

Mind-wandering and attention control: Examining the role of emotional valence

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Article

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Abstract

Mind-wandering occurs frequently as thoughts shift away from a current task to an unrelated topic. In this study, we investigated the relationship between mind-wandering and attention control, specifically focusing on the impact of the emotional valence of mind-wandering on within- and between- person differences in performance on tasks measuring attention control. The results show that in general, task-unrelated thoughts (TUTs) and mind-wandering are related to differences in attention control performance within and between individuals. Individuals who reported more TUTs and mind-wandering tend to show poorer performance on attention control tasks, and individuals performed worse during instances when they reported TUTs and mind-wandering. However, emotional valence did not moderate this relationship, as has been previously theorized. Negative mind-wandering was not associated with worse performance than positive mind-wandering within or across individuals.

Introduction

When engaged in a task such as reading a book, taking notes during a class, or driving a car, it is common to experience attentional shifts away from the current task to an unrelated topic. This phenomenon, often referred to both colloquially and scientifically as *mind-wandering*, occurs frequently. For example, Killingsworth and Gilbert¹ found that people engaged in mind-wandering in almost half of daily life experience samples, on average, and at least 30% of the samples in almost every daily activity. It is important to develop a clearer understanding of the complexities of mind-wandering due to its potential ramifications. Mind-wandering can have an impact on diverse aspects of life from psychopathology[1] to reduced academic performance and standardized test scores[2–5]. However, it is unclear whether mind-wandering only has harmful consequences, or if it may also have some benefits. Some researchers have demonstrated that mind-wandering harms cognitive performance in areas such as reading[6–8], sustained attention[9–15], and working memory[5, 16, 17]. Mind-wandering can also have more dangerous consequences such as impaired driving,[18–20] traffic accidents[21], and medical-malpractice[22], but others suggest that mind-wandering may have beneficial functions as well, including autobiographical planning and creative problem solving[22]. Smallwood and Schooler[23] also maintain that mind-wandering can be problematic in an educational or academic context, but may play a more positive role in future planning, creativity, and problem-solving and be correlated with the capacity to delay gratification.

Additionally, mind-wandering may be related to certain mental health conditions due to its overlap with symptoms of disorders such as depression. For example, some symptoms of depression are intrusive thoughts and rumination, which can occur during mind-wandering and also be related to executive control failures[24]. Marchetti et al.[1] also suggest that spontaneous thought may contribute to depression by increasing rumination, hopelessness, low self-esteem, and cognitive reactivity, which are all cognitive risk factors for depression. More broadly, mind-wandering has been shown to be correlated with negative mood[25], and experience-sampling has demonstrated that that mind-wandering can be a precursor to unhappiness, and that people are less happy when engaged in mind-wandering, regardless of the activity

they were participating in at the moment[26]. Negative mood has been shown to predict rates of overall task-unrelated thoughts and specifically negatively valenced task-unrelated thoughts[27]. In addition to negative mood and depression, Figueiredo et al.[28] found a positive correlation between mind-wandering and anxiety in adolescents. Anxiety could be related to mind-wandering due to the connection between trait-anxiety and attention control. For example, in one study adults high in trait-anxiety performed worse on response-conflict tasks and displayed lower levels of prefrontal activity[29]. This is important due to the role of prefrontal mechanisms in attention control. Fell et al.[30] also describe the engagement in worry and rumination during mind-wandering as aspects also related to anxiety.

Everything mentioned so far describes that people mind-wander and what its consequences can be. But therein leads to a separate set of questions, particularly surrounding *why* people mind-wander. Prior research indicates rather robustly that people mind-wander due to both stable individual differences, such as cognitive abilities and personality traits, and more momentary contextual factors[25], such as salient personal concerns, stress, and fatigue. One of the cognitive abilities most strongly correlated with mind-wandering propensity is executive attention[2, 4–7, 9, 14, 17, 24, 25, 31–35]. McVay and Kane[24] argue that people mind-wander due to a failure of executive control mechanisms to prevent interference from off-task thoughts. People may fail to control their attention and turn to mind-wandering simply because they are bored or uninterested in their activity[2, 31, 34, 36]. People with certain personality traits, such as neuroticism, may also be more prone to mind-wandering. Neurotic individuals may mind-wander more by thinking about personal concerns that cause their thoughts to shift away from the current task.[33] Robison et al. suggest that executive attention may act as a mediator in the relationship between neuroticism and mind-wandering. In other words, neuroticism may be related to mind-wandering indirectly through executive control.

Mind-wandering can also take many forms and may have different effects depending on dimensions such as temporal orientation and intentionality. Marchetti et al.[1] discuss properties of spontaneous thought, a broader term that includes mind-wandering. One of these properties is temporal projection, in which one may place themselves in the future or another time period in their off-task thoughts (also referred to as episodic future thinking or simulation[37, 38]). People can also mind-wander about the past, retrospectively revisiting events in their lives or imagining alternative pasts. Intentionality—that is, whether a person is deliberately shifting their attention away from the environment – may be another important dimension of mind-wandering to consider. Seli et al.[39] encourage researchers to keep in mind the difference between unintentional and intentional mind-wandering, and research has shown that spontaneous (or unintentional) and deliberate (or intentional) mind-wandering differentially relate to other individual differences, such as executive control and motivation, and are differentially impacted by experimental manipulations. For example, Robison et al.[25] investigated individual differences in intentional vs. unintentional mind-wandering, classifying intentional mind-wandering as a conscious decision to think about something task-unrelated and unintentional mind-wandering as when someone is trying to pay attention to the current task, but unrelated thoughts capture their attention instead. In their study, individuals engaged in more intentional mind-wandering when they were in a negative mood. Deliberate, or intentional mind-wandering appears to be more related to a lack of motivation, while

spontaneous, or unintentional mind-wandering is predicted by working memory capacity and alertness Seli et al.[40–42] also found that spontaneous/unintentional mind-wandering was positively related to symptoms of ADHD, OCD, depression, anxiety, and stress, but deliberate/intentional mind-wandering was not. However, it is important to note that these studies relied on self-report data from mind-wandering questionnaires rather than the thought probe method used in the current study.

Similarly, Banks et al.[43] discuss how mind-wandering can vary in emotional valence and intentionality. Further, Banks and Welhaf[44, 45] posit that individual differences in executive control that influence levels of mind-wandering may be differentially related intentionality and emotional valence. It is therefore important to take into account the emotional valence and intentionality dimensions of mind-wandering.

Present Study

Here we focus on the possibility that the emotional valence of mind-wandering may influence its relationship with attention control. As mentioned earlier, Banks et al.[27] argue that the emotional valence of mind-wandering is particularly important for performance. Specifically, they found evidence for a stronger relationship between negatively valenced task-unrelated thoughts (TUTs) and performance on working memory and sustained attention tasks. Banks and Welhaf[44] similarly found that negative mind-wandering was especially harmful to performance on working memory and attention tasks, such as the Sustained Attention to Response Task (SART). Welhaf and Banks[12] replicated this pattern with results showing a stronger relationship between negative (TUTs) and SART performance, further suggesting that it might be high emotional valence or the intensity of emotion overall that determines a TUT's effect on cognition, rather than specifically negative or positive valence. Banks et al.[43] also argue that the intentionality and emotional valence of mind-wandering or off tasks thoughts are influential in the way that mind-wandering plays out in daily life. Therefore, the goal of this study was to investigate whether indeed the emotional valence of mind-wandering is a moderator of its relationship with attention control, both within and across individuals. First, based upon much prior work, we hypothesized that individuals who report more task-unrelated thoughts (TUTs) and mind-wandering overall would perform worse on cognitive tasks measuring attention control. Second, we hypothesized that moments of TUT and mind-wandering more specifically would be associated with worse task performance (i.e., slower response times and increased error rates) within individuals. Finally, if the notion proposed by Banks and colleagues[12, 27, 44] is accurate, these effects should be particularly pronounced for negative vs. positive mind-wandering. That is, negatively valenced mind-wandering should be more harmful to performance, both within and across individuals, than other TUTs. To test those hypotheses, we analyzed data from a sample of young adults who completed a battery of attention tasks while being probed about ongoing thoughts.

Method

Participants and Procedure

All participants were undergraduate students from the human subjects pool at the University of Oregon ($N = 174$; $M_{\text{age}} = 19.38$; $SD_{\text{age}} = 1.50$; 69% female; 31% male). All participants read and signed informed consent documents prior to completing any tasks. Here we will focus on performance and thought probe responses embedded in four attention tasks: the antisaccade task, the psychomotor vigilance task, the color-word Stroop task, and the singleton-search task. As part of the same two-hour cognitive battery, participants also completed three complex span tasks, a change-detection working memory task, and a syllogistic reasoning task. However, these data will not be reported upon here. All data were collected during the Winter 2016 academic term. The protocol was approved by the Institutional Review Board at the University of Oregon, and all participants were granted partial course credit in exchange for their participation. All participants were treated according to the ethical guidelines of the American Psychological Association.

Tasks

Antisaccade[46]

On each trial, a set of asterisks (***) appeared centered on the screen for an interval ranging from 200 to 1,800 ms. Then, a cue (=) flashed on either the right or left side of the screen for 250 ms. Then a target letter (B, P, or R) appeared briefly on the opposite side of the screen for 100 ms, followed by a backward mask (H) over the target letter's location for 50 ms, then an 8 until the participant made a response. Participants used keys labeled B, P, and R on a number pad to make their response. Responses were unspeeded but carried 10-s timeout before the next trial began. Trials were separated by a 400-ms blank intertrial interval. The task started with 10 trials of response mapping (i.e., identifying a letter that appeared at the center of the screen), 10 trials of a prosaccade task (i.e., identifying a letter that flashed in the same location as the cue), 10 trials of antisaccade practice, and 50 experimental trials of the antisaccade task. The dependent variable was proportion correct on the experimental trials. There were 11 thought probes spaced randomly throughout the task.

Attention Capture (Singleton Search)[47]

On each trial, participants were presented with six shapes equally spaced around an invisible circle. The shapes were always a set of five circles and one diamond or five diamonds and one circle. The participants' task was to locate the unique shape and report upon the orientation of a line inside that shape. The lines could be angled 45° to the left or 45° to the right. If the line was angled left, participants were to press the 'z' key on the keyboard; if the line was angled right, participants were to press the '/' key. The shapes and lines appeared as white circles against a black background. On 50% of trials, one of the non-target shapes appeared in red, producing an "additional singleton" distractor. There were 10 practice trials followed by 144 experimental trials. Thought probes appeared randomly after 15 trials. The dependent variable was each person's average RT on distractor-present trials subtracted from their average RT on distractor-absent trials. Only accurate responses were used for the computation of average RTs.

Psychomotor Vigilance[48, 49]

On each trial, a set of zeros (00.000) appeared at the center of the screen in blue font. Then, after a delay interval ranging randomly and uniformly from 1 to 10 s (in 500-ms intervals), the numbers began counting forward like a stopwatch. The participants' task was to stop the timer as quickly as possible by pressing the spacebar. Upon pressing the spacebar, the timer turned to red font and showed the response time (e.g., 00.432) for 1 s. There were 8 practice trials, then the experimental trials lasted exactly 10 min (~ 75 trials). Thought probes appeared after 20% of trials (~ 15 probes). The dependent variable for performance was the mean of each individual's slowest quintile of trials.

Stroop[50]

On each trial, the words "red", "green", or "blue" appeared in either red, green, or blue font. The participants' task was to indicate the font color as quickly as possible using keys labeled with the three colors on the numberpad of the keyboard. On congruent trials, the font color matched the word; on incongruent trials, the font color was one of the other two colors. There were 15 response mapping trials on which a colored square appeared in red, blue, or green. Then, there were 6 practice trials of the color-word task, followed by 135 total experimental trials (90 congruent, 45 incongruent). After a response, the screen cleared and there was a jittered intertrial interval ranging from 1 to 2 s. Probes appeared after 21 incongruent trials. The dependent variable was the average RT on incongruent trials minus the average RT on congruent trials. Only accurate responses were used in the computation of average RTs.

Exclusions

For the PVT task, we excluded RTs outside of 200 and 3,000 ms. For the Stroop and attention capture tasks, we excluded RTs outside 200 and 5,000 ms. We also excluded participants with accuracy lower than 33% on the antisaccade task.

Thought Probes

Each task included thought probes to measure how often the participants engaged in mind-wandering during the tasks. Each thought probe asked participants: "What were you thinking about just before this screen appeared?" The response options included: 1) I am totally focused on the current task, 2) I am thinking about my performance on the task, 3) I am distracted by sights/sounds/physical sensations in my environment, 4) I am thinking about things unrelated to the task, which are positive in nature, 5) I am thinking about things unrelated to the task, which are negative in nature, and 6) I am not very alert/my mind is blank. We considered options 3–6 to be task unrelated thoughts (TUTs), options 4 and 5 to be mind-wandering, option 4 as positive mind-wandering, and option 5 as negative mind-wandering. We coded response 1 as on-task, response 2 as task-related interference, and response 3 as external distraction. We measured the proportion of TUTs by the frequency that participants selected options 3–6, mind-wandering by the frequency that participants selected options 4 or 5, and specifically positive mind-

wandering by the frequency that participants selected option 4 and negative mind-wandering by the frequency that they selected option 5.

For the within-person (i.e., trial-level) analyses, we examined RTs for the PVT, Stroop, and attention capture tasks prior to reports of each probe response and accuracy prior to each probe response for the antisaccade task.

For the between-person analyses, we analyzed the correlations among the frequency of TUTs, mind-wandering, and specifically positive and negative mind-wandering and performance on the cognitive tasks. For estimates of reliability for task performance, we used an odd/even trial split and calculated the dependent variable on each half, correlated the halves, then applied Spearman-Brown split half correction to the correlation.

Data Analysis

We analyzed the data in R using the *tidyverse*[51] suite of packages and the *psych*[52], *corr*[53], *lavaan*[54], *lmerTest*[55], *lme4*[56] and *papaja*[57] packages. For the latent variable analyses, we used the χ^2 test, comparative fit index (CFI), Tucker-Lewis Index (TLI), root mean squared error of approximation (RMSEA), and standardized root mean residual (SRMR) as measures of fit. We used CFI and TLI $\geq .90$ and RMSEA and SRMR $\leq .08$ as thresholds for acceptable model fit. For all models we reported the standardized parameter estimates. Unless otherwise noted, we used an α level of .05 to assess statistical significance.

Results

To examine performance differences within individuals, we ran a series of linear mixed effects models comparing response times (RTs) and accuracy based on the responses to the thought probes. For these analyses, we only examined trials followed immediately by a probe. For each task, we first compared any TUT (external distraction, positive mind-wandering, negative mind-wandering, and mind-blanking) to on-task responses; then we compared mind-wandering (collapsing across valence) to on-task responses; then we specifically compared positive and negative mind-wandering responses to each other.

For the antisaccade task, participants were significantly more accurate when on-task compared to when engaged in TUTs and when on-task compared to mind-wandering. However, there were no accuracy differences when comparing positive to negative mind-wandering. For the attention capture task, there were not significant differences in participants' RTs when comparing on-task trials to TUTs, nor when comparing on-task responses to mind-wandering, nor when comparing positive to negative mind-wandering. For the PVT, participants had significantly faster RTs when on-task compared to when engaged in TUTs and significantly faster RTs for on-task compared to mind-wandering. There was again no significant difference in RTs when comparing positive and negative mind-wandering. Finally, for the Stroop task, there was not a significant difference in RTs between on-task and TUTs, nor between on-task and mind-wandering. However, there was a significant difference between positive and negative mind-wandering, such that trials on which people reported positive mind-wandering were accompanied by

faster RTs than trials on which people reported negative mind-wandering (see Table 1 for summaries of all models).

Table 1
Linear Mixed Effects Model

Task	Comparison	<i>b</i>	<i>SE</i>	<i>p</i>
Antisaccade	On-task vs. TUT	-0.62	0.13	< .001
	On-task vs. MW	-0.59	0.18	.00
	Pos vs. Neg MW	0.15	0.33	.65
Attention Capture	On-task vs. TUT	244.30	157.8	.123
	On-task vs. MW	1.78	49.93	.97
	Pos vs. Neg MW	50.89	106.29	.63
PVT	On-task vs. TUT	69.33	10.72	< .001
	On-task vs. MW	61.82	12.08	< .001
	Pos vs. Neg MW	-16.21	35.41	.65
Stroop	On-task vs. TUT	56.26	33.94	.10
	On-task vs. MW	41.32	46.13	.37
	Pos vs. Neg MW	-169.04	73.81	.03
<i>Note.</i> <i>b</i> = regression coefficient, <i>SE</i> = standard error of coefficient. For the antisaccade task, the model was a binomial generalized linear mixed effects model on accuracy, so the units for the regression coefficient are in log odds. For the three other tasks, the models were linear mixed effects models on RTs, so the units are in milliseconds.				

The next set of analyses focused on between-person differences. Descriptive statistics for all relevant measures are shown in Table 2. Most measures had acceptable values for skew and kurtosis. However, positive and negative mind-wandering for all four tasks and all mind-wandering for the attention capture and Stroop tasks had relatively high skew values. The positive and negative mind-wandering for all four tasks and all mind-wandering for the attention capture and Stroop tasks all had relatively high kurtosis values. The distributions for these measures are positively skewed and leptokurtic. The antisaccade task had acceptable reliability, attention capture had good reliability, PVT had high reliability, and Stroop had low reliability. The correlation matrices used for the latent variable models are shown in Tables 3, 4, and 5.

Table 2
Descriptive Statistics

Measure	N	Mean	SD	Skew	Kurtosis	Reliability
Antisaccade (accuracy)	138	0.50	0.12	0.61	-0.66	0.70
Antisaccade positive MW	166	0.06	0.13	2.75	8.16	---
Antisaccade negative MW	166	0.04	0.09	3.32	14.16	---
Antisaccade all MW	166	0.09	0.16	2.00	3.67	---
Antisaccade all TUT	166	0.28	0.32	0.89	-0.53	---
Attention Capture (distractor effect)	157	118.16	122.11	-0.17	0.46	0.81
Attention Capture positive MW	170	0.10	0.17	2.68	8.78	---
Attention Capture negative MW	170	0.03	0.09	4.39	24.04	---
Attention Capture all MW	170	0.13	0.20	2.02	4.36	---
Attention Capture TUT	170	0.40	0.35	0.38	-1.35	---
PVT (slowest RT quintile)	160	500.92	81.86	0.48	-0.29	0.97
PVT positive MW	170	0.14	0.18	2.02	4.84	---
PVT negative MW	170	0.06	0.14	3.04	10.28	---
PVT all MW	170	0.20	0.22	1.46	1.95	---
PVT TUT	170	0.40	0.29	0.47	-0.71	---
Stroop (congruency effect)	168	141.92	80.75	0.34	-0.42	0.49
Stroop positive MW	172	0.05	0.13	4.36	24.32	---
Stroop negative MW	172	0.02	0.08	4.76	26.70	---
Stroop all MW	172	0.07	0.15	2.92	10.43	---
Stroop TUT	172	0.21	0.28	1.40	0.91	---

Table 3
TUT Correlations

Measure	1.	2.	3.	4.	5.	6.	7.
1. Antisaccade (accuracy)							
2. Attention Capture (distractor effect)	– .07						
3. PVT (slowest RT quintile)	– .27*	.00					
4. Stroop (congruency effect)	– .14	.09	.11				
5. Antisaccade TUT	– .18*	.17*	.19*	.22*			
6. Attention Capture TUT	– .18*	.06	.29*	.17*	.52*		
7. PVT TUT	– .20*	.13	.41*	.13	.51*	.60*	
8. Stroop TUT	– .09	.15	.20*	.14	.57*	.74*	.57*
Note: PVT = psychomotor vigilance task; TUT = task unrelated thought. *indicates a significant correlation at $p < .05$.							

Table 4
All Mind-wandering Correlations

Measure	1.	2.	3.	4.	5.	6.	7.
1. Antisaccade (accuracy)							
2. Attention Capture (distractor effect)	– .07						
3. PVT (slowest RT quintile)	– .27*	.00					
4. Stroop (congruency effect)	– .14	.09	.11				
5. Antisaccade MW	– .02	.15	.20*	.18*			
6. Attention Capture MW	– .03	.11	.17*	.05	.43*		
7. PVT MW	– .10	.14	.30*	.18	.38*	.39*	
8. Stroop MW	– .02	.10	.24*	.10	.48*	.60*	.32*
Note: MW = mind-wandering; PVT = psychomotor vigilance task. *indicates a significant correlation at $p < .05$.							

Table 5
Positive and Negative Mind-wandering Correlations

Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Antisaccade											
2. Attention Capture	– .07										
3. PVT	– .27*	.00									
4. Stroop	– .14	.09	.11								
5. Antisaccade pos. MW	.00	.14	.29*	.21*							
6. Antisaccade neg. MW	– .04	.06	– .09	.03	.09						
7. Antisaccade pos. MW	– .03	.15	.15	.05	.47*	.06					
8. Antisaccade neg. MW	– .01	– .04	.09	.02	.05	.19*	.00				
9. PVT pos. MW	– .03	.15	.24*	.12	.39*	.01	.44*	– .06			
10. PVT neg. MW	– .17*	.01	.15	.07	.01	.33*	– .11	.49*	– .07		
11. Stroop pos. MW	.05	.16*	.26*	.06	.62*	– .03	.69*	.02	.32*	– .06	
12. Stroop neg. MW	– .10	– .05	.04	.09	– .02	.34*	– .02	.44*	– .07	.49*	.05
<i>Note:</i> MW = mind-wandering; PVT = psychomotor vigilance task. *indicates a significant correlation at $p < .05$.											

Next, in order to examine differences between individuals, we specified three latent variable analyses. The models are shown in Figs. 1, 2, and 3. In all three models, the antisaccade, attention capture, PVT, and Stroop tasks loaded onto an attention control latent variable. In the model for TUT mind-wandering, the antisaccade TUT, attention capture TUT, PVT TUT, and Stroop TUT loaded onto a latent variable. TUT variables represented proportions of time that people reported external distraction, positive or negative mind-wandering, or mind-blanking. In the model for all mind-wandering, all mind-wandering for the antisaccade, attention capture, PVT, and Stroop tasks loaded onto an all mind-wandering latent variable. All mind-wandering variables represent the sum of positive and negative mind-wandering. In the model for positive and negative mind-wandering, positive mind-wandering for the antisaccade, attention capture,

PVT, and Stroop tasks loaded onto a positive mind-wandering latent variable. Negative mind-wandering for the antisaccade, attention capture, PVT, and Stroop loaded onto a negative mind-wandering latent variable.

In the first model, the attention control and TUT factors were significantly negatively correlated, indicating that individuals with higher attention control reported few TUTs, overall. However, it is worth noting that the factor loadings for the attention control factors were rather low, and the loading for attention capture was non-significant. This is due to the low zero-order correlations among these particular measures of attention control (within the exception of PVT and antisaccade). When these data were collected, the issues surrounding the psychometrics of this set of measures had not been thoroughly discussed. However, in recent years these issues have been well documented and resolved with the advent of newer and more psychometrically evaluated measures of attention control[58–68]. These issues notwithstanding, the fit of the model was acceptable, $\chi^2(19) = 38.96$, CFI = .94, TLI = .91, RMSEA = .08[.04, .11], SRMR = .06.

The fit of the second model was also acceptable, $\chi^2(19) = 29.29$, CFI = .96, TLI = .94, RMSEA = .05[.00, .09], SRMR = .06. In this model, the attention control and mind-wandering factors are negatively correlated. This indicates that participants with higher attention control reported less mind-wandering. This is consistent with prior research demonstrating a relationship between attention control and mind-wandering.

The fit of the positive and negative mind-wandering model was acceptable, $\chi^2(51) = 75.74$, CFI = .94, TLI = .92, RMSEA = .05[.02, .08], SRMR = .06. In this model, the attention control factor was negatively correlated with the positive and negative mind-wandering factors, but the correlation between the attention control and negative mind-wandering factors was not significant. Positive mind-wandering and negative mind-wandering had a near-zero correlation. According to this model, negative mind-wandering did not have a stronger negative relationship with attention control than positive mind-wandering.

Discussion

In this study, we examined whether the emotional valence of mind-wandering moderated its relationship with attention control, within and/or across individuals. To do so, we periodically probed participants' thoughts during four attention tasks. We allowed participants to report a variety of thoughts, including on-task thoughts, task-related interference, external distraction, mind-wandering, and mind-blanking. Importantly, we allowed participants to separately indicate whether their mind-wandering was positive or negative in emotionality. For the analyses, we considered any thought that was not on-task or task-related as a TUT. Overall, our results supported our hypotheses that individuals who report more TUTs and mind-wandering would perform worse on the attention tasks, and that moments of TUT and mind-wandering would be associated with worse task performance within individuals. However, the results did not support the hypothesis that negative mind-wandering would have a more detrimental relationship with attention control performance than positive mind-wandering within and across individuals.

The results from the antisaccade and PVT tasks suggest that TUTs and mind-wandering harm performance on cognitive tasks within individuals. The attention capture and Stroop tasks did not show significant differences within individuals while on-task compared to while engaged in TUTs or mind-wandering. In contrast to Banks and colleagues' prior research[12, 27, 45], our analyses did not consistently show significant differences in performance when negatively mind-wandering compared to positively mind-wandering. The exception was the Stroop task in which individuals performed better (i.e., responded faster) during trials on which they reported positive mind-wandering compared to trials on which they reported negative mind-wandering.

The latent variable analyses suggested that an aggregate estimate of propensity toward task-unrelated thoughts (TUTs) and mind-wandering are also related to differences in attention control between individuals. However, our model separating positive and negative mind-wandering onto separate factors, despite fitting acceptably and having significant loadings for all four tasks onto each factor, did not show that the correlation is more pronounced for negative mind-wandering than positive mind-wandering. This is inconsistent with previous work[12, 27, 45].

One reason why we may have failed to find moderation of the relation between mind-wandering and attention is that negative mind-wandering was very rarely reported and showed a highly zero-inflated distribution. That is, most people never reported a single instance of negative mind-wandering: 80% of people on the antisaccade task, 78% on the attention capture task; 72% on the PVT; and 84% of people on the Stroop task never reported an instance of negative mind-wandering. Overall, 53% of people never reported negative mind-wandering on any task. This not only poses statistical problems for analyzing those reports, it may also complicate interpretability. Therefore, future research could involve inducing more negative mind-wandering experimentally or looking at a population more prone to negative mind-wandering, such as a clinically anxious or depressed population.

Additionally, it may be that another factor, such as intentionality, is more influential in the relationship between mind-wandering and attention control. Several previous studies[25, 34, 40–42, 45] have investigated the difference between spontaneous (or unintentional) and deliberate (or intentional) mind-wandering and their relationship with executive control, motivation, mood, stress, and symptoms of ADHD, OCD, depression, and anxiety. It could also be beneficial to examine whether intentional or unintentional mind-wandering is more strongly associated with decreased performance on attention control tasks.

Another future direction could be to investigate the emotional valence of mind-wandering as it relates to some of the other potential ramifications of mind-wandering, such as mental health. Negatively valenced mind-wandering could potentially have a stronger relationship with symptoms of internalizing disorders such as anxiety and depression. In the future, we could also use tasks more closely related to everyday academic tasks such as reading or taking notes on a lecture video to clarify the relationship between mind-wandering and academic performance.

This study had several limitations. First, the thought probe method relies on participants' ability to accurately monitor and label their experiences when they respond to the thought probes. It could be beneficial to include several different measures of mind-wandering or to include mind-wandering both in the lab and outside the lab in daily life. Second, the cognitive tasks had varying levels of reliability, with the Stroop task having especially low reliability. This could have produced inconsistent results across the tasks. Third, the sample was limited to students at one university, which limits the generalizability of our findings to certain populations, such as children.

Although we did not find evidence for a relationship between specifically negatively-valenced mind-wandering and decreased attention control, our results suggest that mind-wandering is robustly related to individual differences in attention control between individuals. This has implications for educational and occupational contexts as well as safety and health, as poor attention control can harm individuals' abilities to excel academically and professionally and lead to situations as dangerous as traffic accidents and medical malpractice. Therefore, it is important to continue to develop a clearer understanding of the dimensions of mind-wandering and how decreasing mind-wandering may improve attention control.

Declarations

Data Availability

All trial-level data and analysis scripts are available on the Open Science Framework: <https://osf.io/vxu47/>

Additional Information

Competing Interests

The authors declare no competing interests.

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Author Contribution

A. L. S. performed the data analysis and wrote the manuscript. M. K. R. collected the data, assisted with data analysis, and edited the manuscript.

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All trial-level data and analysis scripts are available on the Open Science Framework: <https://osf.io/vxu47/>

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Figures

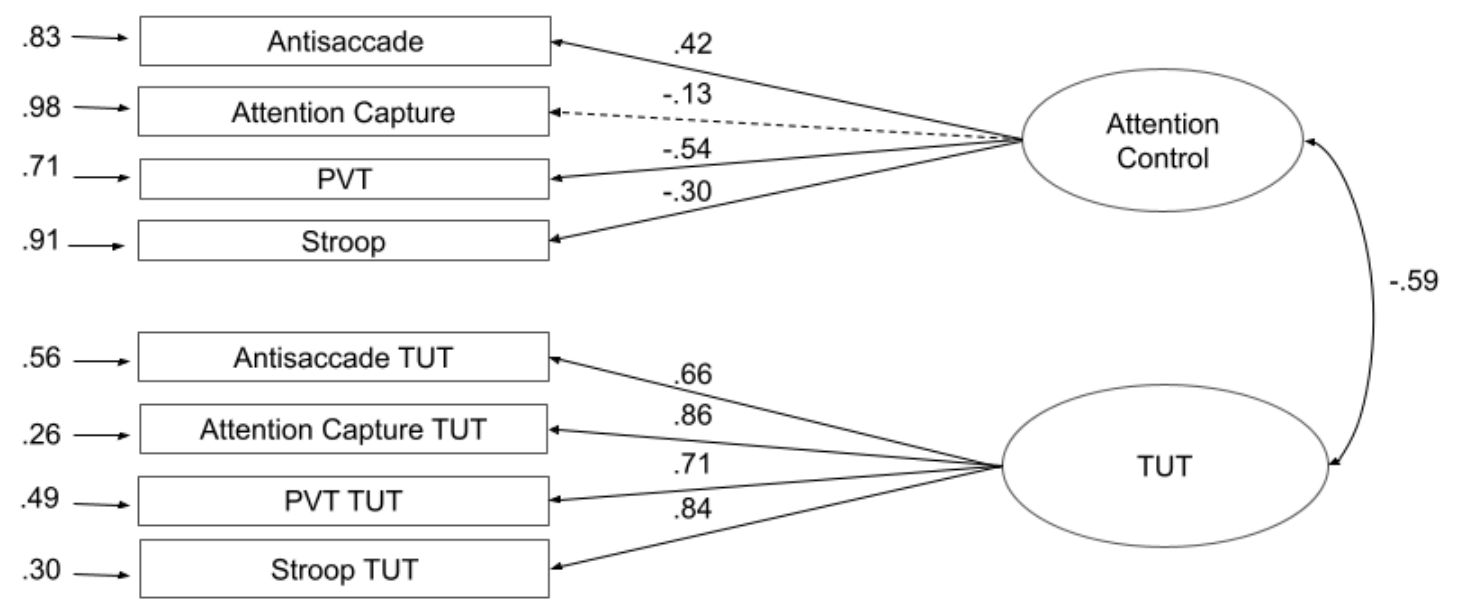


Figure 1

Latent variable analysis model of task unrelated thoughts (TUTs) and attention control. The antisaccade, attention capture, PVT, and Stroop tasks were entered as predictors of attention control and antisaccade TUT, attention capture TUT, PVT TUT, and Stroop TUT were entered as predictors of TUT overall. Solid lines represent significant paths at $p < .05$. Dotted lines represent nonsignificant paths.

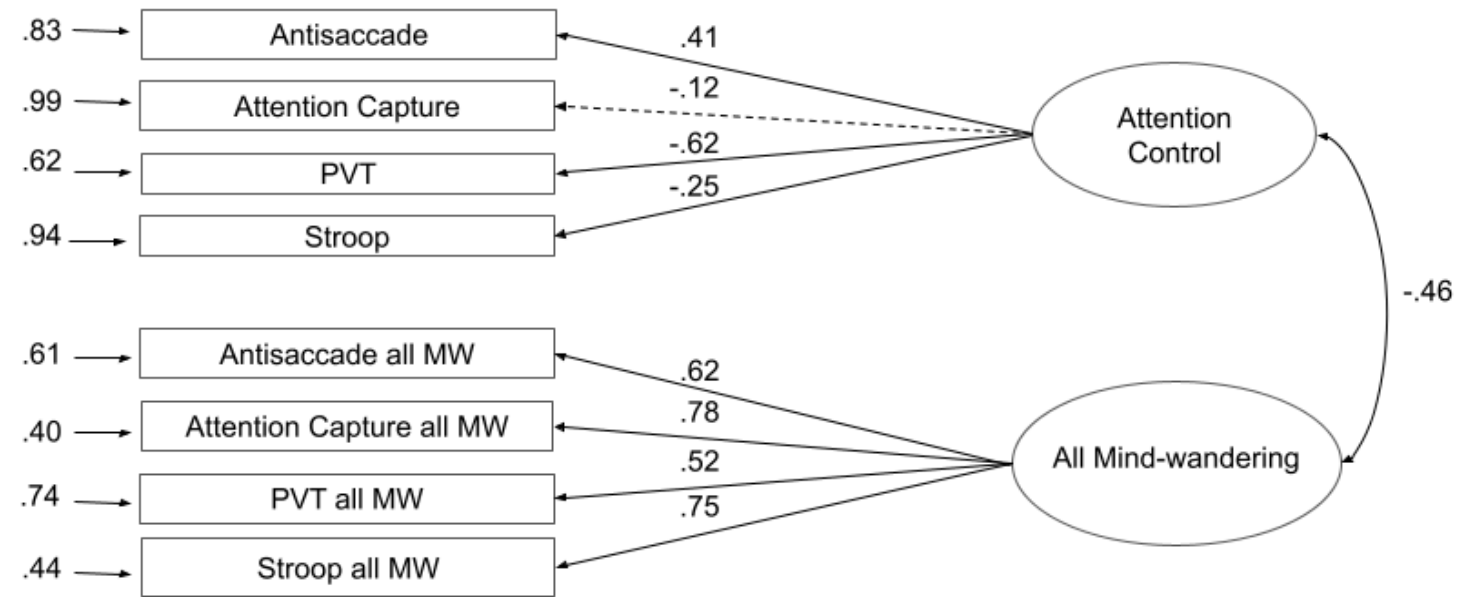


Figure 2

Latent variable analysis model of all mind-wandering and attention control. The antisaccade, attention capture, PVT, and Stroop tasks were entered as predictors of attention control and all mind-wandering during the antisaccade, attention capture, PVT, and Stroop tasks were entered as predictors of all mind-wandering. Solid lines represent significant paths at $p < .05$. Dotted lines represent nonsignificant paths.

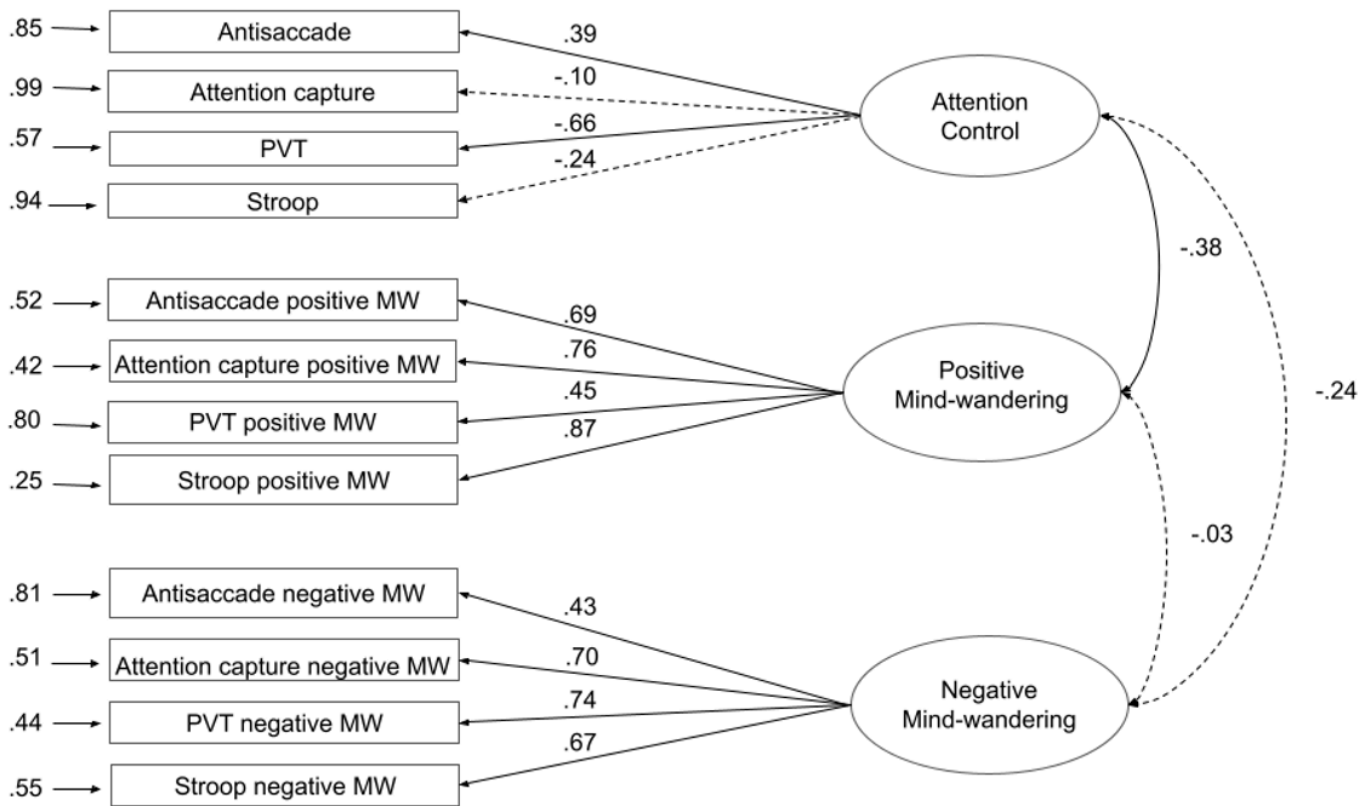


Figure 3

Latent variable analysis model for positive and negative mind-wandering and attention control. The antisaccade, attention capture, PVT, and Stroop tasks were entered as predictors of attention control, positive mind-wandering during the antisaccade, attention capture, PVT, and Stroop tasks were entered as predictors of positive mind-wandering, and negative mind-wandering during the antisaccade, attention capture, PVT, and Stroop tasks were entered as predictors of negative mind-wandering. Solid lines represent significant paths at $p < .05$. Dotted lines represent nonsignificant paths.