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ORIGINAL ARTICLE

Re-examining the effect of motivation on intentional and unintentional task-unrelated thought: accounting for thought constraint produces novel results

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Abstract
It has been proposed that motivating participants to perform well on a cognitive task ought to lead to decreases in rates of intentional, but not unintentional, task-unrelated thought (TUT; a commonly studied variety of mind wandering). However, at odds with this prediction, research has found that increasing motivation results in decreases in both intentional and unintentional TUTs. One possible explanation for this surprising finding is that standard assessments of TUT may inadvertently conflate TUTs with another variety of mind wandering: unconstrained thought. If so, then deconfounding task-unrelated and unconstrained varieties of mind wandering might produce the predicted effect of a decrease in intentional, but not unintentional, TUT when motivation is increased. To explore this possibility, in the present study, participants completed a sustained-attention task after receiving standard instructions (normal-motivation condition) or instructions informing them that they could leave the study early if they achieved a certain level of performance (motivated condition). Throughout the task, we assessed rates of TUT (both intentional and unintentional) and unconstrained thoughts. Consistent with prior work, the results indicated that motivated participants reported being on-task significantly more frequently than non-motivated participants. However, unlike previous work, we found that when deconfounding TUTs and unconstrained thoughts, participants in the motivation condition reported significantly fewer bouts of intentional TUT than those in the non-motivation condition, but no differences in rates of unintentional TUT were observed between groups. These results suggest that (a) motivation specifically targets intentional TUT and (b) standard assessments of TUT conflate task-relatedness and thought constraint.

Introduction

In this article, we report a follow-up investigation of a rather curious finding—one that we documented last year (Seli, Schacter, Risko & Smilek, 2019)—regarding the influence of task-related motivation on rates of mind wandering. In the context of that work, we defined 'mind wandering' as a mental state in which the mind is engaged with thoughts that are peripheral to, or even completely disconnected from, the primary task at hand (i.e., task-unrelated thoughts; TUTs, Smallwood & Schooler, 2006). Following Giambra (1995), we also distinguished between unintentional TUT, which occurs spontaneously, despite a person's best attempts to remain focused on the task at hand, and intentional TUT, which occurs when an individual deliberately engages in off-task thought (e.g., Seli, Risko & Smilek, 2016; Seli, Wammes, Risko & Smilek, 2016; Seli, Risko, Smilek & Schacter, 2016). Our prior work (Seli et al., 2019) showed that increasing participants' task-related motivation through instruction-based incentives reduced rates of both intentional and unintentional TUT. Yet, upon closer reflection, the finding that increasing motivation influenced unintentional TUT (rather than just intentional TUT) is peculiar because modulating task engagement based on motivational instructions ought to influence controlled (intentional) processes, and not processes that are unintentional and outside of one's control. Here, we explore the possibility that this curious finding might be, at least in part, due to the nature of the TUT measure we employed. Before describing our study in more detail, we first offer a brief conceptual context for our investigation.

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Intentional and unintentional inattention

A naïve reader of the literature on human inattention might conclude that people have little control over their rates of inattention, despite their best intentions to remain focused on a particular task. This conclusion might be drawn in part because researchers often assume that, while completing standard laboratory tasks, participants intend to fully focus on the assigned task. The common assumption is that inattention occurs because cognitive control fails and, consequently, automatic processes are free to drive selective attention. Indeed, distractors are said to automatically capture attention (e.g., Theeuwes, 1994,2004), and episodes of off-task thought have been attributed to—if not defined as—failures of cognitive control (e.g., McVay & Kane, 2010). However, what has been largely neglected until recently (with a few notable historical exceptions; e.g., Giambra, 1995; Seli, Carriere, & Smilek, 2015), is that in many laboratory situations, inattention may also occur—and might even often occur—because participants have intentionally decided to direct their attention away from the prescribed task.

Consistent with this view, in the context of media multitasking, it has been shown that people will voluntarily engage with a task-unrelated media stream even to the detriment of their performance on a primary laboratory task. For example, Ralph et al. (2018 Experiment 2) had participants complete a 0-back (easy) or 2-back (difficult) working-memory task with and without the option to press a key to turn on (and off) a video that could be viewed above the task stimuli. Participants were informed that the video was unrelated to the task and that they could view it voluntary. Among other things, Ralph et al. found that many participants voluntarily turned on the task-unrelated video during the task, even though they reported that such media multitasking generally degraded task performance. Going beyond the laboratory, the foregoing findings are consistent with studies documenting (sometimes detrimental) voluntary media-multitasking in real world situations (e.g., people will deliberately use their smartphones or laptops during an undergraduate lecture; Anshari, Almunawar, Shahrill, Wicaksono & Huda, 2017; McCoy, 2016; Wammes et al., 2019). Thus, in the context of media multitasking, intentional inattention is not uncommon.

Investigations of the TUT variety of mind wandering have also revealed (sometimes) high rates of intentional inattention during various laboratory and real-world tasks (e.g., Seli, Risko & Smilek, 2016; Wammes et al., 2016). For example, Seli, Risko, and Smilek (2016) had participants complete an easy or difficult version of the Sustained Attention to Response Task (SART; Robertson et al. 1997), and intermittently asked them whether their thoughts were on task, unintentionally wandering, or intentionally wandering. For participants completing the easy version of the SART, Seli, Risko, et al. found higher rates of intentional TUT, whereas for those completing the difficult version, they found higher rates of unintentional TUT. Moreover, in live undergraduate lectures, it has been suggested that the lion's share of TUT may be intentional (intentional MW = 19%; unintentional MW = 14%; Wammes et al., 2016). Taken together, these findings suggest that TUTs can comprise another form of intentional inattention.

Motivation and intentional inattention

The fact that TUT can occur intentionally has important implications for interventions designed to prevent inattention. One such intervention targeting intentional inattention involves increasing task-related motivation. Specifically, motivation levels have been linked to levels of inattention in a variety of contexts (Robison & Unsworth, 2018; Seli, Wammes et al., 2016; Seli, Cheyne et al., 2015; Wammes et al., 2016; Unsworth & McMillan, 2013), and directly increasing motivation to perform a task via incentives has been shown to reduce inattention (Mrazek et al., 2012; Antrobus, Singer & Greenberg, 1966). The intuitive notion here is that increasing task-related motivation might influence the engagement of voluntary control processes that would decrease inattention, help to maintain focus on a prescribed task, and thus improve task performance (Seli, Risko, Smilek & Schacter, 2016).

One context in which this explanation appears to be relevant is in the aforementioned context of volitional media multitasking. In situations wherein media multitasking is allowed, increased task-related motivation is associated with reduced voluntary engagement in media multitasking. For example, Calderwood, Ackerman, and Conklin (2014) found that students reporting greater motivation to learn during a study session engaged with task-unrelated media less frequently than their less motivated counterparts. Relatedly, Wammes, Ralph, et al. (2019) found that self-reports of motivation at the beginning of the academic term were correlated with a decreased tendency to media-multitask during lectures. Building on these correlational findings Ralph, Smith, Seli and Smilek (2019) provided experimental evidence to support the notion that increases in task-related motivation reduce volitional media multitasking. Ralph et al. used the media multitasking paradigm described earlier, wherein participants completed an attention task during which they were allowed to press a key to turn on (and off) a video that would appear in the upper portion of the screen, above the task-relevant stimuli. Motivation was manipulated via task instructions: whereas half of the participants (the motivated group) were informed that they could leave the experiment early if, partway through the task, they had achieved a high level of performance, the other half of the participants (the Control group) were not given this option. The results showed that participants in the Motivated group were less likely to have the video on (i.e., they were less likely to media multitask) than those in the Control group. Moreover, task performance in the motivated group was also better than in the Control group. These findings suggest that increasing task-based motivation (causally) reduces intentional inattention.

A similar conclusion has been forwarded in the context of mind-wandering (i.e., TUT) research. Seli et al. (2019) had participants complete a sustained-attention task that involved pressing a button on the keyboard in synchrony with a rhythmic auditory tone (the Metronome Response Task; MRT; Seli, Cheyne, & Smilek, 2013). Intermittently throughout experimental session, the task was paused and participants were presented with a thought probe asking them to report the locus of their attention just before the task was interrupted. Specifically, participants were asked to indicate whether they were (a) focused on the task, (b) intentionally engaged in TUT, or (c) unintentionally engaged in TUT (Seli et al., 2019). Critically, half of the participants were told that if, partway through the task, their MRT performance was sufficiently high, they could leave the experiment early (the Motivated Group); the other half of the participants (the Control Group) were given no such instruction. As expected, the results showed that, relative to those in the Control group, participants in the motivated group reported fewer bouts of *intentional* TUT. As with the abovementioned media multitasking research, Seli et al.'s findings indicate that increasing motivation can reduce intentional inattention.

Motivation and unintentional inattention

Although the finding that increasing motivation led to decreases in intentional TUT was consistent with Seli et al.'s (2019) theorizing, there was an aspect of their results that was less straightforward and somewhat puzzling: they found that, in addition to showing that the motivational instructions (relative to standard instructions) reduced intentional TUT, the motivational instructions also reduced levels of unintentional TUT. In fact, the motivational instructions led to equivalent decreases in both intentional and unintentional TUT. As we noted at the outset this article, this finding appears to be counterintuitive because one would assume that motivation ought to influence controlled processes (intentional TUT), but have relatively little (if any) influence on uncontrolled processes (unintentional TUT). One possible explanation for Seli et al.'s puzzling finding is that increasing motivation strengthens the grip of attention on the primary task, thereby making one more resistant to thoughts that arise, regardless of intentionally. Another possibility, however, is that participants' judgments of their intentionality of TUT might be contaminated by another characteristic of mind wandering, such as the degree of constraint they are exerting over their thoughts (Christoff et al. 2016; Mills et al. 2018).

Expanding on this latter possibility, Christoff et al (2018) recently argued that mind wandering involves "thoughts [that] arise and proceed in a relatively, free, unconstrained fashion" (p. 958; Box 1). They further suggest that thought constraint (i.e., the extent to which thoughts are freely moving) is the key definitional characteristic of mind wandering (but see Seli, Kane, Metzinger, et al., 2018; Seli, Kane, Smallwood, et al., 2018). Among other things, studies conducted by Mills et al. (2018) have found that participants frequently report that their off-task thoughts (TUTs) were also unconstrained (see also Brosowsky et al. 2020; O'Neill et al., 2020). This interesting observation might have some bearing on people's reports of TUT intentionality. Specifically, this observation raises the possibility that when participants are asked only about the intentionality of their TUT (and not about thought constraint), they might misconstrue the question and inaccurately report moments of unconstrained thought as instances of unintentional TUT. In other words, when participants are not given the option of reporting on TUT intentionality and thought constraint as separate dimensions, they might conflate episodes of unconstrained thoughts with episodes of unintentional TUT. This may be because instructions used in previous research have not differentiated between agency of thought (intentionality) and the degree to which thoughts flow freely (thought constraint). As such, people may infer the intentionality of their TUT from how constrained their thoughts are. For example, during a bout of unconstrained thought, one's thoughts "flow with ease" (Mills et al., 2018, p. 27), and a participant may report this experience as unintentional TUT, even if that participant had in fact intentionally engaged in TUT.

This possibility is important to consider given recent findings demonstrating that the intentionality and the constraint dimensions of TUT are dissociable (see O'Neill et al., 2020). The possibility that participants misconstrued the thought–probe question in our previous study (Seli et al., 2019) might explain why we found that an instruction-based motivation manipulation reduced unintentional TUT: It could be that increasing motivation via instructions reduces rates of unconstrained thought, but not unintentional TUT. However, because participants in our previous study were not given the opportunity to report on their levels of thought constraint, if they did indeed experience a potential reduction in unconstrained thoughts, this might have manifested in terms of decreased reports of unintentional TUT.

The present study

To explore this more nuanced explanation of the influence of an instruction-based motivation manipulation on rates of (un)intentional TUT, we conducted a study in which participants had the opportunity to report on both the intentionality of their TUTs and thought constraint. As in Seli et al. (2019), participants completed the MRT (Seli, Cheyne, & Smilek, 2013) after being told that they could (a) leave the experiment after completing the task (the Standard group) or (b) leave the experiment early if they achieved a certain (unspecified) level of performance on task, while still receiving full remuneration (the Motivated group; see Seli et al., 2019). Throughout the task, participants were intermittently presented thought probes asking them to report whether their thoughts were on task, intentionally focused on task-unrelated content, or unintentionally focused on task-unrelated content (Seli, Cheyne, Xu, Purdon, & Smilek, 2015). After providing a response to this first question, participants were prompted to indicate whether their thoughts were freely moving (unconstrained) or not (constrained; as per Mills, Raffaelli, et al., 2018). We reasoned that the inclusion of a question assessing unconstrained thought would allow participants to disentangle the dimension of intentionality from the dimension of thought constraint and, consequently, reduce the number of instances in which participants conflate the two. With a less-contaminated measure of TUT intentionality, we hypothesized that—in contrast to Seli et al. (2019) results—the present study would show that the motivation manipulation would influence rates of intentional TUT, but not rates of unintentional TUT. In addition, we hypothesized that, thought constraint may be greater when participants are motivated to focus on the task, because thoughts would be more constrained to the task at hand; as such, compared to those in the Standard group, those in the Motivated group should report fewer instances of unconstrained thought.

Method

We report how we determined our sample size, all manipulations, all measures, and all data exclusions in this study. Anonymized data and data analysis code are available on OSF (https://osf.io/3jqcr/).

Participants

It was determined, in advance, that we would aim to collect data from 250 participants, as this is a reasonably large sample for between-subject comparisons and would allow us to detect small-to-medium sized effects with relatively high power. In total, 259 undergraduate students from the University of Waterloo participated in exchange for partial course credit, with 128 participants in the Standard group ($M_{age\,=}$ 20, 125 female, 1 non-binary) and 131 participants in the Motivated group ($M_{age\,=}$ 20, 121 female, 1 non-binary). No data were removed from the subsequent analyses. We typically exclude participants who omit 10% or greater of the MRT trials (e.g., Seli et al., 2013; Seli, Jonker, Cheyne, Cortes, & Smilek, 2015), here, as in Seli et al. (2019), however, we reasoned that our motivation manipulation might influence omission rates and as such we did not exclude any participants.

The metronome response task (MRT)

The MRT (Seli et al., 2013) is a sustained-attention task in which participants monitor a sequence of tones and are required to provide a key press in synchrony with the tone. The rationale behind the MRT is that, during periods of TUT, participants' estimation of the onset of each tone will be hindered, and key-press responses will be more variable. Consistent with this view, numerous previous studies have found that self-reports of TUT during the MRT are positively associated with response variability (Seli, Cheyne & Smilek, 2013; Seli, Carriere et al., 2014), and that, during self-reported periods of TUT (5-trial windows), participants' response variability tends to be higher than it is during self-reported periods of on-task focus (Seli, Cheyne & Smilek, 2013; Seli, Carriere et al., 2014).

As in previous work (e.g., Seli, Cheyne, & Smilek, 2013), each MRT trial began with 650 ms of silence, followed by presentation of a tone lasting 75 ms, followed by a further 575 ms of silence. Each trial was therefore 1300 ms in duration. Participants were instructed to press the spacebar synchronously with the onset of each tone, such that their responses were made at the exact time at which each tone was presented. Participants completed 18 practice trials, followed by 900 experimental trials.

Manipulation of task-related motivation

Following Seli et al. (2019), task-related motivation was manipulated between groups following the practice trials at the beginning of the experiment. Task-related motivation was manipulated by varying the presence of a performance-contingent reward. Consistent with prior literature (e.g., Seli et al., 2019), while we acknowledge that there may be considerable individual differences in participants' internal motivations, we assumed that our experimentally induced performance-contingent reward manipulation would be effective at modulating task-related motivation for the bulk of our participants. Specifically, participants were randomly assigned to a Motivated or Standard group. Participants in the Standard group received a standard set of instructions (outlined above) on how to complete the MRT. Participants in the motivated group were provided the same standard set of instructions, but were additionally informed that they could leave the study early if they achieved a certain (unspecified) level of performance while still receiving full credit. The motivation instructions presented to participants in the motivated group were as follows:

> "The practice trials are now over.
> Before you begin, there is one more thing you should know. As you know, this task will take approximately 1 h to complete. However, depending on how well you do on the task, you may be able to leave about halfway through the task while still earning the full credit.
> To determine whether you get to leave early, during the task, the computer will monitor your performance on the task. After about 30 min, the task will temporarily stop, and the computer will compute your overall performance on the task up until that point, and then you will be notified if you have achieved a high enough level of performance to be let out of the study early while still receiving the full participation credit. If you do not achieve a high enough level of performance on the task, then you will have to complete the task for an additional 30 min, for a total time of nearly 1 h, as initially stated on SONA.[1]
> Do you have any questions?"

As in Seli et al. (2019), one concern with these instructions was that they may lead participants to falsely report that they were "on task," in cases wherein they were actually engaging in TUT, so that they could deceive the researcher into thinking they achieved a high level of performance and, consequently, leave the experiment early. As in Seli et al., we addressed this concern by presenting additional instructions to participants in the motivated group:

> ''One thing that is very important to note is that your responses to the thought-sampling questions will NOT be used determine whether you get to finish the study early or not; only your performance on the task will matter when we decide whether to let you leave early or not, so please be completely honest when responding to each of the thought-sampling questions."

Because these instructions potentially primed participants in the Motivated group to respond more honestly to the thought probes (Vinski & Watter, 2012), we presented participants in the Control group a similar instruction:

> ''Please be completely honest when responding to each of the thought-sampling questions.''

Regardless of the group, all participants completed the experiment for the same duration (approximately 25 min).

Motivation probe

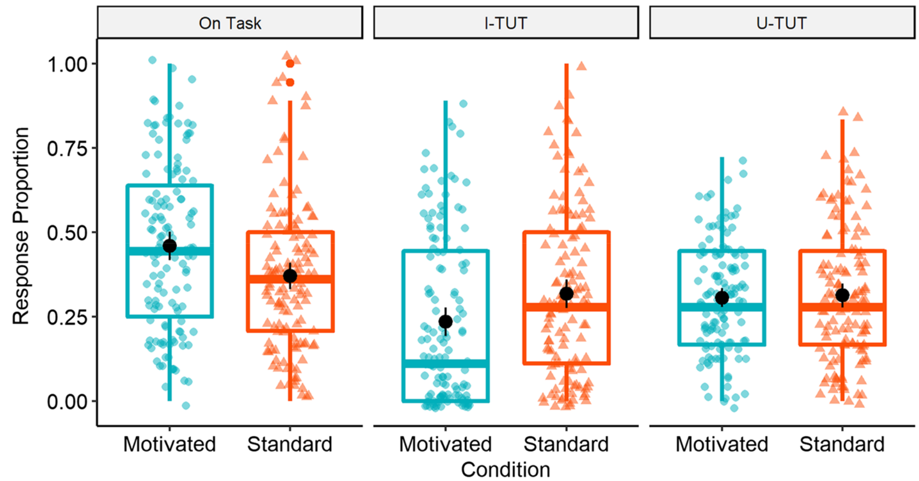
We included two probes of task-related motivation as a manipulation check to verify that participants in the Motivated group were in fact more motivated to perform well on the task than participants in the Control group (as in Seli et al., 2019). The first motivation probe was presented prior to the experimental trials (after the motivation-related instructions were given), whereas the second motivation probe was presented at the end of the experimental trials. Participants were asked to respond to the question, "How motivated [are/were] you to do well on the primary task?" on a 7-point scale, with response options ranging from (1) "Not Motivated at All" to (7) "Very Motivated" (Seli, Cheyne, Xu, et al., 2015).

Thought probes

Throughout the MRT, TUT, and its intentionality, were sampled using intermittent thought probes. Participants were presented one probe during the MRT practice trials, and eighteen probes during the experimental trials. When a probe was presented, the MRT stopped and the participant was presented with the following instruction: "Just prior to the onset of this screen, I was:" The possible response options were: "(1) Focused on the task," "(2) Not focused on the task, but I was trying to focus on it" (i.e., unintentional TUT) or "(3) Not focused on the task, but I was not trying to focus on it" (i.e., intentional TUT; O'Neill et al., 2020). Participants were instructed to click on the option that best characterized their mental state just prior to the probe. After responding, participants were then asked to report on whether their thought constraint: "The thoughts I was experiencing were moving freely: (1) Yes or (2) No." After responding to this second question, the probe disappeared and the MRT resumed.

[1] In the Motivated group, to meet the performance criterion for leaving the experiment early, participants merely had to respond (via a spacebar press) to at least one of the 900 MRT tones (Seli et al., 2019). All participants met and surpassed this criterion and were therefore allowed to leave the experiment early (after completing 900 MRT trials). Participants in the Control group were informed, after completing 900 MRT trials, that they could leave the experiment early, irrespective of their performance on the MRT (although all of these participants likewise met and surpassed the criterion that we had set for the Motived group).

Fig. 1 Proportion of reports of on-task focus, intentional TUT (I-TUT), and unintentional TUT (U-TUT) in the motivated and standard groups (grouped by response)



Results

Approach to analyses

All analyses were performed in R (R Core Team 2019). We used the afex, car, and ez packages to perform the Null Hypothesis Significance Tests (Singmann et al. 2019; Fox and Weisberg 2019) and the BayesFactor package to perform Bayesian analyses (Morey and Rouder 2018). A custom script was written to perform a non-parametric randomization test (Howell 2012) on the thought probe responses.

We supplemented each of the Null Hypothesis Tests with Bayes Factor analyses (Rouder et al. 2009). Using conventional frequentist testing, it is not possible to quantify the evidence for a null effect. A Bayes Factor is a continuous measure of the relative strength of evidence for one model over another and can quantify the evidence in favor of the null over the alternative hypothesis (Dienes 2014; Rouder et al. 2009). All Bayesian analyses were performed using the R package BayesFactor, and Bayes Factors (BFs) were calculated using its default settings (Morey & Rouder, 2018). BF_{10} indicates evidence in favor of the alternative hypothesis, whereas BF_{01} indicates evidence in favor of the null hypothesis. For simplicity, we report the Bayes Factor in the direction the data supports (e.g., BF_{01} when there is more evidence in favor of the null over alternative hypothesis). We refer to $BF > 3$ as "moderate" and $BF > 10$ as "strong" evidence, as per prior recommendations (Jeffreys 1961; Rouder et al. 2009).

Finally, it is worth noting that the dependent measure in the task-unrelated thoughts analysis is ipsative (i.e., proportions sum to 1) and violate assumptions typically required for an Analysis of Variance (ANOVA). However, ANOVA has been shown to be robust against violations of assumptions resulting from ipsativity: this is particularly true when the Greenhouse–Geisser correction is applied, as we have done here (Greer and Dunlap 1997). Moreover, to corroborate the results of the ANOVA, we also report a non-parametric randomization test that does not rely on assumptions about the underlying statistical distribution and can be applied even if parametric conditions are not met (Howell 2012). The empirical null distribution was estimated using the following randomization procedure: first, we randomized proportion scores within-subjects; second, we randomized participants between-groups; third, we calculated the F value using the randomized data. We performed 10,000 iterations of this procedure and calculated the probability of obtaining the observed F value (from the conventional ANOVA) under the null distribution (Fig. 1).

Manipulation check

To ensure that participants in the motivated group had greater motivation than those in the Standard group, we conducted a mixed repeated-measures analysis of variance (ANOVA). Motivation probe timing (pre-experiment, post-experiment) was entered as the within-subject factor, and group (Motivated, Standard) was entered as the between-subject factor. Ratings of motivation, we entered as the dependent measure. Validating the motivation manipulation, there was a main effect of group, $F(1, 257) = 20.18$, $MSE = 3.16$, $p < 0.001$, $\hat{\eta}_p^2 = 0.07$, such that individuals in the Motivated group reported greater overall motivation than those in the Standard group. There was also a main effect of motivation probe timing, $F(1, 257) = 28.84$, $MSE = 0.65$ $p < 0.001$, $\hat{\eta}_p^2 = 0.01$, indicating that participants were less motivated at the end of the experiment compared to the beginning. There was also a group by motivation probe timing interaction, $F(1, 257) = 5.53$, $MSE = 0.65$ $p = 0.019$, $\hat{\eta}_p^2 = 0.02$.

Post hoc tests indicated the Motivated group was significantly more motivated than the Standard group at the beginning of the experiment (after receiving the motivation-related instructions but before beginning the experimental

Table 1 Mean reports of pre-experimental and post-experimental motivation and motivational change by group

Group	Pre-experiment motivation	Post-experiment motivation	Motivation change (post–pre)
Motivated	5.50 (1.31)	5.28 (1.35)	− 0.21 (1.16)
Standard	4.96 (1.32)	4.41 (1.53)	− 0.55 (1.12)

Brackets denote standard deviation

trials; $t(257) = 3.28$, $p = 0.001$, $d = -0.41$, 95% CI [−0.65, − 0.16], with strong evidence in favor of the alternative hypothesis, $BF_{10} = 20.73$), and after completing the experimental trials ($t(257) = 4.83$, $p < 0.001$, $d = -0.60$, 95% CI [−0.85, − 0.35], with strong evidence in favor of the alternative hypothesis, $BF_{10} = 6340.27$). When comparing the motivational change from pre- to post-experiment, *t* tests revealed a greater decrease in motivation in the Standard group as compared to the Motivated group, $t(257) = 2.35$, $p = 0.02$, $d = -0.29$, 95% CI [−0.54, − 0.05], with anecdotal evidence in favor of the alternative hypothesis, $BF_{10} = 1.85$ (see Table 1).

Task-unrelated thoughts

Of particular interest was whether motivational cues influenced the relative amount of time participants spent on-task versus intentionally or unintentionally engaging in TUT. To examine this, we submitted thought–probe response proportions to a mixed ANOVA with probe response (on-task, intentional TUT, and unintentional TUT) as the within-subjects factor and motivation (Motivated and Standard groups) as the between-subjects factor. The mixed ANOVA revealed a significant interaction between motivation and probe response, $F(1.8, 463.11) = 6.39$, MSE = 0.08, $p = 0.003$, $\hat{\eta}_p^2 = 0.024$, 90% CI [0.01, 0.05]. This was corroborated by a non-parametric randomization test (see "Approach to analyses" above), which also revealed a significant interaction, $p = 0.0012$. For completeness, the main effect of probe response was significant, $F(1.8, 463.11) = 18.19$, MSE = 0.08, $p < 0.001$, $\hat{\eta}_p^2 = 0.066$, 90% CI [0.03, 0.1], and the main effect of motivation was non-significant, $F(1, 257) < 0.01$, $MSE = 0.00$, $p > 0.999$, $\hat{\eta}_p^2 < 0.001$, 90% CI [0, < 0.001].

To further analyze the interaction, we performed follow-up tests comparing the Motivated to Standard group within each probe response. We found a significantly higher proportion of on-task reports in the Motivated group ($M = 0.46$) as compared to the Standard group ($M = 0.37$), $t(257) = 3.03$, $p = .003$, $d = 0.38$, 95% CI [0.13, 0.62], with moderate to strong evidence in favor of the alternative, $BF_{10} = 9.99$. We used a Benjamini–Hochberg correction to control for multiple comparisons. After this correction, this difference remained significant ($p < p$ critical = 0.017). There was also a significantly lower proportion of intentional TUTs in the Motivated ($M = 0.23$) than in the Standard group ($M = 0.32$), $t(257) = -2.71$, $p = 0.007$, $d = -0.34$, 95% CI [− 0.58, − 0.09], with moderate evidence in favor of the alternative, $BF_{10} = 4.27$. Following the Benjamini–Hochberg correction, the difference remained significant ($p < p$ critical = 0.033). Finally, there was no difference in the proportion of unintentional TUT between the Motivated ($M = 0.31$) and Standard groups ($M = 0.31$), $t(257) = -0.28$, $p = 0.781$, $d = -0.03$, 95% CI [− 0.28, 0.21], with moderate evidence in favor of the null hypothesis, $BF_{01} = 7.07$.

Therefore, we found that increasing motivation leads to increased reports of on-task thought and decreased reports of intentional TUT. However, we found in differences in reports of unintentional TUT between groups.

Thought constraint

To examine how thought constraint differed across groups, we first analyzed the difference in overall proportion of unconstrained thought across groups, then we analyzed all the pairwise contrasts between groups (see Table 2). For the pairwise comparisons, we used the Benjamini–Hochberg correction to adjust for multiple comparisons. As with the

Table 2 The mean proportion of on-task, intentional and unintentional TUT probe responses (taken as a proportion of all thought probe responses) as a function of thought constraint by motivation group (brackets indicate standard deviation)

TUT probe response	Thought constraint response	Motivated group	Standard group	Thought constraint difference (standard—motivated)
On task	Unconstrained	0.19 (0.21)	0.19 (0.19)	0.00
	Constrained	0.26 (0.24)	0.18 (0.20)	− 0.08*
Intentional TUT	Unconstrained	0.18 (0.21)	0.27 (0.23)	0.09*
	Constrained	0.05 (0.10)	0.05 (0.08)	0.00
Unintentional TUT	Unconstrained	0.26 (0.16)	0.26 (0.20)	0.00
	Constrained	0.05 (0.07)	0.05 (0.08)	0.00

*Indicates significant differences between groups after controlling for multiple comparisons previous analyses, we also supplement each Null Hypothesis test with a corresponding Bayesian analysis.

Overall thought constraint and motivation

First, we examined the difference in thought constraint between groups by examining the proportion of probe responses in which participants indicated that their thoughts were constrained or unconstrained. There was significantly higher proportion of unconstrained thoughts in the Standard group ($M = 0.72$) than the Motivated group ($M = 0.63$), $t(257) = -2.88$, $p = 0.004$, $d = -0.36$, 95% CI [0.11, 0.60], with moderate evidence in favor of the alternative hypothesis, $BF_{10} = 6.57$.

On-task thought and thought constraint

For on-task reports, there was no difference in unconstrained thought between groups, $t(257) = 0.08$, $p = 0.937$, $d = -0.01$, 95% CI [−0.25, 0.23], with moderate evidence in favor of the null hypothesis, $BF_{01} = 7.14$). There was however, a significant difference in constrained thought, $t(257) = 3.17$, $p = 0.002$, $d = -0.39$, 95% CI [−0.64, −0.15], with strong evidence in favor of the alternative hypothesis, $BF_{10} = 15.19$. Specifically, those in the Motivated group reported more on task thought that was constrained than those in the Standard group. After the Benjamini–Hochberg correction, this difference remained significant ($p < p$ critical $= 0.02$).

Unintentional TUTs and thought constraint

Motivation did not influence rates of unconstrained thought during bouts of unintentional TUT, $t(257) = -0.23$, $p = 0.819$, $d = 0.03$, 95% CI [−0.22, 0.27], and there was moderate evidence in favor of the null hypothesis, $BF_{01} = 7.19$. There were also no differences were detected between groups in unintentional TUTs that were constrained, $t(257) = -0.13$, $p = 0.897$, $d = 0.02$, 95% CI [−0.23, 0.26], and there was moderate evidence in favor of the null hypothesis, $BF_{01} = 7.23$.

Intentional TUTs and thought constraint

Interestingly, as motivation increased, unconstrained thoughts were less common during intentional TUT, $t(257) = -3.14$, $p = 0.002$, $d = 0.39$, 95% CI [0.14, 0.63], with strong evidence in favor of the alternative hypothesis $BF_{10} = 13.89$. Following the Benjamini–Hochberg correction, this difference remained significant ($p < p$ critical $= 0.008$). However, there was no difference between groups in intentional TUT that was constrained, $t(257) = 0.356$, $p = 0.722$, $d = -0.04$, 95% CI [−0.29, 0.20], and there was moderate evidence in favor of the null hypothesis, $BF_{01} = 6.90$.

Thus, we found increasing motivation led to less unconstrained thought overall. During on-task thought, the motivated group reported more constrained thought than the Standard group. No differences were found between groups on unconstrained thought that was on-task. Increasing motivation did not influence constrained or unconstrained thought during unintentional TUT. However, the motivated group reported less unconstrained thought during intentional TUT than the Standard group, while no differences were observed between groups on constrained thought.

Discussion

The primary goal of this study was to investigate how a motivation manipulation would influence reports of TUT intentionality with the addition of a thought probe assessing thought constraint (or freely moving thought). Contrary to our previous findings (when thought constraint was not measured; Seli et al., 2019), in the present study (in which we measured thought constraint) we found that increasing task-based motivation specifically decreased intentional TUT, but not unintentional TUT. These findings are consistent with notion that when people are given the opportunity to report on both the intentionality and the degree of thought constraint, they are able to distinguish these two dimensions of thought and provide less contaminated reports of TUT intentionality. Under these conditions, the previously puzzling finding (that increasing motivation reduces unintentional TUT; Seli et al., 2019) was no longer observed.

These findings have several important implications beyond qualifying the counterintuitive results reported by Seli et al., (2019). First, they provide another important demonstration that intentional and unintentional TUTs can be dissociated (Seli, Risko & Smilek, 2016; Giambra 1995), thus bolstering the recent suggestion that researchers ought to be cautious when making general claims about TUT without measuring and theoretically distinguishing between these two type of off-task thoughts (Seli, Risko & Smilek, 2016). Second, the findings suggest that prior studies showing an influence of motivation on rates of TUT (or mind wandering; in which intentionality was not indexed; Mrazek et al., 2012; Unsworth & McMillan, 2013) likely reflected an influence of motivation on intentional TUTs rather than on unintentional TUTs. Third, the present findings suggest that theories that cast TUTs as failures of control (McVay & Kane, 2010,2012) are insufficient explanations of TUT. With respect to this last point, it seems unlikely that intentional TUT episodes that are under the control of motivational instructions are the result of control failures; on the contrary, intentional TUTs that occur when task-based motivation is low might in fact reflect a high degree of control. That is, intentional TUT may be utilized strategically, serving a specific function.

While inattention is often cast as being undesirable, there may be cases in which intentional inattention is functional. Indeed, it seems reasonable that individuals with high levels of cognitive control might engage in intentional inattentiveness in certain contexts, particularly when tasks do not require a full complement of attentional resources. For instance, a student high in executive control might intentionally engage in TUT during a section of a lecture in which the lecturer is discussing a familiar topic (as also suggested by Wammes et al., 2016). In such a situation, the student might entertain lecture-unrelated thought content, even if they are motivated to do well in the class, because such TUT is inconsequential to learning. Thus, people may engage in strategic intentional inattentiveness. Prior work (Seli, Carriere, et al., 2018) has provided some evidence for this possibility. Seli et al. had participants monitor a clock face and respond with a button press after each time a full revolution was made (every 20 s). Intermittently, participants responded to thought probes indicating whether they were on task or engaged in TUT. They found the highest rate of intentional TUT took place when the clock hand was between three and six o'clock—the temporal window most distant from the time participants had to make a response.[2] In the same vein, recent neuroimaging studies have provided a potential mechanism for strategic intentional inattentiveness (see Turnbull et al., 2019). Specifically, Turnbull et al., (2019) have documented high levels of activity in the dorsolateral prefrontal cortex (DLPFC)—an area associated with intentional control—during moments of off-task though while participants completed a simple task. If the off-task thoughts participants experienced during the simple task were intentional and strategic, then the results of Turnbull et al.'s (2019) study would suggest that activity in the DLPFC might underlie strategic intentional inattentiveness.

It is important to note that whether unintentional inattention is under motivational control might depend on the type of motivation manipulation that is implemented. In the present work, we increased motivation by providing participants with an instructional message that they had to interpret; if participants were sufficiently motivated based on their interpretation of the instructions, they would then have to choose to apply more attention to the task to obtain a later reward (leaving early). This sort of motivation manipulation clearly involves higher level decision-making processes. It seems that such decision-making processes do not control unintentional inattention. However, it could be that motivational manipulations that target more basic desires (i.e., more fundamental reward and motivation networks, such as those involved in basic regulatory process such as hunger) might be able to reign in even unintentional inattention. This may be because such basic motivational manipulations might be able to exert influence outside of conscious awareness and higher level control systems. We should also note that our manipulation of motivation effectively ignored individual differences in a) participants' motivation levels, b) what they find motivating [such as their current concerns (Marchetti et al., 2016)] and c) how their internal motivations interact with the task context (see Smallwood & Andrews-Hanna's (2013) Context Regulation Hypothesis); these factors might be important for a complete understanding of the motivational influences on strategic inattention. Clearly, more work is needed to delineate the full nature of motivation and strategic inattention.

In the present study, we also replicate prior findings showing that constrained thoughts were not uniquely characteristic of being on task (O'Neill et al., 2020; Mills et al., 2018). Our findings indicate that, across both groups, participants reported their thoughts were on task and unconstrained about 22% of the time. This provides further evidence for the dissociation between TUT intentionality and thought constraint (O'Neill et al., 2020; Mills et al., 2018).

Extending prior findings, we also found that, compared to the Standard group, participants in the motivated group reported more thought constraint (Motivated: 63% versus Standard: 72%). More specifically, increasing motivation decreased rates of unconstrained intentional TUT while increasing rates of on-task constrained thought. Going forward, it will be interesting to examine whether other manipulations of motivation have similar effects on thought constraint.

In summary, the present findings demonstrate the importance of measuring both TUT intentionality and thought constraint in studies of inattention. The results of prior work suggest that without accounting for both the intentionality of a TUT episode and the degree of thought constraint, measures of TUT may become contaminated. Our work demonstrates that motivational (versus standard) instructions decreased reports of intentional TUT, while reports of unintentional TUT remained unchanged between groups. Importantly, our findings indicate that unconstrained thought is also sensitive to a motivational instruction and that increasing motivation specifically decreases intentional unconstrained TUT.

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[2] Also see O'Neill et al., (2020).

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Code availability Program code will be available on OSF (https://osf.io/3jqcr/) following acceptance.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

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