Testing the predictions of the Dynamic Framework of mind wandering

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Abstract

In their seminal paper outlining their "Dynamic Framework" of mind wandering, Christoff et al. (2016) argue for the importance of increased efforts to elucidate the correlates of freely moving thought (FMT; i.e., thoughts that are unconstrained by executive control), and they propose a number of hypotheses linking FMT to creativity and to clinical disorders (e.g., OCD and ADHD). According to this framework, FMT supports spontaneous creative insights and, consequently, ought to be positively correlated with creative performance. Additionally, because FMT is characterized by topical shifts in content, Christoff et al. hypothesized that rates of FMT ought to be negatively associated with OCD (a disorder marked by repetitive thought patterns) and positively associated with ADHD (a disorder characterized by topical shifts in attention). To test these hypotheses, here, we obtained state-level reports of FMT during a cognitive tasks, after which we assessed participants' creativity, and their OCD and ADHD symptoms. Contrary to expectation, we found that participants who reported higher levels of FMT tended to score *lower* on a subsequent test of creativity. Moreover, and contrary to the Dynamic Framework's hypotheses, we found a *positive* relationship between FMT and OCD, and no relationship between FMT and ADHD. These results indicate that the theory guiding the Dynamic Framework of mind wandering is in need of serious revision.

Keywords: mind wandering, freely moving thought, dynamic framework, creativity, task-unrelated thought

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Since it was first integrated into mainstream psychology almost 15 years ago (Smallwood & Schooler, 2006), the topic of mind wandering has garnered considerable attention and there has been growing interest in understanding its nature as a cognitive and neurological state, as well as its causes and consequences (e.g., Smallwood, McSpadden, & Schooler, 2007; Smallwood, Fishman, & Schooler, 2007; Smallwood, Beach, Schooler, & Handy, 2008; Smilek, Carriere, & Cheyne, 2010; Killingsworth & Gilbert, 2010; Thomson, Besner, & Smilek, 2013). In the vast majority of research on the topic, researchers have conceptualized mind wandering in terms of thoughts that are unrelated to a focal task, or, "task-unrelated thought" (TUT). Indeed, as revealed by a recent analysis of the literature (Mills et al., 2018), in 2016, 94.5% of the studies investigating mind wandering had an explicit focus on TUT. More recently, however, in their widely cited review article entitled "Mind wandering as spontaneous thought: A dynamic framework," Christoff et al. (2016) argue for a new approach to the study of mind wandering: one that focuses on an understudied variety of mind wandering: freely moving thought (FMT). To date, with only a handful of studies investigating FMT, much remains to be learned about this newly identified variety of mind wandering. In the present study, we sought to shed light on FMT by examining its relation to various theoretically relevant variables, including task performance, creativity, affective dysfunction, and clinical disorders.

The conceptualization of FMT arose from the recent suggestion that researchers ought to expand their approach to the study of mind wandering by placing emphasis on its dynamics, rather than exclusively focusing on its content (Christoff et al., 2016). Investigation of this newly proposed "Dynamic Framework" of mind wandering departs from the bulk of previous research on the topic because, rather than defining mind wandering in terms of its relation to a task (i.e., "task-unrelated thought"), this framework defines mind wandering as "relatively unconstrained" thought (Mills et al., 2017, p. 21). As argued by Christoff et al., such an approach to the study of mind wandering may be particularly fruitful since, unlike frameworks that focus exclusively on TUT, the Dynamic Framework can offer insights into the causes and evolution of spontaneous thought. This is an intuitively appealing proposition: mind wandering often feels effortlessly fluid, which suggests that conceiving of it in terms of unconstrained thought may more accurately capture people's phenomenological experiences with this mental state (for a similar argument, see Irving et al., under review).

To date, although there exist only a handful of studies examining FMT (Christoff et al., 2016; Mills et al., 2018; O'Neill et al., under review), in their seminal paper, Christoff et al. (2016) generated a number of currently untested hypotheses that predict varying levels of FMT in disorders such as attention-deficit/hyperactivity disorder (ADHD), obsessive-compulsive disorder (OCD), depression, and anxiety. For example, ADHD is widely recognized as a disorder marked by excessive variability in thought content, which is a trait that is plausibly associated with a high frequency of FMT. Conversely, affective constraints that manifest as fixation on symptoms of distress are implicated in depression and anxiety, which have been described as reflecting "excessive stability in thoughts" and "repetitive negative thought patterns," respectively (Gottleib & Joorman, 2010; Nolan-Hoeksema et al., 2008; Watkins, 2008; Matthews & McLeod, 2005). According to the Dynamic Framework, people with depressive or anxious thought patterns should less frequently engage in constrained thought (or "FMT"). Similarly, the Dynamic Framework suggests that FMT ought to be relatively absent in the obsessive (fixed) thought patterns present in OCD, with the prediction that people suffering from OCD should tend to less frequently engage in FMT.

Beyond predicting relations among FMT and clinical disorders, the Dynamic Framework predicts a positive correlation between rates of FMT and creativity (i.e., original, unique, and useful ideas; Christoff et al., 2016). According to this framework, creative thought belongs in the same family of "spontaneous thoughts" as dreaming and mind wandering, and, as such, is characterized by its relative lack of constraint. Novelty of thought content, like the colloquial metaphor of "thinking outside the box," is enabled by one's ability to circumvent conventional and/or obvious ideas and extend an existing idea into new conceptual territory. Since constrained thoughts traverse paths of least resistance in conceptual space, FMT is the dimension that characterizes this process of elaboration. When arriving at the third component of a creative idea (usefulness), a more constrained process is engaged, by which goal-related constraints are applied to the new creative solution (Beaty et al., 2016). Insight may be a result of previously divergent components converging into a coherent and plausible solution.

Here, we test the foregoing hypotheses by investigating whether FMT is, as hypothesized by Christoff et al. (2016), associated with increased creativity and ADHD symptomatology, and (c) lower levels of obsessive thought. To these ends, throughout a 2-back working-memory task,

we intermittently presented thought probes to index participants' rates of FMT. We then examined the relations between rates of FMT during the 2-back and performance on the Alternate Uses Task (AUT; Guilford, 1967), a gold-standard test of verbal creativity. In addition, we acquired self-report measures of depression, anxiety, stress, ADHD, and OCD, to shed light on the clinical associations of spontaneous and fluid thought dynamics.

Method

Participants

Participants were recruited via Amazon Mechanical Turk (www.mturk.com) and were paid $3.60 (USD) for completing the study, which lasted approximately 30 minutes. We decided, in advance, to collect data from 225 participants. However, data from nine participants were removed from the sample due to failures to respond to all of the thought probes. Hence, the final sample consisted of 216 participants (95 women, mean age = 38). All participants provided informed consent and were treated in accordance with guidelines approved by the IRB at Duke University.

Measures

The 2-back working-memory task. On each trial of the 2-back task, we presented participants with one of nine letters (B, F, K, H, M, Q, R, X, Z), pseudorandomized, in the center of the screen for 500 ms, with a fixation cross interstimulus interval of 2,000 ms. Participants were required to press the spacebar whenever the letter presented matched the letter presented two trials ago. This task took approximately 15 minutes to complete.

Thought probes. Over the course of the 2-back task, participants were pseudo-randomly presented with 10 thought probes that indexed (a) task-unrelated thought (TUTs; i.e., "on task" or "off task), (b) the intentionality of any reported TUTs (Seli, Cheyne, et al., 2015), and (c) freely moving thoughts (FMTs). Prior to completing the task, participants were briefed on what to expect and how to interpret the probes. To assess task-relatedness and intentionality of thoughts, participants responded to the following probe: "Just prior to the onset of this screen, I was: (1) Focused on the task. (2) Not focused on the task, but I <u>was</u> trying to focus on it. (3) Not focused on the task, but I <u>wasn't</u> trying to focus on it" (O'Neill, under review). Following their

response to this probe, participants answered either "yes" or "no" to the prompt: "The thoughts I was experiencing were moving freely" (Mills et al., 2018).

Spontaneous and deliberate mind wandering. At the end of the 2-back task, we assessed participants' trait levels of unintentional (or spontaneous) and intentional (or deliberate) mind wandering by administering two trait-level questionnaires developed by Carriere et al. (2013). Participants were asked to rate aspects of their everyday experiences of mind-wandering from 1-7 (i.e. 1 was "rarely" and 7 was "not a lot"). The spontaneous mind wandering (MW-S) questionnaire contains questions that relate to unintentional mind-wandering, such as: "I mind-wander even when I'm supposed to be doing something else," while the deliberate mind wandering (MW-D) questionnaire contains questions related to instances of intentional mind-wandering, such as: "I allow my thoughts to wander on purpose." A new set of questions, designed to capture trait-level differences in freely moving thought, was also included, which included Likert scales for agreement with statements such as: "My thoughts seem to move around on their own, flowing from one thing to another" and: "It feels like my thoughts could land on pretty much anything, and they seem to flow with ease." These measures were included for exploratory purposes and will not be discussed further.

Depression, Anxiety, and Stress Scale (DASS 21): The DASS 21 is a set of three self-report scales of negative emotionality: depression, anxiety, and stress. Chosen for its brevity and high reliability (Ng et al., 2007), this instrument captures aspects of emotional health that we might expect to be related to incidence of mind-wandering or highly constrained, ruminative thought.

Short-Form of the Adult Self-Report ADHD Scale (ASRS): The ASRS is comprised of six questions that capture central features of ADHD symptomatology, such as: "How often do you feel overly active and compelled to do things, like you were driven by a motor?" It has been validated against more exhaustive measures and is commonly used in primary-care settings as an effective screen for ADHD in adults (Hines et al., 2012).

Dimensional Obsessive Compulsive Scale (DOCS): The DOCS addresses four categories of obsessive thought. Within each category, questions are posed related to the "kinds of thoughts," also known as obsessions, as well as behaviors, such as rituals and compulsions. The first category indexed by the DOCS is "concerns about germs and contamination." Second, "concerns about being responsible for harm, injury, or bad luck." Third, "unacceptable

thoughts," and fourth, "concerns about symmetry, completeness, and the need for things to be 'just right'" (Abramowitz, 2010). This questionnaire has since been shown to be reliable and valid in assessing obsessive-compulsive symptoms in both clinical and non-clinical populations (Eilertsen et al., 2017).

The Alternate Uses Task (AUT). Finally, participants completed the Alternate Uses Task (AUT; REF). The AUT is a widely used measure of divergent thinking (REFS), a component of creativity that describes an individual's ability to access and relate semantically distant concepts. For this task, participants are presented the name of an object (e.g., brick), and are asked to generate as many novel and creative uses for this object as possible. In the present study, participants were asked to list novel uses for two separate objects: *marble* and *balloon*. For each object, participants were allotted three minutes to list their generated uses. Three human raters used a 1 (obvious, ordinary, or intractable) to 5 (very imaginative or recontextualized) scale to provide creativity ratings for each of the uses that were generated by participants. Interrater reliability was within the acceptable range (Cronbach's alpha = .68).

Primary measures. Primary performance measures included performance on the 2-back task, performance on the AUT, occurrence of TUTs (both intentional and unintentional) and the occurrence of FMTs. 2-back performance is reported as *d* primes. *D* primes are values that represent the distance between normalized signal and noise distributions that underlie target hits (signal) and foil false alarms (noise), and is commonly applied to performance on recognition tasks such as the n-back (Haatveit et al., 2010).

Results

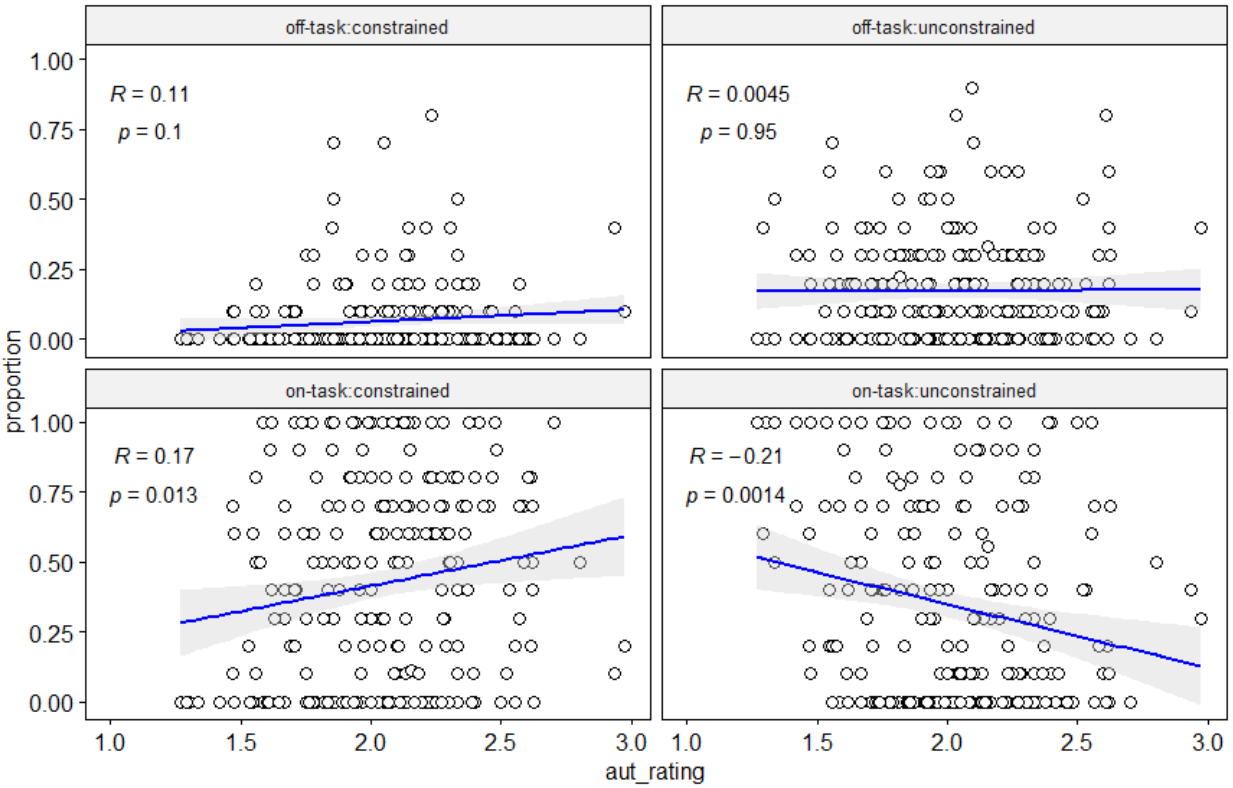
We report all descriptive statistics for the measures of interest in Table 1. All values are the average proportions of thought probes, out of 10, to which participants reported the experience of FMT, on-task thought, or intentional/unintentional mind wandering.

Table 1. *Descriptive Statistics for Primary Measures of Interest*

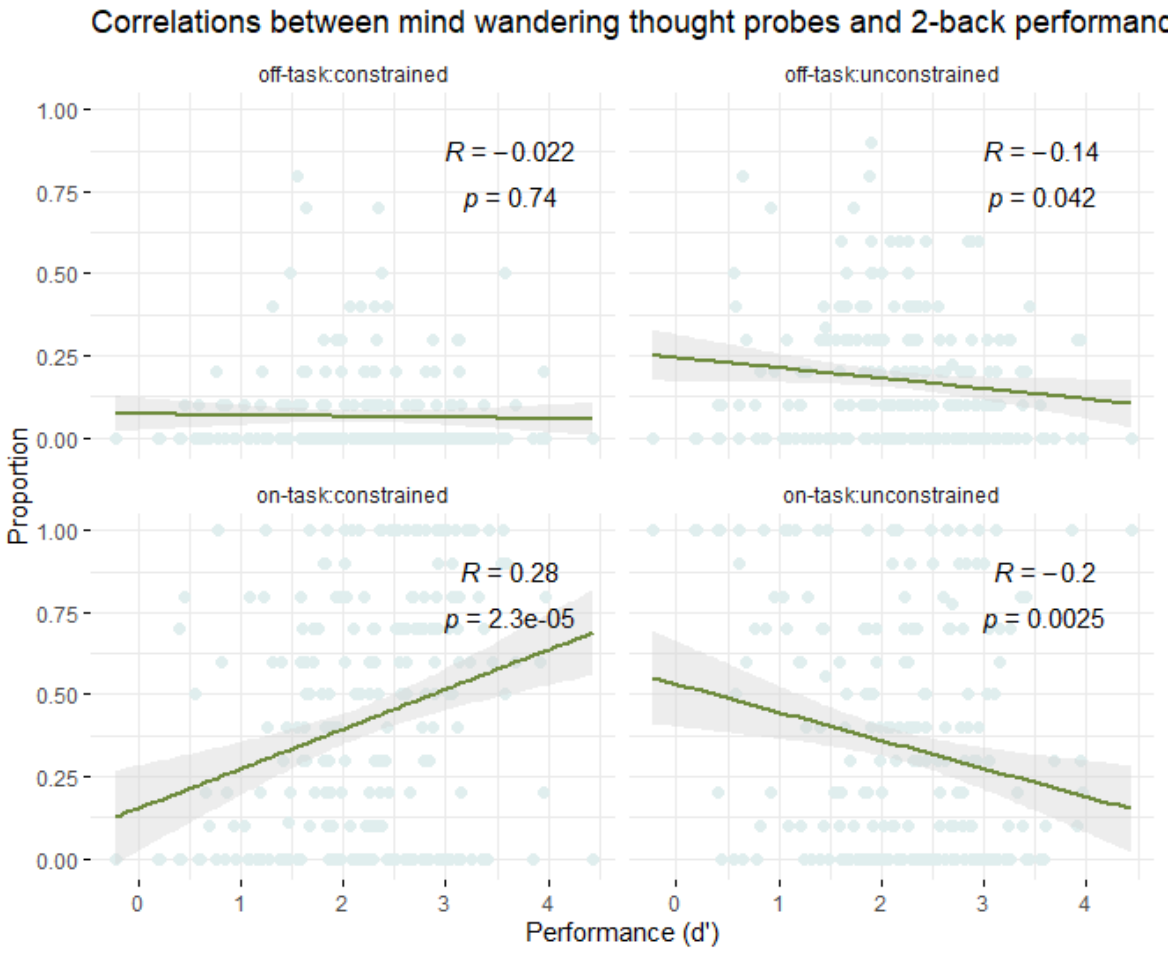
	M	95% CIs	Skewness	Kurtosis

FMT	.52	[.47, .57]	-.01	.02
On-Task	.76	[.73, .79]	-.8	-.12
Unintentional MW	.22	[.19, .25]	.74	-.06
Intentional MW	.02	[.01, .03]	5.09	30.73

FMT and creativity: First, we examined the possibility that rates of FMT during the 2-back task are associated with AUT creativity scores. Recall that Christoff et al. (2016) hypothesized that creative thinking is a form of spontaneous thought that differs from on-task thinking insofar as it is believed to be associated with relatively high levels of FMT. However, contrary to this prediction, a Pearson Product-Moment correlation analysis indicated that FMT was significantly *negatively* correlated with AUT scores (r = -.17, p = .01; see Figure 1), indicating that participants who more frequently engaged in FMT during the 2-back task tended to perform more poorly on the creativity measure provided by the AUT. This distinction becomes clearer when comparing the correlations between the AUT and on-task FMT (r = -.21, p = 0.001) to that between the AUT and on-task constrained thought (r = .17, p = 0.01).



FMT and 2-back performance: Next, we examined the relationship between FMT and 2-back performance. Recall that, according to the Dynamic Framework, FMT characterizes thought patterns that are in opposition to goal-directed thinking. Thus, one would expect that participants who more frequently engaged in FMT ought to perform more poorly on the 2-back. This was indeed the case: performance on the 2-back was significantly negatively related to FMT in both on- and off-task reports



FMT and ADHD, OCD, depression, anxiety, and stress. Next, we examined the relations between FMT and our self-report measures of clinical symptomatology (i.e., ADHD, OCD, anxiety, stress, and depression). Only one significant relationship emerged: namely, OCD was found to be modestly significantly positively correlated with rates of FMT (r = .16, p = .02). Importantly, these results are odds with the predictions that the high levels of thought variability often associated with ADHD would be predictive of probe-caught rates of FMT. Additionally, we predicted that participants scoring higher in the anxiety, stress, and depression questionnaires would less frequently report FMT due to the inclusion of entrenched, ruminative thought patterns symptoms captured in those questionnaires. However, none of these relationships are evident in this sample (all *ps* > .1).

Table 2. *Correlations between FMT and clinical self-report measures*

	FMT	Depression	Anxiety	Stress	ADHD
Depression	.379				
Anxiety	.097	.701***			
Stress	.040	.746***	.776***		
ADHD	.087	.701***	.480***	.546***	
OCD	.162*	.613***	.710***	.710***	.449***

* p < .05; **p < .01; ***p < .001

Discussion

Inspired by historical anecdote, one of the primary aims of this study was to determine whether unconstrained thought patterns, or 'freely moving thought', might describe a particular quality of mentation that is both unobtrusive and beneficial to creating new, semantically distant associations. To encourage task-unrelated thought while still maintaining moderate task demands, we presented participants with the 2-back task, a laboratory test of working memory. Participants were probed throughout the task on the task-relatedness of their thoughts and whether or not their thoughts moved freely. To conclude the session, we addressed our specific hypotheses regarding FMT's link to creativity, and explored its relationship to clinically-relevant extremes of thought constraint, namely the high thought variability present in ADHD symptomatology and strong thought constraint associated with symptoms of obsessive-compulsive disorder, depression, and anxiety.

Inconsistent with the initial predictions, the relationships between thought probes purportedly measuring FMT and the aforementioned clinical self-report measures revealed poorer associated performance on both the AUT and the 2-back task. The FMT thought probe also bore a relationship only to one clinical self-report measure: the Adult Self-Report ADHD Scale. OCD, stress, anxiety, and depression were unrelated to rates of FMT.

Previous studies using these thought probes found task performance to be unaffected by reported rates of FMT (O'Neill et al., in review). The finding that thoughts are described as freely-moving for around 70% of all thought probes, regardless of fluctuating task demands, supported the possibility that FMT might be a key feature of thoughts that come and go in an effortless manner without disrupting the flow of a task. However, there are key differences that may explain why we found a performance decrement on the 2-back task compared to the Mind Wandering Clock task that was employed previously (O'Neill et al., in review; Seli et al., 2018). First, the 2-back task requires active rehearsal of the the incoming stream of stimuli. Unlike the Clock Task, which simply requires participants to anticipate pushing a button at regular intervals, there are no helpful, task-related thoughts during the 2-back task other than what is actively being maintained in working memory. The nature and difficulty of this task detract from making any predictions about task-related thought that can be beneficial, such as those that characterize flow states. However, our study does distinguish FMT from goal-directed focus on the 2-back.

Initially, one might venture that unconstrained thought is a dimension directly adjacent to inattention, and that the loose hold on the stream of thought captured in the freely-moving thought probe reflects a departure from attention to the primary task. From there, strong overlap between off-task thought and unconstrained thought is predicted, as it has in previous studies (O'Neill et al., in review; Mills et al., 2018). However, this is not the case here, as unconstrained thought did not correlate significantly with task-unrelated thought. In fact, the opposite was true: the lack of statistical relationship between FMT and task-relatedness was driven by the ceiling effect that the 2-back task had on goal-directed thought (where 76% of all thoughts were on-task). The occurrence of on-task thoughts that are unconstrained supports the idea that unconstrained thoughts should not be the singular necessary and defining characteristic of mind wandering.

An alternate explanation is that unconstrained thought, even when it is task-related, leads to reduced efficacy in transferring thought content into cognitive outcomes. Scattered, but on-task, thought may only be actionable when it can be pinned down. Applied to the AUT, those participants high in unconstrained thoughts may still be engaging in important cognitive precursors to creative idea generation. In previous work by Beaty et al. (2016), cooperation between diffuse brain networks, such as the default mode network, and more focal control

networks predicts success on the AUT. Our participants whose thought patterns could be presumed as more diffuse may be missing the second, and critical, component of creative cognition: the executive component that can knit together divergent threads of thought in the service of a goal-directed purpose.

Among self-report measures of psychopathological symptoms, the most robust relationships were within the self-report measures themselves. This does not bear on our research questions, but is consistent with abundant evidence of comorbidities between the associated diagnoses, as well as the rarity with which these disorders present in isolation from one another (Caspi & Moffitt, 2018; Eaton et al., 2010; Carter et al., 2005; Fineberg et al., 2005; Bair et al., 2003) . Between self-report measures and mind-wandering, a cautious interpretation could be given to the significant positive correlation between on-task thought and stress. Example questions on the DASS-21 that target stress include: “I was intolerant of anything that kept me from getting on with what I was doing,” and, “I felt that I was using a lot of nervous energy.” Individuals with these tendencies may also be prone to being compulsively on-task in the context of the n-back, which is a task that requires sustained concentration.

The other, significant correlations found between clinical self-report measures and thought probes were the weak associations between intentional mind-wandering and depression, anxiety, stress, and OCD symptoms. Due to the n-back’s moderate-to-high task demands, it is important to draw attention to the low incidence of off-task reports our thought probes yielded, particularly those that indicate deliberate disengagement: of the ten thought probes administered to each participant, an average of 76% of responses indicated on-task thought, with the majority of off-task thoughts (22% of all thought probes) being unintentional and only 2% of thoughts being instances of intentional mind-wandering (Table 1). Therefore, it is difficult to draw any conclusions around the small correlations between intentional mind-wandering and clinical self-report survey scores.

Amidst an array of non-significant, counterintuitive results, what this study offers is a partial answer to the predictions put forth by the Dynamic Framework. Christoff et al. (2016) called for the use of the Dynamic Framework and resulting freely-moving thought probes to be used to “shed new light on mental disorders that are marked by alterations in spontaneous

thought, including depression, anxiety and attention deficit hyperactivity disorder" (Christoff et al., 2016; p. 718). In less explicit terms, it was also predicted that "thought ceases to be spontaneous at the strongest levels of automatic constraint, such as during rumination or obsessive thought" (Christoff et al., 2016; p. 718). Here, those predictions are addressed. The only significant relationship we find with unconstrained thought is its positive correlation with obsessive-compulsive symptoms— the opposite of what was predicted. The lack of evidence that these thought probes capture alterations in thought dynamics typical of depression, ADD, and anxiety is also an indication that it is either inappropriate to classify these disorders by their thought dynamics, or that the FMT thought probe put forth by Mills et al. (2018) does not capture what it set out to.

Before investing research efforts in describing thought by the extent to which it moves freely, future work should seek to refine how we frame these questions to participants. The framing, frequency, and structure of thought probes to capture facets of mind-wandering is a topic of much discussion within the field of mind-wandering research (Robison et al., 2019; Weinstein, 2018; Weinstein et al., 2017), and an equal amount of consideration should be taken as mind-wandering research integrates thought dynamics into its theoretical frameworks.

Another nuance that could be more specifically targeted, alluded to previously, is the timecourse and interplay between unconstrained and directed thought patterns. It follows from the literature that creative idea generation begins with undirected and unconstrained thought but must be channeled according to an increasingly narrowed focus. If capturing this unfolding of dynamic thought is to be the focus, future studies might investigate AUT responses in relation to thought constraint at the beginning versus the end of an allotted amount of time.

This study provides yet another step towards a more coherent understanding of what can and cannot be described by the thought probes currently employed in the study of mind-wandering. Thought dynamics are an inherent quality of mental life at large, and should not be left out of the effort to more precisely describe spontaneous and untethered thinking. However, this study failed to link unconstrained thought to psychopathologies characterized by altered thought dynamics. The current method of probing for freely-moving thoughts, as put forth by Mills et al. (2018) also showed a detriment, rather than improvement, in performance on creative

tasks expected to benefit from unconstrained thought. These findings invite more research into optimization of thought constraint thought probes, in terms of both framing and placement within the primary task. For example, there is likely to be heterogeneity under the descriptor of freely-moving thought, both in its phenomenology, but also in the heuristics individuals attach themselves to when diagnosing their own thought constraint. Thus, while some may respond to a FMT probe affirmatively based on the number of topical shifts they experienced, others may respond on the basis of the ease with which their thoughts flow. Future work should invest in reformulating and testing new thought probes that allow for this heterogeneity to be expressed.

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