Fixation, Flexibility, and Creativity: The Dynamics of Mind Wandering

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Abstract

Mind-wandering research is long on results and short on theory. One notable exception to this is the *Dynamic Framework* of mind wandering (Christoff et al., 2016; Girn et al., 2020; Mills et al., 2018), a theoretical framework that characterizes mind wandering as episodes of thought that are unconstrained by executive-control processes. Critically, this framework makes testable predictions about the associations between mind wandering (characterized as unconstrained thought) and other cognitive traits such as generative creativity (i.e., divergent thinking) and clinical conditions. Predictions include *positive* associations between unconstrained thought and ADHD and divergent thinking, and *negative* associations between unconstrained thought and depression, anxiety, and OCD. In Study 1, to test these predictions, we measured participants' reports of unconstrained thoughts during a cognitive task and assessed divergent thinking and various psychopathological symptoms. We failed to find the predicted associations between unconstrained thoughts and the various clinical conditions (including ADHD, depression, anxiety, and OCD), and observed an unexpected *negative* correlation between divergent thinking and unconstrained thought. In a second study, we more directly assessed the predicted relation between unconstrained thoughts and divergent thinking by manipulating rates of unconstrained thought during a creative-incubation interval. We again failed to find support for the prediction that unconstrained thought is associated with increased divergent thinking. These results, all of which are at odds with the predictions of the Dynamic Framework, suggest either the need to revise the framework, or that current methods are inadequate for the study of unconstrained thought.

Keywords: mind wandering, unconstrained thought, freely moving thought, dynamic framework, creativity

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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, with growing interest in understanding its nature as a cognitive state, its neural underpinnings, and its causal profile (e.g., Killingsworth & Gilbert, 2010; Smallwood, Beach, Schooler, & Handy, 2008; Smilek, Carriere, & Cheyne, 2010; Smallwood, Fishman, & Schooler, 2007; Smallwood, McSpadden, & Schooler, 2007; Thomson, Besner, & Smilek, 2013). Typically, researchers have conceptualized mind wandering in terms of thoughts that are unrelated to a focal task, or *task-unrelated thought* (TUT, for short). A recent analysis of mind-wandering research published in 2016 found that 94.5% of papers implicitly or explicitly characterized mind wandering in terms of TUT (Mills et al., 2018). In fact, only *one* paper marked an exception to this trend: a now highly-cited review article published in *Nature Reviews Neuroscience*, which originally introduced and delineated the Dynamic Framework of mind wandering (Christoff et al., 2016; see also Girn et al., 2020; Irving, 2016; Mills et al., 2018).

The Dynamic Framework marks a significant departure from standard views of mind wandering. Whereas most researchers define mind wandering in terms of the content of thought, the Dynamic Framework defines mind wandering in terms of constraints on thinking. Constraint is defined in terms of sustained topical focus, and the level of constraint is determined by both deliberate, top-down processes (i.e., cognitive control), and automatic, bottom-up processes (i.e., attentional capture by affective or sensory salience). On one end of the spectrum, dreaming is conceptualized as a maximally unconstrained mental state (i.e., frequent, loosely-associated topical shifts); on the other end of the spectrum, goal-directed thinking is conceptualized as a maximally constrained mental state (i.e., sustained topical focus; see Christoff et al., 2016, Figure 1). The Dynamic Framework locates mind wandering between these two poles: it consists in thoughts that are *more* constrained than dreaming but *less* constrained than goal-directed thinking.

In the Dynamic Framework, then, mind wandering is defined not as task-unrelated thought (e.g., Smallwood & Schooler, 2006), but instead as “thoughts that proceed in a relatively free, unconstrained fashion” (Christoff, Mills, et al., 2018, p. 958). This conceptualization of mind wandering has the intuitive implication that this mental experience is fluid and characterized by a lack of guided attention (Irving, 2016): a conceptualization that seems to do a better job of mapping onto the phenomenology of mind wandering than does the TUT conception (for a similar argument, see Irving et al., under review). An important implication of the Dynamic Framework is that thoughts cannot be both unconstrained *and* related to some focal task because goal-directed thought is, by definition, highly constrained (see Christoff et al., 2016, Figure 1). However, this prediction—which has been a topic of contention in the literature (Christoff, Mills, et al., 2018; Seli, Kane, Metzinger, et al., 2018)—has failed to receive empirical support from at least two studies, both of which found that people frequently report thoughts that are both on-task *and* unconstrained (Mills et al., 2018; O’Neill et al., under review).

Although this specific prediction (i.e., that thoughts cannot be both unconstrained and task-related) lacks empirical support, the Dynamic Framework makes a number of other—yet to be tested—predictions about individual-differences correlates of unconstrained thought. First, as Christoff et al. (2016) note, ADHD is widely recognized as a disorder of unconstrained thought that manifests in excessive *variability* of thought content. Hence, Christoff et al. predict that people scoring high on assessments of ADHD ought to more frequently engage in unconstrained thoughts compared to those scoring lower on ADHD assessments. Conversely, depression and anxiety are disorders often marked by a relative lack of variability in thought content. Indeed, depression sometimes reflects excessive stability in thoughts (Gotlib & Joormann, 2010; Nolen-Hoeksema et al., 2008), and anxiety often reflects repetitive negative thought patterns (Matthews & McLeod, 2005; Watkins, 2008). Thus, Christoff et al. predict that people experiencing higher levels of depression and those experiencing higher levels of anxiety ought to engage less frequently in unconstrained thought relative to people experiencing lower levels of depression/anxiety. Those whose thoughts tend to manifest as obsessive (fixed) patterns presenting as OCD should also, according to Christoff et al., exhibit lower rates of unconstrained thinking relative to those with fewer obsessive thoughts.

In addition to predicting associations between unconstrained thought and clinical disorders, the Dynamic Framework predicts a positive correlation between unconstrained thought and creative generation, or, divergent thinking (i.e., a type of thinking involved in the generation of novel, creative ideas; Girn, Mills, Roseman, Carhart-Harris, & Christoff, 2020). According to this framework, divergent thinking belongs in the same family of spontaneous thoughts as dreaming and mind wandering (Fox et al., 2013), and is characterized by its relative lack of constraint. Indeed, as Christoff and colleagues note, "…generating ideas for a divergent thinking task in a process of blind variation (Campbell, 1960) may take place in a mental state more similar to dreaming (with low automatic and deliberate constrains)" (Girn et al., 2020, p. 2). Consistent with this view, it has been argued that the ability to generate novel thought content, or to 'think 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 (e.g., Beaty et al., 2014); and, the Dynamic Framework implies that unconstrained thoughts constitute this explorative process (see also Sripada, 2018). Hence, the Dynamic Framework predicts that people who more frequently engage in unconstrained thoughts ought to perform better on tests of divergent thinking than those who less frequently experience such thoughts.

To date, only a handful of studies have tested the predictions of the Dynamic Framework (Irving et al., under review; Mills et al., 2018; O'Neill et al., under review). This is surprising, both because the 2016 review outlining the Dynamic Framework is one of the most widely cited mind-wandering papers (with 446 citations in just four years[1]) *and* the Dynamic Framework is one of the few systematic theories of mind wandering offered to date. Thus, here, across two studies, our aim was to investigate the Dynamic Framework by examining some of its key predictions. In Study 1, we tested three predictions of the Dynamic Framework:

(a) Unconstrained thinking should be positively associated with ADHD symptomatology.

(b) Unconstrained thinking should be negatively associated with depressive, anxious, and obsessive thought patterns.

(c) Unconstrained thinking should be positively associated with divergent thinking.

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[1] Google Scholar, April 25, 2020.

Study 1

In Study 1, to test the three predictions of the Dynamic Framework, we administered a 2-back task during which we intermittently presented thought probes—developed in Mills et al. (2018)—that indexed rates of unconstrained thought. We then obtained self-report measures of ADHD, depression, anxiety, stress, and OCD, and measures of divergent thinking from the Alternate Uses Task (AUT; Guilford, 1967). Additionally, we administered trait-level measures of deliberate and spontaneous mind wandering (MW-D and MW-S, respectively; Carriere, Seli, & Smilek, 2013). The rationale for the decision to include the deliberate and spontaneous mind wandering trait measures was twofold. First, in line with recent work showing a dissociation between state-level reports of the intentionality and constraint dimensions of mind wandering (O'Neill et al., under review), we wanted to determine whether trait levels of spontaneous and deliberate mind wandering were dissociable from state-level reports of unconstrained thought. Second, and more important, in the case that we did not find the hypothesized relations between thought constraint and the various trait-level measures we administered, we wanted to ensure that any failure to observe the predicted relations was not due to measurement error in the present study. Because the MW-D and MW-S have previously been found to correlate with many of the measures obtained here (i.e., ADHD, depression, anxiety, stress, and OCD; Seli, Beaty, et al., 2019; Seli, Risko, et al., 2018; Seli, Smallwood, et al., 2015), we expected to again observe these previously reported patterns of results. Critically, this would minimize the concern that measurement error in our study precluded our ability to find evidence to corroborate the predictions of the Dynamic Framework.

Method

Participants

Participants were recruited via Amazon Mechanical Turk 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 (95 women, M_{age} = 38.13, SD_{age} = 11.39). We chose this sample size because it would allow us to detect small-to-medium effects with high power. Participants were eligible for this study if they were native English-speaking U.S. residents over the age of 18 and had at least a 90% approval rate on previous Mechanical Turk studies. All participants provided informed consent and were treated in accordance with guidelines approved by the IRB at Duke University.

Materials

The 2-back task.

Instructions and stimuli were displayed in the center of the screen. Stimuli consisted of the letters B, F, K, H, M, Q, R, X or Z and were presented pseudorandomly in a 62- pixel dark gray font in the center of the screen for 500 ms, with a fixation cross inter-stimulus interval of 2,000 ms. Participants completed 20 practice 2-back trials and 250 experimental 2-back trials, with 10 of the experimental trials including thought probes. Participants were instructed to press the spacebar whenever the letter presented on the current trial matched the letter presented two trials ago. During the practice trials, stimuli were presented in a static order containing 4 possible targets and participants were required to correctly respond to at least 2 of the 4 in order to proceed to the task. During the experimental trials the average number of possible targets was 29. Thought probes were also presented randomly throughout, with the exception of the first and last 10 trials, during which no probes were presented**.** The task took approximately 15 minutes to complete.

The dependent variable of the 2-back task was d’. d*’* is an accuracy measure that represents the distance between normalized signal and noise distributions that underlie target hits (signal) and foil false alarms (noise) and is commonly applied to performance in n-back tasks (Haatveit et al., 2010). The formula to calculate *d*’ is as follows: $d' = z(FA) - z(H)$, where FA reflects participants’ rates of false alarms (i.e., trials on which they mistake a foil for a target) and H reflects participants’ hit rates (i.e., trials on which they correctly identify a target); both fit to a normal distribution via a *z*-transform, and were adjusted for extreme values (Hautus, 1995).

Thought probes. Over the course of the 2-back task, participants were pseudo-randomly presented 10 thought probes that indexed (a) TUTs (i.e., “on task” or “off task), (b) the intentionality of any reported TUTs (i.e., intentional versus unintentional TUTs; Seli, Cheyne, et al., 2015), and (c) (un)constrained thought. Prior to completing the task, participants were briefed on what to expect and how to interpret the probes (see Appendix A). 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 was trying to focus on it (3) Not focused on the task, but I wasn’t trying to focus on it” (O’Neill et al., under review). Following their response to this probe, to assess thought constraint, participants answered either “yes” or “no” to the prompt: “The thoughts I was experiencing were moving freely” (Mills et al., 2018).

As noted above, in addition to indexing thought constraint (i.e., freely moving thought), we also indexed the task-relatedness of participants’ thoughts; this was done to maintain consistency with Christoff and colleagues’ initial work examining thought constraint (Mills et al., 2018). However, because the Dynamic Framework’s predictions are silent on the matter of task-relatedness and intentionality, we do not analyze these data in the present manuscript.

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?” This scale 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), and it has been found to be positively associated with trait levels of unintentional mind wandering (Seli, Smallwood, Cheyne, & Smilek, 2015). Questions are rated on a scale of 1 (never) to 5 (often) and are scored by assigning 1 point for ratings 2 or higher on questions 1, 2, and 3, and 1 point for ratings 3 or higher on questions 4, 5, and 6.

Dimensional Obsessive-Compulsive Scale (DOCS): The DOCS assesses 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”; the second assesses, “concerns about being responsible for harm, injury, or bad luck”; the third assesses “unacceptable thoughts”; and the fourth assesses “concerns about symmetry, completeness, and the need for things to be ‘just right’” (Abramowitz, 2010). The DOCS has been shown to be reliable and valid in assessing obsessive-compulsive symptoms in both clinical and non-clinical populations (Eilertsen et al., 2017), and positively correlates with unintentional mind wandering (Seli, Risko, Purdon, & Smilek, 2017). The total DOCS score was computed by summing each 1 (low occurrence) to 4 (high occurrence) scale.

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 might be expected to be positively associated with highly constrained, ruminative thought. Participants are instructed to rate, using a scale from 0 (did not apply to me at all) to 3 (applied to me very much or most of the time), the extent to which the statements applied to their previous week. Example questions include: “I found it hard to wind down,” and “I was worried about situations in which I might panic and make a fool of myself.” There were 7 questions each between depression, anxiety, and stress symptoms, and total scores were summed for each category. Note that, while Christoff et al. (2016) did not make any specific predictions about a potential relation between unconstrained thought and stress, we nevertheless included the stress subscale of the DASS for exploratory purposes (detailed information on content and scoring protocols for these clinical measures can be found in the Supplementary Materials).

The Alternate Uses Task (AUT). The Alternate Uses Task (AUT; Guilford, 1967) is a widely-used measure of divergent thinking (Guilford, 1967), which is a component of creativity that reflects 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. They received the following instructions:

> *For this task, you will be shown the names of common objects (e.g., "a brick") and your task is to come up with creative, unusual uses for this object.*
>
> *For example, here are some unusual uses for a BRICK:*
>
> - *- Use it as a paper weight;*
> - *- Grind it up and use the sand to make paint;*
> - *- Warm it up in the oven and put it in your bed to keep the bed warm;*
>
> *Please express your ideas succinctly. Your responses should be creative, useful and specific to the objects. "Throw it into the ocean" is not a useful response and not specific to a brick, because you could throw anything into the ocean.*

Separate your ideas with a semicolon (;)

You will have <u>three minutes</u> to generate as many creative responses as possible for the object, after which the page will submit.

As in previous work (e.g., Silvia, Beaty, & Nusbaum, 2013; Silvia et al., 2008), we examined two indices of divergent thinking: fluency and creativity ratings. Fluency scores were calculated as the total number of ideas generated. Creativity ratings were provided by three human raters using a 1 (obvious, ordinary, or intractable) to 5 (very imaginative or recontextualized) scale for uses generated for each of the two objects (marble and balloon). For each of the two objects, and for each participant, we computed the average creativity-rating score; we then computed the average of these two averages for a single creativity-rating score for each participant. Interrater reliability was within the acceptable range (Cronbach's alpha = .68).

Spontaneous and deliberate mind wandering. At the end of the study, we assessed participants' trait levels of unintentional (or spontaneous) and intentional (or deliberate) mind wandering by administering two trait-level questionnaires developed by Carriere, Seli, and Smilek (2013). Participants were asked to rate aspects of their everyday experiences of mind-wandering on a 7-pt. Likert scale (1 = "rarely", 7 = "not a lot"). The spontaneous mind wandering (MW-S) questionnaire measures trait susceptibility to unintentional mind wandering. For example, one item reads: "I mind-wander even when I'm supposed to be doing something else." The deliberate mind wandering (MW-D) questionnaire measures trait susceptibility to intentional mind wandering, for example: "I allow my thoughts to wander on purpose."

Procedure

Participants were first briefed on the definition of unconstrained, freely-moving thoughts (see Mills et al., 2018, for exact instructions), after which they began the 15-minute 2-back task. Intermittently, the task paused a total of ten times to probe participants to report on the task-relatedness and constraint of their thoughts. Upon completion of the 2-back task, participants completed two separate prompts on the AUT (balloon and marble) for three minutes each. A text box appeared for them to enter their responses, submitting each response serially. At the end of the AUT, participants completed (in the following order) the ASRS, DOCS, DASS-21, and the MW-S and MW-D questionnaires.

Study 1 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 task-relatedness of their thoughts and their experience of thought constraint.

We supplemented the null hypothesis significance tests with Bayes Factor analyses (Rouder, Speckman, Sun, Morey, & Iverson, 2009). With conventional frequentist testing it is not possible to quantify the evidence for a null effect. However, a Bayes Factor, is a continuous measure of the relative strength of evidence and can quantify the degree to which the data either favor the null or alternative hypothesis (Dienes, 2014; Rouder et al., 2009). Bayes Factors were computed using the R package BayesFactor and Bayes Factors (BFs) using its default settings

(Morey & Rouder, 2018); however, where appropriate we have conducted directional tests to correspond with the null hypothesis test conducted. BF_{10} indicates evidence in favor of the alternative hypothesis whereas BF_{01} indicates evidence in favor of the null hypothesis. To simplify the interpretation, we report the Bayes Factor in the direction the data supports (e.g., BF_{01} when there is more evidence in favor of the null over alternative hypothesis). As per previous recommendations, we refer to a BF > 3 as "moderate" and BF > 10 as "strong" evidence (Jeffreys, 1961; Rouder et al., 2009). Finally, we use +/- to refer to the directional hypotheses (e.g., BF_{0+} would refer to the evidence in favor of the null over a positive-effect model).

Thought constraint and ADHD, depression, anxiety, stress, and OCD

We began by examining the relations between probe-caught rates of unconstrained thought and self-report measures of clinical symptomatology (i.e., ADHD, OCD, anxiety, stress, and depression) (see Figure 1). Here we used directional Bayesian analyses to quantify the evidence for or against the Dynamic Framework predictions. Inconsistent with the Dynamic Framework's prediction that people reporting higher levels of ADHD symptomatology should tend to engage in higher rates of unconstrained thought, we found a non-significant relationship between these variables, $r = .09$, 95% CI [-.04, .22], $t(223) = 1.30$, $p = .193$, with anecdotal evidence in favor of the null, $BF_{0+} = 1.57$. Next, we examined the prediction that participants scoring higher on the anxiety and depression questionnaires would less frequently report unconstrained thought due to the inclusion of entrenched, ruminative thought patterns captured by those questionnaires (Christoff et al., 2016). However, there was no statistically significant correlation between anxiety and unconstrained thought, $r = .10$, 95% CI [-.03, .22], $t(223) = 1.45$, $p = .149$, with strong evidence in favor of the null, $BF_{0-} = 15.11$; and no significant correlation between depression and unconstrained thought, $r = .04$, 95% CI [-.09, .17], $t(223) = 0.57$, $p = .572$, with moderate to strong evidence in favor of the null, $BF_{0-} = 9.56$. Next, we examined Christoff et al.'s prediction of a negative correlation between unconstrained thoughts and OCD symptomatology: here, however, we found a significant *positive* correlation, $r = .16$, 95% CI [.03, .29], $t(223) = 2.46$, $p = .015$, with strong evidence in favor of the null, BF0- = 21.96. Finally, although Christoff et al. did not make any specific predictions about the relation between unconstrained thoughts and stress, for completion, we explored the possibility that these measures would be related. Here, too, we failed to find a significant correlation between stress and unconstrained thought, $r = .04$, 95% CI [-.09, .17], $t(223) = 0.60$, $p = .551$, with moderate evidence in favor of the null, $BF_{01} = 5.97$.

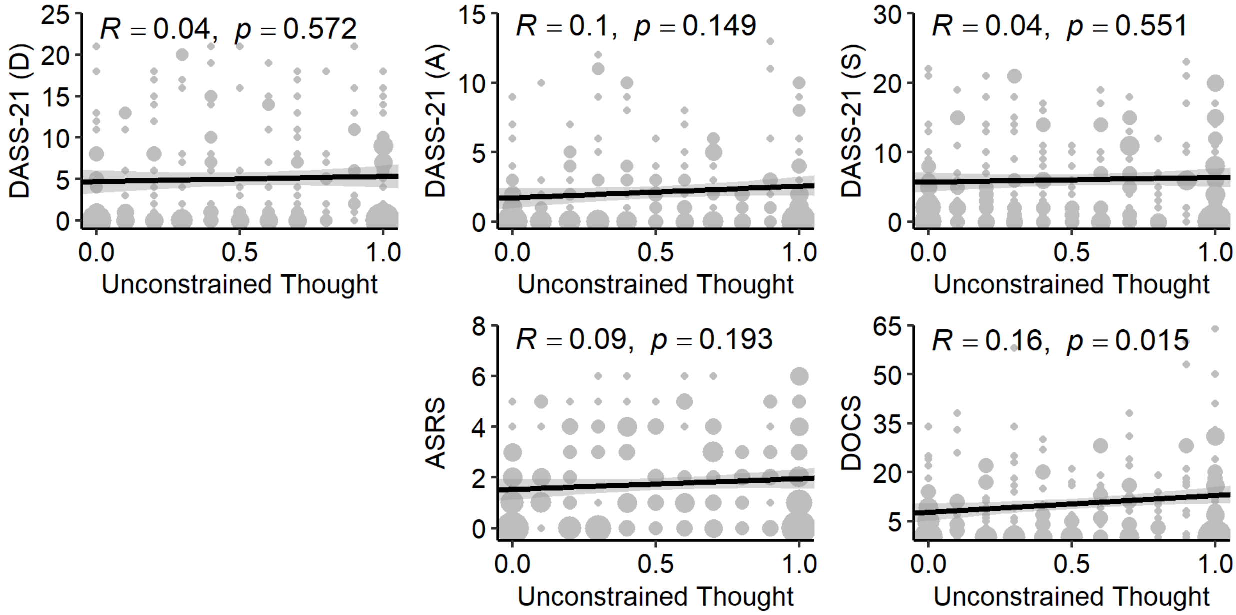

Figure 1. Correlations between proportion unconstrained thought and measures of clinical symptomology including the DASS-21 Depression (D), Anxiety (A), and Stress (S), the ASRS and the DOCS. DASS-21: Depression, Anxiety, and Stress Scale – 21 items; ASRS: Adult Self-Report ADHD scale; DOCS: Dimensional Obsessive-Compulsive Scale.

Unconstrained thought and divergent thinking

Next, we examined the possibility that rates of unconstrained thought during the 2-back task are, as per the Dynamic Framework's prediction, positively associated with AUT performance (i.e., divergent thinking). Contrary to this prediction, we observed a significant, *negative* correlation between unconstrained thoughts and creativity ratings, r = -.20, 95% CI [-.32, -.07], $t(223)$ = -3.03, p = .003 with strong evidence for the null over the predicted positive association, BF_{0+} = 25.95—and strong evidence in favor of the negative association over the null, BF_{-0} = 24.87. Turning to fluency, we found a significant negative correlation, r = -.16, 95% CI [-.29, -.03], $t(223)$ = -2.44, p = .015, with strong evidence in favor of the null over the positive association BF_{0+} = 21.87 and moderate evidence in favor of the negative association over the null, BF_{-0} = 5.41 (see Figure 2).

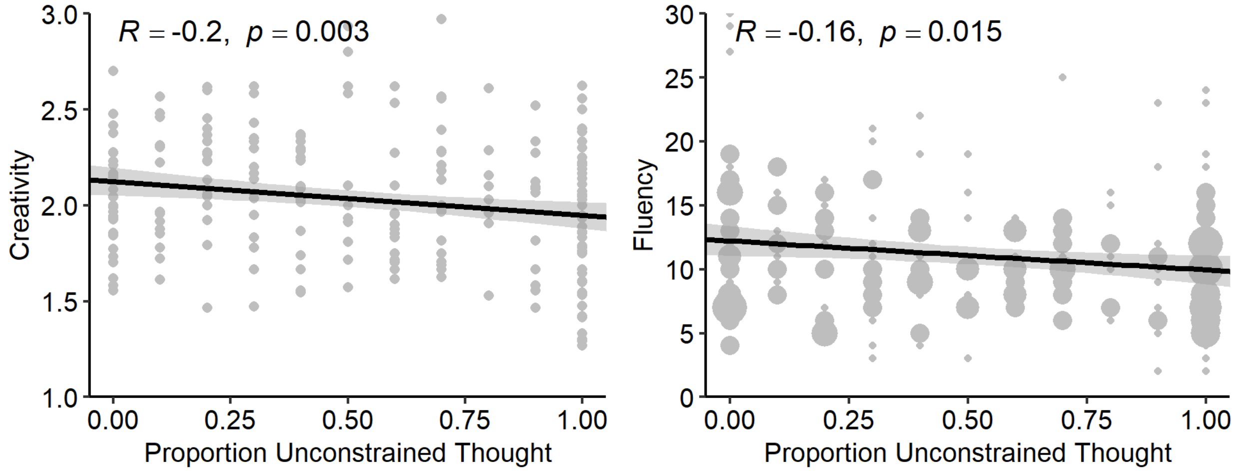

Figure 2. Correlation between AUT creativity and fluency scores and unconstrained thought proportions.

Spontaneous and Deliberate Mind Wandering and Thought Constraint.

To determine whether state-level reports of unconstrained thought are dissociable from trait-level reports of spontaneous and deliberate mind wandering, we analyzed the rates of unconstrained thought using a linear regression with spontaneous (MW-S) and deliberate (MW-D) mind wandering as explanatory variables. We found no statistically significant association between either spontaneous mind wandering, $b = 0.02$, 95% CI [-0.01, 0.05], $t(222) = 1.14$, $p = .254$, or deliberate mind wandering, $b = 0.01$, 95% CI [-0.03, 0.04], $t(222) = 0.32$, $p = .747$; model fit $R^2 = .01$, 90% CI [0.00, 0.03], $F(2, 222) = 0.97$, $p = .379$. Using a Bayesian analysis, we found moderate evidence in favor of the intercept-only model over the full model, $BF_{01} = 3.44$. These findings indicate, consistent with recent work (O'Neill et al., under review), that the thought-constraint and intentionality dimensions of mind wandering are indexing separate constructs.

Mind Wandering and Measures of Clinical Symptomatology

Next, to ensure that our failure to observe significant correlations between rates of unconstrained thought and the various individual-differences measures employed here was not the result of measurement error from measures other than freely moving thought probes, we examined the relationships between these individual-differences measures and the MW-D and MW-S. We analyzed each measure using a linear regression with spontaneous mind wandering and deliberate mind wandering as explanatory variables.

ASRS. We found that spontaneous mind wandering was positively associated with ADHD symptomatology (ASRS), $b = 0.57$, 95% CI [0.44, 0.71], $t(222) = 8.30$, $p < .001$, and deliberate mind wandering was not (though, marginally significant), $b = 0.13$, 95% CI [-0.02, 0.27], $t(222) = 1.72$, $p = .088$; model fit: $R^2 = .30$, 90% CI [0.21, 0.38], $F(2, 222) = 47.58$, $p < .001$. The Bayesian analyses resulted in overwhelming evidence in favor of the full model over the null, $BF_{10} = 5.75 \times 10^{14}$ and the model containing spontaneous mind wandering was preferred over the full model by a factor of 1.92.

DOCS. Spontaneous mind wandering was also positively associated with OCD symptomatology (DOCS), b = 2.20, 95% CI [1.18, 3.22], t(222) = 4.23, p < .001, while deliberate mind wandering was not, b = 1.34, 95% CI [-3.57, 6.26], t(222) = 0.54, p = .591; model fit: R^2 = .09, 90% CI [0.03, 0.15], F(2, 222) = 10.88, p < .001. The Bayesian analyses resulted in strong evidence in favor of the full model over the null, BF_{10} = 554.45, and the model containing only spontaneous mind wandering was preferred over the full model by a factor of 4.26.

DASS-21. Finally, the results are the same for all three DASS-21 measures: spontaneous mind wandering was positively associated with the measure of depression, b = 1.56$, 95% CI [1.05, 2.07], t(222) = 6.07, p < .001, while deliberate mind wandering was not, b = -0.02, 95% CI [-0.57, 0.52], t(222) = -0.08, p = .934; model fit: R^2 = .16, 90% CI [0.09, 0.23], F(2, 222) = 21.06, p < .001. The Bayesian analyses resulted in overwhelming evidence in favor of the full model over the null, $BF_{10} = 2.02 \times 10^6$, and the model containing only spontaneous mind wandering was preferred over the full model by a factor of 5.76.

Spontaneous mind wandering was also positively associated with anxiety, b = 0.66, 95% CI [0.39, 0.94], t(222) = 4.76, p < .001, while deliberate mind wandering was not, b = 0.04, 95% CI [-0.26, 0.33], t(222) = 0.26, p = .793; model fit: R2 = .11, 90% CI [0.05, 0.18], F(2, 222) = 13.67, p < .001. The Bayesian analyses resulted in overwhelming evidence in favor of the full model over the null, $BF_{10} = 5.47 \times 10^3$, and the model containing only spontaneous mind wandering was preferred over the full model by a factor of 4.67. Lastly, spontaneous mind wandering was positively associated with stress, b = 1.54, 95% CI [1.03, 2.05], t(222) = 5.97, p < .001, while again, deliberate mind wandering was not, b = -0.18, 95% CI [-0.72, 0.37], t(222) = -0.64, p = .522; model fit: = R^2 .15, 90% CI [0.08, 0.22], F(2, 222) = 19.22, p < .001. The Bayesian analyses resulted in overwhelming evidence in favor of the full model over the null, $BF_{10} = 4.84 \times 10^5$, and the model containing only spontaneous mind wandering was preferred over the full model by a factor of 4.52.

Collectively, these results suggest that our failure to observe the predicted relations between unconstrained thought and the various measure of clinical symptomatology was *not* a consequence of measurement error (from measures other than the freely-moving thought probes).

Thought constraint and 2-back task performance

Finally, for exploratory purposes, we examined the relation between rates of unconstrained thoughts and performance (measured as d prime) on the 2-back task (see Figure 3). Consistent with recent research suggesting that unconstrained thinking is resource-demanding (Brosowsky et al., under review), we found that participants who engaged in higher rates of unconstrained thoughts tended to perform more poorly on the 2-back task, r = -.26, 95% CI [-.38, -.14], t(223) = -4.04, p < .001, with strong evidence in favor of the alternative over the null, BF_{10} = 338.86.

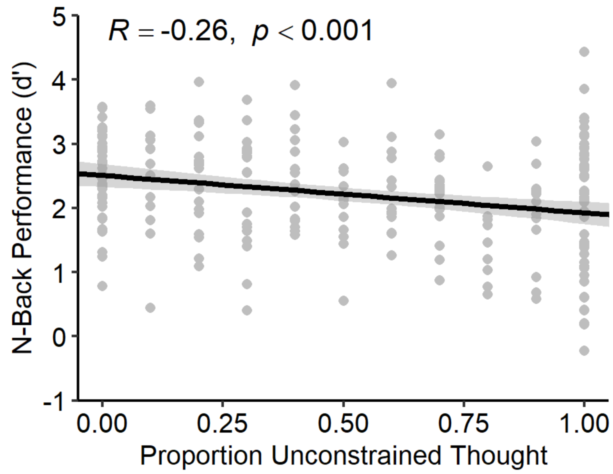

Figure 3. Correlation between performance on the 2-back task (measured as *d* prime) and proportions of unconstrained thought.

Study 1 Discussion

This study aimed to test three predictions of the Dynamic Framework: namely, that unconstrained thinking is (a) positively associated with ADHD symptomatology, (b) negatively associated with depressive, anxious, and obsessive thought patterns, and, (c) positively associated with divergent, creative thinking. Results of Study 1 failed to support any these predictions.

When considering the lack of support for the prediction that unconstrained thought ought to be positively associated with divergent thinking (prediction c), it is important to note that, in Study 1, we merely tested for a positive correlation between divergent thinking and rates of unconstrained thought occurring during a 2-back task, which did not permit creative incubation. Indeed, while engaging in unconstrained thoughts during the 2-back task, participants could not incubate creative uses for the AUT cue since they had not yet been presented the cue (hence, there was nothing to incubate). It could be argued, however, that unconstrained thoughts facilitate creative-idea generation only when such thoughts occur during an interval wherein they can creatively incubate.

Study 2

In Study 2, we tested the prediction that increasing rates of unconstrained thought during a creative-incubation interval would lead to the generation of more creative ideas for the AUT (i.e., increased divergent thinking). To manipulate rates of unconstrained thought, we employed a task-difficulty manipulation that has recently been shown to effectively influence rates of unconstrained thought (Brosowsky et al., under review). In particular, we had participants complete either a 0-back (easy) or 2-back (difficult) task. As in Brosowky et al., we expected to find that participants completing the easy 0-back task would engage in higher rates of unconstrained thought than those completing the more difficult 2-back task.

To create an incubation interval, in both conditions, participants first provided creative uses for a single object (balloon), after which they completed the n-back task (0-back or 2-back), after which they were instructed to produce new creative uses for “balloon” (for a similar design, see Baird et al., 2012). Here, the rationale was that the n-back task could serve as an incubation interval during which participants could engage in unconstrained thoughts that facilitated the generation of new, more-creative uses for the “balloon,” which could then be reported on the second iteration of the AUT (following the task-difficulty manipulation). If, as predicted by the Dynamic Framework, unconstrained thought facilitates divergent thinking, then we should expect that participants engaging in higher rates of unconstrained thinking during the incubation interval (i.e., those completing the easy 0-back task) should, on the second iteration of the AUT, generate more-creative uses for “balloon” than those engaging in lower rates of unconstrained thinking (i.e., those completing the difficult 2-back task).

In addition to examining differences in thought constraint and divergent thinking across the 0-back and 2-back groups, we also, at the end of the n-back phase, asked participants to indicate how often they explicitly thought about the AUT while completing the n-back on a scale of 1 to 5 (never, rarely, occasionally, a moderate amount, or a great deal). We included this question to determine whether participants who more frequently thought about the AUT during the incubation interval were more likely to benefit (in terms of divergent thinking) from unconstrained thoughts during this same interval.

Finally, using a flow-state questionnaire (Marty-Dugas, Howes, & Smilek, under review), we collected retrospective reports of flow three times throughout the experiment: once after the first iteration of the AUT, once after the n-back task, and once following the second iteration of the AUT. These assessments were included to (a) examine potential relations between flow and creativity, and (b) extend a previous examination (Brosowsky et al., under review) of the potential overlap between the experience of flow states and the experience of unconstrained thinking.

Method

Participants

Participants were recruited via Amazon Mechanical Turk and were paid $3.60 (USD) for completing the study, which lasted approximately 30 minutes. We decided, in advance, to collect data from 300 participants (150 per n-back group). We chose this sample size because it would allow us to detect small-to-medium effects with high power. Participants were restricted to US citizens with 98% HIT approval ratings and more than 5000 HITs completed. All participants provided informed consent and were treated in accordance with guidelines approved by the IRB at Duke University.

Materials

The n-back working-memory task.

Instructions and stimuli were displayed in the center of the screen. Stimuli were presented in a 72px black font on an off-white background. Participants completed 20 practice n-back trials, 188 experimental n-back trials, and 12 thought probe trials. Stimuli consisted of the numbers 1 through 8 (4 even and 4 odd). Non-target stimuli were presented in black font and target stimuli were presented in red font. Target stimuli were randomly inserted once in every 8-trial block, with 23 target trials and 156 lure trials in total. In all, this task took approximately 15 minutes.

In both the 0-back and 2-back conditions, participants were instructed to withhold responses to black-colored digits and only respond when a red target appeared. In the 0-back condition, participants indicated whether the red digit was even or odd by pressing ‘e’ or ‘o’ on the keyboard. In the 2-back condition, participants were presented a red question mark and indicated whether the digit presented two trials ago was even or odd. In the 0-back condition, participants were presented a red digit and indicated whether the currently presented red digit was even or odd. Finally, at the end of the n-back task, participants were asked to indicate how frequently they explicitly thought about the AUT while completing the n-back task on a scale of 1 to 5 (never, rarely, occasionally, a moderate amount, or a great deal). This measure was included for exploratory purposes.

Thought probes.

Participants were presented 12 thought probes throughout the experiment. Thought probes were randomly inserted once every 15 trials, excluding the first 4 and final 4 n-back trials (on average, every 60 seconds). Thought probes consisted of a single question gauging thought constraint (“The thoughts I was experiencing were freely moving: YES/NO”), as in Study 1.

The Alternate Uses Task (AUT).

Participants completed two AUT tasks, one prior to the n-back task (i.e., pre-incubation) and one following the n-back task (i.e., post-incubation). For both AUT tasks, participants were presented the name of the same object (balloon) and were asked to generate as many novel and creative uses for the object as possible. For each session, participants were allotted two minutes to list their generated uses. As in Study 1, we examined two indices of divergent thinking: creativity ratings and fluency. Interrater reliability for creativity ratings was within the acceptable range (Cronbach’s alpha = .738).

Procedure

First, participants completed the pre-incubation AUT—with “balloon” as the object—immediately after which they were asked to report on their level of flow during the pre-incubation AUT. Next, they completed the n-back task. Upon completion of the n-back task, participants reported on the extent to which they thought about the AUT object (balloon) during the n-back task, after which they again reported on their level of flow—this time, during the n-back task. Next, they completed the AUT again (post-incubation) with the same object (balloon) from pre-incubation AUT. Finally, participants reported on their level of flow during completion of the post-incubation AUT.

Results

Data from five participants were removed because these participants did not complete all parts of the experiment. At the end of the experiment, we asked participants if they had used any outside resources (e.g., Google) to help them generate ideas during the AUTs. We removed data from 17 participants who responded “yes” to this question. Finally, we removed data from four participants who generated 0 responses in either the pre- or post-incubation AUT (final N = 274; 0-back condition = 135; 2-back condition = 139) (see Tables 2 and 3 for descriptive statistics and correlations among the primary measures of interest, presented separately for the 0-back and 2-back groups).

Thought constraint across n-back groups

First, we compared rates of unconstrained thoughts across n-back groups and found that the 0-back group reported significantly more unconstrained thoughts than those in the 2-back group, M_d = 0.31, 95% CI [0.23, 0.39], $t(255.84) = 7.89$, $p < .001$, with overwhelming evidence in favor of the alternative, $BF_{10} = 6.47 \times 10^{10}$. This confirms that the change in difficulty successfully manipulated the rate of unconstrained thoughts.

Next, we correlated n-back performance with unconstrained thought and found no significant association in the 0-back group, $r < .01$, 95% CI [-.17, .16], $t(133) = -0.05$, $p = .958$, with strong evidence in favor of the null, $BF_{01} = 5.02$. N-back performance was negatively correlated with unconstrained thought in the 2-back group, $r = -.20$, 95% CI [-.35, -.03], $t(137) = -2.36$, $p = .02$, though there was only anecdotal evidence in favor of the alternative, $BF_{10} = 2.72$.

Thought constraint and divergent thinking

The primary question of interest was whether the n-back manipulation influenced AUT performance. To examine this possibility, we analyzed the data using two linear regression models that accounted for participant performance in the pre-incubation AUT. In the first model, we analyzed post-incubation AUT creativity ratings and included pre-incubation creativity ratings and n-back group as explanatory variables, $R^2 = .22$, 90% CI [0.15, 0.29], $F(2, 271) = 37.84$, $p < .001$. We found the effect of pre-incubation creativity ratings was statistically significant, $b = 0.54$, 95% CI [0.42, 0.66], $t(271) = 8.70$, $p < .001$, but n-back group was not, $b = -0.02$, 95% CI [-0.12, 0.08], $t(271) = -0.43$, $p = .668$. Using a Bayesian analysis, the model containing only pre-incubation creativity ratings was preferred over the full model by a factor of 4.03.

In the second regression model, we analyzed post-incubation AUT fluency scores (i.e., the number of generated responses) and included pre-incubation AUT fluency scores and n-back group as explanatory variables, $R^2 = .45$, 90% CI [0.37, 0.52], $F(2, 271) = 109.75$, $p < .001$. Here, we found that pre-incubation scores, $b = 0.77$, 95% CI [0.66, 0.87], $t(271) = 14.65$, $p < .001$, and n-back group, $b = 0.75$, 95% CI [0.23, 1.26], $t(271) = 2.86$, $p = .005$, were both significant predictors of post-incubation AUT fluency scores. However, the effect of n-back group was in the opposite direction than predicted by Christoff et al.: participants in the 2-back group generated more AUT responses than the 0-back group (after taking into account pre-incubation AUT fluency scores). In the Bayesian analysis, the full model was preferred over the model containing only the pre-incubation scores by a factor of 7.09.

To determine whether there was any relationship between participant performance on the AUT and reports of unconstrained thought, we analyzed the data using two additional linear regression models (Figure 4). In the first, we analyzed post-incubation AUT creativity ratings with pre-incubation AUT creativity ratings and unconstrained thought proportion as explanatory variables, $R^2 = .24$, 90% CI [0.17, 0.32], $F(2, 271) = 43.62$, $p < .001$. Here, as before, pre-incubation scores were positively associated with post-incubation scores, $b = 0.51$, 95% CI [0.39, 0.63], $t(271) = 8.33$, $p < .001$. However, unconstrained thought proportions were *negatively* associated with post-incubation creativity ratings, $b = -0.21$, 95% CI [-0.35, -0.07], $t(271) = -3.04$, $p = .003$. Turning to the Bayesian analysis, the full model was preferred over the model only containing the pre-incubation scores by a factor of 9.97.

In the second regression model, we analyzed post-incubation AUT fluency scores with pre-incubation AUT fluency scores and unconstrained thought proportion as explanatory variables, $R^2 = .43$, 90% CI [0.35, 0.50], $F(2, 271) = 102.93$, $p < .001$. Although pre-incubation scores were positively associated with post-incubation scores, $b = 0.75$, 95% CI [0.65, 0.86], $t(271) = 14.13$, $p < .001$, unconstrained thought proportions were not significantly associated with post-incubation scores, $b = 0.24$, 95% CI [-0.49, 0.96], $t(271) = 0.65$, $p = .519$. In the Bayesian analysis, model containing only the pre-incubation scores was preferred over the full model by a factor of 1.24.

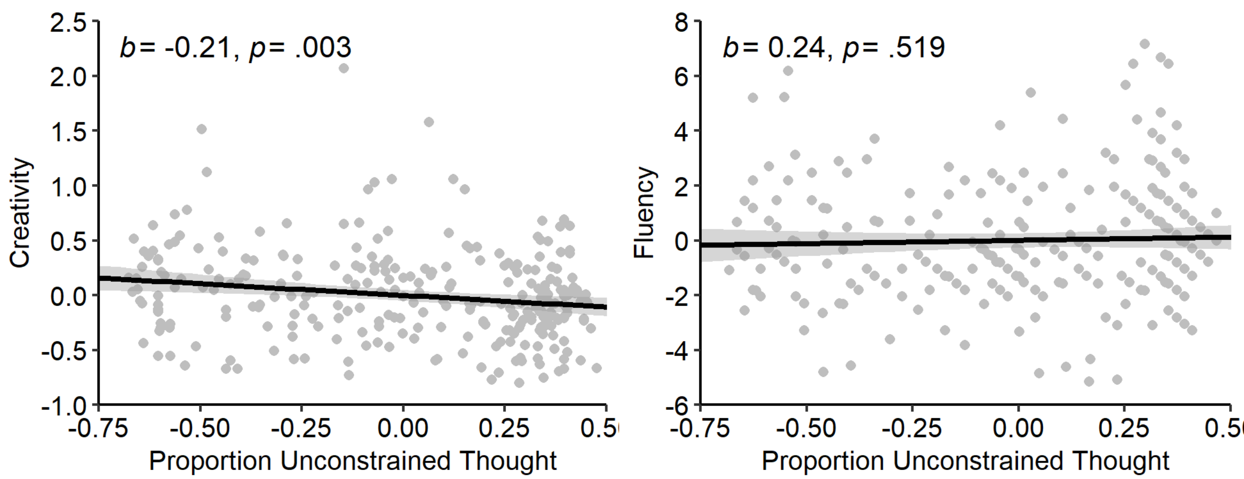

Figure 4. Partial regression plots showing the relationship between post-incubation AUT performance (creativity ratings and fluency scores) and proportion unconstrained thought after adjusting for pre-incubation AUT scores.

Thought constraint, divergent thinking, and time spent thinking about the AUT

Recall that, at the end of the n-back phase, we asked participants to indicate how often they explicitly thought about the AUT while completing the n-back so that we could determine whether thinking about the AUT interacted with thought constraint to increase creative incubation. Most participants responded to this question with “never” ($N = 194$), with few participants responding “rarely” ($N = 50$), and almost no participants responding “occasionally”

(*N* = 8), "a moderate amount" (*N* = 17), or "a great deal" (*N* = 5). Given the limited distribution in responses, we categorized participants into two groups: those who did not think about the AUT (*N* = 194) and those that did (*N* = 80).

Comparing these two groups, we found—perhaps unsurprisingly—lower rates of unconstrained thoughts for those who reported never thinking about the AUT than those who did, $M_{\text{diff}} = -0.13$, 95% CI [-0.21, -0.04], $t(184.05) = -2.90$, $p = .004$, with moderate evidence in favor of the alternative $BF_{10} = 3.75$. To determine whether thinking about the AUT interacted with thought constraint to influence creative incubation, we submitted each of our post-incubation AUT measures to a linear regression model with pre-incubation scores, proportion unconstrained thoughts, AUT thought group (did versus did not think about the AUT), and the interaction between unconstrained thoughts and AUT thought group as explanatory variables.

In the first model, analyzing creativity scores, we found pre-incubation scores were significantly associated with post-incubation scores, $b = 0.51$, 95% CI [0.39, 0.63], $t(269) = 8.20$, $p < .001$ and unconstrained thought was *negatively* associated with post-incubation scores, $b = -0.25$, 95% CI [-0.40, -0.09], $t(269) = -3.15$, $p = .002$. However, AUT thought group was not significantly associated with post-incubation scores, $b = -0.19$, 95% CI [-0.45, 0.07], $t(269) = -1.46$, $p = .145$ and the interaction term was also non-significant, $b = 0.22$, 95% CI [-0.13, 0.56], $t(269) = 1.24$, $p = .217$; model fit: $R^2 = .44$, 90% CI [0.36, 0.51], $F(4, 269) = 52.72$, $p < .001$. Using a Bayesian analysis, the model with only pre-incubation scores and unconstrained thought was preferred over the full model by a factor of 15.78. Therefore, there was no evidence that thinking about the AUT influenced creativity scores or interacted with rates of unconstrained thought.

In the second model, analyzing fluency scores, we found pre-incubation scores were positively associated with post-incubation scores, $b = 0.76$, 95% CI [0.66, 0.87], $t(269) = 14.26$, $p < .001$. However, both unconstrained thought, $b = -0.15$, 95% CI [-0.97, 0.68], $t(269) = -0.35$, $p = .723$, and AUT thought group were non-significant, $b = -1.00$, 95% CI [-2.36, 0.36], $t(269) = -1.44$, $p = .15$. Finally, the interaction between unconstrained thought and AUT thought group was marginal, but also non-significant, $b = 1.69$, 95% CI [-0.11, 3.50], $t(269) = 1.85$, $p = .066$; model fit: $R^2 = .44$, 90% CI [0.36, 0.51], $F(4, 269) = 52.72$, $p < .001$. Turning to the Bayesian analysis, the model containing only the pre-incubation scores was preferred over the full model by a factor 105.14. Therefore, again, we found no evidence that thinking about the AUT influenced creativity scores or interacted with rates of unconstrained thought.

Flow-State Responses

Flow-state responses were coded on a scale from -2 to 2 (strongly disagree, disagree, neutral, agree, strongly agree). Participants completed three flow state questionnaires: one following each of the AUT phases and one following the n-back phase. Comparing responses across the three phases, we found participants reported lower flow-state scores in the n-back phase compared to both the pre-incubation AUT, $M_{\text{diff}} = -0.31$, 95% CI [-0.43, -0.20], $t(273) = -5.17$, $p < .001$, $BF_{10} = 2.10\text{x}10^4$, and the post-incubation AUT, $M_{\text{diff}} = -0.26$, 95% CI [-0.39, -0.14], $t(273) = -4.12$, $p < .001$, $BF_{10} = 233.91$. There was, however, no significant difference between flow state responses in pre- vs. post-incubation AUT phases, $M_{\text{diff}} = 0.05$, 95% CI [-0.05, 0.16], $t(273) = 1.02$, $p = .310$, $BF_{01} = 8.87$. Comparing flow-state responses from the n-back phase across n-back groups, we found that the 0-back group reported higher levels of flow (M = 0.272) compared to the 2-back group (M = 0.034), M_{diff} = 0.24, 95% CI [0.02, 0.45], $t(272) = 2.20$, $p = .029$, $BF_{10} = 1.03$.

Next, we looked at the relationship between flow and creativity. We found no significant correlation between creativity ratings and level of flow, $r = -.02$, 95% CI [-.14, .10], $t(272) = -0.28$, $p = .777$, $BF_{01} = 6.83$, and no significant correlation between fluency and flow, $r = .09$, 95% CI [-.03, .21], $t(272) = 1.50$, $p = .136$, $BF_{01} = 2.38$. Finally, we examined the relationship between flow-state responses following the n-back phase and unconstrained thought proportion (during the n-back) and found a significant positive association, $r = .20$, 95% CI [.08, .31], $t(272) = 3.37$, $p = .001$, $BF_{10} = 32.40$, suggesting that flow and unconstrained thoughts may reflect overlapping experiential states (see also Brosowsky et al., under review).

Study 2 Discussion

In Study 2, we examined the possibility that higher rates of unconstrained thought during a creative-incubation interval would lead to increased creativity (as assessed by divergent thinking). To this end, we used a task manipulation to influence rates of unconstrained thinking between two phases of a divergent-thinking task. The manipulation was successful, with participants engaged in a 0-back task reporting significantly more unconstrained thought. At odds with the prediction from the Dynamic Framework, we found no group differences in post-incubation AUT creativity scores, and no interaction between reports of thinking about the AUT during the interval and thought constraint in predicting creativity scores. For AUT fluency, we found that those engaged in the more difficult 2-back task generated *more* uses for the AUT prompt. This aligns with our finding from Study 1 that rates of unconstrained thought are negatively correlated with average AUT creativity scores. We also found a significant negative correlation between overall rates of unconstrained thought and AUT fluency scores. Hence, there is no dimension along which higher rates of unconstrained thinking is positively associated with higher measures of creativity.

General Discussion

The primary aim of these studies was to test three explicit predictions of the Dynamic Framework:

(a) Unconstrained thinking should be positively associated with ADHD symptomatology.

(b) Unconstrained thinking should be negatively associated with depressive, anxious, and obsessive thought patterns.

(c) Unconstrained thinking should be positively associated with divergent thinking.

Results of both studies failed to support any of these predictions: We failed to identify predicted relationships between unconstrained thought and ADHD symptomatology, OCD, depression, anxiety, and divergent thinking.

Why might we have failed to find support for the Dynamic Framework? Two possible explanations seem most likely. It could be that the framework's predictions are incorrect:

Thought constraint may not be associated with disorders characterized by fixed or flexible thought patterns, or with divergent thinking. Alternatively, it could be that the methodology used to index unconstrained thought (taken from Mills et al., 2018) is invalid. That is, the Mills et al. thought probes that ask people about the movement of their thoughts might not provide an accurate measurement.

With respect to the latter possibility, it is worth noting that Mills et al. (2018) reported a validation of their thought-probe methodology, which (taken at face value) suggests that it may be unlikely that their thought probe is invalid and, hence, responsible for our failure to corroborate the predictions of the Dynamic Framework. For Mills et al.'s validation study, participants were instructed to "think about whatever [they] want" for an interval between 1.5 and 4 minutes, after which they retrospectively reported the extent to which their thoughts were freely moving during these intervals (Mills et al., 2018, p. 22). Immediately after providing these reports, participants typed out the thoughts that they had during the interval, in chronological order, after which they again completed the thinking-rating-typing cycle two to four more times. A rater then provided a subjective rating of the extent to which participants' typed reports reflected freely moving thought, and the authors found a significant positive relation between the participants' reports and the rater's evaluation of the typed reports, lending support to the conclusion that their probe was validated.

There are, however, several reasons to cautiously interpret the results of Mills et al.'s (2018) validation attempt. First, their validation study consisted of a relatively small sample of participants ($N = 23$), which raises some concerns about the robustness (and precision) of their result (Schönbrodt & Perugini, 2013). Second, and consistent with these concerns, the regression analysis that Mills et al. conducted to validate their thought probe produced a p value that was scarcely significant ($p = .046$). Third, careful examination of the Mills et al. validation study suggests that the authors did not attempt to validate the thought probe that they went on to use in another (non-validation) study (the same probe used in the present study), but instead sought to validate a similar, but nevertheless different, retrospective question about thought constraint over a protracted period of time. Indeed, the thought probe that Mills et al. employed in a separate study (again, the same probe used here) required participants to report on the extent to which their thoughts were freely moving *in the moment* just prior to the presentation of each probe, as opposed to *retrospective reports* of thought constraint over the past 1.5 to 4 minutes (as in the validation study). Although this difference may seem trivial, there are reasons to suspect that the retrospective reports are not sufficiently similar to the in situ probe reports, which in turn raises doubts about the validation attempt. For one, when asked to report on the contents of one's thoughts over, say, a 4-minute period, a concern is that participants' memory for their mental experiences are inaccurate, which would render their reports problematic. Perhaps more important, it is possible that participants' initial reports of their thought constraint influenced their recollection (and recording) of their thought patterns; for instance, a participant who reported high levels of freely moving thought may have been compelled to then type out a sequence of thoughts that was highly freely moving; such a report would then likely be rated (by an independent rater) as being highly freely moving, which would artificially produce the observed positive correlation between participants' and rater reports. Thus, although Mills et al.'s study purportedly validated their thought probe, it appears that more work needs to be done to more concretely establish the validity of this probe.[2]

In addition to the aforementioned complications, another problem is that it is difficult to determine what, exactly, the Mills et al. probes assess. Indeed, Mills et al. (2018, p. 27) provide the following instructions for identifying unconstrained ("freely moving") thoughts (the same instructions used in the present study):

Your thoughts move freely when:

1. *They seem to wander around on their own, flowing from one thing to another*
2. *There is no overarching purpose or direction to your thinking, although there may still be some connection between one thought and the next*
3. *Images and memories seem to spontaneously come into your mind*
4. *Your attention lands spontaneously on things in your environment*
5. *Your mind may spontaneously drift between things in the external environment and internal images so it may go back and forth.*
6. *It feels like your thoughts could land on pretty much anything*
7. *Your thoughts seem to flow with ease*

One interpretation of these instructions is that they are asking participants to report on the degree to which their thoughts involved topical shifts (items 1 and 5, and perhaps item 6). Another interpretation is that the instructions are asking participants to report on the extent to which their thoughts are purposeful (item 2). Yet another interpretation is that these instructions are asking participants to report on the intentionality of their thoughts, and whether their thoughts came to mind deliberately or spontaneously (item 3 and 5). Other reasonable interpretations are that the instructions are prompting participants to report on the extent to which their thoughts are (a) focused on images or memories (item 3), (b) continuously shifting from the external environment toward internal images (item 5), and/or (c) effortless and flow with ease (items 1 and 7).

Given the multiple different interpretations of these instructions, it is not possible to know what participants intend to communicate when they report that their thoughts were "freely moving." Moreover, it seems quite possible that the way these instructions are interpreted will vary from one person to the next (and perhaps even within-person over time), since the probe instructions do not clearly communicate what, exactly, is meant by unconstrained thought. This would in turn contribute noise to the assessment of unconstrained thought. Such an outcome would lead to complications when attempting to test the predictions of the Dynamic Framework, and could well be the reason that, in the present study, we failed to find support for any of the predictions tested.

[2] Note that Mills et al. (2018) also conducted a validation study in which they found that retrospective reports of freely moving thought, occurring during a stream of consciousness task, were positively associated with retrospective reports of positive feelings experienced during the task. Although the authors take these results to provide further validity for their thought probe, this validation study likewise assessed retrospective reports of thought constraint over relatively long periods of time, not in situ reports, so it is not clear that this additional study helps to validate their thought probe.

The foregoing complications with the current methodology used to index unconstrained thoughts raise an important question: Methodological problems aside, what makes thought unconstrained? Do such thoughts reflect topical shifts in content, purposeless musings,[3] unintentional drifts, effortless attention, some combination of all of these, or perhaps something altogether different? To date, there does not appear to be a clear answer to this question.

One reasonable conjecture is that unconstrained thought consists either in thoughts that jump from one topic to another, thoughts that occur without a top-down influence of cognitive control/intention, or thoughts that have both of these characteristics. Consistent with this view, Mills et al. (2018) defined such thoughts as those that “move in an unconstrained manner from one to the next: the last time you spoke to your best friend, a memory with your friend years ago, plans with a different friend for dinner, to your favorite dishes at a restaurant” (p. 21). Christoff et al. (2016) defined unconstrained thoughts in a similar manner: Thoughts that “are free to move ‘hither and thither’” (p. 719). At the same time, Christoff et al. (2018) define such thoughts as those that “arise and proceed in a relatively free, unconstrained fashion” (p. 958) (note that this definition does not specify whether topical shifts must be present). Of course, it is possible that proponents of the Dynamic Framework intend to posit that unconstrained thoughts are those that are characterized *both* by content shifts and by a relative lack of top-down control/intention.

In any case, the current probe methodology does not adequately disentangle these thought characteristics: If the intention is to study unconstrained thought as topical shifts in attention, then probes must specifically (and exclusively) ask participants whether, over some—yet-to-be-specified—period of time, they experienced topical shifts in the content of their thought; on the other hand, if the intention is to study thoughts that are relatively unbound by top-down control or intention, then probes must specifically (and exclusively) ask participants whether their thoughts were engaged and maintained with intention; and if the intention is to study thoughts that have both of these characteristics, then probes must separately assess topical shifts and top-down control.

Although a wealth of research suggests the feasibility of assessing top-down control/intention in studies of mind wandering (see Seli, Risko, Smilek, & Schacter, 2016), what remains less clear is whether it is possible to validly assess topical shifts via self-report (but see Welhaf, Smeekens, et al., 2019; Zanesco, 2020). Probes intended to index such topical shifts would rely on participants’ ability to make complex judgments about the dynamics of their thoughts, and it is not clear how to craft probes that could validly and reliably index such dynamics. For instance, it is unclear how many different thoughts must occur before one ought to report topical shifting. Relatedly, it is unclear how different thoughts must be from one another to constitute a shift in content. Also unclear is the duration of the interval over which participants should make these judgements. To further complicate matters, it is plausible that a lack of meta-awareness and/or memorial problems could hinder participants’ ability to accurately report on topical shifts, especially if the interval of which participants are to monitor for topical shifts is long.

[3] Note that Christoff and colleagues define unconstrained thoughts as “purposeless,” though they predict that such thoughts should promote creative (and hence, purposeful) divergent thinking (Girn et al., 2020).

One possible way to circumvent these problems might be to use semantic analysis algorithms to assess topic-shifting in talk-out-loud paradigms (where researchers create transcripts based on verbalizations of participants' stream-of-consciousness; see Sripada & Taxali, under review). This method provides a measure of whether thoughts are moving outside linguistically-defined semantic links, without relying on self-reports. One issue with this approach is that such measures would assess mind wandering in terms of the content of thought, where the content is considered a proxy of underlying dynamics; however, this would not reflect a turn back to a content-based view of mind wandering. Standard content-based views of mind wandering assess mind wandering in terms of how mental content relates to the informational demands of task performance. According to these content-based views, mind wandering is assessed in terms of how mental content relates to itself and changes over time. This way of measuring content might reliably track underlying dynamics in a way that the relation between thought contents and tasks do not. One limitation of this approach is that forcing participants to verbalize their thoughts adds additional constraints, as language is a serial process, and increased meta-awareness, as participants must monitor their mental content while also attending to speaking. Moreover, instructing people to talk aloud would likely influence the content and dynamics of the thoughts that people experience. Despite these limitations, however, results from verbalization paradigms might provide a useful model system that illuminates the dynamics of thinking in a way that thought probes cannot, and we therefore encourage future research to examine this possibility.

Concluding Remarks

The present study failed to bear out many of the predictions of the Dynamic Framework. At the very least, our studies suggest the need to more clearly delineate the defining features of unconstrained thought, and to accordingly modify the thought probes put forth by Mills et al. (2018) for probing unconstrained, freely moving thoughts. Additionally, alternative methods for identifying thought constraint and dynamics—such as talk-out-loud paradigms— might prove fruitful for advancing the study of unconstrained thinking, and may be used to complement (or supplement) the common paradigm of measuring mind wandering with thought probes.

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Table 1: Means, Standard Deviations, and Pearson Correlation Matrix from Study 1.

		M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.	UT	0.52	0.37											
2.	Creativity	2.03	0.33	-0.20*										
3.	Fluency	11.05	5.23	-0.16*	0.08									
4.	N-Back (d`)	2.21	0.83	-0.26**	0.19*	0.31**								
5.	N-Back (c)	0.46	0.26	0.05	0.11	-0.01	-0.03							
6.	MW-S	3.89	1.57	0.09	0.08	0.03	-0.12	-0.04						
7.	MW-D	3.93	1.47	0.05	0.07	0.03	-0.04	0.07	0.37**					
8.	ASRS	1.75	1.79	0.09	0.12	-0.04	-0.06	0.08	0.54**	0.29**				
9.	DASS-21-D	5.02	6.11	0.04	0.13	-0.06	-0.03	-0.03	0.40**	0.14*	0.50**			
10.	DASS-21-A	2.16	3.22	0.10	0.04	-0.11	-0.14	-0.03	0.33**	0.14*	0.48**	0.70**		
11.	DASS-21-S	6.05	6.09	0.04	0.12	-0.03	-0.08	-0.07	0.38**	0.1	0.55**	0.75**	0.78**	
12.	DOCS	10.49	11.87	0.16*	0.02	-0.11	-0.22	0.11	0.30**	0.13	0.45**	0.61**	0.71**	0.67**

UT: Unconstrained Thought; MW-S: Spontaneous Mind Wandering; MW-D: Deliberate Mind Wandering; ASRS: Adult Self-Report ADHD scale; DASS-21: Depression (D), Anxiety (A), and Stress (S) Scale – 21 items; DOCS: Dimensional Obsessive-Compulsive Scale.

*$p < .05$

**$p < .001$

Table 2: Means, Standard Deviations, and Pearson Correlation Matrix from the 0-Back Group in Study 2.

		M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	UT	0.78	0.28										
2.	Creativity (Pre)	2.15	0.44	-0.15									
3.	Fluency (Pre)	5.87	2.71	0.11	-0.15								
4.	Creativity (Post)	2.33	0.50	-0.23**	0.45*	-0.24**							
5.	Fluency (Post)	5.33	2.82	0.14	-0.10	0.64**	-0.31**						
6.	N-Back (d`)	2.92	1.94	<.01	0.13**	0.04	0.27	<.01					
7.	N-Back (c)	0.29	0.92	0.01	0.05	0.08	0.21**	0.06	0.86**				
8.	TAA	1.56	0.98	0.01	-0.21*	-0.24	-0.08	-0.11	-0.15	-0.06			
9.	Flow (N-Back)	0.27	0.86	0.17*	-0.09	-0.06	-0.07	<.01	-0.03	-0.08	-0.15		
10.	Flow (Pre)	0.48	0.69	-0.09	0.02	0.07	-0.05	-0.03	-0.03	-0.03	0.01	0.06	
11.	Flow (Post)	0.42	0.76	0.02	0.10	-0.17*	0.02	0.06	0.12	0.11	0.01	0.17	0.12

UT: Unconstrained Thought; TAA: Thinking about the AUT during the AUT

*$p < .05$

**$p < .001$

Table 3: Means, Standard Deviations, and Pearson Correlation Matrix from the 2-Back Group in Study 2.

		M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	UT	0.47	0.37										
2.	Creativity (Pre)	2.20	0.39	-0.11									
3.	Fluency (Pre)	5.65	2.28	0.13	-0.06								
4.	Creativity (Post)	2.36	0.45	-0.26*	0.49**	-0.01							
5.	Fluency (Post)	5.91	2.94	0.20*	-0.08	0.70**	-0.26*						
6.	N-Back (d`)	2.91	1.14	-0.20*	0.12	-0.22*	0.19*	-0.16					
7.	N-Back (c)	0.98	0.45	-0.08	-0.05	-0.06	-0.08	0.06	0.51				
8.	TAA	1.45	0.92	0.20*	-0.13	0.07	-0.30**	0.13	-0.19*	<.01			
9.	Flow (N-Back)	0.46	0.69	0.15	-0.03	0.04	0.06	0.06	0.12	-0.03	-0.09		
10.	Flow (Pre)	0.41	0.82	0.14	-0.02	0.15	0.09	0.1	0.04	0.03	0.03	0.36**	
11.	Flow (Post)	0.03	0.93	0.16	-0.05	0.06	-0.17*	0.27*	<.01	0.01	0.05	0.30**	0.46**

UT: Unconstrained Thought; TAA: Thinking about the AUT during the AUT

**p* < .05

***p* < .001

Appendix A

Thought probe instruction text for Study 1:

As you complete the task, you may find yourself thinking about things other than what you are doing. These thoughts are referred to as ‘task-unrelated thoughts.’ Having task-unrelated thoughts is perfectly normal, especially when you have to do the same thing for a long period of time.

While you are completing this task, we would like to determine how frequently you are focused on the task and how frequently you are thinking about thoughts that are unrelated to the task. To do this, every once in a while, the task will temporarily stop and you will be presented with a thought-sampling screen that will ask you to indicate whether, just before seeing the thought-sampling screen, you were focused on the task or focused on task-unrelated thoughts.

Being focused on the task means that, just before the thought-sampling screen appeared, you were focused on some aspect of the task at hand. For example, if you were thinking about your performance on the task, or if you were thinking about when you should make a button press, these thoughts would count as being on-task.

On the other hand, experiencing task-unrelated thoughts means that you were thinking about something completely unrelated to the task. Some examples of task-unrelated thoughts include thoughts about what to eat for dinner, thoughts about an upcoming event, or thoughts about something that happened to you earlier in the day. Any thoughts that you have that are not related to the task you are completing count as task-unrelated.

Importantly, task-unrelated thoughts can occur in cases where you are trying to focus on the task, but your thoughts unintentionally drift to task-unrelated topics, OR they can occur in cases where you are not trying to focus on the task, and you begin to think about task-unrelated topics. When the thought-sampling screen is presented, we will ask you to indicate which (if any) of these two types of task-unrelated thoughts you were experiencing.

To do this, we will present you with a thought-sampling screen that looks like this:

Just prior to the onset of this screen, I was:

1. Focused on the task
2. Not focused on the task, but I **was** trying to focus on it.
3. Not focused on the task, but I **wasn't** trying to focus on it.
4. I prefer not to answer.