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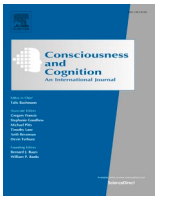

On the relation between mind wandering, PTSD symptomology, and self-control

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ABSTRACT

Here we examined the association between mind wandering, post-traumatic stress disorder (PTSD) symptomology, and self-control. In a large undergraduate sample (N = 5,387), we assessed trait-levels of spontaneous and deliberate mind wandering, self-control, and PTSD symptomology. Results indicated that, while PTSD symptomology was uniquely positively associated with spontaneous mind wandering, it was negatively associated with deliberate mind wandering and self-control. These findings suggest that the mechanism(s) underlying everyday mind wandering may also underlie PTSD symptomology and traumatic intrusions. Moreover, the unique negative association between PTSD symptomatology and self-control suggests that PTSD is characterized not only by impairments in inhibiting unwanted thoughts (as indexed by mind wandering), but also by impairments in inhibiting other unwanted behaviors.

1. Introduction

After a traumatic event, people commonly experience intrusive thoughts and memories. For most people, the frequency and severity of these traumatic intrusions subsides over time (Bonanno & Mancini, 2008; Mayou, Bryant, & Duthie, 1993; for a review, see Iyadurai et al., 2019). However, persistent traumatic intrusions can be symptomatic of post-traumatic stress disorder (PTSD), a disabling trauma- and stressor-related disorder that develops in response to terrifying, life-threatening, or otherwise traumatic events (Brewin & Holmes, 2003; Brewin, 2014; Ehlers & Clark, 2000). By definition, PTSD-associated intrusions are "recurrent, involuntary, and intrusive distressing memories of the traumatic event" ((American Psychiatric Association & American Psychiatric Association, 2013). However, even when traumatic intrusions do not meet the full DSM-5 diagnostic criteria, such thoughts can still be associated with clinical impairment (sub-threshold PTSD; Zlotnick, Franklin, & Zimmerman, 2002). Accordingly, traumatic intrusions are typically considered to lie on a continuum with other non-clinical forms of involuntary thought (e.g., Iyadurai et al., 2019; Meyer, Otgaar, & Smeets, 2015).

Intrusive thoughts are central to PTSD symptomology because they can activate other symptoms and consequences of the disorder (Bryant et al., 2017; see also, Haag, Robinaugh, Ehlers, & Kleim, 2017; Iyadurai et al., 2019). For instance, experiencing a traumatic intrusion can cause emotional distress (Ehlers & Steil, 1995) and the distraction by internal thoughts can cause cognitive failures (e.g.,

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Boals & Banks, 2012; Clark & Mackay, 2015; Pineles, Shipherd, Mostoufi, Abramovitz, & Yovel, 2009) that disrupt day-to-day functioning (Holmes et al., 2017). Predictably, the intrusive thoughts that are characteristic of PTSD are associated with poor self-control (Walter, Gunstad, & Hobfoll, 2010) and, more specifically, impairments of inhibitory control (Anderson & Levy, 2009; Bomyea & Lang, 2015; DeGutis et al., 2015; Verwoerd, Wessel, & de Jong, 2009). These relationships indicate that general deficits in control might amplify traumatic intrusions. Thus, it is important to understand what kinds of self-regulatory deficits might indicate heightened susceptibility to traumatic intrusions.

One potentially important (and relatively under-explored) factor is individual differences in trait tendencies for mind wandering, which is most often characterized as the orientation of attention toward internal thoughts and feelings (e.g., Brosowsky et al., 2020, 2021; Smallwood, McSpadden, & Schooler, 2007; Smallwood & Schooler, 2015). On the surface, mind wandering and intrusive thoughts (particularly those symptomatic of PTSD) appear intimately connected. Mind wandering, like intrusive thought, is associated with negative affect (Killingsworth & Gilbert, 2010), increased cognitive failures across different performance domains in daily life (Gil-Jardiné et al., 2017; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Szpunar, Khan, & Schacter, 2013; Yanko & Spalek, 2014), poor sustained attention (Seli, Carriere, Levene, & Smilek, 2013; Seli, Cheyne, & Smilek, 2013), and poor self-control (Moon, Converse, Merlini, & Vaghef, 2020; Phillips, Mills, D'Mello, & Risko, 2016), particularly when it comes to shielding oneself against distraction (Brosowsky et al., 2020, 2021a; Smallwood & Schooler, 2006).

Moreover, neural evidence suggests that the mechanisms underlying mind wandering and PTSD symptomology might overlap, although the evidence is mixed. Some research indicates that both mind wandering and PTSD symptomology are associated with the default mode network (DMN), which is a set of brain regions that increase in functional connectivity during periods of internally-focused (typically self-oriented) thought (Andrews-Hanna, 2012; Buckner, Andrews-Hanna, & Schacter, 2008; Danckert & Merrifield, 2018; Gusnard, Akbudak, Shulman, & Raichle, 2001; Mason et al., 2007; Raichle et al., 2001). However, whereas mind wandering is associated with *increased* DMN activation (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Gusnard et al., 2001; Mason et al., 2007; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011), PTSD symptomology is associated with *decreased* DMN activation (Patriat, Birn, Keding, & Herringa, 2016; Sripada, 2018; Terpou et al., 2020). This would suggest that, although both are associated with the same brain regions, they are dissociable at the neural level.

More recent research, however, has examined the functional connectivity between the DMN and the midbrain periaqueductal gray (PAG) and its relation to PTSD symptomology and mind wandering. The PAG refers to the gray matter located around the cerebral aqueduct of the midbrain and is associated with fight or flight defense responses (Brandão, Zanoveli, Ruiz-Martinez, Oliveira, & Landeira-Fernandez, 2008; De Oca, DeCola, Maren, & Fanselow, 1998; Fenster, Lebois, Ressler, & Suh, 2018). Terpou et al. (2020) found that individuals diagnosed with PTSD demonstrated stronger functional connectivity between the DMN and the PAG relative to healthy controls. Interestingly, the same pattern of functional connectivity between DMN and PAG is also observed in mind wandering (Kucyi, Salomons, & Davis, 2013), which suggests a similar underlying mechanism.

Despite the neural and cognitive similarities between mind wandering and PTSD, there has been surprisingly little research investigating their potential relations. Takarangi, Strange, and Lindsay (2014) examined people's frequency of intrusive thoughts immediately following exposure to trauma-like stimuli (i.e., a distressing film depicting a car accident) and found that participants often lacked meta-awareness of intrusive trauma-related thoughts. Meta-awareness, here, refers to the ability to explicitly appraise the contents of consciousness (e.g., Schooler, 2002). Because mind wandering often occurs without meta-awareness (see Schooler et al., 2004), Takarangi et al. argued that their results provide a conceptual link between mind wandering and traumatic intrusions. However, to the best of our knowledge, no work has yet directly examined the relationship between mind wandering and PTSD symptomology.

One complicating factor in the investigation of the relationship between mind wandering and PTSD is that mind wandering is considered a multi-dimensional construct that encompasses a range of experiences with non-overlapping attributes (Seli et al., 2018). And, importantly, these different dimensions might differentially relate to intrusive thoughts characteristic of PTSD. Prior research has shown that mind wandering can occur either intentionally (deliberately) or unintentionally (spontaneously) (Seli, Risko, Smilek, & Schacter, 2016). These two forms of mind wandering are associated with different trait- and state-level variables both in the laboratory (Agnoli, Vanucci, Pelagatti, & Corazza, 2018; Giambra, 1995; Robison, Miller, & Unsworth, 2020; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Wammes, Risko, & Smilek, 2016) and in everyday life (Carriere, Seli, & Smilek, 2013; Seli, Carriere, & Smilek, 2015; Seli, Smallwood, Cheyne, & Smilek, 2015), and can be dissociated neurally (Golchert et al., 2017).

Some of these empirical dissociations are relevant to predicting potential relationships between mind wandering and PTSD. For instance, unintentional and intentional mind wandering are differentially associated with specific individual-differences variables. Whereas, individuals who report more frequent unintentional mind wandering also report more symptoms associated with attention-deficit/hyperactivity disorder (Seli, Smallwood, et al., 2015) and obsessive-compulsive disorder (Seli, Risko, Purdon, & Smilek, 2017), individual differences in the frequency of intentional mind wandering shows no such associations. Conversely, whereas intentional mind wandering has been shown to be negatively associated with task motivation, there is little evidence for an association between motivation and unintentional mind wandering (Seli, Cheyne, et al., 2015; Seli, Wammes, et al., 2016; Smith, Brosowsky, Ralph, Smilek, & Seli, 2021). Finally, intentional and unintentional mind wandering differ in their relationship with mindfulness, the act of bringing one's complete attention to the experiences of the present moment (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). For instance, the tendency toward non-reactivity to internal experiences—one facet of mindfulness—is positively associated with intentional mind wandering and negatively associated with unintentional mind wandering (Seli, Carriere, et al., 2015). More broadly, unintentional mind wandering bears the hallmark of a control failure as it is associated with self-control deficits, (Isacescu, Struk, & Danckert, 2017; Phillips et al., 2016) and an inability to maintain focused thought (McVay & Kane, 2010). Intentional mind wandering, in contrast, may, at times, reflect a successful exercise of control in directing attention internally (Carriere et al., 2013; O'Neill,

Smith, Smilek, & Seli, 2020; Robison & Unsworth, 2018; Seli, Carriere, et al., 2015; Seli, Cheyne, et al., 2015; Seli, Risko, et al., 2016).

Based on the foregoing considerations, here we predict that PTSD symptomology will differentially associate with intentional and unintentional mind wandering. Given the evidence listed above, we expect positive associations between unintentional mind wandering and traumatic intrusions partly because both involve deficits in control (Aupperle, Melrose, Stein, & Paulus, 2012; Bomyea & Lang, 2015; DeGutis et al., 2015; Isacescu et al., 2017; Phillips et al., 2016; Verwoerd et al., 2009). However, we might expect intentional mind wandering to be negatively associated with PTSD symptomatology. This is because, whereas intentional mind wandering is thought to reflect successful control over attention and is associated with a desire to direct attention internally (Carriere et al., 2013), intrusive thoughts are thought to reflect a failure of control and PTSD is often associated with the avoidance of internally directed attention due to the aversive nature of trauma-related thoughts (e.g., Aupperle et al., 2012; Foa & Kozak, 1986).

Although considerations of cognitive etiology suggest that there ought to be associations between mind wandering and PTSD symptomology, the phenomenological features of these two experiences provide evidence for dissociability. On the one hand, traumatic intrusions are often in the form of vivid memories of highly distressing and negative experiences. In fact, they are so vivid that they are sometimes likened to re-living the past as in a flashback. Both unintentional and intentional mind-wandering episodes, on the other hand, are not usually so emotionally intense (Seli, Ralph, et al., 2017). Moreover, as noted above, some mind wandering is intentional, while traumatic intrusions are exclusively unintentional. Finally, traumatic intrusions, by virtue of being traumatic, require some awareness of the event *as* distressing. Unintentional mind wandering, however, often occurs without such meta-awareness (e.g., Schooler et al., 2011; Seli, Ralph, et al., 2017; Smallwood et al., 2007). Thus, although we predict an association between PTSD symptomology and mind wandering, there is some evidence to suggest that mind wandering and intrusive thoughts are distinct constructs (Meyer et al., 2015) in which case, we may not observe an associative relationship (see also Berntsen, 2021).

1.1. The present study

In the present study, we examined the relations between mind wandering, self-control, and PTSD symptomology. We were interested in determining whether unintentional and intentional mind wandering would be uniquely associated with PTSD symptomology above and beyond general impairments in control. Similarly, given that a failure to control thoughts and memories is the hallmark of PTSD, we were also interested in determining whether general failures in self-control uniquely predict PTSD symptomology after taking into account unintentional and intentional mind wandering.

To these ends, we conducted a large survey of undergraduate psychology students assessing (1) trait levels of intentional mind wandering (assessed by the Mind Wandering: Deliberate Scale; MW: D; (Carriere et al., 2013), (2) trait levels of unintentional mind wandering (assessed by the Mind Wandering: Spontaneous Scale; MW: S; Carriere et al., 2013), (3) PTSD symptomology (assessed by the DSM-version of the PTSD checklist; PCL-5 (Weathers et al., 2013, 1993); and (4) trait levels of self-control (assessed by the brief self-control scale; BSCS; Tangney, Baumeister, & Boone, 2004).

2. Material and methods

2.1. Participants

Participants were 6,707 undergraduate psychology students at the University of Waterloo (mean age was 21; 5129 identified as female, 1560 as male, and 18 unidentified) collected between September 2019 and October 2020. Each participant completed a series of questionnaires within the first two months of the semester. Included were the scales of interest (spontaneous and deliberate mind wandering scales, the brief self-control scale, and the PCL-5) as well as numerous other questionnaires that were of interest to other researchers and not analyzed in the present study. The order of the questionnaires was randomized, and participants were unaware of the relatedness of our scales. Participants received partial course credit for completing the study.

Prior to conducting any analyses, we removed data from participants who chose not to respond to any of the questions within the scales of interest, including age and sex. This reduced our final sample size to 5,387 participants.

To estimate our sensitivity to detect various effect sizes, we used the 'WebPower' R package (Zhang & Mai, 2021) which calculates the power to detect changes in R^2 across two linear regression models in terms of Cohen's f^2. We estimated our ability to detect changes in R^2 between our full model containing the mind wandering and self-control measures and the reduced model containing only the age and sex covariates. With 5000 participants we were well-powered (~99%) to detect an f^2 as small as 0.005 (see Appendix A for the resulting power curves). Cohen suggests f^2 values of 0.02, 0.15, and 0.35 represent small, medium, and large effect sizes, respectively (Cohen, 1988). Assuming the final model has an R^2 of 0.2, an f^2 of 0.005 corresponds to an increase in R^2 of 0.004 from the reduced to full model. Therefore, with such a large sample we were well-powered to detect extremely small effect sizes.

2.2. Measures

2.2.1. Deliberate and spontaneous mind wandering

To measure mind wandering, we used the four-item spontaneous mind wandering scale (MW: S) and the four-item deliberate mind wandering scale (MW: D) for unintentional and intentional mind wandering, respectively (Carriere et al., 2013). The deliberate mind wandering scale includes items related to intentional mind wandering, such as: "I allow my thoughts to wander on purpose," whereas the spontaneous mind wandering scale includes items related to unintentional mind wandering, such as: "I find my thoughts wandering spontaneously." Both scales are scored using a seven-point Likert scale with "rarely" (1) and "a lot" (7) as anchors.

Table 1
Descriptive statistics ($N = 5387$).

Measure	*M*	*SD*	Skew	Kurtosis	Cronbach's α
MW: D	4.29	1.47	−0.20	2.49	0.89
MW: S	4.16	1.39	−0.13	2.66	0.88
BSCS	3.07	0.67	0.08	2.82	0.84
PCL-5 Subscales					
Re-Experiencing	5.94	5.05	0.70	2.64	0.90
Avoidance	2.78	2.41	0.51	2.19	0.88
Cognitions and Mood	8.56	6.9	0.60	2.48	0.90
Arousal and Reactivity	6.50	5.35	0.75	2.91	0.85
PCL-5 Total	23.89	17.75	0.61	2.62	0.95

Note: BSCS = Brief Self-Control Scale; MW: S = Spontaneous Mind Wandering; MW: D = Deliberate Mind Wandering.

Table 2
Pearson's product-moment correlations.

	2.	3.	4.	5.	6.	7.	8.
1. MW: D	0.42***	−0.24***	0.09***	0.10***	0.12***	0.12***	0.13***
2. MW: S	–	−0.43***	0.33***	0.29***	0.37***	0.38***	0.39***
3. BSCS		–	−0.22***	−0.22***	−0.34***	−0.35***	−0.34***
PCL-5 Subscales							
4. Re-Experiencing			–	0.77***	0.74***	0.69***	0.89***
5. Avoidance				–	0.68***	0.61***	0.81***
6. Cognitions and Mood					–	0.78***	0.93***
7. Arousal and Reactivity						–	0.88***
8. PCL-5 Total							–

***$p < .001$; **$p < .01$; *$p < .05$.
Note: BSCS = Brief Self-Control Scale; MW: S = Spontaneous Mind Wandering; MW: D = Deliberate Mind Wandering.

2.2.2. PCL-5 (PTSD checklist for DSM-V)

The PCL-5 is a 20-item self-report measure that assesses all DSM-5 PTSD symptoms (Weathers et al., 2013). Responses are rated on a scale of 0 to 4, with 0 indicating no experience of a symptom and 4 indicating an extreme experience with a symptom. Participants were instructed to indicate the extent to which they were bothered by each symptom in the past month. The PCL-5 has been found to exhibit strong reliability and validity in psychometric evaluation (Blevins, Weathers, Davis, Witte, & Domino, 2015). An item-level score of 2 or more indicates a clinical endorsement (Weathers et al., 2013). A cut-off score of 31 and greater indicates probable PTSD (Bovin et al., 2016).

The PCL-5 can also be divided into four subscales corresponding to symptom clusters. These clusters include (1) *re-experiencing*, which measures intrusive symptoms such as repeated reoccurring thoughts and memories of the traumatic event, (2) *avoidance*, which assesses the avoidance of reminders of the traumatic event including thoughts, feelings, people, and places, (3) *cognitions and mood*, which assesses negative alterations in cognitions and mood such as poor memory, negative beliefs about yourself, negative emotions, and loss of interest, and (4) *arousal and reactivity*, which assesses negative alterations in arousal and reactivity such as irritability, difficulty concentrating, impulsivity, and problems sleeping.

We administered the PCL-5 without the Criterion A assessment. Participants were given the following instructions: "Below is a list of problems that people sometimes have in response to a very stressful experience. Please read each problem carefully and then select one of the numbers to the right to indicate how much you have been bothered by that problem in the past month."

2.2.3. Brief self-control scale

Self-control was assessed using the brief self-control scale (BSCS), a 13-item self-report measure of general self-control (Tangney et al., 2004). Participants used a 5-point scale to indicate how well statements described them (i.e., "I am good at resisting temptation"). The BSCS focuses on processes that directly involve self-control (e.g., working towards long-term goals or breaking a habit) and has shown good reliability and validity among college students (De Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012; Tangney et al., 2004).

3. Results

All analyses were performed in R (R Core Team, 2021) using a variety of notable R packages (Kassambara, 2020; Lüdecke, Ben-Shachar, Patil, Waggoner, & Makowski, 2021; Lüdecke, 2018; Revelle, 2021; Wickham, François, Henry, & Müller, 2021; Wilke, 2020; Zhang & Mai, 2021). All data and analysis code have been made publicly available via Open Science Framework and can be accessed at https://osf.io/yq9kx/.

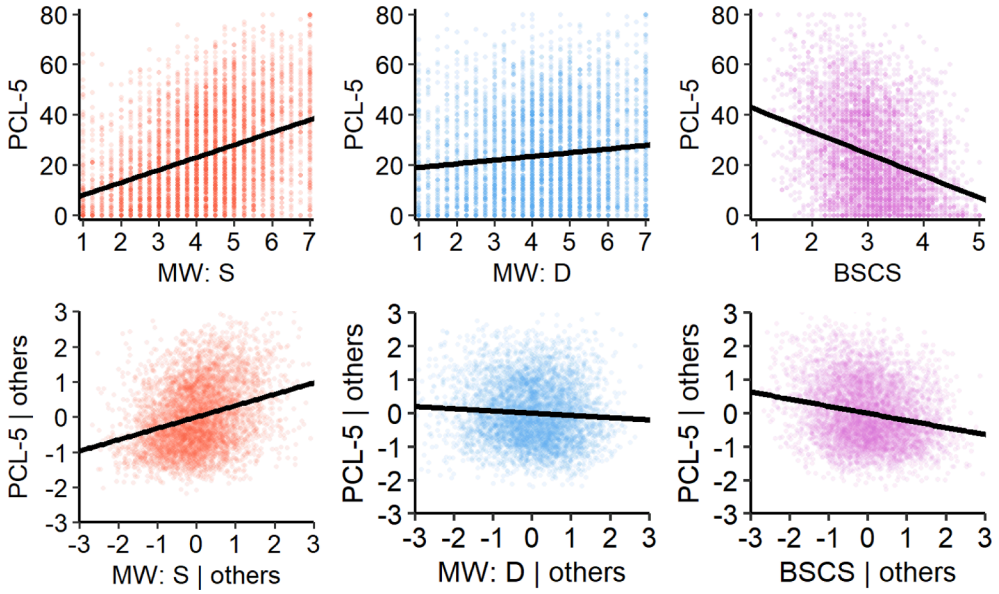

Fig. 1. Pearson's product-moment correlations are plotted in the top panel. The PTSD Checklist for DSM-V (PCL-5) scores are plotted against spontaneous mind wandering (MW: S; top-left), deliberate mind wandering (MW: D; top-center) and self-control (BSCS; top-right). Partial regression plots using standardized scores are presented in the bottom panel. PCL-5 scores are plotted against spontaneous mind wandering (bottom-left), deliberate mind wandering (bottom-center) and self-control (bottom-right).

Table 3
Stepwise Hierarchical Regression Analyses.

Step 1					
	Predictors	Estimates	95% CI	*t*	*p*-value
	(Intercept)	−0.13	−0.18 to −0.07	−4.5	<0.001***
	Age	−0.07	−0.1 to −0.05	−5.47	<0.001***
	Sex: Female	0.17	0.1–0.23	5.14	<0.001***
	R^2/R^2 adjusted	0.01/0.01			
Step 2					
	Predictors	Estimates	95% CI	*t*	*p*-value
	(Intercept)	−0.17	−0.22 to −0.12	−6.47	<0.001***
	Age	−0.06	−0.08 to −0.03	−4.62	<0.001***
	Sex: Female	0.22	0.16–0.28	7.38	<0.001***
	BSCS	−0.34	−0.36 to −0.31	−26.33	<0.001***
	R^2/R^2 adjusted	0.123/0.123			
Step 3					
	Predictors	Estimates	95% CI	*t*	*p*-value
	(Intercept)	−0.13	−0.18 to −0.08	−5.14	<0.001***
	Age	−0.04	−0.07 to −0.02	−3.47	<0.001***
	Sex: Female	0.17	0.11–0.23	5.86	<0.001***
	BSCS	−0.21	−0.24 to −0.19	−15.63	<0.001***
	MW: S	0.32	0.3–0.35	22.23	<0.001***
	MW: D	−0.07	−0.09 to −0.04	−4.92	<0.001***
	R^2/R^2 adjusted	0.198/0.198			

$^{***}p < .001$; $^{**}p < .01$; $^{*}p < .05$.
Note: BSCS = Brief Self-Control Scale; MW: S = Spontaneous Mind Wandering; MW: D = Deliberate Mind Wandering.

3.1. Descriptive statistics and correlations

Descriptive statistics for the MW: D, MW: S, BSCS and PCL-5 are presented in Table 1. As seen in Table 1, the skewness and kurtosis values for all the measures included in the study were within an acceptable range (i.e., skewness < 2 and kurtosis < 4; Kline, 1998).

Next, we examined the Pearson product-moment correlation coefficients for all measures (see Table 2 and Fig. 1). Here, we see that intentional and unintentional mind wandering were both positively associated with PCL-5 scores and negatively associated with BSCS scores. Moreover, as shown in previous studies (Carriere et al., 2013; Seli et al., 2014; Seli, Risko, et al., 2017; Seli, Smallwood, et al., 2015), unintentional and intentional mind wandering were positively correlated, $r = 0.42$, $p < .001$.

Table 4
Regression analyses of PCL-5 subscales.

Re-Experiencing					
	Predictors	Estimates	95% CI	t	p-value
	(Intercept)	−0.05	−0.08 to −0.02	−3.19	0.001**
	Age	−0.01	−0.03–0	−1.83	0.07
	Sex: Female	0.07	0.03–0.1	3.63	<0.001***
	Avoidance	0.45	0.43–0.47	42.84	<0.001***
	Cognitions and Mood	0.29	0.26–0.31	21.57	<0.001***
	Arousal and Reactivity	0.19	0.17–0.22	15.78	<0.001***
	BSCS	0.06	0.04–0.08	6.92	<0.001***
	MW: S	0.05	0.03–0.06	4.91	<0.001***
	MW: D	−0.02	−0.03–0	−1.83	0.07
	R^2/R^2 adjusted	0.696/0.696			
Avoidance					
	Predictors	Estimates	95% CI	t	p-value
	(Intercept)	−0.05	−0.08 to −0.01	−2.63	0.008**
	Age	−0.01	−0.02–0.01	−0.86	0.389
	Sex: Female	0.06	0.02–0.1	3	0.002**
	Re-Experiencing	0.57	0.54–0.59	42.84	<0.001***
	Cognitions and Mood	0.23	0.2–0.26	15.19	<0.001***
	Arousal and Reactivity	0.04	0.01–0.06	2.57	0.01*
	BSCS	0	−0.02–0.02	−0.36	0.722
	MW: S	−0.01	−0.03–0.01	−0.62	0.537
	MW: D	0.02	0–0.04	1.8	0.072
	R^2/R^2 adjusted	0.617/0.617			
Cognitions and Mood					
	Predictors	Estimates	95% CI	t	p-value
	(Intercept)	3.38	2.36 – 4.40	6.48	0.108
	Age	0.00	−0.03 – 0.03	−0.22	0.825
	Sex: Female	−0.22	−0.46 – 0.02	−1.83	0.068
	Re-Experiencing	0.38	0.34 – 0.41	21.62	<0.001***
	Avoidance	0.51	0.44 – 0.57	15.17	<0.001***
	Arousal and Reactivity	0.57	0.54 – 0.60	40.84	<0.001***
	BSCS	−0.80	−0.97 – −0.63	−9.12	<0.001***
	MW: S	0.13	0.04 – 0.22	2.92	0.004**
	MW: D	−0.02	−0.09 – 0.06	−0.4	0.7
	R^2/R^2 adjusted	0.707/0.706			
Arousal and Reactivity					
	Predictors	Estimates	95% CI	t	p-value
	(Intercept)	0	−0.03–0.04	0.25	0.803
	Age	0	−0.01–0.02	0.5	0.617
	Sex: Female	−0.01	−0.04–0.03	−0.28	0.777
	Re-Experiencing	0.23	0.2–0.26	15.78	<0.001***
	Avoidance	0.03	0.01–0.06	2.57	0.01*
	Cognitions and Mood	0.53	0.51–0.56	40.72	<0.001***
	BSCS	−0.08	−0.1 to −0.06	−8.53	<0.001***
	MW: S	0.08	0.06–0.1	7.91	<0.001***
	MW: D	−0.03	−0.04 to −0.01	−2.88	0.004**
	R^2/R^2 adjusted	0.646/0.646			

***$p < .001$; **$p < .01$; *$p < .05$.
Note: BSCS = Brief Self-Control Scale; MW: S = Spontaneous Mind Wandering; MW: D = Deliberate Mind Wandering.

3.2. Regression analyses

A three-step hierarchical regression was conducted with PCL-5 scores as the dependent variable (see Table 3 and Fig. 1). Prior to the analyses, we standardized all measures and dummy-coded the sex variable (Male = -1 and Female = +1).

The occurrence of traumatic events has been shown to vary with age—the peak age for trauma exposure is 16 to 20 years of age (Breslau, 2009)—and women tend to suffer from PTSD more frequently than men (Tolin & Foa, 2006). Therefore, as a first step, age and sex were added to the model to determine how much variance could be explained without our variables of interest. This model accounted for only 1% of the variation, $F(2, 5384) = 28.4$, $p < .001$. Replicating prior work, we find that PTSD symptomology decreased with age (Breslau, 2009) and participants who identified as female reported higher PCL-5 scores than male participants (Tolin & Foa, 2006).

At step two, we added the self-control measure to determine how much additional variance could be explained by self-control alone. BSCS scores were added to the model, significantly improving the amount of variance explained, $F(1, 5383) = 252.5$, $p < .001$, accounting for an additional 11.3% of the variance. Again, replicating prior work, we find that self-control was negatively associated with PTSD symptomology (Walter et al., 2010).

Finally, at step three, we added our mind wandering measures to determine whether mind wandering explained any additional

variance above-and-beyond our general measure of self-control and age and sex covariates. Adding the MW: S and MW: D scores again significantly improved the model, $F(2, 5381) = 266.7$, $p < .001$, accounting for an additional 7.5% of the variance.

In the final model, we found that, whereas spontaneous mind wandering was positively associated with PCL-5 scores, deliberate mind wandering, and self-control was still negatively associated with PCL-5 scores.

In addition to the hierarchical regression analyses, we also examined the relation between mind wandering and each of the PTSD symptom clusters (see Table 4). For each analysis, we included the mind-wandering and self-control measures as explanatory measures together with age, sex, and the remaining subscales. The results of these analyses revealed significant positive associations between unintentional mind wandering and the Re-Experiencing subscale, Cognitions and Mood, and Arousal and Reactivity subscales. Interestingly, intentional mind wandering was *negatively* associated with Arousal and Reactivity. Finally, self-control was positively associated with the Re-Experiencing subscale, negatively associated with both the Cognitions-and-Mood and Arousal-and-Reactivity subscales, and not associated with the Avoidance subscale.

4. Discussion

In the current study, we found that PTSD symptomology (as assessed by the PCL-5) was positively associated with unintentional mind wandering and negatively associated with intentional mind wandering after controlling for individual differences in self-control and the other mind-wandering measure. Interestingly, unintentional mind wandering was the largest predictor of PTSD symptomology, and considerably larger than intentional mind wandering. These unique associations suggest that both PTSD and unintentional mind wandering may be governed by the same underlying mechanism. The current results are consistent with neural evidence that has implicated a role for the default mode network in both mind wandering (Christoff et al., 2009; Gusnard et al., 2001; Mason et al., 2007; Stawarczyk et al., 2011) and PTSD symptomology (e.g., Patriat et al., 2016; Sripada, 2018; Terpou et al., 2020).

However, the negative association between intentional mind wandering and PTSD symptomology, although considerably smaller than the association between unintentional mind wandering, is suggestive of a more complicated relation. We hypothesized that intentional mind wandering might be negatively associated with PTSD symptomology if it is assumed that intentional mind wandering reflects, to some degree, one's ability to successfully control one's attentional focus and intrusive traumatic thoughts reflect a failure of control. However, we also speculated that a negative association may arise because of one's desire to engage in—or avoid—internally directed attention. Importantly, although some items on the deliberate mind wandering scale could be characterized as measuring intentional control (e.g., "I allow my thoughts to wander on purpose"), other items could be characterized as measuring one's desire to direct attention internally (e.g., "I enjoy mind wandering"). PTSD is often associated with a desire to avoid internally directed attention because of the negative consequences of entertaining trauma-related thoughts. Avoidance is a common coping strategy for those with PTSD and, though adaptive in the short-term, can lead to diminished inhibition of unwanted thoughts and persistent inadvertent direction of attention inward (e.g., Aupperle et al., 2012; Foa & Kozak, 1986). Thus, the negative association between intentional mind wandering and PTSD symptomology may reflect the avoidance of internally directed attention, rather than diminished control over attention. However, given the mind wandering scale conflates these two dimensions, more work is needed to tease apart these possibilities.

We also found a negative association between self-control and PTSD symptomology. These results reinforce prior work demonstrating dissociations between intentional and unintentional mind wandering (e.g., Carriere et al., 2013; Seli, Carriere, et al., 2015; Seli, Smallwood, et al., 2015) and add to the growing evidence demonstrating the link between poor self-control and PTSD symptomology (e.g., Walter et al., 2010). Interestingly, the negative association remained even after controlling for the mind-wandering measures. The failure to control thoughts and memories is the hallmark of PTSD and one might have predicted that PTSD symptomology would only be associated with self-control to the extent that it is related to thought-control specifically, rather than other forms of behavioral control. Yet here we find a robust association between PTSD symptomology and self-control even when individual differences in thought-control are accounted for (i.e., intentional and unintentional mind wandering).

Additionally, some particularly intriguing results came from the subscale analyses of the PCL-5. Unsurprisingly, we found unintentional mind wandering was positively associated with the Re-Experiencing subscale. Given that this subscale includes questions about the frequency of re-experiencing trauma-related thoughts and memories, one might have expected to find an association. In contrast, the Arousal and Reactivity subscale was positively associated with unintentional mind wandering, and negatively associated with intentional mind wandering. These results are important because intentional mind wandering is, at times, associated with beneficial functions like the ability to reflect on one's inner experiences in a non-reactive manner (Seli et al., 2014) and creativity (Agnoli et al., 2018). Thus, these results suggest that mind wandering might not only be associated with PTSD symptomology in terms of failing to inhibit unwanted thoughts, but also in terms of successful control over internally directed attention. Lastly, unintentional mind wandering was positively associated with the Cognitions and Mood subscale, consistent with prior work showing that mind wandering is associated with negative emotions (e.g., Killingsworth & Gilbert, 2010).

The present finding that spontaneous and deliberate mind wandering both predict PTSD symptomology points to some interesting avenues for future research. First, in the current study, we relied on solely self-report measures. A logical next step would be to use behavioral measures of mind wandering (e.g., Brosowsky, Murray, Schooler, & Seli, 2021b; Smith et al., 2021) and traumatic intrusions (e.g., Takarangi et al., 2014) to better understand the relation between mind wandering and PTSD symptomology. PTSD, for instance, can be associated with negative beliefs and cognitions about oneself. One possibility here is that negative beliefs bias self-reports of mind wandering and, consequently, participants who suffer from PTSD symptoms are overestimating their lack of control over their thoughts. If that were the case, we might expect that the association between behavioral and self-report measures of mind wandering would be moderated by PTSD symptomology.

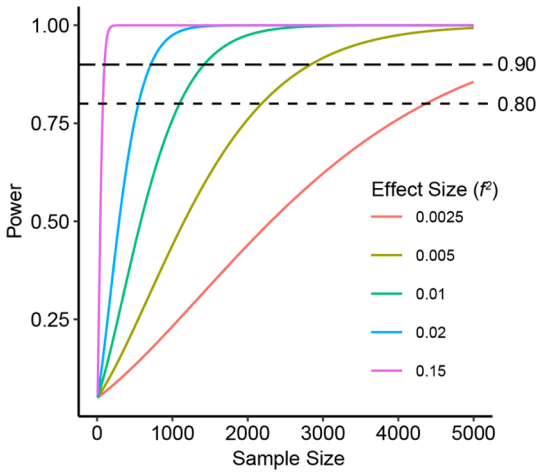

Fig. A1. Results of the sensitivity analysis. Power to detect a range of effect sizes (f^2) are plotted against the required sample size.

Second, the mind-wandering measures we adopted do not distinguish between different conceptualizations of mind wandering (e.g., stimulus-independent thought, perceptual decoupling, task-unrelated thought, unconstrained thought; see Seli et al., 2018). Such distinctions might be important for understanding the relationship between intrusive thoughts, PTSD symptomology, and mind wandering (e.g., Berntsen, 2021). Thus, future research would surely benefit from developing measures that distinguish between these different facets of mind wandering to explore how our finding generalizes across different varieties of mind wandering.

Finally, the potentially interactive relationship between mind wandering and intrusive thoughts remains unclear. On the one hand, the occurrence of an intrusive trauma-related thought could potentially trigger prolonged mind wandering episodes, intentionally or unintentionally. On the other hand, trauma-related thoughts might be more likely to intrude when one is engaged in mind wandering, perhaps potentially triggered by thoughts and memories that occur during the mind wandering episode. Understanding the interplay between mind wandering and intrusive trauma-related thoughts could have important implications for developing interventions to reduce trauma-related intrusions. If, for instance, intrusions are more likely to occur during mind wandering episodes, one could focus interventions on reducing mind wandering to indirectly influence the frequency of traumatic intrusions.

5. Compliance with Ethical Standards

Funding: No funding was received for conducting this study.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the University of Waterloo and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

CRediT authorship contribution statement

Nicholaus P. Brosowsky: Conceptualization, Formal analysis, Data curation, Writing – original draft, Visualization. **Alyssa C. Smith:** Conceptualization, Investigation, Writing – review & editing. **Dan Smilek:** Conceptualization, Investigation, Writing – review & editing, Supervision. **Paul Seli:** Conceptualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Sensitivity Analysis

Using the 'WebPower' R package, we estimated the sample sizes required to detect a range of effect sizes. Effect size was operationalized as a change in R^2 across two linear regression models in the form of Cohen's f^2. We calculated our power to detect an increase in R^2 in our final model with five parameters (Table 3, Step 3) as compared to our reduced model with two parameters (Table 3, Step 1). Fig. A1 illustrates the resulting power curves for effect sizes of 0.0025, 0.005, 0.01, 0.02, and 0.15. Note that Cohen suggested an f^2 of 0.02, 0.15, and 0.35 represent small, medium, and large effect sizes (Cohen, 1988).

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