake you are at this very moment.

For the first question, participants responded using the numbers 1-5 on the keyboard. For the subsequent three questions, participant's responses were recorded using a slider scale. The slider scales appeared on the same screen as the question with the value automatically appearing at 50. Participants were then able to adjust their corresponding numerical answer to each of the questions by using the left and right arrow keys, and then press the spacebar to confirm their answer. All four questions appeared in the order listed above. Following a response to the final probe, the task immediately resumed.

Data and Statistical Analysis

The percentage of commission errors was calculated as the number of errors on no-go trials divided by the total number of no-go trials. Mean reaction time was computed based on correct responses to go trials. For the subjective approach, these analyses were performed on the 10 trials preceding each probe. Given that no-go trials occurred on 10% of trials, this window allowed us to assess performance accuracy on no-go trials during on-task versus TUT periods. To examine which types of TUTs were associated with objectively defined out-of-the-zone periods, paired t-tests were conducted comparing the percentage of task-related and task-unrelated thought reports between in-the-zone and out-of-the-zone states. Similarly, paired t-tests were conducted to compare in-the-zone versus out-of-the-zone periods on self-reported effort, opportunity cost, and arousal. Conversely, to explore whether subjectively reported on-task and TUT periods differed in the percentage of time spent out of the zone and in other subjective reports, paired t-tests were also conducted. A two-tailed significance level of .05 was used for all tests.

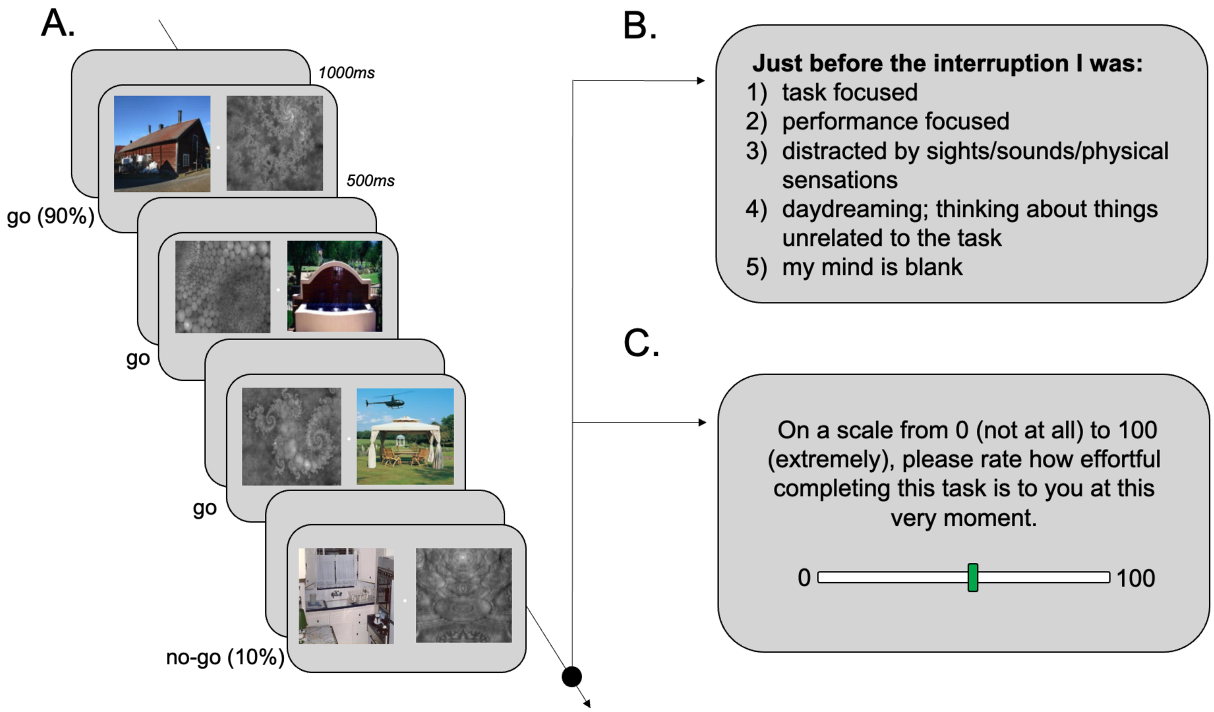

Figure 1. Bilateral go/no-go task with subjective probe. A. Participants were instructed to respond to outdoor scenes (go trials – 90%) and withhold their response to indoor scenes (no-go trials – 10%). Scene categories were counterbalanced across participants. B. Subjective probes assessed the type of task-unrelated thoughts experienced by participants. C. Additional probes measured other subjective experiences, such as perceived effort to perform the task.

RESULTS

Descriptive statistics

Participants reported experiencing task-unrelated thoughts 40.3% of the time (SE = 5.47). More precisely, participants reported being focused on the task 34.3% of the time (SE = 4.23), thinking about their performance 25.3% (SE = 3.83), distracted by external stimuli 8.6% (SE = 1.46), daydreaming 25.4% (SE = 4.80), and experiencing mind-blanking 6.4% (SE = 2.31).

Before reporting how many probes were associated with in-the-zone versus out-of-the-zone periods, we first sought to verify whether our real-time tracking of attentional states could distinguish periods of high versus low attention. A paired t-test on no-go errors revealed no significant difference between in-the-zone periods and out-of-the-zone periods, $t(25) = –0.83$, $p = .207$, $d = –0.17$, suggesting that our real-time approach did not successfully track objective attentional states. We therefore recalculated attentional states offline, following the approach used in previous studies (Esterman et al., 2013; Chidharom et al., 2025). The mean VTC values from the three trials preceding each probe were computed (deBettencourt et al., 2019). If the average value was above the median split of the VTC distribution, the corresponding probe was categorized as objectively out-of-the-zone; if it was below, the probe was categorized as in-the-zone. Using this procedure, 58.1% (SE = 1.91) of probes were classified as out-of-the-zone. For the remainder of the paper we thus define in-the-zone and out-of-the-zone probes based on the offline states calculation.

The discrepancy between online and offline calculations of objective attentional states may stem from the fact that the online method did not account for reaction time speeding, a common effect in CPTs (deBettencourt et al., 2018). Previous studies that used RT-based triggering to present stimuli during attentive or inattentive states addressed this time-on-task effect by removing the linear drift in RTs—from the beginning of the task up to the current trial—before inferring attentional state (deBettencourt et al., 2018). Future research could test whether this correction improves the consistency between online and offline state estimates.

Performance

Commission Errors

A paired t-test revealed that participants made significantly more no-go errors when they were out of the zone (M = 58.4%, SE = 3.55) compared to when they were in the zone (M = 51.3%, SE = 4.46), $t(25) = –3.68$, $p = .001$, $d = –0.72$ **(Figure 2A)**. Moreover, participants made significantly more no-go errors during TUT periods (M = 61.3%, SE = 6.32) compared to on-task periods (M = 45.9%, SE = 4.90), $t(24) = –2.77$, $p = .011$, d = –0.56 **(Figure 3A)**.

Reaction Times

The paired t-tests performed on reaction times revealed that participants were significantly faster during in-the-zone periods (M = 363 ms, SE = 12.7) compared to out-of-the-zone periods (M = 371 ms, SE = 13.5), $t(25) = –4.05$, $p < .001$, d = –0.80 **(Figure 2B)**. Conversely, reaction times were significantly slower during on-task periods (M = 386 ms, SE = 19.0) compared to TUT periods (M = 359 ms, SE = 19.2), $t(25) = 3.46$, $p = .002$, d = 0.68 **(Figure 3B)**.

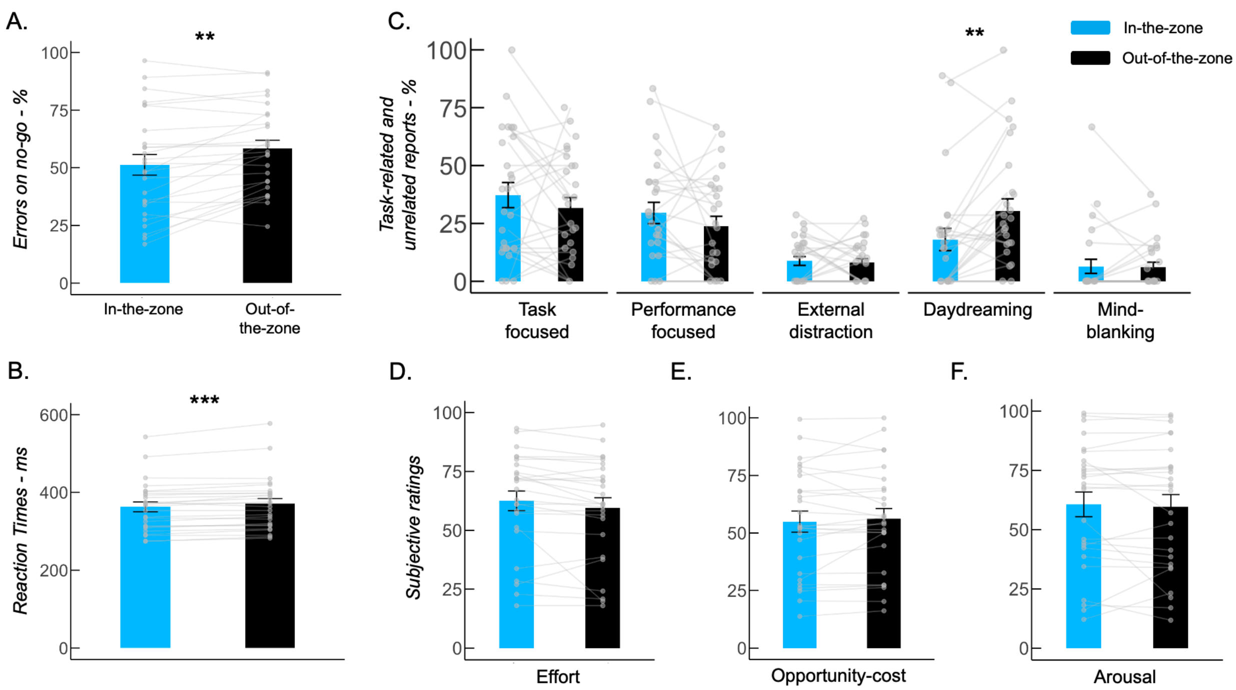

Figure 2. Results of the objective measures of attentional states (in-the-zone vs. out-of-the-zone). Effect of attentional states on no-go errors (A) and reaction times on correct go trials (B), as well as subjective reports of task-related and task-unrelated thoughts (C), in addition to other subjective reports concerning effort (D), opportunity cost (E), and arousal (F). Error bars represent the group-level standard error. **p < .01; ***p < .001.

Subjective reports during objective attentional states

To further address the question of whether a participant's subjective experience of task-unrelated thoughts corresponds with objective in-the-zone and out-of-the-zone attention fluctuations, we performed a paired t-test between subjective reports of task-unrelated thoughts. The results revealed that participants were significantly more likely to report task-unrelated thoughts during out-of-the-zone periods of attention (44.6%, SE = 5.95%) than during in-the-zone periods (33.2%, SE = 5.50%), $t(25) = -2.82$, $p = .009$, $d = -0.55$.

Breaking down participant responses even further, we performed paired t-tests to explore the extent to which objectively defined out-of-the-zone periods were associated with specific types of task-unrelated thoughts. First, participants did not report being significantly more focused on the task during in-the-zone periods (M = 37.2%, SE = 5.41) compared to out-of-the-zone periods (M = 31.6%, SE = 4.55), $t(25) = 1.11$, $p = .279$, $p_{\text{Bonferroni}} = 1$, $d = 0.22$. Similarly, participants did not report focusing more on their performance during in-the-zone periods (M = 29.5%, SE = 4.60) compared to out-of-the-zone periods (M = 23.8%, SE = 4.26), $t(25) = 1.34$, $p = .192$, $p_{\text{Bonferroni}} = .96$, $d = 0.26$. However, participants reported significantly more daydreaming during out-of-the-zone periods (M = 30.4%, SE = 5.21) compared to in-the-zone periods (M = 18.0%, SE = 4.80), $t(25) = -3.44$, $p = .002$, $p_{\text{Bonferroni}} = .01$, $d = -0.67$. Other types of subjective TUTs were not associated with objective attentional states. Specifically, participants did not report being more distracted during in-the-zone periods (M = 8.8%, SE = 1.90) than out-of-the-zone periods (M = 8.0%, SE = 1.73), $t(25) = 0.34$, $p = .740$, $p_{\text{Bonferroni}} = 1$, $d = 0.07$. Nor did participants report more mind-blanking during in-the-zone periods (M = 6.4%, SE = 3.05) compared to out-of-the-zone periods (M = 6.2%, SE = 2.07), $t(25) = 0.14$, $p = .889$, $p_{\text{Bonferroni}} = 1$, $d = 0.03$ **(Figure 2C)**.

We hypothesized that other subjective experiences might also be associated with objectively defined out-of-the-zone periods, including perceived effort, opportunity cost, and arousal. The paired t-test performed on subjective effort did not reveal a significant difference, suggesting that participants did not report exerting more effort during out-of-the-zone periods (M = 59.6%, SE = 4.25) compared to in-the-zone periods (M = 62.5%, SE = 4.18), $t(25) = 2.01$, $p = .055$, $d = 0.39$ **(Figure 2D)**. Similarly, participants did not report a greater desire to engage in alternative tasks (i.e., higher opportunity cost) during out-of-the-zone periods (M = 56.2%, SE = 4.43) compared to in-the-zone periods (M = 55.0%, SE = 4.58), $t(25) = –0.93$, $p = .363$, $d = –0.18$ **(Figure 2E)**. Finally, participants did not report feeling significantly more aroused during in-the-zone periods (M = 60.6%, SE = 5.22) compared to out-of-the-zone periods (M = 59.5%, SE = 5.26), $t(25) = 0.61$, $p = .550$, $d = 0.12$ **(Figure 2F)**.

Objective performance during subjective attentional states

In a complementary analysis, we also examined whether subjective TUT periods were associated with objectively defined out-of-the-zone states. The paired t-test revealed that participants spent significantly more time out of the zone during TUT periods (M = 55.8%, SE = 1.66) compared to on-task periods (M = 45.6%, SE = 1.85), $t(25) = –4.74$, $p < .001$, $d = –0.93$ **(Figure 3C)**. To explore this effect in more detail, an ANOVA was conducted on the percentage of time spent out of the zone as a function of the five types of subjective reports. The analysis revealed a significant main effect of subjective report type, $F(4, 16) = 3.08$, $p = .046$, $\eta^2_p = .435$. However, Bonferroni-corrected post-hoc comparisons did not reveal any statistically significant differences between conditions **(Figure 3D)**. This may be due, in part, to the low frequency of distraction and mind-blanking reports, which likely limits the reliability of comparisons involving these categories.

We also examined whether TUT periods were associated with other subjective experiences. We found that task-unrelated thought periods were associated with significantly lower arousal compared to on-task periods (M = 54.0%, SE = 5.57 vs. M = 66.3%, SE = 5.16), $t(25) = 4.59$, $p < .001$, $d = 0.90$ **(Figure 3G)**. However, participants did not report a significant change in perceived opportunity cost during task-unrelated thought periods (M = 57.0%, SE = 4.46) compared to on-task periods (M = 53.0%, SE = 4.40), $t(25) = –1.65$, $p = .111$, $d = –0.32$ **(Figure 3F)**. Participants also did not report exerting more effort during task-unrelated thought periods (M = 61.2%, SE = 4.08) compared to on-task periods (M = 61.5%, SE = 4.69), $t(25) = 0.09$, $p = .927$, $d = 0.02$ **(Figure 3E)**.

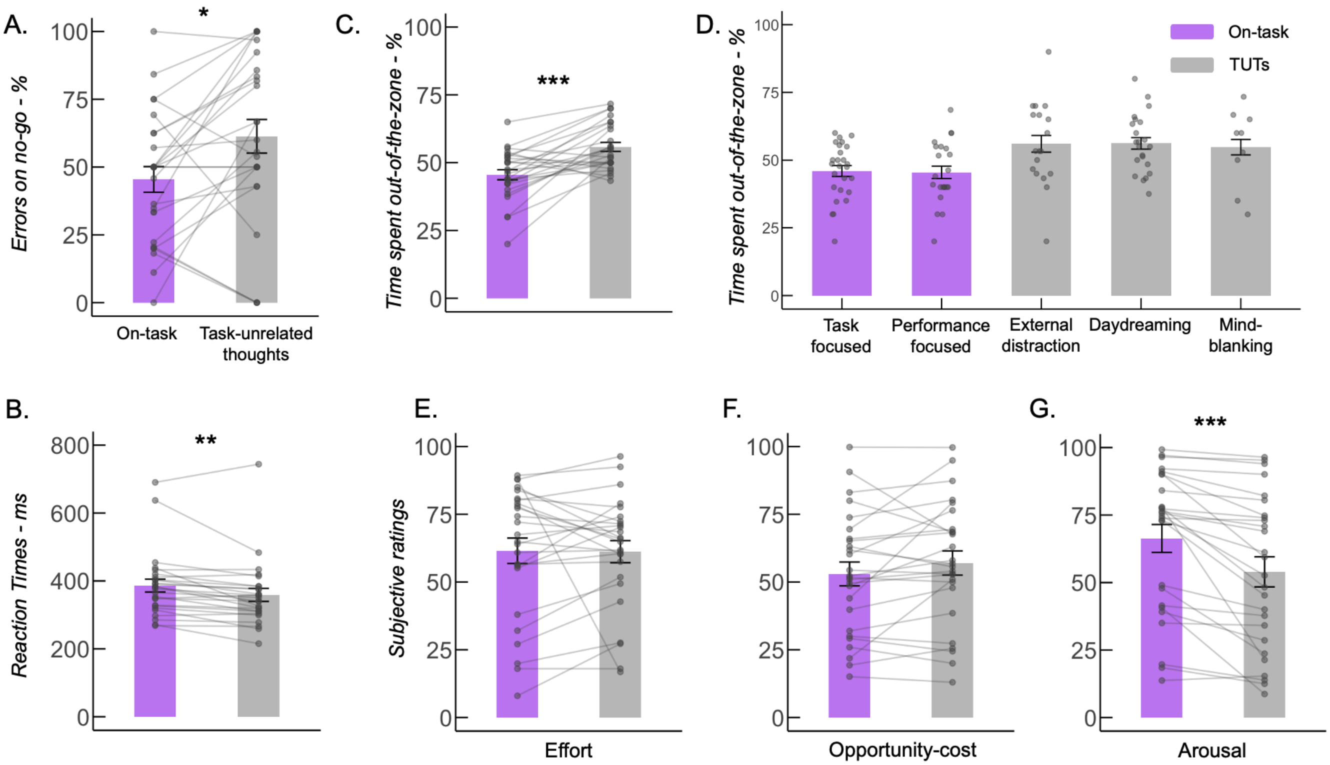

Figure 3. Results of the subjective measures of attentional states: on-task vs. task-unrelated thoughts (TUTs). Effect of attentional states on no-go errors (A) and reaction times on correct go trials (B), as well as the time spent out-of-the-zone (C-D), in addition to other subjective reports concerning effort (E), opportunity cost (F), and arousal (G). Error bars represent the group-level standard error. *p < .05; **p < .01; ***p < .001.

DISCUSSION

The aim of this study was to better characterize the subjective experiences underlying objectively defined periods of low and high attention. Our results showed that participants reported significantly more task-unrelated thoughts during out-of-the-zone periods compared to in-the-zone periods, supporting the consistency hypothesis, which posits that both methods capture the same attentional fluctuations. However, the inconsistency hypothesis—which suggests that periods of high variability are not necessarily underpinned by TUTs—is also supported by several findings. For instance, a mismatch between subjective and objective states was observed in reaction times: in-the-zone periods were associated with faster RTs, whereas subjectively on-task periods were linked to slower responses. Similarly, the two approaches diverged in their effects on arousal: arousal was reduced during TUT periods but did not differ between in- and out-of-the-zone periods. Taken together, some of these findings support the consistency hypothesis, suggesting that subjective and objective approaches to attentional fluctuations converge. However, other results align more with the inconsistency hypothesis, pointing to a more nuanced picture of how different methods capture attentional dynamics.

Our main finding suggests a consistency between subjective and objective approaches to studying attentional fluctuations. Specifically, we found that TUTs were more frequently reported during out-of-the-zone periods compared to in-the-zone periods. These results are in line with previous studies showing that increased reaction time variability is associated with TUTs (Anderson et al., 2021; Seli et al., 2013; Welhaf & Kane, 2024; Jalava & Wammes, 2024). However, this raises the question of why such consistency was not observed in Chidharom et al. (2025). One methodological explanation may lie in the structure of the task—specifically, the inter-trial interval (ITI). Indeed, the convergence between subjective and objective measures reported in prior studies and in the current one appears primarily when the ITI is fixed. In Chidharom et al. (2025), the ITI was variable, which may have reduced the likelihood of observing coherence between the two approaches. Future studies should be needed to test the effect of ITI on reaction time variability and TUTs reports.

In this study, we also aimed to further characterize the consistency between subjective and objective approaches by specifying the types of TUTs reported. We found that out-of-the-zone periods were more strongly associated with daydreaming, whereas other forms of task-unrelated thoughts, such as external distraction or mind-blanking, were not linked to objectively defined low-attention periods. This finding adds nuance to the consistency hypothesis and suggests that not all forms of subjective task-unrelated thoughts are necessarily associated with objectively low attention.

To explore whether other subjective experiences were associated with out-of-the-zone periods, we also asked participants to report on effort, opportunity cost, and arousal—factors that, according to prior literature, may be linked to periods of high reaction time variability. Our results showed that none of these subjective measures differed between in-the-zone and out-of-the-zone periods, suggesting that only daydreaming appears to co-fluctuate with reaction time variability.

Although these results taken together support the consistency hypothesis, several additional findings nuance this interpretation and instead lend support to the inconsistency hypothesis. First, the effects of subjective and objective approaches on performance are not always aligned. Indeed, while both subjectively defined TUT periods and objectively defined out-of-the-zone periods were associated with increased no-go errors, their effects on reaction times diverged. Reaction times were shorter during in-the-zone periods compared to out-of-the-zone periods.

According to the consistency hypothesis, one would expect a similar pattern, with shorter reaction times during on-task compared to TUT periods. However, our results showed the opposite: reaction times were slower during on-task periods than during TUT periods.

The second finding that supports the inconsistency hypothesis is the absence of any significant difference between in-the-zone and out-of-the-zone periods in terms of subjective on-task reports, including attention to the task and focus on performance. While out-of-the-zone periods were associated with increased daydreaming, in-the-zone periods were not specifically associated with task-related thoughts. This result suggests that the consistency hypothesis may apply primarily to low-attention states, where objective out-of-the-zone periods and subjective TUT reports converge, whereas the inconsistency hypothesis may better account for high-attention states, where objectively in-the-zone periods do not consistently align with subjectively reported on-task experiences.

A third finding supporting the inconsistency hypothesis concerns the differential patterns of arousal reports during subjectively defined TUT periods versus objectively defined out-of-the-zone periods. Specifically, we found that participants reported reduced arousal during TUT periods, whereas arousal levels did not differ between objectively defined in-the-zone and out-of-the-zone periods. This dissociation suggests that reduced arousal may contribute to the emergence of TUTs like previously suggested (Unsworth et al., 2018; Andrillon et al., 2021), while objectively out-of-the-zone periods may reflect low attention periods driven by other mechanisms.

LIMITATIONS

Several limitations of this study should be acknowledged. First, regarding self-reported TUTs, participants reported more frequent instances of daydreaming compared to external distraction or mind-blanking, which may limit the reliability of findings related to the latter two categories. It would therefore be valuable for future studies to replicate the absence of effects for these forms of TUTs in larger samples. Similarly, effort, opportunity cost, and arousal did not differ between in-the-zone and out-of-the-zone periods; however, this does not necessarily imply that these factors are unrelated to attentional fluctuations. It is possible that individual differences influence the degree of effort participants invest in sustained attention tasks, their perception of opportunity costs, or their arousal levels. Future research should explore these questions using interindividual approaches.

CONCLUSION

To conclude, this study highlights a partial consistency between subjective and objective approaches—most notably through the link between self-reported daydreaming and reaction time variability. It also reveals important points of inconsistency, particularly regarding on-task reports, arousal levels, and reaction times. We argue that subjective and objective measures of attention do not always reflect the same underlying processes and may instead capture distinct facets of attentional dynamics. Future research should aim to better characterize the differences between these two approaches in order to more precisely capture the fluctuations of sustained attention.

AUTHOR CONTRIBUTION

Samantha Bertschi: Conceptualization; data curation; formal analysis; investigation; methodology; validation; visualization; software; writing – original draft; writing – review & editing; **Edward K. Vogel:** Resources; funding acquisition; supervision; writing – review & editing; **Monica D. Rosenberg:** Resources; supervision; funding acquisition; project administration; writing – review & editing; **Matthieu Chidharom**: Conceptualization; data curation; formal analysis; methodology; software; validation; visualization; writing – original draft; writing – review & editing; project administration; supervision.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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TRANSPARENCY AND OPENNESS

All data, analysis code, and research materials are available at (https://osf.io/nmy6r/).

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